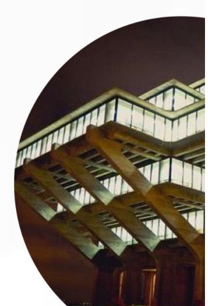
U.S. National Science Foundation
WHERE DISCOVERIES BEGIN

RIG
RESEARCH INFRASTRUCTURE GUIDE

NSF guidance for full life cycle oversight of **Major Facilities** and **Mid-scale RI**

NSF Office of Budget, Finance and Award Management/ Research Infrastructure Office



SUMMARY OF SIGNIFICANT CHANGES

The *Research Infrastructure Guide (RIG)* [NSF 21-107] expires 12/31/2024. Through an Office of Management and Budget (OMB) extension, it will remain in effect until the revised version of the RIG is published.

The purpose of this revision of the *RIG* is to enhance its clarity, accessibility, and usefulness for a broad audience, including users within and beyond NSF. Key updates include eliminating redundancies, clarifying requirements, and adding essential guidance to better support users. A summary of specific changes in this revision is provided below.

Chapter 1 – Introduction

- **Section 1.1 Purpose and Scope** clarifies that the term *project* specifically refers to the Construction Stage for Major Facilities and implementation for Mid-scale Research Infrastructure (RI), including consistent terms for other stages, and also defines the terms *should* and *must* and their usage throughout the document.
- **Section 1.3.1 Award Instruments** establishes a framework for making the *RIG* award instrument neutral.
- **Section 1.4.11 Build America, Buy America – BABA** includes applicable legislation and NSF policy content that aligns with government practices.

Chapter 2 – NSF Life Cycle Oversight

- Each life cycle stage section has a separate oversight subsection.
- **Section 2.1 NSF Staff Roles and Responsibilities for Management and Oversight** is relocated from Chapter 6.
- **Section 2.2 Internal Management Plan** is relocated from Chapter 3.
- **Section 2.7.4 Recapitalization During Operations** provides guidance on recapitalization mechanisms.
- **Section 2.8 Major Facility Disposition Stage** introduces the shift in terminology from Divestment to Disposition for the last RI life cycle stage.
- **Section 2.9 Mid-scale Research Infrastructure Guidance** is relocated from Chapter 5; clarifies and differentiates guidance for Mid-scale RI from Major Facilities.

Chapter 3 – Research Infrastructure Life Cycle Planning

- **Section 3.2 Tailoring, Scaling, and Progressively Elaborating Plans** provides new contextual guidance for overall planning.
- **Section 3.4 Design Stage Planning** contains new guidance for a Design Execution Plan.
- **Section 3.5 Construction Stage and Implementation Planning** provides enhanced guidance for drafting a Project Execution Plan and the ten components required for

both Mid-scale RI and Major Facility projects.

- **Section 3.6 Operations Stage Planning** contains improved guidance on the Annual Work Plan and Facility Condition Assessment of a Major Facility.

Chapter 4 – Fundamental Elements of Project Management

- **Section 4.5 Monitoring Progress Against Plan** includes enhanced guidance.
- **Section 4.6 Risk Management** is streamlined, provides clarity, and applies to all life cycle stages.
- **Section 4.7 Contingency Estimating and Management** is decoupled from risk management.

Chapter 5 – Supplemental Guidance

- **Section 5.2 Cyberinfrastructure** includes guidance on a Cyberinfrastructure Plan for Major Facilities and Mid-scale Research Infrastructure.
- **Section 5.3 Information Assurance** previously Cybersecurity, includes guidance on an Information Assurance Management Plan for Major Facilities and Mid-scale Research Infrastructure.
- **Section 5.4 Environmental Considerations** contains information on the Disposition Stage.
- **Section 5.9 Agile Guidance** provides new content and guidance on applying Agile methodologies to NSF awards.

Chapter 6 – References

- Updated, and no significant changes.

Chapter 7 – Acronyms and Abbreviations

- Updated, and no significant changes.

Chapter 8 – Lexicon

- Updated, and no significant changes.

Chapter 9 – Appendices

- **Appendix B – Outline of Plans by Life Cycle Stage** includes a new List of Plans with descriptions of plans by life cycle stage.

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1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

The U.S. National Science Foundation (NSF) invests in Research Infrastructure (RI), which is essential to the U.S. science, engineering, and education enterprise. NSF defines RI as any combination of facilities, equipment, instrumentation, computational hardware and software, and the necessary human capital in support of the same. Historically, NSF has supported diverse types of RI, including particle accelerators, detectors, radio and optical telescopes, remote research stations, research vessels and aircraft, high-performance computing, and geographically distributed observatories, as well as large-scale surveys and data sets. In support of RI activities, the *Research Infrastructure Guide (RIG)* is provided to:

- Articulate NSF's oversight policies, processes, and procedures during each Major Facility and Mid-scale RI life cycle stage.[1]
- Based on accepted program and project management good practices, provide guidance to interested organizations in support of proposal development and effective management of the activities funded under the award.

The *RIG* applies to Major Facilities and Mid-scale RI across all life cycle stages. These categories of RI are designated based on the cost to construct, acquire, or implement them. For the purposes of this *Guide*, the term *project* is associated specifically with the Construction Stage for Major Facilities and implementation for Mid-scale RI, even though project and program management elements may be associated with other life cycle stages. Likewise, the term *Total Project Cost* (TPC) is only associated with the Construction Stage or implementation award. For other life cycle stages, the term is either the *proposed project* (Development, Design, and sometimes Disposition) or the *Science Support Program* (Operations and Disposition), with the budget to execute the proposed activities referred to as the *award amount, either proposed or authorized*. Major Facilities are RI with a TPC of $100 million or more, while Mid-scale RI have a TPC between the upper limit of the Major Research Instrumentation (MRI) program, currently $4 million, and the lower threshold for a Major Facility, as determined by the statute (see below).

NSF typically supports RI activities from two appropriations: the Major Research Equipment and Facility Construction (MREFC) and the Research and Related Activities (R&RA) accounts. The MREFC account was created in 1995 as the Major Research Equipment (MRE) account to fund the acquisition, construction, commissioning, and upgrading of significant science and engineering infrastructure that Directorates could not otherwise support without a severe negative impact on their budget for science programs. The R&RA account supports other RI-related activities that the MREFC account is not authorized to support, including planning

[1] There are five stages in the Major Facility life cycle – Development, Design, Construction, Operations, and Disposition. Chapter 2 NSF Life Cycle Oversight of this *Guide* describes each of these stages in more detail. Mid-scale RI have analogous stages, but they are less formalized than those for Major Facilities and NSF may play little to no role in one or more of the stages.

and development, design, operations and maintenance, disposition, and scientific research.[1] There is no prohibition on using R&RA to construct and acquire Major Facilities if adequate funding is available. Construction and implementation projects with a TPC of less than $100 million are generally supported by the R&RA account. Still, they can also be funded from dedicated programs within the MREFC account, as determined by NSF and appropriated by Congress.

The *RIG* is published by the Research Infrastructure Office (RIO), formerly the Large Facilities Office (LFO), within NSF's Office of Budget, Finance, and Award Management.[2] The guidance flows from statutory requirements, NSF policies, and long-standing practices, including industry good practices related to project and program management. As a result, the *RIG* is updated periodically to reflect any changes in requirements or recommended practices. As part of its RI Knowledge Management Program, NSF will continue to identify and adopt good practices to improve agency oversight and Awardee management of RI projects and Science Support Programs to enable the most efficient and cost-effective delivery of research tools to the U.S. science, engineering, and education communities.[3] The *RIG* provides extensive flexibility based on the size and technical nature of the proposed project or science program supported by the RI. Proposing organizations are encouraged to use the flexibility provided and document accordingly in the Design Execution Plan, Project Execution Plan, or Annual Work Plan, as appropriate.

The terms *must* and *should* are used consistently throughout this *Guide*, adhering to federal plain language principles.[4] ***Must*** conveys an obligatory action or legal requirement by the Proposer or Awardee, whereas *should* signifies a strong recommendation or good practice, but not a mandatory requirement. This distinction is intended to ensure clarity between requirements (either statutory or NSF policy), and project/program management good practices to give appropriate flexibility, where possible, on the various types of RI awards that NSF funds.

[1] Production-level design and development may be included as part of a Construction Stage or implementation award. What is considered "production-level design" varies based on the technical nature of the project and the acquisition strategies used by the Awardee to deliver (i.e., produce) the various components. It can range from prototyping activities, responses to design-build packages and development of detailed fabrication drawings depending on what is appropriate for the selected vendors to accomplish the work under their sub-contract or subaward. Production-level design normally includes some degree of value engineering.
[2] LFO was renamed RIO in 2023.
[3] https://researchinfrastructureoutreach.com/knowledge-gateway/
[4] https://www.plainlanguage.gov/guidelines/conversational/use-must-to-indicate-requirements/

1.2 RIG DOCUMENT STRUCTURE

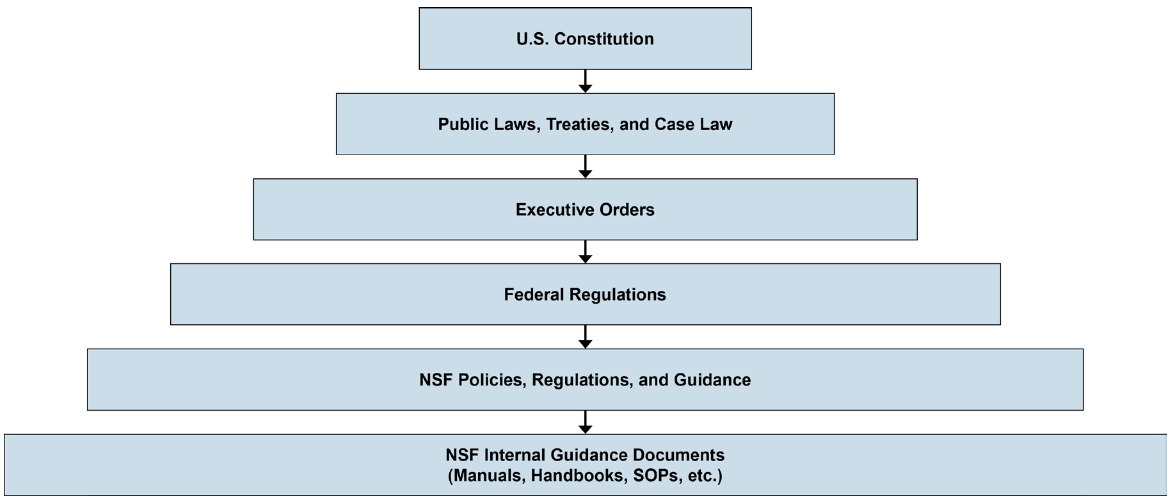
The *RIG* is organized as follows:

- **Chapter 1 Introduction**. Introduces the *RIG's* purpose, scope, and historical perspective, including pertinent legislation, NSF policy, and authorized award instruments.
- **Chapter 2 NSF Life Cycle Oversight.** An outline of the life cycle stages, and the process and principles NSF uses during each stage for Major Facilities and Mid-scale RI.
- **Chapter 3 Research Infrastructure Life Cycle Planning.** A description of the Awardee requirements for preparing and following the various detailed management plans required by each life cycle stage.
- **Chapter 4 Fundamental Elements of Project Management.** Expands the compendium of several NSF key requirements and management principles. It includes detailed descriptions of planning, acquiring, and managing Major Facility and Mid-scale RI processes.
- **Chapter 5 Supplemental Guidance.** Supplementary information on specific topics concerning NSF's role in the planning, oversight, and assurance of Major Facilities and Mid-scale RI, including important explanatory and procedural information on technological, financial, environmental, and human resource considerations.
- **Chapter 6 References, Chapter 7 Acronyms and Abbreviations, and Chapter 8 Lexicon.** Reference materials and definitions of acronyms, abbreviations, and terminology used in this *Guide*.
- **Chapter 9 Appendices.** Includes auxiliary information relevant to construction projects and Major Facilities.

1.3 DOCUMENT PRECEDENCE AND AWARD INSTRUMENTS

The organization receiving the NSF award, herein referred to as the Awardee, and NSF staff need to be knowledgeable about the laws, regulations, and policies that pertain to RI awards. NSF strives to ensure that its policies are consistent with higher authorities and appropriate delegations of authority. In the event of a conflict between policies issued at a lower tier versus policies issued at a higher tier, the higher tier policy will take precedence. Awardees are urged to reach out to their Awarding Official (AO) for guidance as soon as possible any time a conflict is identified. A general hierarchy of authorities for NSF is as follows:

Figure 1.3-1
General Hierarchy of Authorities



Award Terms and Conditions are typically considered to be in the same tier as NSF Policy within the General Hierarchy of Authorities. However, Awardees are advised to consult their AO any time a conflict exists between the terms and conditions of their award and any regulation, policy, or guidance at any tier.

The Federal Acquisition Regulation (FAR) and the Uniform Guidance (2 CFR 200) are federal regulations. The *Proposal Award Policies and Procedures Guide (PAPPG)*, *NSF Acquisition Regulation,* and the *RIG* are considered NSF policies, regulations, and guidance and are publicly available. NSF internal guidance documents, such as the *NSF Acquisition Manual*, are not publicly available and are referenced only for information purposes.

1.3.1 Award Instruments

The National Science Foundation Act of 1950 (Organic Act, Public Law 81-507, as amended) establishes that NSF's relationship with the scientific community is to fund and facilitate scientific and engineering research and education programs, and to appraise the impact of research upon industrial development and general welfare. NSF's Organic Act further states that NSF "*shall not, itself, operate any laboratories or pilot plants*" as other federal agencies do. NSF makes awards to a variety of external parties (Awardees), including nonprofit organizations, universities, and the private sector, to undertake the design, construction and operation of RI using a variety of award instruments.

NSF has the statutory authority to use a variety of award instruments including financial assistance (grants and cooperative agreements [CA]), contracts, and Other Arrangements/ Transactions (OA/T) to fund scientific programs, RI, and to otherwise execute the agency's mission. The selection of award instruments is based on the primary purpose of the award, the beneficiary of the award, and other factors. NSF's responsibility is to oversee the Awardee's funded activities and assuring proper and effective use of taxpayer dollars in support of the scientific enterprise. The Awardee is responsible for managing the day-to-day activities funded under the award in accordance with the terms and conditions.

Post award requirements in executing the project or Science Support Program are based on the award terms and conditions where necessary requirements from the funding announcement (Notices of Funding Opportunities, Request for Proposal, Dear Colleague Letter, etc.) and other foundational documents in the hierarchy as shown in Figure 1.3-1 above should be incorporated, either expressly or by reference.[1]

1.3.1.1 Financial Assistance Awards – Grants and Cooperative Agreements

The Federal Grant and Cooperative Agreement Act of 1977, or Grant Act, (Public Law 95-224) requires that executive agencies use financial assistance when the "*principal purpose*" of the relationship between the agency and a non-federal entity is to "*transfer a thing of value*" to the non-federal entity or "*to carry out a public purpose of support or stimulation authorized by a law of the United States*." Individual federal agencies also need to be authorized by law in order to enter into financial assistance agreements. The NSF authorization to enter into these types of agreements comes from Section 11(a) of the NSF Act (42 USC §1870).

2 CFR §200, *Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards* (Uniform Guidance), provides a regulatory set of rules and requirements for federal financial assistance awards. The NSF *PAPPG*, in conjunction with other supporting documents incorporated by reference and the applicable award terms and conditions, serves as NSF's implementation of the Uniform Guidance. For example, the *RIG* is referenced under the *Research Infrastructure Proposals* section of the *PAPPG*, among others.

In general, the reasons underlying the selection of financial assistance as the appropriate award instrument for RI funded by NSF are when the science community is the primary beneficiary and is receiving the *thing of value*, generally property and other deliverables such as data. In addition, unless specified in the terms and conditions of the award, title to property should vest with the Awardee. NSF should hold the title to assets as government-owned property only in circumstances with clear operational benefits or other needs for NSF. Under CA, having a *conditional interest* in the title to property allows NSF to be involved with

[1] Funding announcement refers to all methods used by NSF to announce a funding opportunity or actively soliciting proposals, including Notices of Funding Opportunities, Requests for Proposals, Request for Information, Broad Agency Announcements, Dear Colleague Letters, and Program Announcements. The precise method is specific to the award instrument.

disposition decisions, particularly on long-term Major Facility awards such as the Operations Stage.

A grant is used when the Awardee is assumed to be able to successfully execute the activities funded under the award without agency collaboration or participation and in full compliance with published requirements. CA are to be used when substantial involvement by the federal agency is expected.[1] While there is no government-wide definition of *substantial involvement*, it includes such things as:

- Participation by NSF in resolving technical, management, or scheduling problems.
- NSF monitoring to permit specified kinds of direction or redirection of the work because of relationships with other projects, organizations, or agencies.
- The existence of established performance goals or agency requirements that need to be met and reviewed by NSF before proceeding with additional objectives to another stage of work or before receiving additional funding.
- NSF approval prior to changes in senior/key personnel.
- NSF approval and/or involvement in the source selection process or the development of substantial provisions and resulting documents for proposed subawards and subcontracts.

Grants and CA allow oversight and accountability mechanisms to be built into the award terms and conditions, including flexibility to tailor award-specific requirements and add performance metrics. CA, however, tend to allow for greater oversight due to substantial government involvement. Under CA, NSF involvement is primarily to monitor the sufficiency of progress to justify continued funding, ensure appropriate use of funding, often with NSF approvals, and support adherence to award terms and conditions. However, award administration and oversight activities may not be conducted for inspection or acceptance, assuming overall control of the project, or for otherwise directing project activities. In addition, NSF does not maintain the unilateral right to change or redirect work under the agreement.

At NSF, many large RI awards consist of a master CA as an umbrella award, establishing the overall basic provisions of the award and separate cooperative support agreements funded individually under the master agreement. Each cooperative support agreement has its own terms and conditions so that NSF can separately monitor the funded activities from the overall objectives of the master CA. Typical uses include separating design from construction, operations and maintenance from disposition activities, or other research activities co-sponsored by other agencies.

For RI financial assistance proposals, the Awardee's estimating system **must** be able to prepare the budget in two formats: a Work Breakdown Structure (WBS) format and the standard NSF Budget Category format. The use of a WBS format is described further in

[1] See 2 C.F.R. §200.1 for CA definition. https://www.ecfr.gov/current/title-2/subtitle-B/chapter-XI/subchapter-A/part-1104

Section 4.2 Scope and Work Breakdown Structure. The NSF Budget Category format is prescribed in the *PAPPG* and depicted in Table 1.3.1.1-1 below. The NSF Budget Category format allows for entry of the proposed budget into NSF's award system. For RI, it is the WBS format that primarily supports the NSF cost analysis in alignment with U.S. Government Accountability Office (GAO) good practices. In addition, the WBS format allows for monitoring actual costs against the approved baseline budget and assessing progress against the plan. If the elements of cost associated with each WBS element are binned and coded by the appropriate NSF Budget Categories in the Awardees estimating and accounting systems, then the proposed budget can be organized in both formats simultaneously. The cost data can be sorted, reported, and analyzed for cost reasonableness in different ways.

Table 1.3.1.1-1

NSF Financial Assistance Budget Category Format[1]

NSF Financial Assistance Budget Categories
A – Senior Personnel
B – Other Personnel
B.1 – Postdoctoral Scholars
B.2 – Other Professionals (Technicians, Programmers, etc.)
B.3 – Graduate Students
B.4 – Undergraduate Students
B.5 – Secretarial – Clerical
B.6 – Other
C – Fringe Benefits
D – Equipment
E – Travel
E.1 – Domestic
E.2 – Foreign
F – Participant Support
F.1 – Stipends
F.2 – Travel
F.3 – Subsistence
F.4 – Other
G – Other Direct Costs
G.1 – Materials and Supplies
G.2 – Publication, Documentation, Dissemination
G.3 – Consultant Services
G.4 – Computer Services
G.5 – Subawards
G.6 – Other
H – Total Direct Costs
I – Indirect Costs

[1] This table does not include the lines for cost-share or fee that may also be relevant categories, especially for larger awards. These lines don't display by default but are available, if needed.

Due to their complex nature, the following requirements in the *PAPPG* have been or may be modified through the funding announcement to accommodate Major Facility or Mid-scale RI proposals:

- Maximum length of Budget Justification(s) for the Proposal and Subaward: The Cost Book and Basis of Estimate, including supporting information, are typically much more extensive than five pages stipulated in Part I, Chapter II.D.2.f.
- Maximum length of the Project Description and Supplemental Documents.
- Requirements for certain RI-specific documentation such as the Design Execution Plan, Project Execution Plan, or Annual Work Plan.

The above list is not intended to be comprehensive. Proposing organizations should consult the funding announcement for specific programmatic guidance.

1.3.1.2 Contracts

A federal contract is used primarily when supplies, property, goods, or services (including construction activities) are being acquired for the direct benefit of the government. As a result, title to all property vests with the agency. Federal contracts can also be used to fund research and development activities, and for other purposes, where appropriate. The Grant Act requires that an executive agency use a procurement contract when the principal purpose is to:

- To acquire, by purchase, lease, or barter, property or services for the direct benefit or use of the United States government; or
- When the agency decides in a specific instance that using a procurement contract is appropriate.

Common examples of activities that may be considered for the direct benefit or use of the federal government include, but are not limited to:

- Construction, acquisition, maintenance, or upgrade of NSF-owned property, including buildings and equipment.
- Deliverables necessary for executing NSF's mission or required for NSF by statute.
- Training, conferences, or seminars for the benefit of NSF employees.

FAR, 48 CFR 1, is the principal regulation governing procurement activities for executive agencies. The FAR reflects the codification and publication of uniform policies and procedures for federal agencies to follow in the acquisition process. NSF supplements the FAR with procurement regulations, policies, and procedures specific to NSF acquisitions in its FAR supplement (NSF Acquisition Regulation, 48 CFR 25) and the NSF *Acquisition Manual,* which is an internal NSF document. Requirements to follow the *RIG* are referenced in the funding announcement and the award terms and conditions. In addition, contracts that contain construction activities are subject to the Davis-Bacon labor standards and related Acts.

For RI contracts, at minimum, the budget **must** be submitted in an appropriate WBS format (see Section 4.2 Scope and Work Breakdown Structure). The WBS format supports NSF's proposal evaluation as well as post-award monitoring of progress against the plan, or expenditures against the original proposed budget. The budget may also be required to be presented in other formats as described in the funding announcement (i.e., Request for Proposals).

1.3.1.3 Other Arrangements/Other Transactions

Other Arrangements (OA) and Other Transactions (OT) are separate and distinct from contracts and financial assistance but can be broadly used for scientific or engineering activities. OA/T are considered non-procurement, non-assistance, contract-like instruments that are generally executed as legally binding with enforceable terms and conditions. Using OA/T can potentially enhance the relationship between the Awardee and NSF, broaden the community response to funding opportunities, leverage investment in technology development, and facilitate collaboration and innovation. Among other things, OA/T also grant more flexibility to structure business relationships in numerous ways, including joint ventures, partnerships, consortia, or multiple agencies joining together to fund an agreement encompassing multiple providers. However, OA/T should not be considered a panacea since the benefits described come with potential risks.

As stated above, the NSF's Organic Act provides the agency with broad authority, within the limits of available appropriations, to use OA. The Creating Helpful Incentives to Produce Semiconductors and Science Act (P.L. 117-167) Section 10396 (42 USC § 19116) provided the NSF Director the authority to use OT in carrying out activities of the Technology, Innovation, and Partnerships Directorate. OT and OA may be used for similar purposes but are subject to different statutory requirements. Internal NSF guidance pertaining to OA and OT are included in the NSF *Other Arrangements/Transactions Guide,* an internal NSF document.

For RI OA/T, the budget **must** be submitted in an appropriate WBS format (see Section 4.2 Scope and Work Breakdown Structure). The WBS format supports NSF's proposal evaluation and post-award monitoring of progress against the plan or expenditures against the original proposed budget. The budget may also be required to be presented in other formats as described in the funding announcement.

1.3.1.4 Review of Proposals and Awards

Major Facility and Mid-scale RI proposals considered by NSF, regardless of award instrument type, are subject to appropriate pre- and post-award review and the appropriate internal management approval process. The review process is generally described in the funding announcement and/or the *PAPPG* with internal details for NSF staff included in the Internal Management Plan for Major Facilities and the Management Plan for Mid-scale RI programs. Reviews may include merit review (Intellectual Merit and Broader Impacts criteria), programmatic/technical review, and periodic progress reviews. The level of review and approval for CA and contracts will differ substantially from that required for standard grants, as will the level of post-award oversight needed to ensure appropriate progress and proper accountability for federal funds. This *Guide* provides additional information on the review and approval processes for Major Facilities and Mid-scale RI.

Due to the rigor of the review process, funding constraints, changing NSF priorities, and competing interests within the research community, only a limited number of RI projects and Science Support Programs can be funded. To improve the chances of success with receiving NSF support, organizations supporting RI should review any associated funding announcements carefully and become familiar with the entire contents of the *RIG* when developing their proposals.

1.4 APPLICABLE LEGISLATION AND NSF POLICY

1.4.1 Research Infrastructure

NSF defines RI as any combination of facilities, equipment, instrumentation, computational hardware and software, and the necessary human capital to support the same. Major Facilities and Mid-scale RI are subsets of RI. Major Facilities are RI with a TPC of $100 million or more, while Mid-scale RI currently have a TPC between $4 million and $100 million. NSF's RI investments are described in the agency's annual budget request to Congress.

1.4.2 Major Research Equipment and Facilities Construction Threshold

The MREFC threshold for projects and programs is set by NSF and authorized by Congress as part of the annual budget process.

1.4.3 Major Multi-User Research Facility Project – Major Facility

Per Section 110 of the 2017 American Innovation and Competitiveness Act (AICA), a Major Multi-user Research Facility project was initially defined as a science and engineering facility project that:

- Exceeds the lesser of
  - 10 percent of a Directorate's annual budget; or
  - $100,000,000 in TPC; or
  - Is funded by the MREFC account, or any successor account.

This language was subsequently amended by Section 267 of the National Defense Authorization Act of FY 2021 by striking the text above and inserting the following:

> MAJOR MULTI-USER RESEARCH FACILITY PROJECT. The term 'major multi-user research facility project' means a science and engineering facility project that exceeds $100,000,000 in total construction, acquisition, or upgrade costs to the Foundation.

NSF interprets the above to mean the TPC is defined by the investment in construction or acquisition, not the operations or associated science program costs. If the TPC for a RI project is above the Major Facility project threshold as defined by statute, it is considered a Major Facility throughout its full life cycle.

For the purposes of this *Guide*, the term *Major Facility* is used throughout to equate to the Congressional term Major Multi-User Research Facility.

1.4.4 Oversight Requirements

The policies and procedures established in this *Guide* and supporting internal NSF guidance documents fulfill the Major Facility oversight requirements in Section 110 of AICA 2017, as listed below:

- Prioritize the scientific outcomes of a major multi-user research facility project and the internal management and financial oversight of the major multi-user research facility project.

- Clarify the roles and responsibilities of all organizations, including offices, panels, committees, and directorates, involved in supporting a major multi-user research facility project, including the role of the MREFC Panel.[1]
- Establish policies and procedures for the planning, management, and oversight of a major multi-user research facility project at each phase of the life cycle of the major multi-user research facility project.
- Ensure that policies for estimating and managing costs and schedules are consistent with the best practices described in the *GAO Cost Estimating and Assessment Guide*, the *GAO Schedule Assessment Guide*, and the Office of Management and Budget (OMB) Uniform Guidance (2 CFR. Part 200).
- Establish the appropriate project management and financial management expertise required for Foundation staff to oversee each major multi-user research facility project effectively, including by improving project management training and certification.
- Coordinate the sharing of the best management practices and lessons learned from each major multi-user research facility project.
- Continue to maintain a RIO to support the research directorates in the development, implementation, and oversight of each major multi-user research facility project, including by:
    - Serving as the Foundation's primary resource for all policy or process issues related to the development, implementation, and oversight of a major multiuser research facility project.
    - Serving as a Foundation-wide resource on project management, including providing expert assistance on nonscientific and nontechnical aspects of project planning, budgeting, implementation, management, and oversight.
    - Coordinating and collaborating with research directorates to share best management practices and lessons learned from prior major multi-user research facility projects.
    - Assessing each major multi-user research facility project for cost and schedule risk.
- Appoint a senior agency official whose responsibility is oversight of the development, construction, and operations of major multi-user research facilities across the Foundation.[2]

[1] The MREFC Panel has been superseded with the Facilities Readiness Panel and the Facilities Governance Board. See Chapter 2 NSF Life Cycle Oversight of this *Guide* for the roles and responsibilities of these governing bodies.
[2] Chief Officer for Research Facilities (see Section 2.1 NSF Staff Roles and Responsibilities for Award Management and Oversight).

1.4.5 Mid-Scale Project and Mid-scale Research Infrastructure

Per Section 109 of AICA, a Mid-scale RI project is research instrumentation, equipment, and upgrades to major research facilities or other RI investments that exceed the maximum funded by the MRI program and are below that of a major multi-user research facility project (Major Facility).

Like Major Facilities, NSF interprets the above to mean the TPC is defined by the investment in construction, acquisition, or implementation, not the design, operations, or associated science program costs. If the TPC is within the Mid-scale RI project range as defined by statute (currently $4M to $100M), it is considered Mid-scale RI throughout its full life cycle. Unlike Section 110 for Major Facilities, Section 109 contains no statutory oversight requirements for Mid-scale RI. Refer to Section 2.9 Mid-Scale Research Infrastructure Guidance for planning and oversight requirements of Mid-scale RI as determined by NSF.

1.4.6 National Science Board Policy on Recompetition

National Science Board statement 2015-45 and resolution 2015-46 address competition, renewal, and divestment of Major Facilities. NSF assesses whether to renew the award, compete the management of, or otherwise dispose of a Major Facility through non-renewal, transition, or divestment during the Operations Stage (see Section 2.7 Major Facility Operations Stage).

1.4.7 NSF No Cost Overrun Policy

NSF's No Cost Overrun Policy (NCOP) was codified for Major Facility projects in the fiscal year (FY) 2009 Budget Request to Congress which reads:

> NSF is implementing a No Cost Overrun Policy, which will require that the cost estimate developed at the Preliminary Design Stage have adequate contingency to cover all foreseeable risks and that any cost increases not covered by contingency be accommodated by reductions in scope. NSF senior management is developing procedures to ensure that the cost-tracking and management processes are robust and that the project management oversight has sufficient authority to meet this objective. As project estimates for the current slate of projects are revised, NSF will identify potential mechanisms for offsetting any cost increases in accordance with this policy.

The policy has been continually reinforced in subsequent budget requests to Congress for the purpose of instilling diligence and rigor in establishing the TPC at award and a strong NSF oversight position for Major Facility projects. This policy does not apply to Major Facility Development, Design, Operations, or Disposition Stage awards, or to any Mid-scale RI award.

NSF's implementation of the NCOP is defined fully in Section 2.6.1 Construction Award Management and Oversight, but details are based on the award instrument used.

1.4.8 NSF Performance Metrics

In support of the Government Performance and Results Modernization Act (Public Law 111-352), NSF has developed goals to measure agency performance based on the Awardee's Earned Value Management (EVM) metrics (see Section 4.5 Monitoring Progress Against Plan). For projects that utilize EVM and are between ten and ninety percent (10-90%) complete, the performance goal is to maintain overall cost and schedule variances at, or above, negative ten percent (-10%).[1] When variances exceed negative ten percent, NSF considers what actions it needs to take, if any, as the funding agency based on the circumstances.

1.4.9 Legislation on Congressional Notification of Total Project Cost Increases

Congressional notification is required when there is reason to believe the Construction Stage TPC may increase by 10% or more. Public Law 116-93, Section 518 reads:

> If at any time during any quarter, the program manager of a project within the jurisdiction of the Departments of Commerce or Justice, the National Aeronautics and Space Administration, or the National Science Foundation totaling more than $75,000,000 has reasonable cause to believe that the total program cost has increased by 10 percent or more, the program manager shall immediately inform the respective Secretary, Administrator, or Director. The Secretary, Administrator, or Director shall notify the House and Senate Committees on Appropriations within 30 days in writing of such increase, and shall include in such notice: the date on which such determination was made; a statement of the reasons for such increases; the action taken and proposed to be taken to control future cost growth of the project; changes made in the performance or schedule milestones and the degree to which such changes have contributed to the increase in total program costs or procurement costs; new estimates of the total project or procurement costs; and a statement validating that the project's management structure is adequate to control total project or procurement costs.

1.4.10 Legislation on Congressional Notification of Divestments of NSF-owned Facilities or Capital Assets

The Science Appropriations Act of 2019 included the following under NSF's Administrative Provisions:

> The Director of the National Science Foundation (NSF) shall notify the Committees on Appropriations of the House of Representatives and the Senate at least 30 days in advance of any planned divestment through transfer, decommissioning, termination, or deconstruction of any NSF-owned facilities or any NSF capital assets (including land, structures, and equipment) valued greater than $2,500,000.

This provision has been repeated annually and remains in force. Sections 2.8 Major Facility

[1] EVM metrics become less meaningful when the project is outside of this percent complete range. NSF generally monitors milestones to completion when above 90% complete.

Disposition Stage and 3.7 Disposition Stage Planning discuss the Disposition Stage of the Major Facility life cycle and provide guidance and procedures associated with the divestment of NSF-owned facilities covered by this legislative language. The disposition of NSF capital assets valued greater than $2,500,000 is governed by the federal property management requirements and award terms and conditions.

1.4.11 Build America, Buy America – BABA

When funds are awarded through financial assistance agreements, the requirements of 2 CFR 184, Buy America Preference for Infrastructure Projects, will apply to the project. 2 CFR 184.1(b) states that:

> None of the funds made available for a federal award for an infrastructure project may be obligated unless all the iron and steel, manufactured products, and construction materials incorporated into the project are produced in the United States.

Additional information on the BABA requirements, including the criteria and necessary justifications for requesting a waiver for BABA, can be found in the following:

- CFR 184, Buy America Preferences for Infrastructure Projects
- Office of Management and Budget Memorandum M-24-02, Implementation Guidance on Application of Buy America Preference in Federal Financial Assistance Programs for Infrastructure

Up to date guidance specific to NSF's implementation of the BABA requirements, and the process for requesting waivers, can be found on the agency's website.

2.0 NSF LIFE CYCLE OVERSIGHT

2.1 NSF STAFF ROLES AND RESPONSIBILITIES FOR AWARD MANAGEMENT AND OVERSIGHT

Section Revision: TBD 2025
Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

2.1.1 Overview

NSF is responsible for conducting pre-award review activities, overseeing the Awardee's funded activities, as well as assuring proper and effective use of taxpayer dollars in support of the scientific enterprise. The Awardee is responsible for managing the day-to-day activities funded under the award in accordance with the award terms and conditions.

The *Research Infrastructure Guide (RIG)* outlines the standard path and processes for each life cycle stage of Major Facilities and Mid-scale Research Infrastructure (RI). However, it acknowledges that variations may arise due to the distinct characteristics of each facility. These deviations reflect the unique requirements and challenges associated with the specific goals and operational demands of individual projects and Science Support Programs. The flexibility inherent in the guidance ensures that the framework can adapt to the varied nature of each facility while maintaining alignment with overall scientific objectives.

Main Participants. The NSF participants with primary oversight roles and responsibilities, including award management, are listed below and illustrated in the NSF organizational chart in Figure 2.1.1-1 NSF Organization Chart of Staff with Primary Oversight of Major Facilities and Mid-scale RI Projects.

Sponsoring Directorate. The NSF Sponsoring Directorate that proposes the project and is committed to funding the pre-construction development and design activities, eventual operations as a Science Support Program, and final disposition. The senior management within the Sponsoring Directorate considers community inputs, discipline-specific studies, advisory committee recommendations and internal NSF factors to prioritize candidate projects, balancing risk with opportunities and competing demands for available resources.

Program Officer (PO).[1] The NSF technical expert, typically a scientist or engineer, having primary oversight responsibility for the activities funded under the award.[2] The PO works within a Division or Section of the sponsoring Directorate. The PO's primary responsibilities depend on the award instrument used and include:

- Acting as the research community's primary interface to NSF.
- Developing the Internal Management Plan for a Major Facility project, or the

[1] NSF's Authorization Act of 2002, 42 U.S.C.1862n-4I, signed into law on December 19, 2002, restricts the choice of the PO to be regular employees of NSF. The statutory language of the Act states:
"PROJECT MANAGEMENT. No national research facility project funded under the major research equipment and facilities construction account shall be managed by an individual whose appointment to NSF is temporary."
NSF has extended this requirement to Major Facilities in all life cycle stages

[2] The PO may have a title such as Program Manager or Program Director.

Management Plan for a broader program that defines NSF's strategy for conducting reviews, managing risk, and providing oversight.

- Under financial assistance, conducting merit and programmatic/technical reviews of proposals, including evaluation of proposed costs, and recommending a proposal be awarded or declined.
- Participating in source selection activities, including the evaluation of proposed costs when contracts are used.
- Preparing required programmatic justifications and documentation for review and approval within NSF.
- Monitoring Awardee performance post-award, including compliance with programmatic award terms and conditions.

Chief Officer for Research Facilities (CORF). This senior executive resides within the Office of the Director, reports directly to the NSF Director, and has full life cycle oversight responsibility for NSF major research facilities.[1] The CORF advises the Director on all aspects of NSF Major Facilities and Mid-scale RI throughout their life cycles and collaborates across NSF on the oversight of the NSF research facilities portfolio. The CORF is a member of the agency's Executive Leadership Team, liaison to the National Science Board's (NSB) Awards and Facilities Committee and chairs the Facilities Readiness Panel and the Facilities Governance Board. A deputy CORF focuses on oversight of the Mid-scale RI portfolio and chairs the Major and Mid-scale Facilities Working Group (MMFWG).

Research Infrastructure Office (RIO). The statutory role of RIO is to support the research Directorates in the development, implementation, and oversight of Major Facilities, by:

- Serving as the agency's primary resource for all policy or process issues related to the development and implementation of Major Facilities.
- Providing expert assistance on the nonscientific and nontechnical aspects of project planning, budgeting, implementation, management, and oversight.
- Coordinating and collaborating with research Directorates to share best management practices and lessons learned from prior Major Facility activities.
- Assessing each Major Facility construction project for cost and schedule risk.

This same role has been extended by the agency to the Mid-scale RI portfolio. Sharing of lessons learned and good practices has also been extended to the scientific community through RIO's Knowledge Management program.[2]

Based on its role, RIO is positioned within the Office of Budget, Finance and Award Management (BFA). The Head of RIO works closely with the CORF Office on a routine basis to help ensure NSF guidance supports full life cycle oversight of the Major Facility and Mid-

[1] American Innovation and Competitiveness Act of 2017, Pub. L. No. 114-329, § 110(a)(H), 130 Stat. 2969, 2975 (2017).
[2] https://researchinfrastructureoutreach.com/knowledge-gateway/

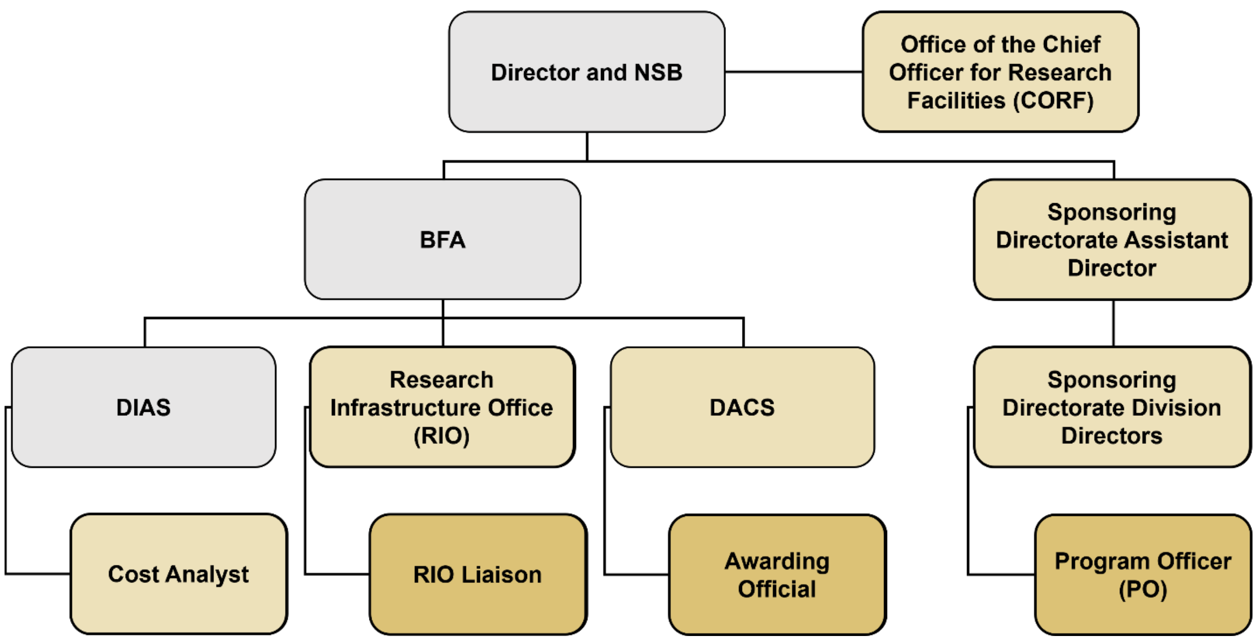
scale RI portfolios. A designated RIO Liaison with subject matter expertise in project management is assigned to each project and Science Support Program by the Head of RIO. The RIO Liaison provides assistance in understanding NSF policy, processes, and procedures and assures that necessary business-related oversight practices are followed.

Awarding Official (AO). The AO works within the Division of Acquisition and Cooperative Support (DACS) and holds the responsibility for award planning, formation, and is the delegated authority to obligate the government. For financial assistance, this is the Grants and Agreements Officer. For contracts, this is the Contracting Officer (CO). The CO is supported by a Contracting Officer's Representative (COR), a role that may be filled by the PO. The specific responsibilities of the AO are based on the award instrument used, but also include:

- Leading the NSF cost analysis and negotiating the final award budget.
- Ensuring compliance with the award terms and conditions.
- Providing approval or authorization for major subawards and subcontracts.
- Acting as the primary point of contact with the Awardee for all business and financial matters, including acceptance of all business-related submittals and reports.

Figure 2.1.1-1

NSF Organizational Chart Highlighting Key Staff with Primary Oversight and Management Responsibilities for Major Facilities and Mid-scale RI, shown in gold with the Core IPT in Darker Gold.

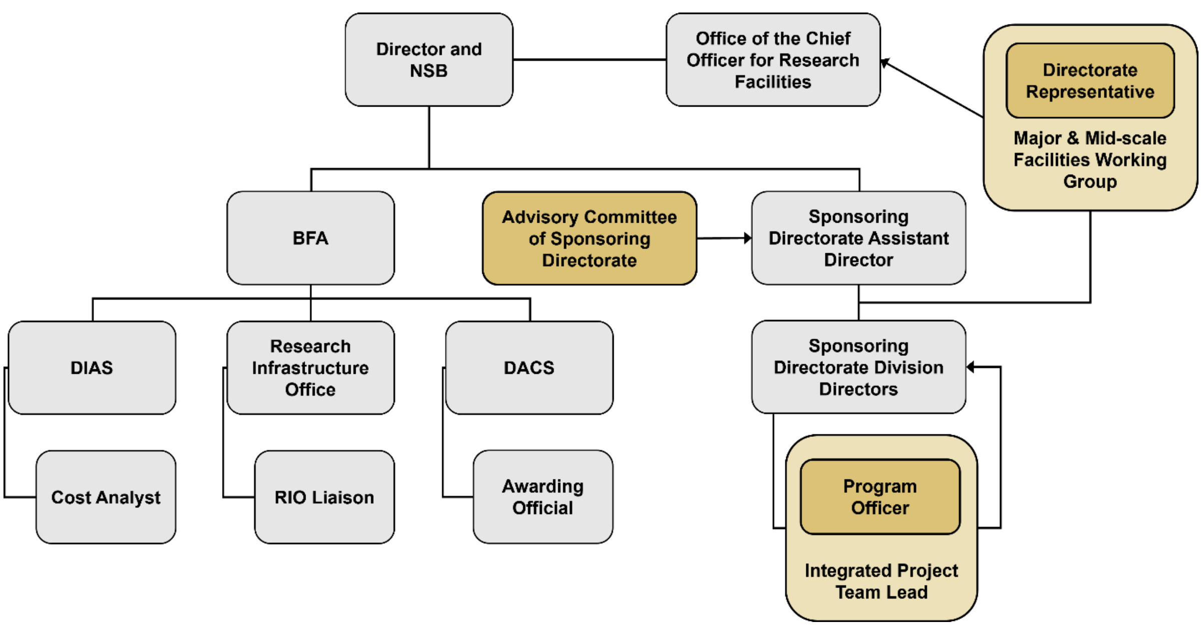


2.1.2 Coordinating and Advisory Bodies

As shown in Figure 2.1.2-1 NSF Organization Chart of Coordinating Primary Staff with Oversight of Major Facilities and Mid-scale RI, various groups within NSF provide coordination and advice that is relevant to the oversight of the RI portfolio:

- **Integrated Project Team (IPT).** The IPT provides coordinated agency oversight for all technical, business, and strategic issues both pre- and post-award. For Major Facilities, the IPT is formed when a project enters the Design Stage and continues throughout Construction and Operations. The Core IPT consists of the PO, AO, and the RIO Liaison who meet routinely, often with the Awardee, to deal with day-to-day issues. Other members of the IPT are selected by the management of the Sponsoring Directorate, in consultation with the PO, based on the life cycle stage and the related agency risks. The IPT is chaired by the PO.
- **Major and Mid-Scale Facilities Working Group.** The MMFWG promotes consistent and effective programmatic oversight related to Major Facilities and Mid-scale RI across the science Directorates. The MMFWG supports the Head of RIO by reviewing internal and external agency guidance and promoting good practices and lessons learned. Its members provide advice to the CORF Office and the Facilities Governance Board regarding strategy, governance, and implementation issues, including advising on the sufficiency and appropriateness of guidance documents developed by RIO. The MMFWG is chaired by the deputy CORF.
- **Advisory Committees.** Advisory Committees, and their subcommittees, which comprise researchers and educators from the scientific community, advise the Sponsoring Directorate on a wide variety of programmatic areas, including strategic issues related to Major Facilities and Mid-scale RI programs when requested.

Figure 2.1.2-1
NSF Organization Chart of Coordinating and Advisory Bodies for Major Facilities and Mid-scale RI Indicated in Gold



2.1.3 Governing and Assurance Bodies

There are also governing and assurance bodies, shown in Figure 2.1.3-1 NSF Organization Chart of Policy and Approval Bodies for Major Facilities and Mid-scale RI, that review and make recommendations on the suitability and readiness, as well as on the allocation of resources for the development, design, construction, and operation of Major Facilities, according to the NSF strategic objectives.

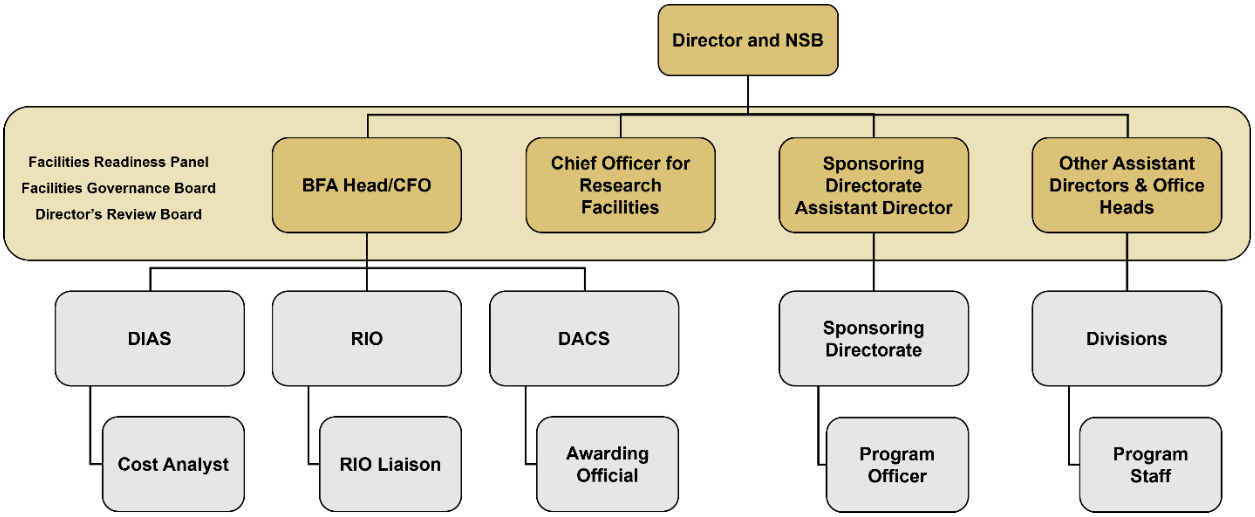
- **Facilities Readiness Panel.** Chaired by the CORF, the Facilities Readiness Panel advises the NSF Director on project and programmatic readiness for advancement of proposed Major Facility projects within the Design Stage. This includes the transition from the Final Design Phase to the Construction Stage. Decisions on readiness to enter the Design Stage and whether to include a proposed project in a future budget request are strategic decisions made separately.
- **Facilities Governance Board.** Chaired by the CORF, the Facilities Governance Board makes recommendations to the NSF Director on all aspects of strategy and governance of Major Facility and Mid-scale RI projects and programs. This review includes significant NSF guidance documents and procedures as well as competition, renewal, and disposition recommendations.
- **Director's Review Board.** Comprising senior representatives from Directorates and Offices, the Director's Review Board reviews materials associated with all topics to be submitted to NSB, including Major Facilities and Mid-scale RI awards and activities above certain funding thresholds.

Finally, there are entities also shown in Figure 2.1.3-1 NSF Organization Chart of Policy and Approval Bodies for Major Facilities and Mid-scale RI that set NSF policy and that approve the advancement, funding requests, and obligation of funds for the construction and operation of Major Facility projects and Science Support Programs.

- **NSF Director.** Responsible for the implementation of NSF policies and practice for agency oversight of RI, and for proposing new Major Facility projects to the NSB, the Office of Management and Budget (OMB), and Congress.
- **National Science Board.** NSB advises on strategic-level agency policy for RI, and reviews NSF's proposed advancement of Major Facility projects, including budget requests and Construction Stage awards. The NSB also provides guidance to the NSF Director on Operations Stage awards that are above certain cost thresholds. By statute, all projects funded from the Major Research Equipment and Facilities Construction (MREFC) account require NSB authorization.

Figure 2.1.3-1

NSF Organization Chart of Policy and Approval Bodies for Major Facilities and Mid-scale RI Indicated in Gold.[1]



[1] Refer to Table 2.3.4-1 and Table 2.3.4-2 for a mapping of the Panels and Boards to the Major Facility life cycle stage and NSF oversight responsibilities.

2.2 INTERNAL MANAGEMENT PLAN

Section Revision: TBD 2025

Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

The Internal Management Plan is the primary internal agency document that describes how NSF plans, coordinates, and conducts oversight of a Major Facility during the Design, Construction and Operations Stages. The Internal Management Plan is written around an individual facility when in the Design or Construction Stages and either an individual facility or a collection of facilities when in the Operations Stage. The primary purposes of an Internal Management Plan are to:

- Define in detail how NSF will conduct its programmatic and business-related oversight activities, including internal and external reviews and required agency approvals.
- Describe how NSF will manage and mitigate agency-held risks.
- Provide budget and schedule estimates for each life cycle stage including disposition liabilities and lay out a strategy for intra-agency coordination.
- Describe any necessary deviations from NSF policies and procedures based on the technical nature of the project or Science Support Program, partnership agreements, or the identified risks.

The Internal Management Plan is considered a living document that is first developed by NSF during the Design Stage, normally the Conceptual Design Phase, and is used until final disposition decisions are made. The Internal Management Plan is updated at transition points between project life cycle stages, or as often as needed, to adjust review criteria and NSF decision points. These updates include refined strategies for renewal or competition and any plans for major upgrades or a technology refresh.

An Internal Management Plan is not required for individual Mid-scale RI projects. In accordance with NSF policy on financial assistance, Mid-scale RI funding programs are required to have a management plan that describes how the overall program, not the individual awards, will be executed and overseen. Mid-scale RI programs awarded through contracts may develop the equivalent of a management plan through the normal acquisition planning process.

2.3 MAJOR FACILITY PROCESS INTRODUCTION

Section Revision: TBD 2025

Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

This section describes the Major Facility life cycle as well as the major activities conducted by NSF and the Awardee during each life cycle stage. Although certain steps and approvals are required, flexibility exists in how each stage is implemented to accommodate the level of prior investment by the funding partners, the technical nature of the project, and the methods used to mitigate risks. Application of these flexibilities should be discussed with the PO before proposal submission and eventually documented in the Design Execution Plan (DEP), the Project Execution Plan (PEP), and the Annual Work Plan (AWP), as appropriate.

2.3.1 Major Research Equipment and Facilities Construction Account

As stated in Chapter 1 Introduction, NSF can fund Major Facilities and Mid-scale RI from various funding accounts, but typically either the MREFC or the Research and Related Activities (R&RA) accounts are used. In 1995, Congress created the Major Research Equipment (MRE) account which provided funding to establish major science and engineering infrastructure projects using *no-year* funding, meaning that funding could be carried over between fiscal years (FY) until expended. The existence of reliable, long-term appropriations funding enables NSF to maintain partnerships and to prevent cost overruns due to schedule delays. The MRE account was renamed the MREFC account in 2005, but the intent is the same. In accordance with legislation, the MREFC account is intended to:

- Provide a dedicated account specifically for acquisition, construction and commissioning of Major Facilities and other infrastructure projects, including major upgrades to Major Facilities.
- Prevent large periodic obligations from distorting the R&RA budgets of NSF Directorates and their Divisions/Program Offices.
- Ensure the availability of funding to complete large projects that are funded over multiple years.

For Major Facilities, the MREFC account is specifically for the Construction Stage. It cannot be used to support Awardee activities related to the Development, Design, Operations or Disposition Stages as defined in this *Guide*. With Congressional approval, MREFC funding can be used for activities related to construction, acquisition, commissioning, and other forms of implementation of Mid-scale RI projects. NSF has used this flexibility, working with Congress, to create dedicated Mid-scale RI programs within the MREFC account.

The MREFC threshold is set by internal NSF Policy (see Section 1.4.2 Major Research Equipment Facilities Construction Threshold).

2.3.2 Eligibility for MREFC Funding

To be eligible for consideration for MREFC funding, each candidate Major Facility project should represent an outstanding opportunity to enable scientific research, spur innovation, support education, and benefit society. Candidate Major Facility projects should also anticipate developing transformative knowledge that has the potential to shift existing paradigms in scientific understanding, engineering processes, and technology. Moreover, each should serve the highest priority research and education needs that will persist well beyond the often-lengthy processes associated with the Development and Design Stages.

In addition, a candidate Major Facility project should:

- Be consistent with the goals, strategies, and priorities of NSF.
- Establish a long-term capability accessible to an appropriately broad community of users
- Require large investments for construction/acquisition, over a limited period, such that the project could not be supported within one or more NSF Directorate(s)/Office(s) without severe financial disruption of their portfolios of activities.
- Have received strong endorsement, based on a thorough external assessment of scientific merit, broader societal impacts, and prioritization within the relevant science and engineering communities.
- Be of sufficient importance that the sponsoring organization is prepared to fully fund the costs of pre-construction planning, design and development, eventual operation and maintenance (O&M), and associated programmatic activities with full awareness of the magnitude of the long-term operations and eventual disposition costs.
- Have been coordinated with partners to ensure complementarity and integration of objectives and potential opportunities for collaboration and cost sharing.
- Be technically feasible with a defined scope and a credible, risk-adjusted cost and schedule.

Mid-scale RI projects funded through the MREFC account are expected to meet the expectations outlined above, except where superseded by criteria described in a funding announcement. Eligibility for MREFC funding for any Mid-scale RI program will be determined by NSF in advance and specific review criteria will be described in the funding announcement, if used.

2.3.3 Major Facility Life Cycles

The purpose of this section is to give an overview of the five NSF life cycle stages. Each stage is expanded upon in the text further below in this chapter. For purposes of NSF oversight, the Major Facility life cycle is characterized by the following five consecutive stages:

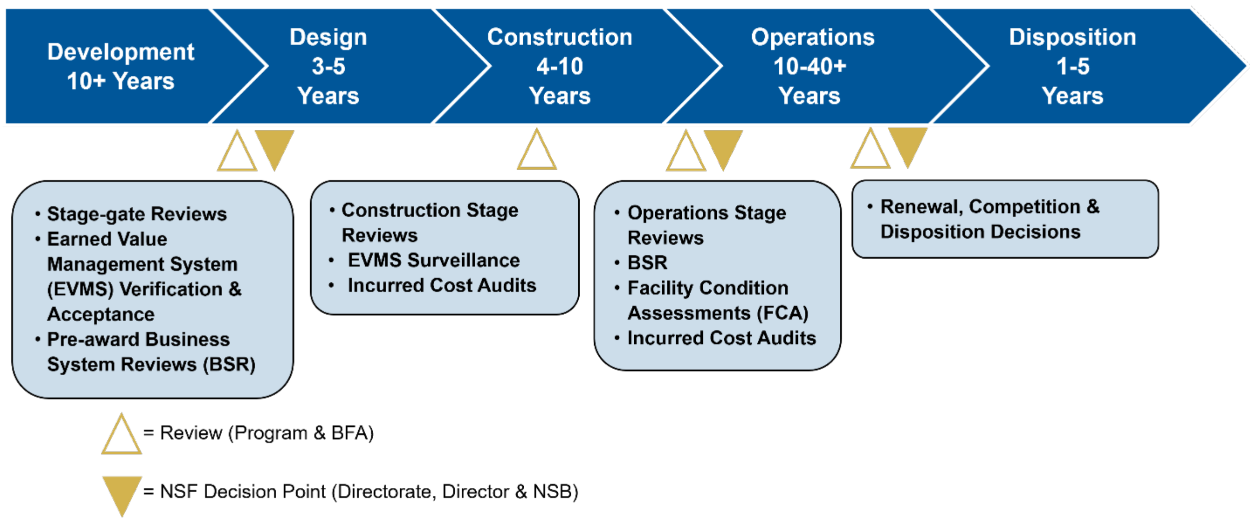
- Development
- Design
- Construction
- Operations
- Disposition

Each life cycle stage involves different activities as well as certain actions by NSF and the

Awardee that are necessary to advance the project to the next stage. These activities include budget development, proposal review, internal NSF reviews and approvals to either advance or request funding, and the creation of awards to support the proposed activities. Descriptions of what is carried out during each stage, and criteria for entry and exit from each stage, are described below, including the required documents and deliverables that are discussed in detail in each life cycle stage section. A high-level graphic of the progression through the stages is given below in Figure 2.3.3-1.

Figure 2.3.3-1

Progressive Steps in the RI Life Cycle Illustrating High-Level Review and Decision Points for Exit and Entry; the Design Stage is Broken Down Further into Phases



2.3.3.1 Development Stage

> **Key Takeaway**
>
> Approval of transition from Development Stage to the Design Stage does not imply a commitment to advance any project to the Construction Stage.

The Development Stage is where initial ideas from the science and engineering community emerge, and a broad consensus is built around the long-term needs, priorities, and general requirements for a new or significantly upgraded Major Facility. Investments in the Development Stage by NSF, other government agencies, or private interests can be focused or sporadic, but annual investments are usually smaller than in the Design Stage. Investments are typically focused on studies, workshops, evaluating potential partnerships, setting priorities across a broad landscape of potential users, developing rough order of magnitude cost estimates and rudimentary schedules, as well as technology development or prototyping. This stage can last ten years or more and the cumulative investment over this period can be quite substantial.

Transition from the Development Stage to the Design Stage can be challenging to navigate because it requires the Sponsoring Directorate to make a strategic decision about the priority of one project among many concepts that it is nurturing. In doing so, the Directorate should carefully consider not only the importance of a proposed project to the research community, but also the landscape of partnerships, federal and other funding, and risk. To exit from the Development Stage, the Sponsoring Directorate sends a memorandum to the CORF recommending that a project is ready to enter the Design Stage, normally at the beginning of the Conceptual Design Phase. If entrance is proposed at a later phase in the Design Stage, the recommendation should be to enter prior to the stage-gate review that aligns with the technical readiness of the proposed project so that the review can be officially conducted in support of subsequent agency decision making (see Section 2.5 Major Facility Design Stage).[1] Depending on the point of entry, the CORF may conduct a senior leadership review focusing on strategic agency, interagency, and science community issues prior to making a recommendation to the NSF Director. The NSF Director may elect to consult with NSB prior to acting on the recommendation. Approval of transition to the Design Stage does not imply a commitment to advance the proposed project to the Construction Stage since numerous decision points that could end NSF's involvement in the proposed project (*off-ramps*) exist within the Design Stage.

2.3.3.2 Design Stage

The Design Stage is where detailed, risk-adjusted cost estimates, credible schedules, technical specifications and drawings, and project management processes are developed by the Awardee and reviewed by NSF. This is also the stage where budget requests to Congress are considered, partnerships are formalized, and decisions are made to obligate construction funding, if appropriated. The technology needed to construct RI may be uncertain, unproven, or immature, requiring substantial refinement over a period of years. Entrance into the Design Stage occurs following approval by the NSF Director and when the Sponsoring Directorate obligates the necessary funding, following approval from the NSF Director, to further refine the estimated scope, schedule, and cost. Although there is no prescribed timeline, this stage typically lasts four to five years.

The cumulative pre-construction investment that occurs during the Design Stage can range from five to twenty-five percent of total construction cost, depending on the complexity of the proposed project, but amounts to about ten percent of the construction cost. The awards for the Design Stage may be solicited or unsolicited.

Proposed projects may encounter *off-ramp* decision points that remove them from the Design Stage due to:

- Decrease in priority over the long term, or eclipse by other proposed projects.
- Failure to satisfy milestones or other criteria defined in the DEP or NSF's Internal Management Plan.
- Collapse of major external agreements.
- Extensive estimated or actual cost increases.

[1] A stage-gate review is a structured decision point at the end of a life cycle stage, where stakeholders evaluate the project's performance against its plan to determine if it should proceed to the next stage, be modified, or be terminated. This process ensures that each stage aligns with the overall project objectives before advancing.

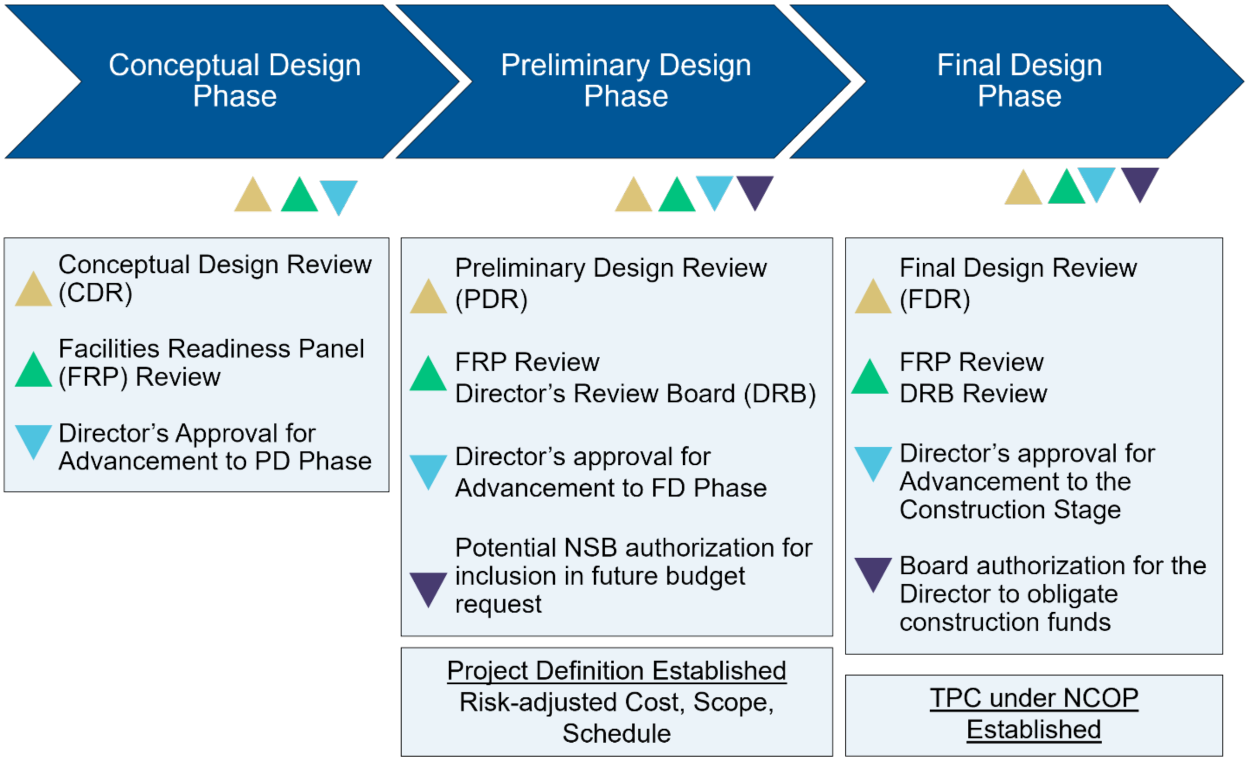
- Significant changes in schedule for design readiness or eventual construction.
- Unexpected technical challenges.
- Changes in the research community indicating eroding support for the project.
- Any other reason the Director deems sufficiently well-founded.

> **Key Takeaway**
>
> Successful completion of any stage-gate review does not guarantee advancement to the next phase.

As shown in Figure 2.3.3.2-1 below, the Design Stage is divided into three phases: Conceptual Design, Preliminary Design, and Final Design. Each Design phase is managed by the Awardee following the DEP and culminates in a rigorous NSF review of the developing and progressively elaborated PEP to ensure technical and project management readiness for advancement to the next design phase or into the Construction Stage. The document package submitted for each stage-gate review should include an updated DEP that includes a proposed budget for the next phase of the Design Stage to support an award, if approved for advancement. There is no prescribed length for any of the Design Phases. The duration of the Conceptual Design Phase and entrance to the Design Stage itself depend on the level of investment during the Development Stage and the project's technical maturity. The minimum duration of the Final Design Phase is set by the federal appropriations process, specifically by the time between submission of a Budget Request and appropriation of funding for a particular FY.

The Awardee's successful completion of the current phase is necessary for advancement to the next phase, but completion of any phase is not the sole guarantor for advancement to a subsequent phase. NSF decision making following each stage-gate review is always a potential off-ramp for the proposed project.

Figure 2.3.3.2-1
Progressive Phases Within the Design Stage Illustrating Review and Decision Points and NSF Award and Budgeting Authorization



Conceptual Design Phase. During this phase the technical requirements are refined, feasibility is determined, and risks are mitigated, often through the development and testing of prototypes, if not done during the Development Stage. By the end of this phase, the estimated costs are parametric in nature (i.e., based on proportional comparisons to similar projects or project components), there is a notional Integrated Master Schedule (IMS) with a Critical Path based on major milestones, and a rudimentary risk analysis. The primary deliverables for the Conceptual Design Review (CDR) are an updated and progressively elaborated PEP along with an estimated cost and DEP for the Preliminary Design Phase. The NSF cost analysis is conducted primarily to give the Awardee additional guidance on refining the bottom-up cost estimate needed for the Preliminary Design Review (PDR). This phase ends with either a decision to off-ramp the proposed project or an approval by the NSF Director to advance and an award for the Preliminary Design Phase.

Preliminary Design Phase. During this phase, the Project Team produces a bottom-up cost estimate, a near-final proposed scope, and a robust schedule (together known as the Performance Measurement Baseline [PMB]), as well as a risk analysis of sufficient maturity to inform the risk-adjusted Total Project Cost (TPC) necessary to request construction funding. A FY for construction start is assumed and required annual funding increments are developed to inform a potential budget request to Congress. The primary deliverables for the PDR are an updated PEP along with an estimated cost and DEP for the Final Design Phase.

The NSF cost analysis, including an Independent Cost Estimate (ICE), is conducted to inform NSF's budget request to Congress.

This phase ends with either a decision to off-ramp the proposed project or an approval by the NSF Director to advance and an award for the Final Design Phase. Inclusion in a future budget request to Congress is a strategic agency decision made separately from the decision to advance, the latter being based on technical and project management readiness. In other words, a proposed project can advance to the Final Design Phase without a decision on budget inclusion being made. An assessment of a proposed project's priority relative to other proposed projects in the Design Stage, as well as a thorough consideration of potential risks and opportunities, along with other factors, informs the agency's decision to move forward with a budget request to Congress.

Final Design Phase. During this phase, the final construction-ready design and PEP are produced and the risk-adjusted TPC for the Construction Stage is confirmed to be within the amount requested from Congress. The Awardee further refines the Project Definition (scope, schedule, cost, and Key Performance Parameters [KPP]) and the PEP submitted at PDR and also demonstrates that project planning and management processes meet NSF requirements for readiness to receive funding and begin construction. The Final Design Review (FDR) can also incorporate events or conditions that were unforeseen when the PDR was conducted. This phase ends with either a decision to off-ramp the proposed project or an approval by the NSF Director, in consultation with NSB, to make a Construction Stage award.

These progressive stage-gate reviews, CDR, PDR, and FDR (see Section 2.5 Major Facility Design Stage) are conducted via external panels of scientific, technical, and project management experts. The panel advises NSF on the sufficiency of progress made during the respective design phase and the technical readiness to advance to the next phase, including project management capabilities of the Awardee's team. NSF uses the findings and recommendations from the external review, together with in-house financial and business-related analyses, as appropriate to the phase, as input to an internal NSF review by a Facilities Readiness Panel. The Facilities Readiness Panel makes a recommendation to the NSF Director on a proposed project's readiness for advancement.

For proposed projects that have received previous development and design funding from NSF, other agencies, or private sources, a Sponsoring Directorate can propose entrance to the Design Stage at the CDR (bypassing the Conceptual Design Phase), or the PDR (bypassing the Preliminary Design Phase) based on the technical maturity of the proposed project. The PDR is the latest point at which a proposed Major Facility project can be considered a candidate for funding since passing this design review is a requirement for consideration of inclusion of the proposed project in a future budget request. The Final Design Phase **must** always be conducted.

2.3.3.3 Construction Stage

The Construction Stage begins when funds are obligated for the acquisition and/or construction of the Major Facility in accordance with the terms and conditions of the award(s). The award amount sets the TPC used by NSF under the No Cost Overrun Policy ([NCOP], see Section 1.4.7 NSF No Cost Overrun Policy). The Construction Stage typically lasts four to ten years depending on the technical nature, scale, and complexity of the project. This stage has the most stringent requirements for monitoring an Awardee's performance in managing the scope, schedule, and budget against the proposed plan, for reporting progress to NSF and other partners, and for the use of other award oversight mechanisms by NSF. Progress is reported against the approved PMB described in the Awardee's revised PEP, submitted following FDR. The project status is reviewed periodically by NSF and any other funding partners, generally annually, to assess whether the Project Team is capable of finishing it within budget and on schedule and what corrective actions, if any, might need to be taken. The Construction Stage normally includes activities, such as commissioning and testing, to transition the Facility into the Operations Stage. This stage ends after delivery and acceptance of the defined scope of work and an initial assessment of a Facility's performance against the Key Performance Indicators described in the PEP. Some Major Facilities may not achieve full performance capabilities until initial operations.

Although the Awardee for the Construction Stage assumes responsibility for initial operations, this is not a requirement.

2.3.3.4 Operations Stage

The Operations Stage includes the day-to-day activities needed to operate and maintain the various pieces of infrastructure associated with the Major Facility and to support scientific research. The term O&M is often used, both of which require strong Awardee management capabilities. Operations Stage awards may encompass one Major Facility or several and may also include Mid-scale RI. This collection of RI may also be designated as a Federally Funded Research and Development Center (FFRDC) if certain conditions are met. How the award(s) is structured depends on the nature of the Science Support Program and the award instrument(s) used. The Operations Stage typically lasts 20-40 years, the total cost of which often greatly exceeds the cost of construction (see Section 3.6 Operations Stage Planning).

During the Operations Stage, the Major Facility is actively collecting, processing, and distributing data for use by the science community. The Concept of Operations (ConOps) Plan, as described in Section 3.5.10.2 PEP Subcomponent 10.2 – Concept of Operations Plans, is refined during the Construction Stage (including robust O&M cost estimates and the proposed governance model) is finalized in preparation for entering the Operations Stage and used to inform the first AWP. Initial operations may include activities necessary to complete the transition from construction to full operational capability. During the lifetime of the Major Facility, activities will include routine refurbishment, recapitalization, and/or technical refresh, and may also include major upgrades. The Operations Stage will eventually include activities that support the transition of the Facility to the Disposition Stage.

During the Operations Stage, NSF conducts periodic reviews that assess the performance of the infrastructure and the Awardee(s). These reviews use external panels to make recommendations that inform NSF oversight as well as periodic internal NSF decisions on continued investment, either through award renewal or competition, or disposition.

2.3.3.5 Disposition Stage

The decision to enter a Major Facility or significant RI components of the Science Support Program into the Disposition Stage is made when NSF, with input from the scientific community, determines that the Major Facility is no longer a priority for NSF investment. Disposal of equipment or system components as part of end-of-service life upgrades or instrument replacements associated with periodic technology refreshes are not considered entering the Disposition Stage, but rather routine property maintenance activities under the award. The Disposition Stage is commonly associated with significant government action, mainly when related to deconstruction (see Section 5.4 Environmental Considerations).

The disposition decision can occur at any time during the Operations Stage. Although the decision may occur after the Science Support Program's primary goals have been achieved, it takes place after many years of operations to maximize the science output. Disposition options include transfer to another entity's operational and financial control (with or without reduction in project scope) or decommissioning. This last option may include complete removal of the infrastructure and site restoration. NSF periodically assesses the plan for eventual disposition as part of Operations Stage reviews, Advisory Committee reviews, or other internal assessments. The first high-level version of this plan is developed as part of the Construction Stage PEP, but it is refined as the Major Facility nears the Disposition Stage.

Entrance into the Disposition Stage occurs when an award is made to cover the costs of decommissioning, deconstructing, or transitioning the Major Facility to its new role. Transitioning from the Operations Stage to the Disposition Stage usually takes the form of an award that ramps down NSF's investment over the award duration with the expectation that no further operations award from NSF will be forthcoming.

2.3.4 Major Facility Execution Process Summary

NSF supports scientific investigation at the frontiers of human knowledge, where the necessary technologies and methodologies are often not firmly established. The agency is also responsible for nurturing the various science and engineering disciplines that it supports. As a result, the various project life cycle stages may best be achieved through the expertise of different organizations such as educational institutions, non-profits, or the private sector (industry) depending upon the technical nature of the RI and the award instrument selected. For example, NSF may provide researchers the funding sufficient to develop compelling research agendas, to refine and prioritize their technical requirements, and to complete research and development on prototypes and other needed technologies, without assuming those researchers will have a direct role in managing either construction or operations. Following successful research and development by scientists and engineers, the entire project may then be further designed and constructed through an award made directly to a competent managing organization, including industry.

As the diagrams in Table 2.3.4-1 and Table 2.3.4-2 indicate, the typical process for pre-construction development and design for a proposed Major Facility project progresses through a sequence of stage-gates with increasing investment, planning, assessment, oversight, and assurance. These stage-gates help ensure that the technical evolution of a proposed project is coordinated with science community needs and NSF requirements, increasing the likelihood that it will qualify for funding of continued planning and eventual construction.

Table 2.3.4-1

Summary Timeline for Proposed Major Facility Projects in the Development and Design Stages

	Development Stage	Conceptual Design Phase		Preliminary Design Phase		Final Design Phase
Budget Evolution	Preconstruction Planning (Typically R&RA Funded)					
	Expend ~5-25% of construction cost on Design Stage activities					
	Initial ROM construction estimate			Develop bottom-up, risk-adjusted TPC to support potential budget inclusion		OMB/Congress negotiations on proposed project and budget profile
	Design Execution Plan (DEP)					
Project Evolution	Initial ideas emerge Broad science community consensus built for potential long-term needs, priorities, and general requirements Develop DEP for Design Stage proposal	Define & prioritize science requirements Develop conceptual project definition Identify critical technologies, high-risk items Formulate initial risk assessment Develop top-down parametric cost and contingency estimates Estimate O&M costs Initial PEP for CDR Refine DEP and estimates for PD Phase		Develop site-specific, preliminary project definition Environmental assessments/impacts Develop enabling technologies Bottom-up cost and contingency estimates, updated risk analysis Develop Project Management Control System Refine O&M cost estimate Revise PEP for PDR Refine DEP and estimates for FD Phase		Verify key technologies are ready for production or detailed production design Refine and confirm bottom-up cost and budget contingency estimates Finalize Risk Assessment & Risk Management Plan Finalize scope and schedule contingencies Complete key staff recruitment Revise PEP for FDR
	NSF Internal Management Plan & Business Processes					
Program & BFA Oversight	PO interface with the research community to support concepts for development Recommendation that a proposed project advance to the Design Stage [Apply 1st and 2nd ranking criteria] Review DEP for Design Stage award	IPT formed Develop IMP Assessment of NSF risks & opportunities Foster international and interagency participation Conceptual Design Review (CDR) CDR Cost Analysis Review DEP for PD Phase award	NSF Director approves Preliminary Design phase	Preliminary Design Review (PDR) Begin EVMS Verification PDR Cost Analysis to inform potential budget request Project Definition established – Risk-adjusted cost, scope and schedule Environmental assessments/impacts (NEPA) Review DEP for FD Phase award	NSF approves submission to NSB	Finalization of interagency and international requirements & agreements Final Design Review (FDR) FDR Cost Analysis - informed by an Independent Cost Estimate (ICE) if not done at PDR Complete EVMS Verification and possible Acceptance Estimating and Accounting System audits
NSF Strategic Review	Internal NSF review regarding advancement to the Design Stage NSF Director approval to Enter the Design Stage [Apply 3rd ranking criteria]	Facilities Readiness Panel Review NSF Director approval for advancement to PD Phase		Facilities Readiness Panel Review DRB Review NSF Director approval for advancement to FD Phase NSF authorization for inclusion in a future budget		Facilities Readiness Panel Review DRB Review NSB authorizes NSF Director to make a Construction Stage award NSF Director approves advancement to construction stage

Table 2.3.4-2

Summary Timeline for Major Facility Projects and Science Support Programs in the Construction, Operations, and Disposition Stages

<table>
<tr><th rowspan="3">Budget Evolution</th><th colspan="2">Construction Stage</th><th>Operations Stage</th><th>Disposition Stage</th></tr>
<tr><th colspan="2">MREFC or R&RA funds</th><th>R&RA</th><th>R&RA</th></tr>
<tr><td colspan="2">Initial ROM construction estimate</td><td>Annual budget planning for O&M</td><td>Targeted appropriations, as needed</td></tr>
<tr><td>Project & Science Support Program Evolution</td><td colspan="2">Execute project per Project Definition, PEP and award terms and conditions
Refine operations budget and develop first Annual Work Plan (AWP) based on Concept of Operations Plan in PEP</td><td>Execute Science Support Program per AWP and the award terms and conditions
Conduct periodic Facility Condition Assessments (FCA)
Periodically revise Disposition Stage plans</td><td>Execute Disposition Plan</td></tr>
<tr><td colspan="5">NSF oversight per Internal Management Plan & NSF Business Processes</td></tr>
<tr><td>Program & BFA Oversight</td><td rowspan="2">Congress appropriates funds</td><td>Review periodic project status reports
Construction Stage reviews
EVMS Surveillance reviews
Site visits
Approval for use of contingencies above established thresholds
Incurred Cost Audits</td><td>Review periodic financial and progress reports
Operations Stage Review
Site visits
NSF Cost Analysis – informed by an independent cost assessment
Accounting System Reviews
Business Systems Reviews
Incurred Cost Audits
Renewal, competition and disposition decisions</td><td>Review of decommissioning and/or disposal of facility assets and environmental obligations</td></tr>
<tr><td>NSF Strategic Review</td><td>Office of the Director's Watch List, as needed
NSF authorization for re-baselining that exceeds Director's delegated authority</td><td>Office of the Director's Watch List, as needed
DRB review of Renewal, Competition and Disposition packages going to the NSB
NSF authorization for awards that exceed thresholds
NSF Director approval of O&M award</td><td></td></tr>
</table>

Although all Major Facilities progress through the five life cycle stages, there are appropriate alternate approaches to the Development and Design Stages, such as funding through another agency or a private entity, and alternate approaches to upgrades during the Operations Stage.

Facilities at the leading edge of scientific endeavor are always in motion. It is not uncommon for Major Facilities to be in an almost continuous state of technical refresh or upgrade following the transition to operations. Therefore, selecting the appropriate management model and structure that matches the proposed activities is vital. Guidance is provided in Section 3.2.1.1 Traditional Waterfall Approach and 3.2.1.2 Cyclical Approach, and 5.9 Agile Guidance on selecting and tailoring the appropriate management method.

NSF upholds the principle that flexibility in managing Major Facility projects does not compromise the rigor of the agency's evaluation process. Every Major Facility project, proposed or otherwise, regardless of its specific nature or unique aspects, is held to the highest standards of review and technical assessment, ensuring quality and accountability throughout the process. The approach used by NSF and the Awardee to monitor performance should be identified early in either the Development Stage and documented in the Design Stage proposal as part of the DEP and eventually in the PEP, as well as in NSF's Internal Management Plan (see Section 2.2 Internal Management Plan). Proposing organizations should discuss the approach envisioned with the cognizant NSF PO.

2.4 MAJOR FACILITY DEVELOPMENT STAGE

Section Revision: TBD 2025

Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

2.4.1 Proposed Major Facility Project Initiation and Development

As with many NSF endeavors, inquiry begins with the research communities, whose members alert NSF program staff to the most promising and exciting questions and the most critical equipment, facilities, and infrastructure needed to explore them. The NSF PO monitors the emergence of breakthrough concepts and actively encourages discussion and planning within the science community and across NSF. In addition, NSF uses National Academies' studies, community workshop reports, professional society activities, Directorate advisory committees, and many other methods to identify opportunities and ensure continuous community input.

Ideas and opportunities identified by the research communities look well into the future and are brought to NSF in the form of proposals requesting funding to imitate and/or continue development activities. Considerations for the award might include:

- Disciplinary trends and identified community priorities.
- Transformative opportunities to advance science.
- The portfolio balance between research infrastructure and science within the Directorate or Division.
- Availability of funds.

If a Sponsoring Directorate intends to propose a project for entrance into the more formal Design Stage, then there should be adequate investment during the Development Stage such that the proposed project is sufficiently well defined and at a level of technical maturity that justifies entrance at the appropriate phase of Design.

2.4.1.1 Development Stage Oversight and Reporting

POs are solely responsible for most oversight activities during the Development Stage, including conducting NSF merit review under financial assistance, recommending awards, and monitoring post-award progress, including attendance at workshops and other engagements funded under the award. Any required deliverables and reporting will be in accordance with the terms and conditions of the award.

2.4.1.2 Development Stage Exit

Exit from the Development Stage occurs once the NSF Director approves a proposed project's entry to the Design Stage. This process is initiated by a request from the Sponsoring Directorate to the CORF in the Director's Office once a proposed project is determined to be ready to advance and its state of technical readiness, which determines where it should enter the Design Stage, is understood. Such a request is made when the Sponsoring Directorate has determined the following.

- The proposed project is a high priority for the scientific community and NSF, and includes showing that:
    - The proposed project's science (research) program will address one or more science objectives, clearly demonstrating a compelling need for the project.
    - The proposed project has been evaluated by the research community and by NSF, in consultation with Directorate Advisory Committees as appropriate, and has been assigned a high priority.
- The Sponsoring Directorate commits to invest in more detailed design activities using the Directorate or Division funding.

Regardless of where the proposed project is recommended to enter the Design Stage, whether CDR or PDR, the formal written request is submitted to the CORF who makes a recommendation to the Director with input from the Facilities Governance Board and other senior agency officials. Based on CORF recommendations and other considerations, the Director then either approves or disapproves the proposed project to enter the Design Stage as a candidate Major Facility project.[1] The CORF or NSF Director might alternatively advise the Sponsoring Directorate to look further into any issues identified and return them for further consideration by the Office of the Director. If approved, no further NSF commitment is implied beyond the Design Phase recommended.

[1] Major Facilities are defined by their cost to construct or acquire, as described in Section 1.4 Applicable Legislation and NSF Policy, not the account from which they are funded. The Sponsoring Directorate may propose the use of Major and Mid-scale Equipment and Facilities Construction (MREFC) funding based on the criteria in Section 2.3.2 Eligibility for MREFC Funding, or Directorate funding. Major Facility oversight requirements are the same, regardless of the funding account.

2.5 MAJOR FACILITY DESIGN STAGE

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Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

The Design Stage is divided into three phases, including the Conceptual Design Phase, Preliminary Design Stage, and the Final Design Stage. However, a proposed project can enter the Design Stage as late as the PDR based on technical readiness for advancement coming out of the Development Stage. The following sections describe in more detail the goals, oversight requirements, and exit criteria for each phase.

2.5.1 Conceptual Design Phase

The goal of this first phase of the Design Stage is the creation of a comprehensive conceptual design that clearly articulates various project elements that NSF will evaluate when considering advancement to the Preliminary Design Phase. These include:

- A description of the RI and technical requirements needed to meet the objectives of the science community or NSF, including a definition and relative prioritization of the research objectives and science questions the proposed project will address. Technical requirements **must** flow down from the science requirements.
- A system-level design, including a definition of all functional requirements and major systems.
- The concept for eventual operations including an initial estimate of annual O&M costs, a range of staffing levels, potential governance models, and other science support activities.
- An initial risk analysis and mitigation strategy for the Construction Stage, identifying enabling technologies, high-risk or long-lead items, and research and development activities needed to reduce project risk to acceptable levels.
- Initial acquisition strategies that address any unique project considerations, technical risks, and uncertainties, such as evolving technologies or design activities that would continue into the Construction Stage.
- Potential environmental and safety impacts to be considered in site selection (see Section 5.4 Environmental Considerations). These may be site-independent, site-specific, or include multiple proposed sites depending on the technical nature and maturity of the proposed project.
- The first iteration of the Project Definition to evaluate technical readiness. This includes budget contingency estimates appropriate to a conceptual design level of maturity that are based on the initial risk analysis and projections for the construction and commissioning schedule (see Sections 4.3 Cost Estimating and Analysis and 4.4 Schedule Development, Estimating, and Analysis).
- A description and proposed cost for the activities to be conducted during the Preliminary Design Phase, if approved for advancement.

During the Conceptual Design Phase, there may be several coordinated and complimentary activities taking place with the Awardee and NSF as shown in Table 2.3.4-1. The Awardee focuses on executing the activities under the award in accordance with the DEP and the award terms and conditions, with the primary deliverable being a revised PEP for presentation at the CDR. NSF forms the IPT and conducts oversight in accordance with the Internal Management Plan.

2.5.1.1 NSF Oversight and Conceptual Design Review

NSF oversight during the Conceptual Design Phase involves monitoring progress against the latest DEP and terms and conditions of the award. The Core IPT is formed at this point, if not done so already. NSF staff on the Core IPT typically attend periodic weekly Project Team meetings and provide appropriate guidance to enable the Project Team to progress toward and prepare for CDR. Formal, monthly written project reports are typically required by the award terms and conditions, which NSF also uses to monitor progress. Use of Earned Value Management (EVM) is not required during the Design Stage, but depending on the complexity of the proposed project, the activities being conducted during the Design Stage, and the desire of the Awardee to build EVM capacity in preparation for the Construction Stage, it may be considered advantageous. Based on progress, NSF may hold an interim review, either using an external panel or NSF staff only, to provide more formal recommendations to the Project Team.

The Conceptual Design Phase culminates in a CDR, where the revised PEP, along with a revised DEP for at least the Preliminary Design Phase, is submitted for NSF review. NSF subjects the CDR package to external review, applying appropriate NSF review criteria based on the award instrument as given in the panel charge.

At CDR, the Project Definition is likely to have significant uncertainties. Cost estimates are commonly parametric in nature. Contingency estimates, representing work scope not yet fully defined but nevertheless essential to the completion of the proposed project, will be a significant fraction of the total project budget estimate. Significant unknowns and uncertainties often remain which will need to be addressed as the design advances. Nevertheless, the system requirements, supporting budget estimates, risk analysis, and forecasts of interagency and international participation should be detailed enough for NSF to assess whether the proposed project warrants further funding.

In conjunction with the CDR, an initial high-level NSF Cost Analysis will be conducted (see Figure 4.3.1-1). This analysis provides the Awardee with guidance on further refining the cost and contingency estimates to meet NSF requirements during the Preliminary Design Phase if approved for advancement. NSF will also conduct the necessary cost analysis of the Preliminary Design Phase proposal, which is based on the latest DEP.

2.5.1.2 Conceptual Design Phase Exit

Exit from the Conceptual Design Phase requires:

- Successful completion of the CDR and a recommendation for advancement by the Sponsoring Directorate.
- Facilities Readiness Panel review and recommendation to advance.
- Approval of advancement to the Preliminary Design Phase by the NSF Director.
- Sufficient funding and an award to support the Preliminary Design Phase in accordance with the revised DEP.

2.5.2 Preliminary Design Phase

The goal of the Preliminary Design Phase is to refine the Project Definition to a point where there is a complete set of KPP to meet science objectives. It should include a clearly defined site-specific scope (excluding mobile platforms), a PEP, and an NSF Internal Management Plan that address anticipated risks during design and construction. Additionally, it requires a realistic cost estimate, based on identified risks, which can be confidently presented to the NSF Director, NSB, OMB, and Congress for consideration for inclusion in a future NSF budget request to support the Construction Stage.[1]

During the Preliminary Design Stage, the design of the proposed project is developed to a preliminary design level of maturity, which means that all significant subsystems and their interconnections are defined, technical specifications and drawings are sufficient to proceed with bid or the development of final construction drawings, and cost estimates are based on vendor estimates or bottom-up engineering estimates. The overall project risk analysis is bottom-up. The Work Breakdown Structure (WBS), Basis of Estimate (BOE), and Resource-Loaded Schedule (RLS) are further refined to reduce uncertainty relative to the earlier conceptual design. The results of these refinements are reflected in the revised PEP. Revisions to the PEP should also incorporate guidance or direction from NSF, which may be informed by CDR panel recommendations and other oversight activities to be conducted during the Preliminary Design Phase. Some activities may be included in the terms and conditions of the Design Stage award. Activities and components of the updated PEP that should receive attention during this phase include:

- Demonstration that key technologies are feasible and can be industrialized if required, plus any updated strategies for managing evolving technologies.
- Environmental Assessments or Environmental Impact Statement, if applicable (see Section 5.4 Environmental Considerations).
- A Scope Management Plan that includes de-scoping options and scope opportunities that can be implemented during construction to augment budget contingency, as necessary.

[1] For guidance on contingency planning refer to Section 4.7 Contingency Estimating and Management. Confidence levels must be in the 70-90% range following PDR depending on the technical nature of the project.

- Implementation of a Project Management Control System and inclusion within the preliminary design of an RLS.[1]
- Updated risk analysis including technical risks, partnership risks, regulatory issues affecting construction, and any risk factors such as inflation, exchange rates and market volatility of commodities beyond what is included in the BOE.
- Updated acquisition plans and timeline, including clear milestones, justification, and risk management considerations for transition to bidding and procurement.
- Governance model for the proposed project during construction, including preliminary partnership arrangements and international participation, oversight of major subawards and contracts, organizational structure, and management of Change Control.
- Updated estimates for future operating costs, anticipated future upgrades, and eventual disposition costs at the end of the Major Facility's service life.
- All costs **must** be in then-year dollars, since Congress typically funds Major Facility projects of multiple years, an annual funding profile capable of meeting project requirements is also provided.

The Awardee also provides a revised DEP, including estimated cost and schedule and any anticipated risks and remaining risk mitigation strategies for the Final Design Phase to inform a potential Final Design Phase award.

2.5.2.1 NSF Oversight and Preliminary Design Review

NSF oversight during the Preliminary Design Phase involves monitoring progress against the latest DEP and terms and conditions of the award. NSF staff on the Core IPT typically attend periodic weekly Project Team meetings and provide appropriate guidance to enable the Project Team to progress toward and prepare for the PDR. The award terms and conditions may require formal, monthly project reports, which NSF also uses to monitor progress. Based on progress, NSF may hold an interim review, either using an external panel or NSF staff only, to provide more formal recommendations to the Project Team.

The Preliminary Design Phase culminates in a PDR, where the revised PEP is submitted for NSF review, along with a revised DEP for at least the Final Design Phase. NSF subjects the PDR package to external review, applying appropriate NSF review criteria based on the award instrument used and as given in the panel charge.

> **Key Takeaway**
>
> The Preliminary Design Review has the most stringent requirements and is the most consequential as it informs a potential budget request to Congress to support the Construction Stage.

At PDR, the Project Definition is based on site-specific bottom-up estimates and alignment

[1] See Figure 4.3.3.3-1 Sample Project Control Systems Relationship Diagram for examples of Project Controls systems inputs and outputs.

with the Government Accountability Office (GAO) good practices is expected. A fully resourced IMS is also expected, with KPP and science requirements clearly defined. The budget contingency estimates should be a lower fraction of the total project budget estimate than seen at CDR, with all significant known risks identified and likelihood and impacts presented along with a statistical risk analysis and proposed confidence levels. Significant unknowns and uncertainties may be minimal, and cost and schedule uncertainties may have decreased since CDR as the design matured. System and sub-system technical drawings and specifications should be available along with preliminary vendor quotes to the maximum extent practicable. The management structure to complete Final Design Phase activities and execute the Construction Stage (if funds are requested and appropriated) should be fully formed, with the credentials of key staff presented. Interagency and international participation should be formalized or on the path to formalization. If more than one site is proposed, the cost for each site and the associated risks **must** be presented. This level of rigor is necessary for NSF to assess whether the proposed project is sufficiently defined to support a budget request to Congress in accordance with the NCOP (see Section 1.4.7 NSF No Cost Overrun Policy), which requires a robust risk-adjusted TPC at PDR.

NSF will use the Awardee's technical drawings and specifications to support the ICE required by statute at the PDR.[1] The ICE is an input to the NSF's second and more detailed cost analysis, which informs the TPC for the Construction Stage used for the budget request to Congress if the proposed project is approved for advancement. NSF will provide guidance to the Awardee on any necessary refinements to the BOE in preparation for the Final Design Phase. NSF also typically uses the Awardee's Project Controls Plans presented at PDR to begin the Earned Value Management System (EVMS) verification process. NSF will also conduct the necessary cost analysis of the Final Design Phase proposal, which is based on the latest DEP.

Depending on the award instrument, NSF may also elect to conduct a pre-construction Business Systems Review (BSR), financial viability review, accounting system audit, or other business-related reviews to ensure the Awardee's processes, procedures, staffing, and tools are suitable to receive a Construction Stage award. Such reviews and audits may also be conducted during the Final Design Phase at the discretion of NSF. Processes, procedures, and staffing are not mature enough during the Conceptual Design Phase to perform these detailed reviews and audits.

2.5.2.2 Preliminary Design Phase Exit

A proposed project exits from the Preliminary Design Phase and enters the Final Design Phase after the following have been completed:

- Successful completion of PDR and support for advancement from the Sponsoring Directorate.
- A review and recommendation by the Facilities Readiness Panel for advancement to

[1] American Innovation and Competitiveness Act (AICA) of 2017, Public Law No. 114-329 (Jan. 6, 2017).

the Final Design Phase.

- NSF Director's approval to advance to the Final Design Phase.
- Award to support the Final Design Phase.

The request for inclusion in a future budget request is commonly associated with advancement to the Final Design Phase. However, advancement to the Final Design Phase may be granted without proceeding with a budget request based on strategic agency considerations.

2.5.3 Final Design Phase

The goals of the Final Design Phase are to develop the construction-ready PEP and confirm that the latest estimated, risk-adjusted TPC is within the budget estimate provided to Congress at a confidence level of 70%–90%. The Preliminary Design Phase PEP is further refined and may incorporate events, conditions, or risks previously unforeseen at the PDR. Revisions to the PEP should also incorporate guidance or direction from NSF, which may be informed by PDR panel's recommendations and other oversight activities during the Final Design Phase, some of which may be included in the terms and conditions of the Design Stage award.

Strategic considerations are not commonly part of the Final Design Phase since they are considered before inclusion in a future budget request to Congress, which may not happen in conjunction with the decision to exit the Preliminary Design Phase. As a result, there is no set duration for the Final Design Phase. However, the first approximation should align with the federal budget process which is a minimum of eighteen (18) months.

Activities and components of the updated PEP that receive particular attention during this phase include:

- Environmental Assessments or Environmental Impact Statement and Record of Decision, if applicable (see Section 5.4 Environmental Considerations).
- Final Project Definition including KPP, bottom-up cost and contingency estimates that are in alignment with GAO good practices as described in Section 4.3.2 Characteristics of a High-Quality Cost Estimate, and a fully integrated RLS that meets GAO good practices as described in Section 4.4.2 Characteristics of a Reliable Schedule.
- Updated Risk Register and risk analysis, including technical risks, partnership risks, regulatory issues affecting construction, and any risk factors such as inflation, exchange rates and market volatility of commodities beyond what is included in the BOE.
- A final Scope Management Plan that includes de-scoping options and scope opportunities that can be implemented during construction to augment budget contingency, as necessary.
- Updated estimates for future operating costs, anticipated future upgrades, and eventual disposition costs at the end of the Major Facility's service life.
- To the maximum extent practicable, final designs, specifications and work packages

can be put out for bid by industry. Depending on the technical nature of the proposed project and the acquisition strategies used, certain bid packages may be timed to coincide with the FDR and remain open until the planned Construction Stage award.

- Industrialization of any key technologies or former prototypes needed for construction.
- Final acquisition plans and timeline for NSF concurrence, including milestone for NSF concurrence on source selection.
- Fully implemented Project Management Control System for project technical and financial status reporting, including EVMS in compliance with EIA-478.
- Mature plans for Quality Assurance and Safety Management during construction and plans for final acceptance.
- Finalization of financial commitments with interagency and international partners for the Construction Stage.
- Refinement of the governance model for eventual operations with any interagency or international partners, the ConOps, and budget estimates for the Operations Stage (including anticipated upgrades) and Disposition Stage, as needed.
- Completing recruitment and hiring of key staff to manage the Construction Stage.

2.5.3.1 NSF Oversight and Final Design Review

NSF oversight during the Final Design Phase involves monitoring progress against the latest DEP and terms and conditions of the award. NSF staff on the Core IPT typically attend periodic weekly Project Team meetings and provide appropriate guidance to enable the Project Team to progress toward and prepare for the FDR. The award terms and conditions typically require formal, written monthly project reports, which NSF also uses to monitor progress. Based on progress, NSF may hold an interim review, either using an external panel or NSF staff only, to provide more formal recommendations to the Project Team.

The Final Design Phase culminates in FDR where the revised PEP is submitted for NSF review. NSF subjects the FDR package to external review, applying appropriate NSF review criteria based on the award instrument as given in the panel charge. Like CDR and PDR, the PO organizes the review in consultation with the RIO Liaison and AO, who provide business and project management related inputs to the panel charge, panel membership, and review agenda.

> **Key Takeaway**
>
> Final Design Review delivers the construction-ready PEP and confirms that the latest risk-adjusted TPC remains within the budget request to Congress at a 70-90% confidence level.

At the FDR, NSF will use the Awardee's technical drawings and specifications to support the ICE required by statute, if not conducted with PDR. If an ICE was conducted at the PDR, NSF may revisit the ICE as an input to the NSF's third and final cost analysis to inform the TPC for the Construction Stage award if the proposed project is approved for advancement. NSF will provide guidance to the Awardee on any necessary refinements to the BOE in preparation for the Construction Stage Award. NSF also uses the Awardee's Project Controls Plan presented at PDR to begin the EVMS acceptance process, which is generally completed complete prior to the start of physical construction in accordance with NSF practice.

2.5.3.2 Final Design Phase Exit

A proposed project exits from the Final Design Phase and enters the Construction Stage after the following have been completed:

- The successful completion of the FDR and support for advancement from the Sponsoring Directorate.
- A review and recommendation by the Facilities Readiness Panel for advancement to the Construction Stage.
- The NSF Director approves advancement and recommends NSB authorization for a Construction Stage award.
- A review of the NSB package by the Director's Review Board.
- NSB authorizes a Construction Stage award.
- NSF makes a Construction Stage award.

2.5.3.3 Approval by NSF Director – Transition to Construction Stage

The Director evaluates the Facilities Readiness Panel recommendation and, if satisfied, recommends to NSB that a Construction Stage Award be authorized. In the event the proposed project's construction estimated TPC or funding profile is determined to be inconsistent with the budget request to Congress or available appropriations, NSF may:

- decrease the scope of the project, or
- justify the increase to OMB and Congress and request additional funding as part of the budget process, or
- cancel (off-ramp) the project.

2.5.3.4 National Science Board Authorization for Construction

NSB reviews the recommendation and, if satisfied, authorizes the NSF Director to obligate funds for a Construction Stage Award(s) at their discretion. If it does not authorize the Construction Stage award, NSB may recommend to the Director that the proposed project remain in the Final Design Phase or that the proposed project be cancelled (off-ramped).

Following the Director's subsequent approval to obligate funds, the final award terms are negotiated between NSF and the Awardee, and the award is made. Construction activities begin in accordance with the PEP, which is normally incorporated by reference in the award terms and conditions.

The authorized TPC establishes the not-to-exceed cost under the NCOP. The practices that NSF uses to implement and manage against the NCOP are described in Section 1.4.7 NSF No

Cost Overrun Policy.

2.6 MAJOR FACILITY CONSTRUCTION STAGE

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Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

2.6.1 Construction Award Management and Oversight

After Congress appropriates funds for the project, NSF can proceed with a Construction Stage award with authorization from the NSF Director. The primary document used by the Awardee to manage the project and for NSF to monitor progress and performance during the Construction Stage is the PEP. NSF's primary oversight tool in controlling costs is the NCOP, as described in Section 1.4.7 NSF No Cost Overrun Policy. The NCOP is intended to instill diligence and rigor in establishing the risk-adjusted TPC with Congress and give NSF a strong oversight position during the Construction Stage.

2.6.1.1 Implementation of NSF's No Cost Overrun Policy

Although the first risk-adjusted TPC is presented to Congress in the initial budget request for a project in accordance with the NCOP, the Construction Stage award establishes the TPC against which the agency implements the policy. Mechanisms for offsetting potential cost increases include, in order of precedence and assuming appropriate use of each mechanism in accordance with NSF policy and practice:

1. Re-planning.[1]
2. Use of budget contingency for known risks.[2]
3. De-scoping in accordance with the Scope Management Plan.
4. Use of management reserve for unforeseen events and agency-held risks, if authorized.
5. Re-baselining and seeking re-authorization of the TPC through either the NSF Director's delegated authority or engaging the NSB in accordance with NSF policy

NSF uses the following practices to implement NCOP:

- The determination of budget and schedule contingencies **must** include a combined cost and schedule risk analysis using Monte Carlo methods and selecting a confidence level in the 70-90% range at the PDR. At the FDR and the award for construction, it is confirmed that the confidence levels remain within this range when compared against the budget request and anticipated appropriations.
- To assess risk exposure, a combined cost and schedule risk analysis using Monte Carlo methods should be rerun at least annually.
- NSF Directorates are responsible for the first 10% of cost overruns that exceed the

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[1] See definition of Re-planning in Chapter 8 Lexicon. Re-planning is nearly continuous on most projects and may include rebudgeting between WBS elements in accordance with the terms and conditions of the award.

[2] This captures the use of schedule contingency since schedule extensions normally have a corresponding cost factored into the budget contingency (see Section 4.7 Contingency Estimating and Management).

authorized TPC, as determined by the NSF Director.

- Identified de-scoping options should have a total value equal to at least 10% of the baseline budget at the PDR.
- Scope opportunities cannot be added after the start of the Construction Stage. The Awardee should anticipate NSF de-obligating any unused funds.
- Although the initial TPC becomes public through the budget request to Congress after the PDR, the TPC under the NCOP is set at the Construction Stage award (post-FDR). This allows for further refinement of the Project Definition during the Final Design Phase.
- NSF will hold budget contingency through project completion, in an amount up to 100% of the total NSF-approved contingency budget, until it can be justified for obligation. NSF will obligate and allocate contingencies based on the needs and performance of the Awardee.
- The overall status of remaining contingency, future liens on contingency, and all allocations and returns of contingency funds (as risks are realized or retired) are reported periodically as specified in the terms and conditions of the award. At a minimum, balances will be monitored against the total NSF-authorized budget contingency and the amount of budget contingency obligated and allocated to date.
- Although use of contingency is traceable as a *take* from the contingency budget, once applied, contingency becomes part of the PMB and is no longer separately identifiable as contingency once incorporated.

If there is reason to believe that re-baselining will require additional funding above the NSF-authorized TPC, the Sponsoring Directorate will notify the CORF. In accordance with statute (see Section 1.4.9 Legislation on Congressional Notification of Total Project Cost Increases), NSF is required to notify Congress in writing within 30 days when there is reasonable cause to believe that the TPC will increase by 10% or more.

2.6.1.2 Construction Stage Reporting and Reviews

During the award period of performance, the Awardee provides periodic financial and technical status reports to NSF according to the terms and conditions of the award. Construction Stage reports are typically monthly and include the following:

- **Project Status.** A narrative to include the accomplishments and challenges during the reporting period, including major scientific and/or technical accomplishments and milestones achieved. Management information such as changes in Key Personnel (KP), budget issues, subaward/contractor performance, as well as any other information about which the PO needs to be aware should also be included.
- **Current Photos.** Recent photos with a written description and acknowledgments.
- **High-level Depiction of the Integrated Master Schedule.** Chart or table of performance reporting milestones pulled from the IMS, indicating which are on the baseline Critical Path, the current PMB and forecasted completion date, and other key

milestones on which EVM is based.

- **Financial Summary and Projections.** A narrative describing the amount of construction funding obligated by NSF to the Awardee to date and the costs incurred to date, including a discussion of Earned Value metrics with attention to changes from the prior month, an estimate of the risk exposure for completing remaining scope compared to actual remaining contingency funds and a funding summary and projections indicating actual funding and projected funding by FY.
- **Earned Value Management Data Table.** Earned Value metrics (Budget at Completion, Cost Variance, Earned Value, Actual Cost, Cost Variance, Cost Performance Index, Schedule Variance, Schedule Performance Index, Estimate at Completion, Estimate to Complete) extending to at least WBS Level 2; Percent Complete (Planned and Actual), Scheduled and Budget Spent percentages; PMB and forecast completion dates, remaining budget and schedule contingencies; and risk exposure.
- **Total Construction S-Curve.** S-curve showing the Actual Cost of Work Performed (ACWP) with the Budgeted Cost of Work Performed by quarter within each FY up until the present quarter; and the Budgeted Cost of Work Scheduled for those quarters and extending to the end of the Construction Stage.
- **Twelve-Month S-Curve.** S-curve table depicting the same data as the previous table in a twelve-month snapshot centered on the month of the report.
- **Schedule Variance/Cost Variance and Cost Performance Index/Schedule Performance Index Trend Graphs.** Cost and schedule variances and performance indexes (Cost Variance and Schedule Variance, Percent Cost Variance and Percent Schedule Variance, Cost Performance Index, and Schedule Performance Index) over a rolling twelve-month period.
- **Discussion of Variances and Corrective Actions.** Review of current or anticipated problem areas and corrective actions in a variance report at an appropriate control account, work package, or WBS level as agreed upon with NSF for all cost and schedule variances > ±10%, including explanation of causes, impacts at completion, and management actions.[1]
- **Contingency Balances.** Available total balances of budget and schedule contingency, as a total amount (dollars or calendar days) and for budget contingency as a percentage of the Estimate to Complete; a Liens List of projected amounts of possible future calls on contingency; an updated Change Log indicating all contingency use (puts and takes) and available balances against both the total authorized amount and the amount obligated and allocated to date.
- **Risk Management.** Identify top risks, including the probability-weighted cost exposure and trigger dates; a narrative on risk updates, including new risks, revised

[1] Variance reports provided by Awardees are used by NSF in its metrics for construction project performance goals, in accordance with the GPRAMA of 2010 (see Section 1.4.8 NSF Performance Metrics).

estimates of impact, mitigation strategies, etc.; update remaining risk analysis results (at least annually).

2.6.1.3 Construction Stage Reviews

NSF conducts periodic external panel reviews that examine technical progress (including quality of deliverables) and performance by the Awardee in executing the project on cost and schedule and within scope. In conjunction with the periodic Construction Stage review, NSF will conduct an EVMS surveillance review as needed. These reviews are commonly held at the work site or the Awardee(s) institution and conducted annually. More frequent NSF reviews may be scheduled based on the project's expenditure rate or due to any technical or management issues that arise.

The external panel reports directly to NSF and provides advice to NSF in accordance with the panel charge.[1] The reviews are organized and conducted by the PO in consultation with the RIO Liaison and AO. The PO is responsible for organizing the review and, throughout the review process, acts as the interface between NSF and the Awardee. The PO authors the review charge and organizes the review panel. The RIO Liaison and AO strengthen the review process by specifying language for incorporation within the charge and for aspects of the review agenda pertaining to project management and business-related issues and recommending panelists able to advise NSF in non-science related areas of the review. Because panel recommendations are to NSF and not the Awardee, NSF will typically issue written guidance to the Awardee for subsequent response and action leveraging recommendations from the panel report.

Change during the Construction Stage is expected to be continuous. However, the Awardee's project management team needs to respect the PMB, maintaining each adjustment to the PMB in adherence to the Change Control process outlined in the PEP. This method allows the Awardee and NSF to systematically track the evolution of the PMB from its initial release through all subsequent changes.

2.6.1.4 Re-planning

Modifications to the PMB that are within the defined scope and do not change the Total Project Duration (TPD) or TPC are referred to as re-planning. Re-planning may be due to adjustments or re-organization of the project plan and/or may signify that contingency is being used as expected. If the allocations of budget and schedule contingency are below the budget or schedule thresholds identified in the award instrument (Cooperative Agreement or contract agreement) between NSF and Awardee, the Change Requests are approved unilaterally by the Project Team. NSF approval is required when the Change Control Board recommends re-planning actions that exceed the agreed-upon budget or schedule

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[1] Many Projects conduct internal reviews to advise their senior management, such as the Project Director (PD) or Project Manager (PM) or other technical leads, on the readiness of plans or technical progress. Such reviews are not a substitute for NSF-organized external oversight reviews.

thresholds. Approval levels for scope changes are typically outlined in the award instrument.

Minor changes in scope may also fall under re-planning activities. The Project Team maintains a Scope Management Plan (see Section 3.5.3.2 PEP Subcomponent 3.2 – Scope), which describes the process for maintaining control of the scope and outlines scope changes that can be implemented depending upon the Awardee's forecast of its ability to complete the project within the approved TPC and TPD. The Awardee can implement minor de-scoping options or defer scope through the Change Control Process if necessary to maintain the contingency amount as part of the strategy to prevent potential cost overruns. It can also elect to implement project enhancements that are within the existing scope of work definitions, following the project Change Control Process and approval process as set in the award or contract terms and conditions.

2.6.1.5 Re-baselining

While Project Managers (PM) typically describe any change to the PMB as a re-baseline, re-baselining from an NSF oversight perspective occurs when the overall boundary conditions of the award change. These include:

- Increases in the NSF-authorized TPC.
- A project schedule extension requiring an increase to the award duration.
- Significant changes in scope beyond the items listed in the NSF-approved Scope Management Plan.

When the proposed changes reach the re-baselining level, the approval process may involve the highest levels of NSF management and leadership, including NSB, in accordance with NSF policy and practice. For re-authorization of the TPC, refer to the NCOP section earlier in this section. For changes in the project end date, NSF will follow the award extension policies based on the award instrument utilized; approval of the Director and notification to NSB may be necessary. Like the use of budget contingency, the use of scope contingencies should follow the Change Control Process, including appropriate NSF approval thresholds. NSB may be consulted on any major changes in scope beyond those listed in the Scope Management Plan to help determine if the project is still scientifically viable.

Re-authorization of the TPC following a re-baseline is not guaranteed, and major changes in scope can negate the project's original goals. On rare occasions, Major Facility projects under construction may encounter unforeseen budget, schedule, technical, or programmatic challenges that are substantial enough to be considered grounds for termination or

Key Takeaway

Re-authorization of the Total Project Cost is uncertain, and significant changes in scope may lead NSF to terminate or substantially modify the original project goals.

significant modification to the original project goals.[1]

At an appropriate time, approaching or following completion of construction, NSF will conduct a final Construction Stage review. This review is intended to assess the extent to which the required scope was delivered or will be delivered, in accordance with the PEP and award terms and conditions.

2.6.2 Construction Award Extension and Close-out

2.6.2.1 Project Close-out Process

As the project nears completion, close-out activities will become a regular discussion between NSF and the Awardee. All NSF awards have final reporting and close-out procedures to ensure funds have been properly used and the objectives met.

One step in the award-close-out process is for the Awardee to submit a final project report that should clearly map the accomplishments and deliverables to those articulated in the PEP and the terms and conditions of the award. The outcome of the final Construction Stage review may inform the final project report. The final steps will involve the close-out of the financial and administrative award, which may take up to two years to complete beyond the project's end date. This period is used to reconcile final invoices and indirect cost rates and de-obligate any remaining funds.

2.6.2.2 Schedule Extension

Since nearly all schedule changes impact cost, the Awardee should exercise sound project management practices and continually strive to meet the original project schedule. However, this is not always possible for various reasons. The primary goal is to utilize all available risk management tools to bring the project in at or below the authorized TPC. The process of extending the award duration without increasing the authorized TPC depends on the award instrument used. NSF does not have a No Schedule Extension Policy, but a project is technically re-baselined when the award duration is extended as stated above.

> **Key Takeaway**
>
> NSF does not have a *No Schedule Extension Policy*; therefore, Awardees should utilize all available risk management tools to keep the project at or below the authorized Total Project Cost.

Even if the award duration is extended, project management good practice suggests that all activities that can be closed out by the original award end date should be. In other words, all risks and contingency liens for those tasks can also be closed out, and no funds should be carried forward for remediation of risks related to those tasks. The close-out of completed tasks also allows for a more precise calculation of the remaining cost variance and/or contingency needs, which facilitates good decision-making on the part of the Awardee and

[1] Joint NSB-NSF Management Report: Setting Priorities for Large Facility Projects Supported by the National Science Foundation (NSB-05-77); September 2005.

NSF. To help justify the award extension without incurring any additional cost, the appropriate documentation should be provided to NSF that shows:

- A list of the tasks to be completed during the extension period and justification that they are within the approved project scope including:
  - Associated WBS element and a short justification of how the tasks fit within existing project scope.
  - The total burdened estimated cost for each task and any associated risks (by Risk ID)
  - One or more of the following categories: (1) open purchase orders and invoices associated with items whose delivery is delayed beyond the current award period of performance, (2) rework of existing tasks within the approved scope due to workmanship or performance issues, (3) existing tasks within the approved scope that have not yet been completed, and (4) activities to address remaining performance issues of completed tasks.
- An indication of which tasks are potential late-stage de-scoping options if resources (time, staff, budget, etc.) become limited.[1]
- An indication of which tasks from the Scope Management Plan are likely potential scope opportunities, assuming approval from NSF.
- A description of what funds will be used to complete the proposed tasks, such as remaining contingency if associated with a known risk and risk mitigation, unexpended PMB budget, positive Cost Variance, or partner funds.
- The Estimate to Complete with all tasks included and remaining risk exposure for comparison to remaining contingency and the authorized TPC, the confidence level for completing all work within budget, including the use of any scope contingency options.
- A summary schedule or schedule highlights of the extended tasks, including significant milestones and the new project end date.

Table 2.6.2.2-1 further illustrates the information described above.

[1] Scope contingency and management is defined in Section 4.7 Contingency Estimating and Management.

Table 2.6.2.2-1

Sample of a Schedule Extension Tasks Table

Task #	Task Description	Burdened Subtotals ($K)	WBS	Justification
1	Modifications to electronics control boards	40.5	3.7 Environmental Systems ADCs	Rework of existing in-scope task; technology not performing as intended
2	Delivery of 3 cryo-pumps	114.9	4.2 Vacuums Systems	Existing in-scope task; Late delivery on open contract with obligated funds
3	General purpose utility carts	25.8	2.4.5 Monitoring and Maintenance Equipment	Existing in-scope task; Late delivery; One unit added based on revised needs estimate
4	Vendor contract to test relationship of performance versus temperature on sample size widgets	32.4	5.2.3 Systems Engineering Integrated testing	Risk mitigation added to address in-scope performance issues for integrated systems. Risk Register ID #14-31
5	Labor extensions for project management and business offices	184.2	1.2 Project Controls	Existing in-scope task; revised effort, salary, and overhead estimates, including escalation
	Total ($K)	397.8		

2.7 MAJOR FACILITY OPERATIONS STAGE

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Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

The Awardee responsible for the Construction Stage is typically the same Awardee that assumes O&M responsibility of a new Major Facility given its history with the Science Support Program and connections with the science community. However, the Operations Stage may be managed by a different entity depending on circumstances, including the determination of the award instrument used for each stage and the point in the Major Facility's life cycle.

2.7.1 Initial Operations Stage Awards

As the Construction Stage is nearing completion, the Sponsoring Director may decide to make an initial Operations Stage award to facilitate the phased transition of staff and any equipment that is fully commissioned and ready to support science operations separate from the Construction Stage award or to otherwise ready the Major Facility to reach full operational tempo. The duration of this award may be less than the typical five years. However, it can be supplemented and extended in accordance with the award instrument used and the associated NSF policies. Because these awards may overlap in time and typically use different appropriations, MREFC and R&RA, the scope of each **must** be clearly delineated. The Awardee should follow the process and procedures in their Segregation of Funding Plan (see Section 3.5.7.5 PEP Subcomponent 7.5 – Business and Financial Controls Plans), submitted as part of the PEP, to ensure all charges for labor, equipment, operations, and maintenance, and other services are allowable and allocated to the correct award.

2.7.2 Operations Stage Awards

> **Key Takeaway**
>
> Operations Stage proposals and awards are exempt from following the GAO Schedule Estimating Guide, nor does the NCOP apply.

The Science Support Program, often referred to as O&M, is typically funded through the R&RA account. Operations Stage awards involve all day-to-day activities required to manage the Major Facility, including staffing, scheduling of activities, maintenance, repairs, and upgrade of all associated property, as well as education, outreach and administration of any research programs. It is the responsibility of the Awardee and their management team to ensure that the Major Facility is operating efficiently and cost-effectively, all aspects of it are properly maintained, and to provide technical enhancements when needed to maintain state-of-the-art research capabilities. The duration of Operations Stage awards is typically five years but may be renewable for a second five-year period. Extension of an Operations Stage award is done in accordance with NSF policy and the award instrument used.

The content of the first Operations Stage proposal and subsequent award should be aligned with the ConOps Plan established in the Construction Stage PEP. The proposal structure should align with the funding announcement, if used, or with guidance provided by the cognizant PO and will follow the format needed for an AWP as described in Section 3.6.3.2

Components of an Annual Work Plan.

While the Awardee is free to use project management good practices internally, NSF does not conduct its oversight of the Operations Stage with a project management lens as it does with the Construction Stage. Operations Stage proposals are only required to follow the *GAO Cost Estimating and Assessment Guide* as described in Section 4.3 Cost Estimating and Analysis.[1] Budget contingency may be requested, but it is not expected by NSF, as there are other ways to account for cost uncertainty and risks during the Operations Stage, such as allowances (see Section 4.3.3.4 Uncertainty, Accuracy, and Allowances). Although an Operations Stage award may involve what are considered projects, for example routine building renovations or system upgrades, Operations Stage proposals are not required to follow the *GAO Schedule Assessment Guide*.[2] If project management practices for scope, schedule, and budget are considered necessary, for example, a significant upgrade to a building or instrument in the Mid-scale RI range, NSF may fund the activities under a separate award so that appropriate guidance can be followed, and the necessary terms and conditions applied. Furthermore, NCOP does not apply to Operations Stage Awards. As a result, project management terminology such as re-planning, re-baselining, and PEP should be avoided, and the use of an IMS and EVM are not appropriate.

2.7.3 Operations Stage Reporting and Oversight

There are several key elements that are part of NSF's oversight of Operations Stage Awards:

- Periodic and annual reporting by the Awardee.
- Review of the AWP.
- Periodic Operations Stage reviews.
- Facility Condition Assessments (FCA).
- BSR.
- Other reviews and audits conducted by the cognizant federal agency.

Periodic and Annual Reports. Periodic reporting to NSF will be required in accordance with the award terms and conditions. The precise format and details of Operations Stage reporting are at the discretion of the PO and are based on the size and complexity of the Science Support Program, including interim reports such as periodic financial reporting of actual expenses against the proposed budget in operational WBS format and the annual report. The annual report may be a requirement by NSF policy based on the award instrument and the AWP may constitute the annual report as determined by the PO. NSF may request additional reports and information to support agency oversight based on Awardee performance and other factors, including requests from the Office of the Inspector General, GAO, OMB, and Congress.

The annual report, if required, should describe in detail the activities of the Major Facility in

[1] https://www.gao.gov/products/gao-20-195g
[2] https://www.gao.gov/products/gao-16-89g

the previous year for NSF to assess performance against the goals described in the AWP. Due to changing research priorities or external factors, not all performance goals may be met each year, but an explanation of progress on each goal and the reasons why the goals were not achieved should be included in the annual report.

Annual Work Plan. Like the PEP in the Construction Stage, the AWP is the primary document that the Awardee uses to manage the Science Support Program and NSF's primary document to monitor progress and performance. The elements of the AWP, as described in Section 3.6.3 Annual Work Plan, are intended to describe what the Awardee and the Major Facility expect to accomplish within the upcoming period of performance. The AWP should include a series of high-level performance goals, which will naturally vary from facility to facility and should be agreed upon between the Awardee and the PO.

Operations Stage Reviews. NSF conducts periodic Operations Stage reviews using an external panel of experts spanning the principal range of functions necessary to sustain Major Facility operations in accordance with the panel charge. Frequency is at the discretion of the PO and depends on the scale and complexity of the Science Support Program. The scope of the review may involve a review of the AWP and the results of a recent FCA, for example. The external panel reports directly to NSF and provides advice to NSF in accordance with the panel charge. Whenever possible, the review is conducted at the Major Facility itself.

The reviews are organized and conducted by the PO in consultation with the RIO Liaison and AO. The PO has overall responsibility for organizing the review and, throughout the review process, acts as the interface between NSF and the Awardee. The PO authors the review charge and organizes the review panel. The RIO Liaison and AO help strengthen the review process by specifying language for incorporation within the charge and for aspects of the review agenda pertaining to business-related issues and recommending panelists able to advise NSF in non-science related areas of the review. Because panel recommendations are to NSF and not the Awardee, NSF will typically issue written guidance to the Awardees for subsequent response and action leveraging recommendations from the panel report.

When NSF partners with other entities to fund operations, the Memorandum of Understanding between the partners usually defines the process for oversight and monitoring.

Facility Condition Assessment. The PO will request a periodic FCA and associated Asset Management Plan in accordance with the terms and conditions of the award (see Section 3.6.2 Facility Condition Assessment of a Major Facility). The FCA process is intended to help inform NSF and the Awardee of the anticipated major maintenance and upgrade expenses that could cause a significant departure from the routine funding profile, allowing NSF, as part of its budget formulation and allocation process, to proactively address these issues before they become emergencies that could potentially disrupt operations.

Business Systems Review. While a BSR may be conducted prior to a Design or Construction Stage award to ensure the Awardee has appropriate business systems in place, BSRs are routinely used during the Operations Stage under financial assistance awards. Analogous reviews are used for Federal Acquisition Regulation (FAR)-based contracts. Whether to execute a BSR is based on an internal annual portfolio risk assessment conducted by NSF with input from the Core IPT for each Major Facility in operations. The scope of the BSR is adjusted to align with any risks identified. BSRs are intended to assess the Awardee's processes, procedures, staffing, and tools to ensure they are suitable to receive or continue to receive an Operations Stage award.

Other Reviews and Audits. Depending on the award instrument, NSF may also elect to conduct a Financial Viability review, Accounting System Analysis, or Incurred Cost Audit prior to the award, or during the award period of performance. Awardees may also need to respond to audit requests from NSF's Office of the Inspector General. Per the American Innovation and Competitiveness Act, NSF requires an independent cost analysis for Operations Stage proposals.

2.7.4 Recapitalization During Operations

Recapitalization refers to the process of reinvesting in or upgrading existing assets to maintain or enhance their performance, extend their service life, and/or ensure they continue to adhere to operational standards and regulatory requirements. Recapitalization is an ongoing process that requires careful planning, budgeting, and execution to ensure that Major Facilities remain safe, functional, and effective in meeting their intended purposes throughout their service lives.

Effective recapitalization requires a proactive approach to asset management that includes monitoring operational trends to ensure optimal performance and resilience in dynamic environments, thorough assessment of funding needs, careful consideration of the appropriate funding mechanism, and a strategic allocation of resources. As described in Section 3.6.2.1 Facility Condition Assessment Components, recapitalization needs are informed by the FCA process, which in turn is used to develop the Asset Management Plan that outlines the anticipated costs associated with the recapitalization activities. These estimated future costs have the potential to significantly deviate from the standard routine maintenance funding profile seen in Operations Stage awards.

Ideally, Major Facility recapitalization activities would be addressed as part of the O&M award (see Section 4.2 Scope and Work Breakdown Structure). At the discretion of NSF, other mechanisms for support may be offered, such as targeted supplemental funding requests, dedicated recapitalization programs, and Mid-scale RI programs, since these projects can include upgrades to Major Facilities (see Section 1.4.5 Mid-Scale Project and Mid-scale Research Infrastructure). Close consultation with the NSF PO is essential in determining the most appropriate funding mechanism based on the availability of funds and other factors.

2.7.5 Federally Funded Research and Development Center Designation

FFRDC are defined in FAR 2.1 to mean:

> "activities that are sponsored under a broad charter by a Government agency (or agencies) for the purpose of performing, analyzing, integrating, supporting, and/or managing basic or applied research and/or development, and that receive 70 percent or more of their financial support from the Government; and
>
> (1) A long-term relationship is contemplated;
>
> (2) Most or all of the facilities are owned or funded by the Government; and
>
> (3) The FFRDC has access to Government and supplier data, employees, and facilities beyond that common in a normal contractual relationship."

An FFRDC is created by a federal agency and receives the preponderance of its resources from that particular agency. NSF sponsors several Major Facilities in the Operations Stage that are designated as FFRDCs. FAR Part 35.017 sets forth the federal policy regarding the establishment, use, review, and termination of FFRDCs and related sponsoring agreements which NSF adheres to regardless of the award instrument used. In accordance with the FAR, an FFRDC **must** meet special long-term research or development needs that cannot be met as effectively by existing in-house or contractor resources. They enable agencies to use private sector resources to accomplish tasks integral to the sponsoring agency's mission and operation. To discharge its responsibilities to the sponsoring agency, an FFRDC has access to government information and resources (including sensitive and proprietary data, employees, installations, equipment, and real property) beyond that which is common to the normal contractual relationship. An FFRDC is required to conduct its business in a manner befitting its special relationship with the government, operate in the public interest with objectivity and independence, be free from organizational conflicts of interest, and fully disclose its affairs to the sponsoring agency. An FFRDC cannot use its privileged information or access to other resources to compete with the private sector, although it may perform other work under the Economy Act or other applicable legislation when the work is not otherwise available from the private sector.

While the sponsoring agreement may take various forms and the content may vary depending on the situation, a FFRDC **must** be clearly designated through a sponsoring agreement that addresses the minimum criteria defined in 48 CFR 35.017-1(c) and (d).[1] Establishing, changing, using, review, and termination **must** follow the requirements defined in 48 CFR 35.017-2 through 35.017-7.[2]

Approval to continue or terminate NSF sponsorship rests with the NSF Director. When NSF's need for an FFRDC no longer exists, the sponsorship may be transferred to one or more government agencies, if appropriately justified. If an FFRDC is not transferred, it will be considered for disposition.

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[1] https://www.ecfr.gov/current/title-48/section-35.017-1

[2] https://www.ecfr.gov/current/title-48/chapter-1/subchapter-F/part-35

2.7.6 Competition, Renewal and Disposition Decisions

At least two years prior to the end of an Operations Stage award, NSF will begin the process of making a determination of whether to renew the award with the existing managing organization, compete for a new managing organization, or otherwise dispose of the Major Facility and its associated infrastructure through a variety of methods.[1] The results of the annual Operations Stage reviews and other information, such as inputs from NSF Advisory Committees, Decadal Surveys, *Blue Ribbon* panels, National Academies studies, and professional societies, are used to help inform this decision.

2.7.6.1 Disposition

To remain at the frontiers of science and support new, cutting-edge RI, NSF will consider decreasing or eliminating investments in existing Major Facilities when the science they enable is considered a lower priority than science that could be enabled by alternate use of the funds. Such decisions require careful consideration by NSF in consultation with the community and other stakeholders. In some cases, where a Major Facility can continue to be productive, it may be possible to transfer stewardship and final ownership to another agency, a university, or a consortium of universities. It is the responsibility of the Directorates and Divisions to periodically review their Major Facility portfolio and to consider which facilities may have reached the point where disposition is appropriate.

Disposition is the general term that means the act of divesting or transitioning a Major Facility or capital asset, either in whole or in part, or non-renewal of a Major Facility award.[2]

Divestment. The transfer of property ownership from NSF to another entity, including relinquishing any conditional claims. It can involve a full facility, components, or assets, and may include decommissioning if necessary. After divestment, the assets are no longer NSF-funded, though NSF may still support research using those assets.

Transition. The change from a Major Facility to another class of RI or scale of activity, but NSF retains ownership and oversight. Forms of transition include mothballing assets or leasing property long-term. After transition, the assets are no longer considered NSF-funded Major Facilities, though new awards and oversight conditions apply.

Non-renewal. The decision not to extend its funding agreement with the managing organization, without owning or having an interest in the assets. After non-renewal, the assets are no longer considered part of an NSF-funded Major Facility.

Environmental, historic, and cultural assessment activities may be initiated if the decision is made to dispose of a Major Facility, or component of a Major Facility (see Section 5.4 Environmental Considerations).

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[1] See Section 1.4.5 Mid-Scale Project and Mid-scale Research Infrastructure regarding NSB Policy on re-competition.
[2] NSF's current threshold for a capital asset is property currently valued at $2.5M or greater.

2.8 MAJOR FACILITY DISPOSITION STAGE

Section Revision: TBD 2025

Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

The purpose of the Disposition Stage is to execute the disposition decision(s) made during the Operations Stage. The Disposition Stage begins when an award is made to fund the disposition activities, which could include the transition of all property and equipment to sponsorship by another entity (federal or non-federal), disposal of some or all property, de-commissioning or de-construction of the entire Major Facility or components of the Major Facility, and other costs related to liabilities such as employee separations. Disposition Stage awards are seldom competitive in nature unless NSF decides to de-commission or de-construct a Major Facility itself. Non-renewals, by definition, do not require a Disposition Stage award.

Major Facility Disposition Plan. Guidelines and requirements for creating disposition plans are included in Section 3.7 Disposition Stage Planning. Since divestment strategies and liabilities may influence construction strategy, a divestment plan is a necessary element (see Section 3.5.10.3 PEP Subcomponent 10.3 – Concept of Disposition Plans) for a Major Facility and thus, a draft plan should be created early in the Design Stage planning.

Oversight and Reporting during the Disposition Stage. Given the inherent complexities of disposition, particularly around property and environmental considerations, engagement by the NSF Core IPT is necessary to ensure that both programmatic and business-related oversight requirements are met. Reporting and other deliverables will be defined in the terms and conditions of the award and are based on the Disposition Plan negotiated with NSF.

2.9 MID-SCALE RESEARCH INFRASTRUCTURE GUIDANCE

Section Revision: TBD 2025

Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

2.9.1 Introduction

In Section 1.4.5 Mid-Scale Project and Mid-scale Research Infrastructure, Mid-scale RI projects are defined as RI having a cost to construct, acquire, or otherwise implement, between the upper limit of NSF's Major Research Instrumentation (MRI) program and the lower threshold for what constitutes a Major Facility.[1] Mid-scale RI can be standalone projects or associated with an NSF-funded Major Facility.

This section should not be interpreted as standalone, comprehensive guidance for Mid-scale RI. Rather, it should be viewed as a complement to all other relevant sections of this *Guide*. A central theme throughout is the expectation that proposers should tailor and scale proposed management methodologies to the technical nature, complexity and risk profile of the Mid-scale RI project or operations award. Similarly, NSF will tailor and scale the review and oversight methodologies to the technical nature, complexity, and risk profile of the project or operations award.

NSF's investments in Mid-scale RI may also support development and design activities as well as operations. NSF funds these investments through multiple funding accounts and programs, some of which are managed exclusively by the Program Offices and others centralized at the agency level.[2] In all cases, the intent of Mid-scale RI investments is to meet the RI needs of the science community on shorter timescales than typically seen for Major Facility investments.

Although Mid-scale RI proceed through all life cycle stages from development through eventual disposition, they do not fall under the five life cycle stages for NSF oversight of Major Facilities as described in Sections 2.2–2.8 (see Section 2.9.3 Mid-scale RI Life Cycle Stages). In addition, NSF may only be engaged in some of the life cycle stages. NSF typically funds the design and implementation of Mid-scale RI. O&M may be funded by NSF, in part or whole, based on the ConOps described in the proposal. If a Mid-scale RI project is an upgrade to an existing Major Facility, it is expected that the O&M costs will become part of the Operations Stage award for that Major Facility.

NSF Programmatic Oversight. At the appropriate point in award formation, each Mid-scale RI award is assigned to an NSF PO with the responsibility for award oversight as determined by the award instrument utilized. NSF uses the IPT approach for oversight of Mid-scale RI awards (see Section 2.1.2 Coordinating and Advisory Bodies). However, the IPT only needs to consist of the PO, the AO, and the RIO Liaison, i.e., the Core IPT; others may be added to address various expertise needs. Mid-scale projects consisting of upgrades to existing NSF

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[1] The current upper limit of an NSF award under the MRI program is $4M, which does not consider cost share.

[2] Centralized funding programs include Mid-scale RI Tracks 1 and 2, with Track 1 funded from the R&RA account and Track 2 from the MREFC account.

Major Facilities are coordinated through the NSF IPT for that Major Facility.

In accordance with NSF policy on financial assistance, the PO(s) creates a Management Plan documenting the planned oversight approach for the funding program. The Management Plan is developed in conjunction with the funding announcement and articulates NSF's plans for oversight of the program and any resulting awards. Therefore, an Internal Management Plan is not required for individual Mid-scale RI projects. Unlike the more stringent requirement that PO assigned to Major Facilities **must** be permanent NSF employees per statute, NSF has broader discretion on employment status when assigning PO to oversee Mid-scale RI awards.

Non-applicability of the No Cost Overrun Policy. Although substantial rigor is required in establishing the TPC for a Mid-scale RI implementation award, these projects are not subject to the NCOP used for Major Facilities, as defined in Section 1.4.7 NSF No Cost Overrun Policy. NCOP is based on having a risk-adjusted TPC that is developed at the PDR to support a potential budget request to Congress on a project-specific basis, and since Mid-scale RI projects do not go through the formal stage-gate review process, there is no PDR. In addition, Mid-scale RI projects are often funded under a broader program and not articulated in NSF's budget request by individual projects. However, any potential cost increases that could impact the award amount (i.e., that cannot be addressed through re-planning, use of budget contingency, or de-scoping) should be discussed with the PO and AO as early as possible and be addressed in accordance with NSF's policy based on the appropriation and award instrument used.

2.9.2 Expectations for Mid-scale RI Proposers and Awardees

Mid-scale RI Management Team. Given the expectation to deliver a certain scope within cost and schedule, or to provide an on-going Science Support Program to the community, NSF has different expectations for Mid-scale RI awards compared to research awards which are often standard grants. Proposers of Mid-scale RI projects should form a Management Team capable of planning and executing the activities that would be funded under an award. The expectations for personnel (see Section 5.7 Personnel and Competencies), while not required for Mid-scale RI, may be used to inform the subject matter expertise of individuals on the Management Team based on whether the award activities are for design, implementation, or operations; each of which having its own set of challenges and risks. For example, projects consisting of simple acquisitions of commercially available components generally have very low risk. The Management Team may only be the Principal Investigator and their institution's contracting office.

For more complex Mid-scale RI projects, the PM should be identified and consulted early in the process, ideally prior to initial proposal submission to assist with interpretation of this *Guide*. Some professional organizations provide general guidance on the size and formation of the Management Team, but a qualified PM can also help ensure adequate, competent staffing is proposed and hired.[1] Proposing organizations may also be able to leverage available in-house resources, such as business management, architectural, or engineering departments, or project management staff in the facilities (non-academic) arm of the institution. It is also advisable to have discussions with peer organizations in the respective fields of research and with project management consultants, to help ensure adequate staffing. Experienced PM can be an asset when considering the tailoring and scaling flexibility allowed by NSF on Mid-scale RI projects and help avoid over- or under-implementation during proposal submission and post-award.

Concept of Operations. When NSF is considering an investment in the design or implementation of a Mid-scale RI, it is essential that the agency understands the proposing organization's plan for and cost of O&M as part of the proposal review process. As a result, Mid-scale RI proposals **must** include a ConOps Plan that is aligned with the technical maturity of the RI. For a design proposal, the ConOps Plan should be presented as envisioned, with the operations cost estimates and funding strategy refined with maturation of the PEP (see Section 3.5 Construction Stage and Implementation Planning). If implementation is eventually funded, the ConOps Plan would then be refined further as the infrastructure moves toward delivery. If NSF commits to supporting long-term operations, a proposal that includes a detailed AWP would eventually be submitted based on the refined ConOps Plan developed during implementation (see Section 3.6 Operations Stage Planning).

Tailoring and Scaling the Project Management Approach. Proposers should plan and Awardees should execute Mid-scale RI projects using well-established project management methodologies. However, NSF allows flexibility in tailoring and scaling the methodology used based on the size, complexity, technical nature of the project, and identified project risks. Project management practices include reliable cost estimating and schedule development, risk identification and risk mitigation, consideration of needed contingencies, and the ability to monitor progress against the plan so that corrective actions can be taken. The level of project management effort and resources employed should be carefully considered such that the cost does not outweigh the benefit.

Cost Estimating. Budget estimates for Mid-scale RI investments for design, implementation, and operation awards should be supported by a well-documented BOE developed in accordance with the four characteristics and the twelve steps of the *GAO Cost Estimating and Assessment Guide*, as described in Section 4.3 Cost Estimating and Analysis. However, the primary focus should be on meeting the four characteristics of a reliable estimate (well-documented, comprehensive, accurate, and credible) to support NSF's assessment of cost reasonableness. The twelve steps should be considered when deemed advantageous to the Proposer's estimating process for the given life cycle stage, and NSF will review accordingly as part of the agency's cost analysis process. At minimum, the estimate should be easily understood, describe the methodology, and show calculations traceable to supporting documentation (well-documented), follow a WBS (comprehensive), be validated to be an

[1] e.g., Project Management Institute (PMI)

error-free representation of most likely costs (accurate) and consider risks and uncertainties (credible).

Schedule Development. Schedules should be tailored to the technical nature and complexity of the project and the needs of the Project Management Team to monitor progress against the plan. Schedules can be as simple as a time-sequenced list of significant milestones or, when using EVM, as complex as a fully developed IMS. No matter how simple or complex, the schedule proposed should meet GAO's four characteristics of a reliable schedule (comprehensive, well-constructed, credible, and controlled). The ten best practices should be considered when deemed advantageous to the Proposer and Awardee's scheduling process for the given life cycle stage, and NSF will review accordingly. At a minimum, the schedule should establish milestones for all key events at reasonable durations (comprehensive), be logically sequenced (well-constructed), consider risks and inclusion of adequate float or schedule contingency (credible), and be updated routinely by authorized individuals with actual progress to provide a current forecast for comparison to the planned schedule ([controlled], see Section 4.4 Schedule Development, Estimating, and Analysis).

Contingencies. Scope, schedule, and budget contingencies are highly encouraged on Mid-scale RI implementation awards and may be considered on design and operations awards. Budget and schedule contingencies give credibility to their respective estimates. Scope contingency provides pre-vetted options to manage further risk if budget contingency becomes inadequate during implementation or adds capabilities if the risk impact isn't fully realized. In other words, all three contingencies can work together to provide flexibility to cover risk exposure and deliver the full scientific scope within the authorized TPC.

If proposed, the budget contingency estimate should be developed using a rigorous risk management approach as described in Section 4.6 Risk Management. NSF is under no obligation to award budget contingency and may choose to handle risk realization in other ways per Section 4.7.1 Allowable Contingencies. If awarded, NSF may hold up to 100% of the budget contingency until needed.

Since the schedule for a Mid-scale RI project can range in complexity, proposers should assess the benefit of schedule contingency to their project. If a simple milestone schedule is used, the use of schedule contingency may add no practical value. The Awardee and NSF may simply be monitoring milestones and extending the award duration as needed to complete the project, provided that sufficient funding remains. If EVM and a full IMS are employed, then schedule contingencies may be added to each major work package in accordance with project management good practices and following formal Change Control procedures (see Section 4.7 Contingency Estimating and Management).

A Scope Management Plan is a valuable risk management tool. Scope contingency should be proposed at a level appropriate to the project and acceptable to the Program Office. It does not need to have a value equivalent to at least 10% of the baseline budget, as with Major Facilities projects. If proposed, de-scope options (as well as scope opportunities) should be well-documented, time-phased, prioritized to minimize or maximize scientific impact and have an appropriate threshold for NSF approval in the PEP.

The use of contingencies is always managed through the formal Change Control Process as described in the PEP or AWP. NSF approval thresholds are then codified in the terms and conditions of the award.

> **NSF Requirement**
>
> - Major Facilities must use a verified EVMS to monitor progress against the Performance Measurement Baseline.
> - Mid-scale RI must have an objective means to monitor progress against the plan.

Monitoring Progress Against Plan. Mid-scale RI projects are required to use an objective method of monitoring progress against the plan that is considered sufficient for the Project Management Team to manage the project. If the method used is deemed sufficient to manage the project during the NSF review process, it should be considered sufficient for NSF oversight of the award. Any adjustments to the method will be made during award negotiation. If EVM is used, tailoring and scaling should be used to balance administrative burden with sufficient project management insight. Refer to Section 4.5 Monitoring Progress Against Plan for other means of monitoring progress against a plan and Section 4.5.4 Earned Value Management for more information on scaling EVM.

2.9.3 Mid-scale RI Life Cycle Stages

Mid-scale RI follows a structured pathway through five life cycle stages, similar to Major Facilities. These stages cover the entire RI life cycle—from development to eventual disposition—although NSF may only be directly involved in some of these stages. NSF distinguishes the oversight and guidance for Mid-scale RI by referring to each stage as an *award*. This terminology reflects NSF's tailored approach to supporting the specific needs and scale of Mid-scale RI, while also emphasizing their distinction from Major Facilities.

- Development award
- Design award
- Implementation award
- Operations award
- Disposition award

Mid-scale RI Development Award. Development of Mid-scale RI projects generally happen on significantly shorter time scales compared to Major Facilities. A vision for a time-sensitive solution enabling scientific advances might lead directly to the submission of a proposal for the design of a Mid-scale RI and subsequent award. NSF may also fund activities such as community workshops to develop ideas and build consensus around the needed infrastructure. At the appropriate level of maturity, this could lead to the submission of a formal proposal for design either through a formal program or via an unsolicited proposal. If the proposed RI is an acquisition, submission of an implementation proposal (bypassing development and design) may be appropriate. If the project is an upgrade to an existing

Major Facility, the Mid-scale RI development may happen as part of the Major Facility Operations Stage award with the approval of NSF PO. In all cases, communication with the appropriate NSF PO is essential to successfully advance the vision beyond an initial idea to a formal design activity or a potential implementation project.

Mid-scale RI Design Award. Proposed Mid-scale RI projects are not required to undergo the formal design stage-gate reviews that are mandatory for Major Facilities. However, proposed Mid-scale RI projects **must** demonstrate an appropriate level of design maturity before proceeding from design to implementation. This level of maturity is comparable to that of a FDR, as described in Section 2.5.3 Final Design Phase.

Mid-scale RI design awards **must** have a DEP, in accordance with programmatic requirements, that leads to the submission of the PEP as a final deliverable. To minimize technical risk, design activities may include prototyping that has its own PEP tailored and scaled to this level of activity embedded within the DEP. Section 3.4 Design Stage Planning describes the suggested contents of a DEP. The expected deliverable at the end of design is a comprehensive PEP ready for consideration of an implementation award.

Mid-scale RI Implementation Award. The implementation activities proposed for a Mid-scale RI may include construction, acquisition, or a wide variety of other activities necessary to deliver the intended scope based on the technical nature of the project. Production-level design activities and prototyping not accomplished during design may also occur during implementation. Mid-scale RI projects may be all instrumentation, all software, or a mixture, depending on the needs of the scientific community. This high degree of variability requires alignment between the project management approach and the needs of the RI type.

Some Mid-scale RI projects approaching $100M may use many of the project management methods typically used for Major Facilities. Smaller projects, particularly those at the lower end of the Mid-scale RI cost threshold, are expected to implement project management methods only to the extent necessary to manage the project effectively. If, during the NSF review process, the methods are deemed suitable to manage the project, they will generally be suitable for NSF's oversight purposes.

> **Key Takeaway**
>
> Given the wide range in scale, complexity, and technical nature of Mid-scale RI projects, NSF expects greater tailoring and scaling on Mid-scale RI PEP compared to Major Facilities.

As with Major Facilities, the PEP establishes the Project Definition, documents how progress against the plan will be monitored, establishes Change Control and contingency use procedures, and describes the ConOps and other Plans described in Section 3.5 Construction Stage and Implementation Planning. As with Major Facilities projects, all PEP components and subcomponents should be considered and addressed unless otherwise noted in the funding announcement. PEP components and subcomponents may be omitted (tailored) with a brief justification of its omission. However, if included, they should be scaled (adjusted) to the size, complexity, and technical nature of the project, as well as the associated project risks. If a PEP component or subcomponent is omitted, indicating that it is not applicable and a brief description as to why should be given to indicate it was considered but determined not to be needed. All ten PEP components are needed for Mid-scale RI projects. However, given the wide range in scale, complexity and technical nature of Mid-scale RI projects, NSF expects greater tailoring and scaling on a Mid-scale RI PEP compared to Major Facilities. The extent to which the PEP is tailored and scaled will be subject to NSF review to guard against both under and over implementation.

The final NSF-approved PEP is largely incorporated by reference into the terms and conditions of the implementation award. However, the PEP is considered a living document and, as such, periodic post-award PEP revisions are expected. The Awardee should submit revised PEP sections to the NSF PO for approval as described in the terms and conditions of the award.

As with Major Facilities, both re-planning and re-baselining may occur during implementation. Scope, schedule, and budget contingencies, if proposed and awarded, are expected to be used in accordance with the Change Control Processes described in the PEP and the award terms and conditions.

Mid-scale RI Operations Award. If NSF commits to long-term operation of a Mid-scale RI, then the Awardee **must** submit an AWP using an operational WBS (see Sections 3.5 Construction Stage and Implementation Planning and 4.2 Scope and Work Breakdown Structure). Reporting during operations is based on the terms and conditions of the award. If the Mid-scale RI operations award is associated with a Major Facility, then the operational details may be included as part of the AWP for that facility and reporting included along with the facility reporting requirements.[1] At the Program Office's discretion, periodic operations reviews may be used to inform award renewals or competition, assess Awardee's performance, inform the need for upgrades to meet emerging science requirements, or other oversight needs (see Section 3.6 Operations Stage Planning).

Mid-scale RI Disposition Award. As stated above, NSF may not have any long-term operational investment in Mid-scale RI and, therefore, plays no part in disposition decisions. Whether the property is government-owned or whether NSF has a conditional interest in the property funded under the award depends on the award instrument utilized. Under contracts, all property is federally owned, and eventual disposition would follow government-wide practices. Under financial assistance, government ownership and NSF's conditional interest at the end of the award (if any) is stated explicitly in the award terms and conditions. The expectation for a Mid-scale RI under financial assistance is that title to property would vest with the Awardee at the end of the award. Eventual disposition at the end of service life would be the sole responsibility of the Awardee. Disposition planning with NSF would only be necessary if the agency had ownership or conditional interest in specific property in accordance with the terms and conditions of the award. For more information on disposition, refer to Section 2.8 Major Facility Disposition Stage.

[1] Larger Mid-scale RI upgrade projects are commonly funded as a separate award with distinct reporting requirements.

2.9.4 Summary of NSF Oversight for Major Facilities and Mid-scale RI

Given the wide range in implementation costs and the kinds of projects funded under Mid-scale RI programs, management by the Awardee and the oversight by NSF is expected to be tailored and scaled to the unique characteristics of the RI, such as an assessment of the associated technical and programmatic risks, the technical scope, and the type and mix of work being performed. However, NSF is committed to the principle that this flexibility does not preclude a requirement for appropriate rigor on the part of NSF or the Awardee.

The following table is provided to help clarify the factors influencing NSF oversight and illustrate the differences in the level of oversight for Mid-scale RI and Major Facilities based on statutory requirements and agency policy.

Table 2.9.4-1

Requirements for Major Facilities versus Mid-scale RI

Requirement	Major Facilities	Mid-scale RI
Statutory Oversight Requirements	Yes AICA 2017; Section 110 Construction and Operations Stages	No AICA 2017; Section 109 speaks only to developing a strategy for Mid-scale RI. All oversight is based on internal NSF policy and practice.
Life Cycle Stages	Yes Development, Design, Construction, Operations, and Disposition Stages	Yes Primary focus on design, implementation, and operations awards
Stage-gate Reviews	Yes CDR, PDR, and FDR	No Technical readiness assessed by NSF in accordance with the funding announcement or separate assessment, if unsolicited
NSF NCOP	Yes Per Section 2.6.1.1	No The NCOP relates to a risk-adjusted TPC at PDR to support a budget request to Congress. Mid-scale projects do not undergo PDR and budgets requests are generally formulated at the program level
Use of GAO Good Practices for Cost	Yes AICA 2017; Section 110	Yes Per NSF practice and as described in the associated funding announcement
Use of GAO Good Practices for Schedule	Yes AICA 2017; Section 110	Yes Per NSF practice and as described in the associated funding announcement
Budget Contingency	Yes For Construction Stage, Monte Carlo simulation methods to demonstrate 70-90% confidence	No, but highly recommended Simplified algorithmic method to full Monte Carlo simulation, if proposed
Schedule Contingency	Yes	No, but possible if using more complex scheduling methodologies and budget contingency
Scope Contingency	Yes At least 10% of baseline cost	No Recommended based on project complexity and risk profile

Requirement	Major Facilities	Mid-scale RI
Management Reserve	Yes Authorized by NSF as part of the TPC for unforeseen events; held by NSF and awarded as supplemental funding	No Standard NSF supplemental funding requests procedures based on the award instrument and authorization for use of funds depending on the appropriation (MREFC vs R&RA)
DEP	Yes Design Stage	No Design Activities; based on the funding announcement and other program requirements
PEP	Yes Construction Stage All components and subcomponents should be tailored and scaled to match the project	Yes Implementation award All components and subcomponents should be tailored and scaled to match the project
AWP	Yes Operations Stage	Yes Operations award, or Operations Stage if associated with a Major Facility
EVM	Yes Construction Stage Scaled to the project	No Only an objective means to monitor progress against the plan; if EVM is used it should be tailored and scaled to the project
Periodic Construction Stage Reviews	Yes Joint PO and RIO	No At Program Office discretion
Periodic Operations Stage Reviews	Yes	No At Program Office discretion
NSF IPT	Yes	Yes Core IPT members only
Awardee Core Competencies	Yes As described in Section 5.7 Personnel and Competencies and required per the terms and conditions of the award	Yes Matched to the technical nature of the project or program or as required per the terms and conditions of the award
Disposition of Property	Either federally owned or NSF has conditional interest, depending on the award instrument and the award terms and conditions; NSF is engaged in property disposition decisions throughout and at the end of award	Property title generally vests with the Awardee; disposition planning with NSF is only necessary if NSF has ownership or conditional interest, per the award terms and conditions

3.0 RESEARCH INFRASTRUCTURE LIFE CYCLE PLANNING

3.1 INTRODUCTION

Section Revision: TBD Early 2025
Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

This chapter offers detailed descriptions and guidance for Awardees in developing essential plans and documents to manage and oversee Major Facilities and Mid-scale Research Infrastructure (RI). It covers the formulation of key plans such as the Design Execution Plan (DEP), Project Execution Plan (PEP), Strategic Plan, Annual Work Plan (AWP), Asset Management Plan, and plans for Disposition activities. The chapter emphasizes the importance of tailoring, scaling, and progressively elaborating these plans according to the specific nature of the activities involved.

3.2 Tailoring, Scaling, and Progressively Elaborating Plans. Plans should be appropriately tailored and scaled to reflect the nature, scale, and complexity of the RI, as well as should be progressively elaborated.

3.3 Development Stage Planning. There are no required plans due to wide variability in early-stage ideas across scientific disciplines.

3.4 Design Stage Planning. Formulates the DEP detailing tasks. Major Facilities undergo submission for the Conceptual Design Review and Preliminary Design Review in preparation for the Final Design Phase. The Mid-scale RI DEP is reviewed as per the funding announcement.

3.5 Construction Stage and Implementation Planning. Details of the PEP for managing construction, outlining requirements and development components.

3.6 Operations Stage Planning. Includes the Strategic Plan, Facility Condition Assessments, Asset Management Plan, and AWP. Covers operational timelines, maintenance, upgrades, research, and education programs.

3.7 Disposition Stage Planning. Provides guidance for planning RI disposition under NSF awards, including options like transfer, decommissioning, and site restoration after NSF funding ends.

3.2 Tailoring, Scaling, and Progressively Elaborating Plans

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Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

This section gives an overview of the process for tailoring, scaling, and progressively elaborating Major Facility and Mid-scale Research Infrastructure (RI) management plans for each life cycle stage based on the nature of the proposed activities, the proposer's initial experience and background, and the life cycle stage. The sections dedicated to each life cycle provide detailed discussions with specific guidelines and best practices for tailoring, scaling, and progressively elaborating life cycle plans.

NSF recognizes that the unique nature of the activities under these awards and the related efforts, as described in these plans, should inform how the Awardee approaches its planning and management. A one-size-fits-all approach to development and management can be overly burdensome on smaller efforts and might cloud the objectives for more extensive, complex efforts. Therefore, the ability to select (*tailor*) and adjust (*scale*) the proper management methodologies, which will also aid in establishing the appropriate level of NSF oversight, should be based on the effort's characteristics and allow the managing organization to mature as well. This approach by NSF does not negate the use of project or program management good practices or any requirements established in the funding announcement or the eventual terms and conditions of the award. Instead, it allows Awardees to use their judgment when proposing to NSF and for NSF to apply the appropriate level of oversight without reducing rigor. Such flexibility is essential to avoid over-implementation and undue burden on the Awardee's life cycle stage management methods.

The ability to progressively elaborate management methods and life cycle plans helps avoid falling into over-implementation early on, as well as present documents to NSF for review that align with project maturity, knowing full well that they will improve with time. This section provides general guidance for tailoring, scaling, and progressively elaborating concepts. These concepts are defined as follows:

- **Tailoring:** The process of selecting an appropriate framework to define and organize the scope, management, organization, schedule, cost detail, and performance measurement methods.
- **Scaling:** The process of adjusting the level of detail, degree of formality, tools, and management processes to the characteristics of the planned work and the performance processes.
- **Progressively Elaborating:** The process of iteratively increasing the level of detail and sufficiency in a management plan appropriate to the life cycle stage (i.e., the Design Execution Plan [DEP] for the Design Stage, the Project Execution Plan [PEP] for implementation, and Annual Work Plan [AWP] for the Operations Stage) as more accurate information becomes available, commensurate with project or Science Support Program maturity.

3.2.1 Tailoring

When tailoring, Awardees select management models and structures that match the proposed activities. For example, a proposed project that consists mainly of design and labor activities spread throughout the entire period of performance, may need a different management approach than a project that is mostly made up of acquisition efforts where purchases are mostly included in the first half of the period of performance. Most life cycle management plans and methods fall into three major types, but the resulting plans can be a hybrid of those types. The three types are:

- Traditional waterfall approach that is product oriented.
- Cyclical approaches that are team- and process-oriented.
- Level-of-Effort (LOE) activities that are service-oriented.

All three employ acceptable methods for managing Major Facilities and Mid-scale RI throughout their life cycles, as long as the methods are well-matched to the activity's characteristics, the life cycle stage, and the institutional culture and experience. The sections below are intended to provide guidance on how the life cycle management plans and methods should be described and documented.

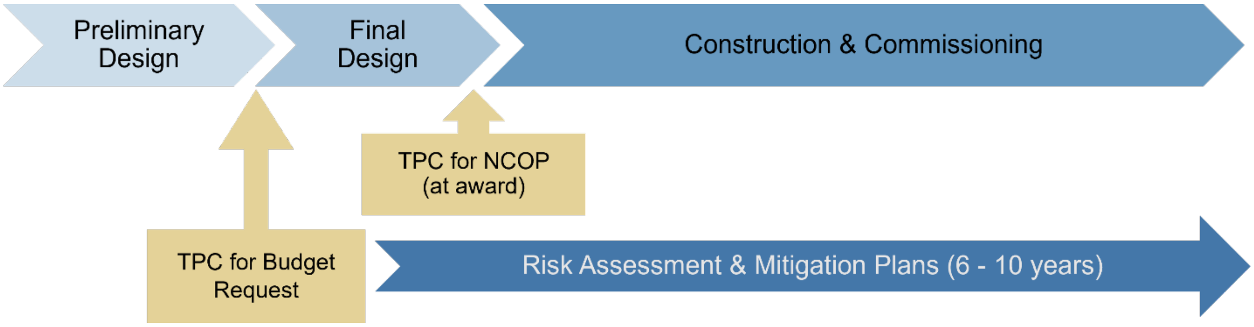
3.2.1.1 Traditional Waterfall Approach

Traditional waterfall project management methods are suited to efforts that can be divided into work plans or phases with well-defined deliverables having concrete timelines and sequencing of events. Significant constraints on time, scope, and cost are well understood and can be easily documented. Work flows logically from one phase to the next. Teams are organized hierarchically with clear authorities, roles, and responsibilities and work linearly toward set goals. Work is complete at the end of each work plan and does not repeat.

One common method of measuring performance against the baseline within the traditional waterfall approach is Earned Value Management ([EVM], see Section 4.5 Monitoring Progress Against Plan).

Construction and demolition, for example, are traditionally structured for waterfall project management practices. The method can also be applied to design and development activities and to software programming, although cyclical methods are often preferred for the latter. Still, any shortcomings should be recognized and accommodated with adaptations that ensure proper management insights and status reporting (see Chapter 2 NSF Life Cycle Oversight for further information regarding project reporting).

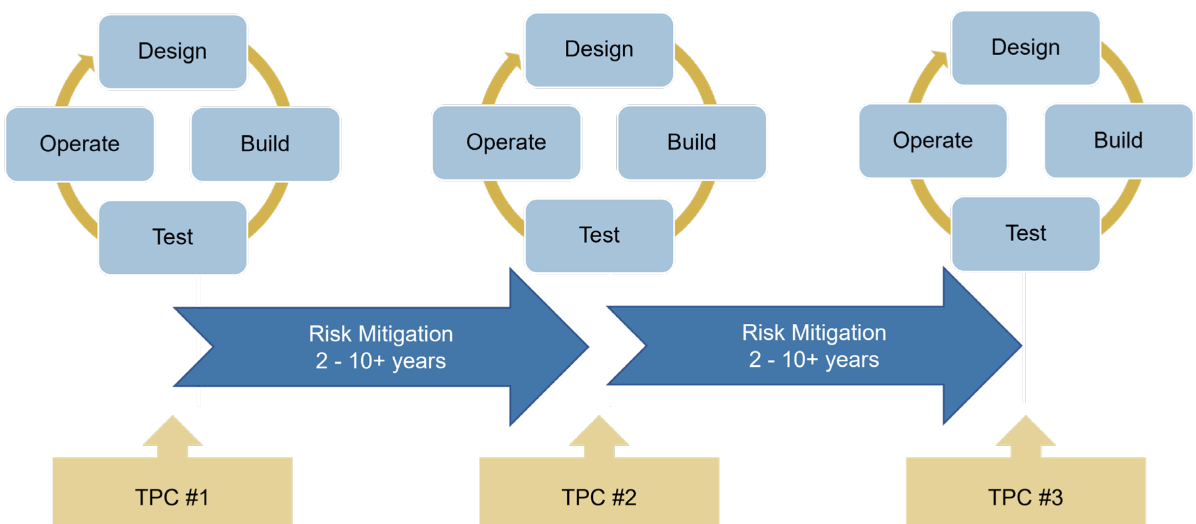
Figure 3.2.1.1-1
Waterfall Model of Design Through Construction Stages



3.2.1.2 Cyclical Approach

Cyclical project management methods are particularly suited when a detailed path toward the final goal is uncertain or where the significant constraints are not initially well understood. Cyclical approaches assume that the goal will be achieved in several iterative, cycles (which may be short or span several years) rather than linear, as in waterfall methods. Efforts that evolve in time or do not initially have a clear scope and requirements and/or require teams to work closely on numerous interdependent tasks are good candidates for cyclical management methods. Examples include RI projects with substantial IT elements, RI projects that have significant research and development needs where defining the final cost, scope, schedule and capabilities holds too much risk, and commissioning activities (tests, trials, and acceptance) as part of the Construction Stage.

Figure 3.2.1.2-1
Cyclical Development Process



Agile is one such cyclical method, initially designed for software development project management, that can be applied to many projects in some form. Within Agile frameworks, multi-disciplinary teams work cooperatively in stages to model solutions, incorporate feedback, and adjust scope as needed throughout the project life cycle. Analysis, design, implementation, and testing are repeated within very short cycles. Rather than employing hierarchical organizational structures, an Agile framework is often matrixed, with team members adapting their roles as needed. Performance management is based on cycles and delivery of capabilities, rather than discrete physical deliverables.

The *Government Accountability Office (GAO) Agile Assessment Guide* offers best practices at a high enough level to be used for any incremental development program, regardless of what type of product or service is being delivered.[1] Agile is not right in all environments. Managing organizations should spend time upfront assessing the technical nature of the proposed project as well as the environment and culture to determine readiness to employ Agile processes (see Section 5.9 Agile Guidance).

3.2.1.3 Level-of-Effort Approach

LOE is a method in which staff or vendors provide a variety of services that span long time frames and where progress is typically tracked through monthly salary or periodic invoicing (also known as cost-weighted milestones), rather than discrete tasks and activities. Since the performance measurement is focused on cost-weighted milestones, EVM may not be the most valuable method for performance management if the project or program is composed mainly of LOE activities. However, almost all projects have some component that is LOE, and these activities can be a significant part of larger projects that are using EVM. If that is the case, appropriate earning rules need to be applied to these activities.

When tailoring a management model, consider that the LOE approach can be suited for project management staff, service contracts, and multi-disciplinary teams that share roles on a limited number of tasks.

3.2.2 Scaling

When deciding on the appropriate approach to scaling, it is important to consider the project or program characteristics. The appropriate scaling level will emerge by matching the characteristics to the level of detail, degree of formality, tools, and management processes needed for success.

Level of Detail. Simple projects or programs might only develop the Work Breakdown Schedule (WBS) to Level 3, which is considered the minimum by industry good practices. In contrast, large construction projects may extend to WBS Level 10 in some areas to capture the work packages in the appropriate detail for cost estimating and monitoring performance.

Control Accounts, where scope, schedule, budget, and estimated/actual cost are integrated and compared to earned value for performance measurement, should be set to minimize accounting efforts while providing insights into status and issues.

Schedules. Schedules should be developed to track work packages accurately. This *right level* for achieving an appropriate or optimal standard for capturing and reporting will vary depending on the scope of work. For example, procurement efforts might have a less

[1] https://www.gao.gov/assets/gao-20-590g.pdf

detailed schedule than those involving design, prototyping, demolition, and construction activities.

Degree of Formality. The degree of formality built into processes and plans is an important consideration as excessive process can detract from the real focus of project management. For example, on a Mid-scale RI design effort an appropriate Change Control Plan might be a simple Change Log authorized by the Project Manager. On a Major Facility project, it is generally a formal process with tiered thresholds for authorization (including NSF approval), Change Request Forms, reviews by Change Control Boards, and controlled implementation. These are both appropriate given the scale of the project and the size of the project management teams.

Tools. A spreadsheet with cost-weighted milestones may be adequate for simple, straightforward project or program for cost and schedule tracking. More complex projects may need commercial software to develop and maintain Resource-Loaded Schedules (RLS) and perform variance analysis.

Management Processes. Performance management processes also have varying degrees of formality. For example, NSF oversight requires a Major Facility to have an EVM system that is verified, accepted, and has periodic surveillance reviews during construction. In contrast, a Mid-scale RI project electing traditional waterfall methods can use a system to monitor progress against the plan using its own institutional standards or something as simple as weighted-milestone tracking (see Section 4.5 Monitoring Progress Against Plan). For operations, the management process may be handled though routine activity status reporting to NSF with actual costs against the proposed budgets for each operational WBS element.

3.2.3 Progressively Elaborating

The progressive elaboration process refines and advances planning of activities from initial, high-level, rough plans to detailed, mature plans as they pass through life cycle stages, review process milestones such as stage-gate reviews during the Design Stage, or internal readiness reviews. The progressive elaboration of plans is both necessary and expected, not only because of the maturity of the project but also the nature of the project or program itself.

For example, in Agile methodology for Performance Measurement and Management (PMM), prototypes support the concept of progressive elaboration because they are used in iterative cycles of mock-up creation, user experimentation, feedback generation, and prototype revision to reduce risk. Rolling wave planning, which involves detailed planning (work package or equivalent) for near-term efforts and more summary-level planning (planning packages or equivalent) for subsequent attempts, may also be considered a type of progressive elaboration that increases detail for near-term work.

Consider design efforts for Major Facilities in the Conceptual Design Phase or a pre-proposal for a Mid-scale RI based on the funding announcement. The Level of Detail might have the following characteristics:

- Budgets are based on parametric estimates or determined top-down.
- WBS and schedule might be only at Level 2 or 3.
- Management processes and organization for the Construction Stage or implementation may be in early development.
- Initial risk analysis is quantitative, but not yet comprehensive.
- A process describing how further plans will be developed or matured should be outlined in the DEP.

As the design progresses and the Construction Stage or implementation nears, more details are provided through the Final Design Phase or the Mid-scale RI full proposal. The Level of Detail will have been progressively elaborated to show the following characteristics:

- Detailed WBS and dictionary in the latest PEP.
- Bottom-up budget estimates with a robust GAO-compliant Basis of Estimate (BOE).
- Detailed schedules, time-phased budget, and funding profile.
- In-depth risk analysis and risk exposure estimate are used to set contingencies.
- Management plans are fully developed (e.g., Change Control, cost estimating and cyberinfrastructure [CI]), Information Assurance (IA), tailored and scaled to project complexity.

Some planning cannot be completed until after the Construction Stage or implementation has begun, for example:

- Process for Quality Assurance/Quality Control (QA/QC) should be well defined, but specific plans may need to be developed later.
- Refined commissioning plans may need to be informed by test results.
- Some late-stage WBS elements may still be at the planning package level.
- Progressive elaboration allows Project Managers to gradually develop a clearer understanding of project requirements, scope, and deliverables, leading to more accurate planning and better project outcomes. By leveraging progressive elaboration, Project Teams can adapt to changes, mitigate risks, and make informed decisions throughout the project life cycle.

3.3 DEVELOPMENT STAGE PLANNING

Section Revision: TBD Early 2025

Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

There are no standard required plans for the Development Stage. As described in Chapter 2 NSF Life Cycle Oversight, the Development Stage is where early ideas for new or upgrades to Major Facilities are formulated, so planning needs vary widely within scientific disciplines. For example, early development activities might require a plan to illustrate how and when workshops and other outreach activities will bring the science community together to draft science mission requirements or the Key Performance Parameters (KPP). Developing a Master Plan is also generally considered to be associated with Development Stage activities. Late-stage development activities might require a plan to illustrate how the design and science requirements will be refined, prototypes utilized, and a rough order-of-magnitude cost estimate prepared to support advancement into the Design Stage. These activities could also be included in the proposal and would not require a separate plan.

Any formal plans required as deliverables would be described in the funding announcement, if used, and the terms and conditions of the Development Stage award(s). Consultation with the Program Officer (PO) is encouraged for Development Stage planning and proposal submission.

3.4 DESIGN STAGE PLANNING

Section Revision: TBD Early 2025

Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

3.4.1 Design Execution Plan

The Design Execution Plan (DEP) describes the work to be conducted by the Awardee as part of a design effort. For Major Facilities, the DEP would first be submitted and reviewed to support an award at the planned point of entry to the Design Stage, normally the Conceptual Design Phase, or soon after entry is approved by NSF. A DEP would then be submitted and reviewed at the Conceptual Design Review (CDR) and Preliminary Design Review (PDR) to support the award of the Preliminary Design Phase and Final Design Phase, respectively. For a Mid-scale RI project, the DEP could be submitted for NSF review in accordance with the funding announcement or other program requirements. Like the Project Execution Plan (PEP), a DEP is considered a living document. If the Design Phase is extended or the proposed activities change, a revision to the DEP may be appropriate.

Regardless of the scale of project, the primary deliverable to NSF from the design activities is a refined PEP for the proposed construction, acquisition, or implementation that may take place in the future, if awarded. Other deliverables the Awardee could provide to NSF to document progress during design may include technical designs and specifications, test reports, prototype assessments, and documentation of actual or planned contributions from other partners. The DEP helps set expectations for all deliverables to NSF for inclusion in the terms and conditions of the award.

The DEP should leverage the 10-section format of the PEP described in Section 3.5 Construction Stage and Implementation Planning, tailored and scaled specifically to the proposed design activities. All ten sections are required, as well as all the subsections should be tailored and scaled appropriately for the Design Stage. However, some sections may not be applicable for all projects, so it is recommended that the proposing organization include a brief discussion on why any main section is omitted to facilitate NSF review. The content of the DEP is at the discretion of the proposing organization and will vary dramatically based on the size, complexity and technical nature of the proposed project. The scope of the DEP should reflect the activities necessary to advance the proposed project to the next level of technical readiness, which may be another phase of design or the start of construction or implementation. The structure and content of the DEP should be as follows:

1. **Design Execution Overview**: Overview of the proposed design effort to advance the proposed project.
2. **Organization**: Description of the organization supporting design, including all partner organizations and Key Personnel (KP), and where they fit into the organizational structure.
3. **Design Baseline**: A Work Breakdown Structure (WBS) format, even for Level-of-Effort (LOE) activities, **must** be included to help illustrate the primary deliverables and how the proposed budget was developed. Describe the activities that will be undertaken

in order to achieve readiness for construction, such as design, prototyping, manufacturing process validation, vendor qualification, modeling and simulation, creation of required project management plans, and forming partnerships. The schedule should be logical and credible, and critical design, review, and deliverable milestones should be listed. A fully developed Integrated Master Schedule (IMS) may be appropriate for large, complex design activities. As noted above, one deliverable from design is always a refined PEP to support eventual construction/implementation, if awarded. The estimate of the total budget required to complete the design, including NSF funding and any contributions from partners and other outside sources, and the planned level of design maturity/detail at major milestones may also be included.

4. **Scope Acquisition and Delivery**: Description of significant procurement activities supporting design and how quality of any deliverables will be assured.
5. **Safety, Health & Environmental Protection**: This section would be generally applicable to design activities that involve laboratory testing, prototyping or field work. Institutional Health and Safety policies can generally be referenced, but anything specific to the award activities should be considered.
6. **Controls**: At a minimum, this section should describe how progress against the proposed plan for design will be monitored and controlled by the Awardee. For larger, more complex projects, Configuration Control for the design itself should also be articulated along with how any internal design reviews will be utilized to advance the design.
7. **Information Management**: At a minimum, this section should describe how any information developed during design (specifications, drawing, test results, etc.) will be managed and controlled (see Section 5.3 Information Assurance).
8. **Risk Management**: This section should include a Risk Register for the design activities and describe planned risk mitigations being conducted during design, including testing and prototyping to reduce risk during construction/ implementation, if awarded. If contingencies are requested for the design award (scope, schedule, or budget), or allowances are included in the estimate of the design effort, they should be described here, along with how each was developed or estimated. Statistical analysis (like Monte Carlo) is not required for estimating budget contingency on design activities.
9. **Award Close-out**: This section should describe the proposed method on how the current award will eventually be closed out, which will depend on the structure of the award and the overall schedule for design. For example, if associated with a Major Facility, the design award may be extended several times through supplemental funding requests and award close-out may not happen until well into the Construction Stage. Consultation with NSF on the award structure is expected for Major Facility Design Stage awards. For Mid-scale RI, award close-out may happen before a decision is made to advance to implementation depending on the funding program.

10. **Post-Award Plans and Expectations**: Post-award in this case means following the end of the current design award. For Major Facilities, post-award plans may include submission of the revised DEP for review and award of a subsequent Design Phase following successful completion of a stage-gate review (see Section 2.5 Major Facility Design Stage). For Mid-scale RI projects, it may be planned submittal of the mature PEP to support a future implementation proposal.

3.5 CONSTRUCTION STAGE AND IMPLEMENTATION PLANNING

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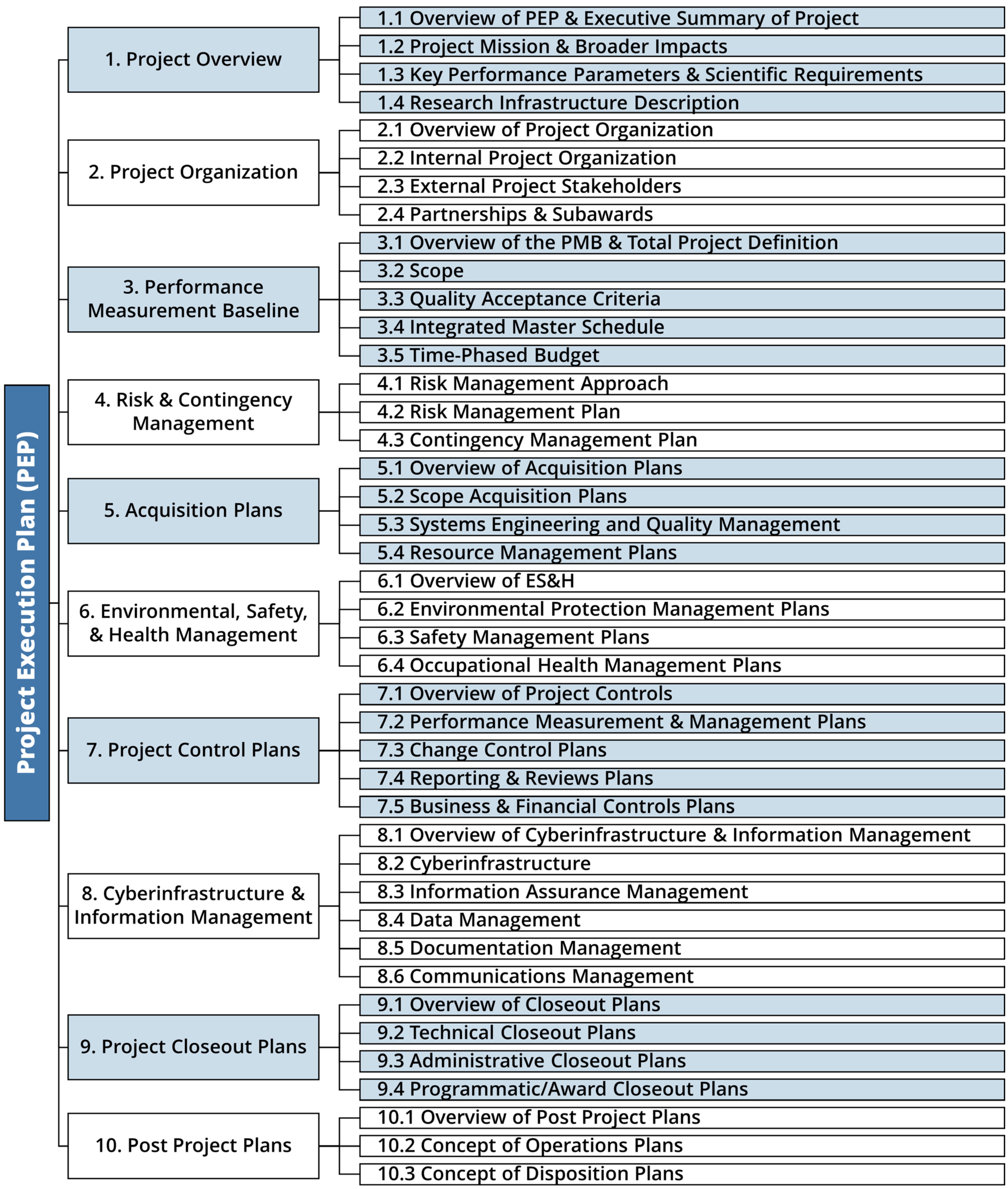
> **NSF Requirement**
>
> Major Facilities and Mid-scale RI projects **must** create a PEP, *including all components and subcomponents*, tailored and scaled appropriately for the Construction Stage or implementation.

The Project Execution Plan (PEP) is an organized presentation of the various plans describing how a project will be planned, managed, executed, and concluded by the Awardee. The PEP should provide a useful description of the project, what the project will deliver, how performance will be measured and reported, details on who will manage the effort, what resources are required to complete the project, how long the project execution phase will last, when identified milestones are to be met, and how much risk or uncertainty is associated with the project plans. The PEP is a living document, and Awardees are expected to carry out the project in accordance with the plan. A PEP is required for all Major Facilities and Mid-scale Research Infrastructure (RI) projects. However, the details of the plan and associated complexity will vary markedly and should be tailored and scaled to match the project characteristics (see Section 3.2 Tailoring, Scaling, and Progressively Elaborating Plans).

The PEP should contain or reference all project-related documents and be the authoritative source explaining how and why the plan meets all project objectives. As noted in the detailed guidance sections, some components of the PEP may be detailed or more extensively presented in appendices or in separate documents, especially living documents like the Risk Register or lengthy documents like the full Work Breakdown Schedule (WBS) dictionary and detailed design drawings. The PEP and all associated files should be presented to NSF as a current, complete, and consistent set, in both PDF and native file formats (e.g., Excel), and updated versions shared regularly. It should summarize and reference these separate documents to convey the complete scope of pre-construction planning and allow for effective evaluation of the project plans. In addition, it is important to note that the PEP is expected to be updated or revised throughout the development and conclusion of the individual project. The PEP should be adjusted to reflect changes in all components described in the following sections.

Detailed guidance on PEP structure and content for NSF-funded Major Facilities and Mid-scale RI projects is included in the following sections to ensure proposers understand the *what, why, and how* of proper project planning. Figure 3.5-1 provides an overview map of the PEP components and subcomponents that proposers requesting NSF support for RI projects should follow unless alternate descriptions or content are specified in a program solicitation or at the direction of the Program Officer (PO) or Officers, who will manage the review of any submitted proposals. **Each PEP component is required, regardless of project size, but some subcomponents may not be applicable for all projects. Proposers must address all components and subcomponents and may indicate *Not Applicable* for any that do not apply and provide a rationale for that determination.** Preparation and presentation of a rigorous and complete PEP will ensure that proposers can present their ideas in the best possible light, support effective merit review, and serve as a critical resource to manage and complete RI projects.

Figure 3.5-1
PEP Overview Map



3.5.1 PEP Component 1 – Project Overview

What Does This Component Describe?

This component provides a succinct, clear, and unambiguous overview of the project. It includes an Executive Summary of the project, including whom the project is intended to serve, the science objectives and purpose of the project (i.e., the driving *why* behind the project), and a summary description of the proposed solution for that purpose. A mission statement for the project is included, along with a brief recap of any scientific and/or broader impacts that will result from the project. Also included is a high-level summary of the deliverables, along with the Key Performance Parameters (KPP) and high-level constraints and assumptions that will be the boundary conditions for the project.

Why Is This Component Important?

First, the overview helps ensure that everyone involved in the project has a shared vision of the goals the project is trying to achieve. A shared perspective can help to avoid misunderstandings and conflicts during project execution. The Project Team and funders gain direction and mission alignment by articulating the *why*. Second, the overview is a guiding beacon throughout the course of the project, helping with decision-making and prioritization. When issues arise that require a choice between competing solutions, returning to the formal *why* of the project will often provide clear direction and guidance. Additionally, the overview helps to foster better understanding and clarity for external stakeholders as to why particular decisions were made. Finally, the overview can help to motivate and engage the Project Team by ensuring everyone understands the ultimate goal and the impact it will have.

How To Develop and Write This Component

There are four subcomponents included in the Project Overview Component, as listed in Table 3.5.1-1 below. The subcomponents provide a high-level summary of the PEP and the project, outline the need and motivation for the project, list the high-level requirements to be met, and finally, describe the Research Infrastructure (RI) solution to the needs and requirements. The Project Team and funders should reach a consensus of the contents of the project description.

Table 3.5.1-1
Project Overview Subcomponents, Products, and Documents with References to Further Material and Related Topics

Component	Subcomponent	Documents/Products	References
1. Project Overview	1.1 Overview of PEP and Executive Summary of Project		
	1.2 Project Mission and Broader Impacts	• Project Mission Statement	In accordance with the award instrument used.
	1.3 Key Performance Parameters and Scientific Requirements	• List of Key Performance Parameters • Science Requirements Table	
	1.4 Research Infrastructure Description		Section 4.2 Scope and Work Breakdown Structure

3.5.1.1 PEP Subcomponent 1.1 – Overview of PEP and Executive Summary of Project

This subcomponent serves two primary purposes.

PEP Overview. This overview should provide a short, high-level overview and understanding of the purpose of the PEP as the project management document, how it is structured and used, and how it will be updated during the course of the project.

Executive Project Summary. The summary includes high-level statements of why the project exists, who it will serve, what the primary science objectives are or how the project supports multiple science objectives, and what will be created and delivered to meet those objectives (i.e., the RI). The summary should list the Total Project Cost (TPC) and Total Project Duration (TPD) as well as the major deliverables. A brief description of the key institutions and partnerships should be included. The summary should be contained in a page or less. More specific details on these items are then described in their respective components and subcomponents that follow.

Good Practices and Practical Considerations

- The primary purpose of the executive project summary is not to promote the project; that's the purpose of the project proposal. Instead, it should clearly and unambiguously describe who the project serves, what will be created and provided (i.e., the RI), and why the RI is needed by the scientific community and then act as a manual for implementing the RI.
- This component provides the project description that is fully agreed upon by the key project stakeholders, team members, and other relevant parties. It also serves as a touchstone during project execution to ensure that plans, decisions, and actions align with the project's overarching purpose and mission.

3.5.1.2 PEP Subcomponent 1.2 – Project Mission and Broader Impacts

This subcomponent describes the overall high-level purposes, scientific objectives, and broader societal impacts of the project. Specifically, the following elements should be described in this subcomponent.

Project Mission. This subcomponent includes a more detailed and complete description of the scientific objectives motivating the RI project than the overview section (i.e., the driving *why* behind the project) and a description of who the project is intended to serve (e.g., the specific scientific community, end users, and benefactors of the RI in operations.)

Broader Impacts. Regardless of the award instrument used, it is important to describe the impacts of NSF's investment beyond simply delivering the infrastructure to technical requirements. This subcomponent provides a description of any meaningful Broader Impacts that advance scientific knowledge and that contribute to the achievement of societally relevant impacts on research communities, the scientific and technical workforce, and the public and society at large.[1]

Good Practices and Practical Considerations

- The best project mission and science objective statements are relatively concise and clearly state the project's goals and purpose. A good rule of thumb is to strive to state the project's mission in one or two paragraphs. Overly verbose statements often suggest that the project purpose is not yet fully distilled, understood, or explainable. Quantitative objectives should be reserved for the KPP and Quality Acceptance Criteria.
- There is a common misconception that Broader Impact activities should only be separate add-ons related to the eventual research activities, but Broader Impacts can also be integral to the project baseline activities. For example, the development of a diverse, globally competitive science, technology, engineering, and mathematics (STEM) workforce trained in RI design, implementation, and commissioning can be addressed by using project activities as practical training to supplement academic training.
- There is a practical cost to meeting Broader Impact goals. The scope of deliverables, activities, and budget that are related to Broader Impacts should be specifically identified in the project baseline described in PEP Component 3 Performance Measurement Baseline.

[1] For financial assistance proposals see https://www.nsf.gov/nsb/publications/2022/merit_review/FY_2021_Merit_Review_Digest.pdf

3.5.1.3 PEP Subcomponent 1.3 – Key Performance Parameters and Scientific Requirements

This subcomponent provides the quantitative descriptions of requirements which provide the basis for determining the attainment of the scientific objectives and, therefore, project completion.

Key Performance Parameters. The KPP are derived from the project mission and science objectives and should include a descriptive list of the high-level KPP and functional requirements of the RI. A KPP is a critical feature, function, requirement, or design element that, if altered, may significantly impact the facility or system's performance, scope, schedule, cost, risk, or the ability of a related project to meet its mission requirements.

Threshold KPP encompass the minimum science parameters against which the project could be considered successful.

Project Team may choose to include objective KPP that describe the optimal or desired technical goals of the project, provided performance is sustained and sufficient resources are available. Objective KPP often enhance operational efficiency or extend science capabilities. Appropriate parameters are those that express performance in measurable terms of accuracy, capacity, throughput, quantity, processing rate, purity, reliability, sustainability, or others that define how well a system, facility, or other project will perform.

The difference between objective and threshold KPP should relate to scope/quality contingency plans. If the Project Team is forced to de-scope or re-baseline, the threshold KPP may need to be accepted (see Section 4.7 Contingency Estimating and Management). Alternatively, the objective KPP may represent an opportunity that can be captured.

Science Requirements. These requirements should include a high-level listing of the primary science requirements to be fulfilled by the RI, derived from the KPP described above. Note that these requirements should in turn serve as a basis for the definition of project scope (deliverables).

Table 3.5.1.3-1
Key Performance Parameters and Science Requirements for a Hypothetical Mission to Build a Next-Generation Ground-Based Optical Telescope

Key Performance Parameters (KPP)		
Description of Scope	**Threshold KPP**	**Objective KPP**
Facility Size	Dome building including control room; utilities building	Threshold spaces plus Admin building with data storage, meeting room, and 8 offices
Observational Capability	Angular resolution capable of resolving exoplanets orbiting stars within 70 light years	Angular resolution capable of resolving exoplanets orbiting stars within 100 light years.
Duty Factor	Observing time in faint object operating mode: More than 1000 hours per year.	Observing time in faint object operating mode: More than 1500 hours per year.
Facility Lifetime	Operating lifetime of observatory of 40 years.	Operating lifetime of observatory of 50 years.
Science Requirements		
Description of Scope	**Threshold Requirement**	**Objective Requirement**
Facility Size	124,000 SF	127,000 SF
Brightness	The telescope must operate at wavelengths from ultraviolet (200-300nm) to near-infrared (1100-2500nm)	The telescope must operate at wavelengths from ultraviolet (200-300nm) to near-infrared (1100-2500nm).
Spatial Resolution	Observing resolution of 0.5 arc-seconds.	Observing resolution of 0.1 arc-seconds.
Signal-to-Noise Ratio	Science instrument achieving signal-to-noise ratios greater than 50:1.	Science instrument achieving signal-to-noise ratios greater than 100:1.

Good Practices and Practical Considerations

- The key science requirements, constraints, assumptions, and other requirements included herein this subcomponent should only include very specific, high-level requirements; the complete list of science requirements, flow-downs to engineering requirements, and all quality acceptance criteria are described below in PEP Component 3 Performance Measurement Baseline.

3.5.1.4 PEP Subcomponent 1.4 – Research Infrastructure Description

This subcomponent describes the infrastructure necessary to obtain research and Broader Impact objectives. Specifically, the following elements should be described herein in this subcomponent.

RI Description. This subcomponent should include a high-level overview of NSF-supported RI, i.e., the project deliverables. The descriptions should correlate directly with the Level 2 product scope (deliverables) of the Work Breakdown Structure (WBS), as described in PEP Component 3 Performance Measurement Baseline below.

Related Infrastructure. If the project deliverables are to be incorporated into or with other infrastructure or deliverables not covered under the funding instrument, the goals of the larger infrastructure should be articulated, along with the relationship of the project deliverables with the wider goals.

Good Practices and Practical Considerations

- This subcomponent serves as an Executive Summary and overview of what the project will create and/or provide; it does not replace the WBS described below in PEP Component 3 Performance Measurement Baseline. Instead, this subcomponent provides a high-level overview of the project deliverables, described at Level 2 of the WBS. The WBS and WBS Dictionary provide the formal definition and description of the project scope.
- It is often helpful/useful to describe key exclusions in this subcomponent, that is, items that are aspects of the RI that might reasonably be expected to be part of the project deliverables but that are provided by other means/funding/entities. Examples might include space and site preparations provided by the host institution or spare equipment to be used and provided by operations.

3.5.2 PEP Component 2 – Project Organization

What Does This Component Describe?

This component describes the internal and external organizational structure necessary for successful project implementation. It includes a description of the Project Organization and defines key roles, responsibilities, and communication lines for both external stakeholders and internal project staff.

Why Is This Component Important?

A Project Organizational structure that matches the characteristics and needs of the Project Team will facilitate successful management and completion. Well-considered positions and assignments avoid miscommunications and misunderstandings and ensure that all stakeholders and project participants are aware of their respective roles, responsibilities, authorities, and lines of communication during the execution of the project.

How To Develop and Write This Component

There are four subcomponents in Component 2 – Project Organization, as listed in Table 3.5.2-1 below. The first three provide an overview of the organization and detailed descriptions of the external and internal participants and stakeholders, and the fourth subcomponent is specific to collaborations or partnerships with other entities and institutions for the project.

The Project Organization should be structured in a manner tailored and scaled to the type, size, complexity, and characteristics of the project. The Project Team and funders may be familiar with the organization and reach consensus of its structure, roles, and authorities. The organization is typically developed in a progressively elaborated approach, as described below in Subcomponents 2.2 – Internal Project Organization and 2.3 – External Project Stakeholders below.

Table 3.5.2-1

Project Organization Subcomponents, Products, and Documents with References to Further Material and Related Topics

Component	Subcomponent	Documents/Products	References
2. Project Organization	2.1 Overview of Project Organization		
	2.2 Internal Project Organization	• Organization Chart • Roles and Responsibilities Table	Section 4.2 Scope and Work Breakdown Structure Section 5.7 Personnel and Competencies
	2.3 External Project Stakeholders	• Organization Chart • Roles and Responsibilities Table	
	2.4 Partnerships and Subawards	• List of Partners, Agreements, and Contributions	Section 5.8 Partnerships

3.5.2.1 PEP Subcomponent 2.1 – Overview of Project Organization

The overview provides a summary of the Project Organization, including the general Project Organizational structure, key participants, external stakeholders, project partners, and any other important organizational information necessary to explain and execute the project successfully.

3.5.2.2 PEP Subcomponent 2.2 – Internal Project Organization

This subcomponent describes the internal organizational structure of the Project Team. The identification of key internal positions and leadership roles should occur early in the project planning process, along with the selection of an organizational structure that is compatible with the project characteristics. The chosen organizational structure should be matched (tailored) to the characteristics of the project and aligned with the key project deliverables as detailed in the project Work Breakdown Structure (WBS) containing all project scope. The organizational structure should dictate roles and lines of responsibility and authority.

An internal organizational chart and a roles and responsibilities table are essential for all implementation and Construction Stage projects in this subcomponent. The organizational chart is a graphic representation of the internal project Organizational Breakdown Structure (OBS) and shows key roles and leadership positions within the Project Team and clear lines of communication and authority. A roles and responsibilities table provides a description of the roles, responsibilities, authorities, and communication linkages between key leadership and management positions in the internal organization.

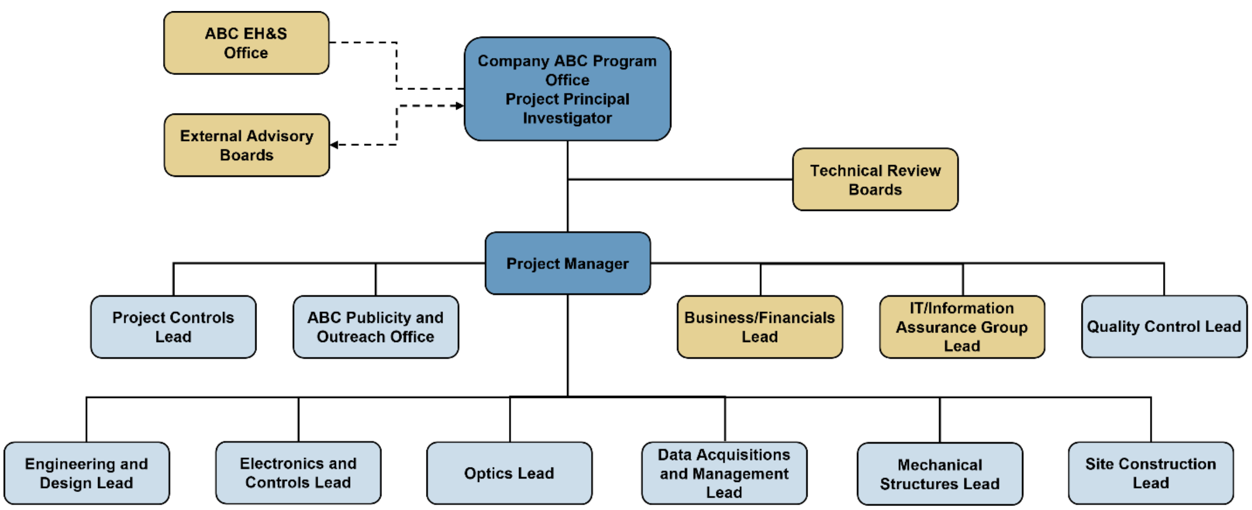
Internal Organizational Chart. The three most common structures for NSF projects are traditional hierarchical, functional, and matrixed. The chosen organizational structure should be negotiated with and approved by NSF.

Traditional organization structures are hierarchical in nature and match a traditional (often called Waterfall) WBS. Project roles are aligned with the deliverables captured in the project WBS. Lines of authority and responsibility for deliverables in the WBS are one-to-one and flow from the top levels of the WBS down to lower levels. Roles and responsibilities can be clearly and simply defined. An example of a traditional Waterfall organization chart is shown in Figure 3.5.2.2-2.

Functional organizations, where leads and teams are aligned with institutional and support functions rather than deliverables, are allowed but are less common. Functional leads report directly to the Project Manager (PM) and manage their staff's assignments to work on deliverables across the WBS. The mapping between leadership below the PM and responsibility for deliverables in functional organizations can be less clear than in traditional hierarchical structures since one individual or support group may serve the same function across several WBS elements. In that case, a Responsibility Assignment Matrix (RAM) that assigns individuals or organizations to all tasks and deliverables becomes essential for assuring that all project scope has assigned and responsible oversight. A typical RAM may have four primary assignments: *Responsible, Accountable, Consulted, and Informed* (and therefore is also called a RACI matrix). An example of a functional organization chart is given in Figure 3.5.2.3-1.

Figure 3.5.2.2-1

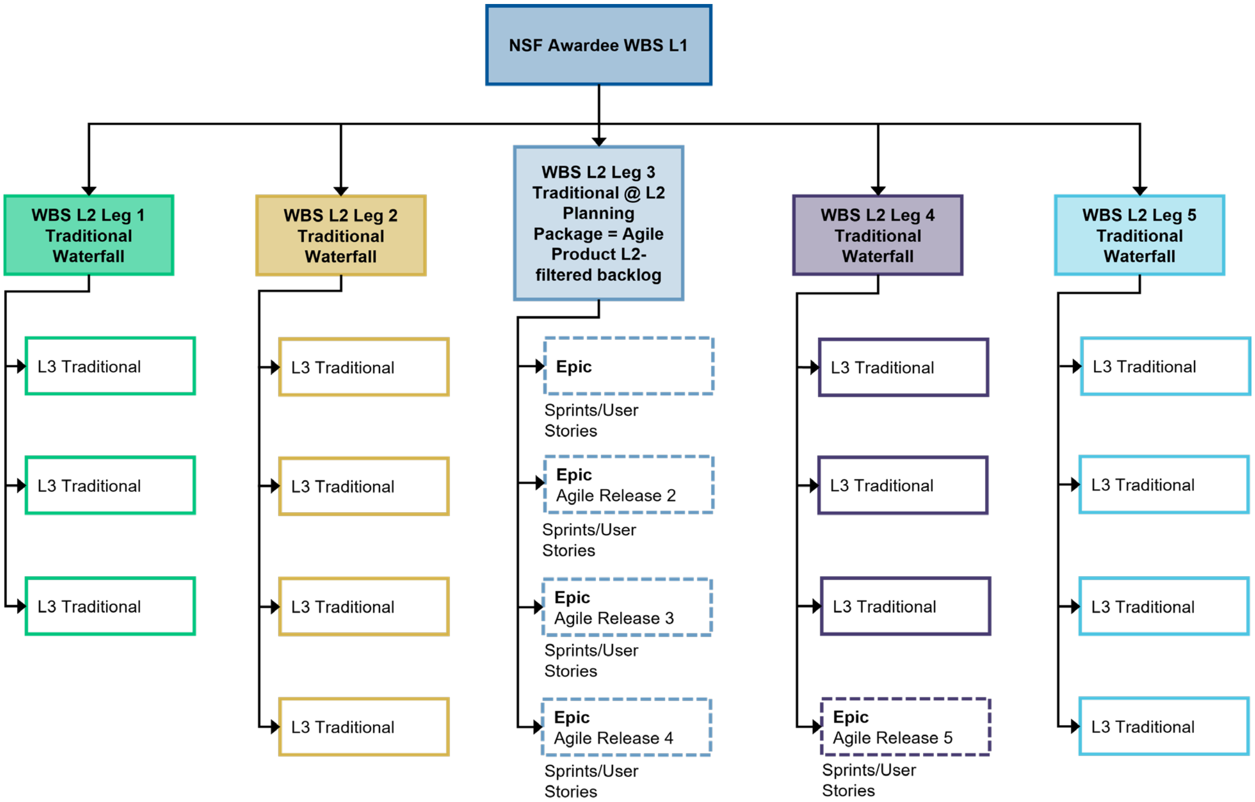
Functional Project Organization: Capability Area Leads Reporting to Project Manager with Deliverable Responsibilities



Projects that are cyclical in nature or that require flexibility and speed, such as software projects based on Agile frameworks, may rely on a matrix or non-hierarchical organization. A matrix organization can be represented by a grid with functional roles on one axis and hierarchical roles along another. Managers and leaders share authority and responsibility for deliverables with others, and workers may report to multiple supervisors. Note that NSF requires a traditional, hierarchical structure down to WBS Level 2 (see Section 3.5.3.2 PEP Subcomponent 3.2 – Scope) but allows flexibility in organizing below those levels along other, well-justified structures such as Agile-based Stories, Epics, or other cyclical work packages. An example of such a hybrid organization that includes an Agile structure at lower WBS levels is shown in Figure 3.5.2.3-2.

Figure 3.5.2.2-2

NSF Program Plans, Reports, Milestones, Schedules WBS L1 and L2, L3 and Below Support, WBS Leg 3 Users Agile to Support Budgeting, Scheduling, and Variances Below WBS L2



Key positions, organizational structure, relationships, and roles and responsibilities should be determined as early as possible in the Project Team. Not all positions may be identified at first, nor will all be filled during early planning. As planning matures and approaches the start of implementation and Construction Stage, roles will become better defined, and individuals can be identified and assigned to the positions in the chart. The Resource Management Plan that is detailed in PEP Component 4–Risk and Contingency Management should provide details of how any unassigned key positions will be filled in a timely manner through hiring or other means (for example, hiring plan schedule and actions to ensure that Key Personnel ([KP], such as a PM) are on board by the start of implementation).

Roles and responsibilities for leadership positions should be aligned with the needs of the position before any consideration of personnel assignments. Personnel selected for leadership and key roles in the Project Team should have all the necessary skills, experience, and qualifications for the assigned position, including scientific, technical, and administrative qualifications. Awardees may want to consult Section 5.7 Personnel and Competencies for assistance in defining the roles and responsibilities. Written and tabulated examples of roles and responsibilities are shown below.

Figure 3.5.2.2-3
Example of Written Descriptions of Roles and Responsibilities

Environmental, Safety, and Health (ES&H) Officer:

- An ES&H staff member trained in safety and shop operations will provide weekly guidance and oversight on safety and compliance. The ES&H Officer will advise on safety-in-design aspects of the design and assembly plans. The ES&H Officer will visit and assess the safety plans for the assembly site and review the safety plans for testing.

Project Manager (PM):

- The PM reports to the Principal Investigator (PI) and is responsible for the oversight of the budget, schedule, change management, and risk management. The PM oversees the work package leads and manages the execution of the project to ensure that the project is completed within the approved cost, schedule, and technical scope. The PM is responsible for the development, documentation, and implementation of effective project management systems, cost controls, and schedule milestones to assess project performance. The PM is responsible for risk evaluation and management in accordance with the project Risk Management Plan. The PM chairs the Change Control Board and is responsible for approvals before passing Change Requests to the PI for final approval.

Table 3.5.2.2-1
Example of a Roles and Responsibilities Table

Roles and Responsibilities		
Title	**Name and Institution**	**Roles and Responsibilities**
Bike Spec and Design Team Lead	Maria Martinez, Tech Univ. Eng. Department	• The Bike Spec. and Design Lead reports to the PM and is accountable for meeting designated work package deliverables. • Responsible for keeping communications open with the PI, the PM, other team leads, and all Project stakeholders. • Responsible for planning and maintaining the technical design, scope, cost, and schedule. • Supervises the resources and contracts for accomplishing the tasks and adjusts the schedule to meet stakeholders' needs. • Assures compliance with technical requirements, Project configuration management, and Tech Univ. policies/procedures regarding procurements and EH&S. • Monitors and controls risks, tracks progress against the plan, and reports status and variances on the defined schedule. • Participates in Change Control Board discussions and follows configuration controls with respect to changes in scope, cost, schedule, and/or performance.

Good Practices and Practical Considerations

- The size and complexity of the organizational chart (the number of leadership roles and layers of authority) should align with the project's characteristics. For example, large complex projects may choose to assign a lead and a deputy for a particular leadership position so that, between the two, both technical and management needs can be met. Smaller and less complex projects may include only one individual for each leadership role, and those individuals may serve in multiple leadership assignments.

- Whether projects combine the PI and PM roles into one, keep them separate or add a third role for a Project Director, each role should be clearly and fully described.
- Carefully consider the number of direct reports to a manager based on the types of positions and level of supervision and management required.
- The organizational structure presented in the PEP should be high-level and include leadership and KP, not every individual working on project tasks. Key positions listed in the internal project organization should include the PI and Co-PI, the Project Director if separated from the PI role, the PM, primary Technical Leads and Control Account Managers (CAM), and any other key leads, such as Safety Officers or Systems Engineers. The complete listing of all project positions is developed in the Staffing Plan described in PEP Subcomponent 5.4 – Resource Management Plans.
- For traditional organizations, it is good practice to include WBS numbers in the organization chart to easily tie responsibility and authority to work packages and deliverables.
- Technical team leadership may be shared between a Lead and a Deputy, with one assuming leadership in scientific or technical aspects and the other leading day-to-day activities and project management responsibilities.
- The focus for the definition of the organizational roles and responsibilities should be the requirements for the position to be filled. It is not necessary to list all the experience, positions, and honors of the assigned key and leadership personnel in this section.
- If additional Project Team training is planned, it should be included in the Staffing Plan as described in PEP Subcomponent 5.4 – Resource Management Plans. Examples may include general project management training as well as specific training for CAM performance reporting and tracking.
- RAM and RACI tables are common ways to capture roles and assignments. Many projects expand their RAM with CAM assignments. The essential goal is to ensure that all WBS elements or deliverables have an assigned individual with responsibility and authority to ensure that all scope is completed within budget and schedule while meeting requirements.

3.5.2.3 PEP Subcomponent 2.3 – External Project Stakeholders

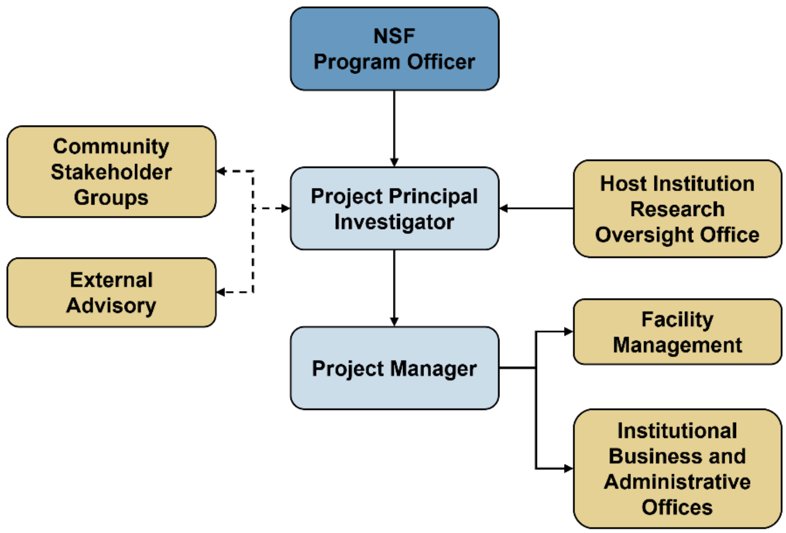
In this subcomponent, key external project stakeholders are identified and described, along with their connection to the project, their expected roles, and their lines of communication and authority. External stakeholders are individuals and entities with relationships to, and interactions with, the project that do not normally involve contributions to day-to-day project activities or deliverables (e.g., NSF, user groups, host institutions, etc.). The following products of this subcomponent include:

- **External Organization Chart.** A graphical depiction of how the project structure relates and interacts with all key external stakeholders.
- **Roles and Responsibilities List.** A table or list with descriptions of the roles, responsibilities, authorities, and communication links between the project and all identified key external stakeholders.

Examples of a sample external organization chart and example roles and responsibilities descriptions are shown in Figure 3.5.2.2-1 and Table 3.5.2.2-1 below. Please note that the figures and tables are only illustrative, and projects should decide and define the structures and roles that best match their needs.

Figure 3.5.2.3-1

External Organization Chart: Authority and Communication Lines in a Traditional Project Structure



Generally, external stakeholder relationships start to be identified or formed during the Project Definition period, with communication and interactions initiated well in advance of the start of the Construction Stage or implementation. The external organization chart becomes more refined as planning advances and becomes mature. For stakeholder relationships not yet established, the Awardee should explain the plans and steps necessary to set up communications and interactions, including details such as identified contacts, frequency of meetings, charters, intellectual property provisions, along with others.

The types and number of external stakeholders included in the external organization varies from project to project, based on project characteristics and needs. External stakeholders may include, but are not limited to, the following:

- **Funding and Oversight Groups**. NSF is typically the primary funding and oversight entity for projects described in this PEP. For projects that are part of a larger endeavor, there may also be other external entities with oversight and responsibility for the overall project, including the NSF-funded portion.
- **Institutional Project Sponsors**. These are typically leaders or departments in the Awardee organization with an interest in the outcome of the project and

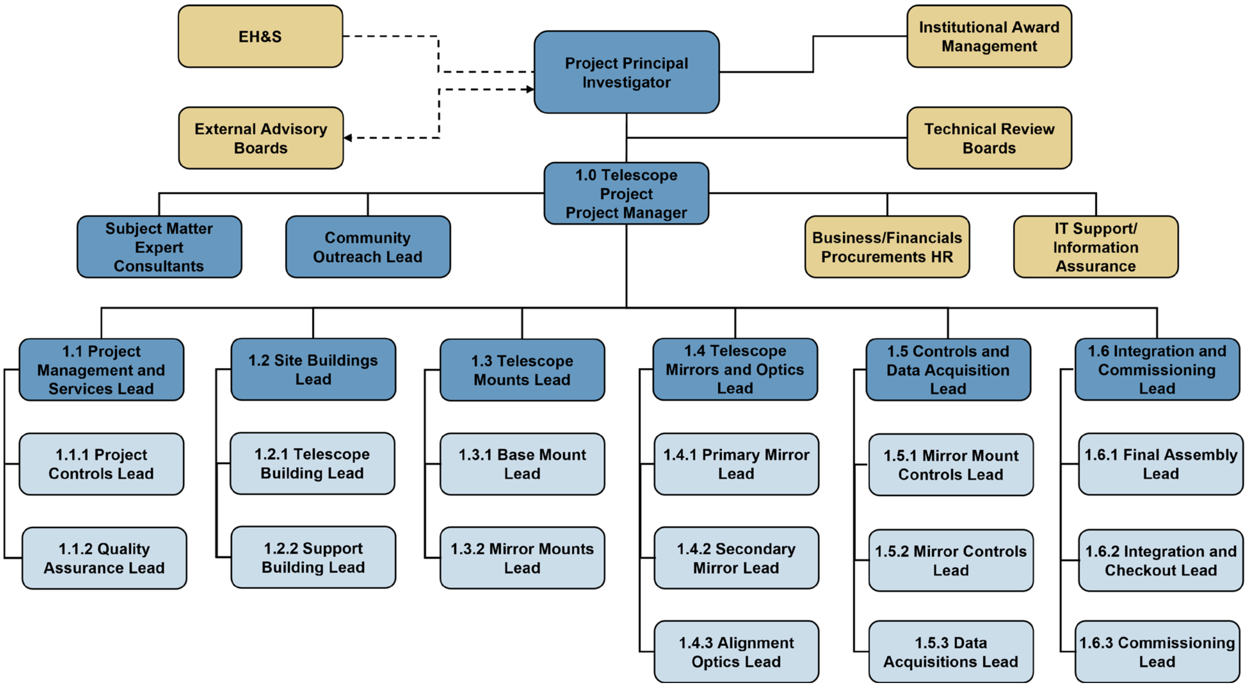
organizational authority to provide resources and overcome barriers to the project. Examples: vice president for research, sponsored research offices, facilities providing space and resources, institutional business, and administrative services departments, and so forth.

- **External Advisory Boards**. Some projects may have a group of Subject Matter Experts (SME) that provide ongoing consultation for science and technical matters, community engagement, programmatic advice, or other relevant topics. The oversight function is the responsibility of NSF and/or other funders.
- **External Technical Review Boards**. These are independent review or readiness panels, organized by the Project Team, that provide the Team advice on various technical topics. They are typically composed of SMEs external to the Project Team but can also include ad hoc internal SMEs from unrelated components of the project. These external, technical review boards are generally in addition to review panels or boards used to verify designs or accept quality testing.
- **Research Community Stakeholder Groups**. Projects may maintain communications with representative groups comprised of researchers interested in using the infrastructure or resultant data and who, therefore, have an interest in the project deliverables and future operations. Examples of these may include a Science Working Group or a user's group. Relationships with these groups are typically for information exchange only.
- **Public Community Stakeholder Groups**. Projects may likely want to establish relationships with representatives of the public who have an interest in the public impacts of project implementation and who may, therefore, have influence on project activities and outcomes. Examples include individuals, communities, organizations, and anchor institutions such as governments, federal, state, and local agencies, schools, libraries, health and social service providers, tribal and indigenous-serving organizations, non-profits, cultural organizations, and businesses.

The most common structure used for an external organization chart for a Mid-scale RI project is the traditional, hierarchical layout, as shown in Figure 3.5.2.2-2.

Figure 3.5.2.3-2

Hierarchical Organization Structure for a Traditional Waterfall Project with Work Breakdown Structure-Aligned Leadership Positions



Note that relationships between project leadership and external stakeholders are indicated with clear lines of communication and authority shown on the chart. Arrows, dotted lines, and position in the chart can indicate the direction of interactions, oversight and authority versus communications, and primary contacts.

Table 3.5.2.3-1

Examples of External Roles and Responsibilities

External Roles and Responsibilities	
External Advisory Board	The Advisory Board is composed of SME, recommended by the project leads, and appointed by the project PI for the duration of the project. The Board provides advice and recommendations on project management and technical issues to the PI.
User Group Board of Representative	The users' group is an independent, external coalition of researchers and potential users of the completed infrastructure, with a stake in the design requirements, performance, and operations of the infrastructure. A Board of Representatives, comprised of volunteer or elected members and serving according to the Group's charter, will meet with the project PI. During the meetings, the PI will update the Board on the status and plans of the project, while the Representatives will provide input on the desired usage of the infrastructure and communicate any concerns or issues that may impact the wider research community.

Good Practices and Practical Considerations

- Advisory groups (technical advisors or user groups) have no oversight or role of authority in the Project Team, and the PI has no obligation to adjust project requirements and goals. However, the PI should be responsive to requests and concerns as allowed by the constraints of the project.

3.5.2.4 PEP Subcomponent 2.4 – Partnerships and Subawards

This subcomponent identifies all partners and Subawardees who are essential contributors to the success of the project, describes their contributions, and identifies the responsible partner contact/lead. Information on funding sources for each partner, the terms and conditions of the partner agreement (Memorandum of Understanding [MOU], subaward, commitment letter, etc.), and details of schedules and interfaces should be provided, and may include discussions of the criticality of the deliverable, along with backup plans if the partner struggles or cannot deliver. For subawards, describe how oversight is to be managed by and through the primary Awardee. This includes specific roles of key partner personnel, frequency of oversight meetings, how Performance Measurement and Management (PMM) will be executed, how financial oversight will be managed, how risk and contingency are managed, and other relevant information necessary to ensure project success. An example of a partnership summary table with relevant partnership information is shown below.

Table 3.5.2.4-1

Example List of Partners: Agreement Types, Lead Contacts, and Areas of Support/Contributions

Partner Type	Partner Institution	Lead	Area of Support
Sub-award	Jim's Custom Bike Builder	Jim Jones	• Provide space, labor, and tools for bike assembly • Develop and Deliver Final Manufacturing and Assembly Plan • Provide staff to work on the bike design team • Work with partner on adapting plans to target audience
In-Kind, Memorandum of Understanding	SportMoto Parts Company	Mike Malone	• Donate 8 moto-bike sand tires for design studies and prototype use
Sub-award	Buffalo Bicycles Subsidiary of World Relief Bicycles	Brian Moonkola	• Provide input on target community needs • Provide a team of 5 riders experienced in testing bikes and components in punishing conditions for up to 100 hours of testing in designated terrain • Distribute the final design and Manufacturing and Assembly Plan to its network of workshops in appropriate areas in Africa

Good Practices and Practical Considerations

- Key considerations for forming partnerships are given in Section 5.8 Partnerships. International partnerships, for example, require early planning and communication of intent to NSF.
- The body of the section should contain the partnership details in text format, but it is good practice to provide a summary table with key information for easy reference.
- If there are external partners, their project roles and responsibilities should also be described.

3.5.3 PEP Component 3 – Performance Measurement Baseline

What Does This Component Describe?

This component describes the Performance Measurement Baseline (PMB) that defines and documents the four objective measures of project success: scope, quality, schedule, and budget. These four elements are captured in a suite of documents, including a Work Breakdown Structure (WBS), WBS Dictionary, Quality Acceptance Criteria, Integrated Master Schedule (IMS), and a time-phased budget. Additionally, this component provides a summary view of the Total Project Definition, which includes the contingency associated with each of the four PMB elements and a yearly funding profile.

Why Is This Component Important?

The PMB is the pre-defined and documented definition of project success. It is the agreed-upon objective target upon which all project activities should be planned and directed. A successful project aims to deliver 100% of the scope as defined in the PMB, meeting all of its quality acceptance criteria, and doing so on schedule and within budget. One cannot fully plan, execute, or close a project successfully without a well-defined and stable PMB.

How To Develop and Write This Component

There are five subcomponents to be included in PEP Component 3 – Performance Measurement Baseline, as listed in Table 3.5.3-1 below. Each subcomponent has several identified documents or products that should be created during the development of this component.

The PMB should be structured in a manner that matches the project characteristics and is agreed upon by the participants and key stakeholders. This entire component should be tailored and scaled to the individual type, size, complexity, and characteristics of the project. Further, the subcomponents should be developed in a progressively elaborated approach, as described in Section 3.2 Tailoring, Scaling, and Progressively Elaborating Plans.

Table 3.5.3-1
Performance Measurement Baseline Subcomponents, Products, and Documents with References to Further Material and Related Topics

Component	Subcomponent	Documents/Products	References
3. Performance Measurement Baseline	3.1 Overview of the Performance Measurement Baseline and Total Project Definition	• Total Project Cost (TPC) and Total Project Duration (TPD) • Summary Milestones • Summary Budget and Funding Profiles	NSF Major Facilities–Earned Value Management Gold Card[1]
	3.2 Scope	• WBS • WBS Dictionary • Scope Management Plan	Section 4.2 Scope and Work Breakdown Structure
	3.3 Quality Acceptance Criteria	• Requirements Documents • Specifications • Test plans • Acceptance criteria	
	3.4 Integrated Master Schedule	• Schedule Basis and Estimating Plan • Integrated Master Schedule (IMS) • Reporting Milestone Table	Section 4.4 Schedule Development, Estimating, And Analysis *Government Accountability Office (GAO) Schedule Estimating Guide*
	3.5 Time-Phased Budget	• Cost Estimating Plan (CEP) • Cost Book and Basis of Estimate (BOE) • Time-Phased Budget	Section 4.3 Cost Estimating and Analysis *GAO Cost Estimating Guide*

3.5.3.1 PEP Subcomponent 3.1 – Overview of the Performance Measurement Baseline and Total Project Definition

This subcomponent serves as an Executive Summary and overview of the project PMB and Total Project Definition, providing all the essential high-level features of the project in one place. The PMB encompasses the four components: scope, quality, schedule, and budget. In addition to the PMB, the Total Project Definition adds contingencies and fees (the profit component of a contract, i.e., fixed fee or cost-plus fee, where authorized) to obtain the TPC_{AWD} and TPD for the NSF award.[2] The Total Project Definition also includes a time-phased budget for the funding required to execute the project, a funding profile for the NSF TPC, and any outside funding necessary to execute the project. The following four subcomponents address the PMB, while contingencies are addressed within PEP Component 4 – Risk and Contingency Management and fees are discussed in Section 4.3 in Cost

[1] https://new.nsf.gov/bfa/rio/evm-gold-card
[2] https://new.nsf.gov/bfa/rio/evm-gold-card

Estimating and Management.

The Subcomponent overview should describe the project scope at WBS Level 2 and state the key elements of the Total Project Definition: the TPC_{AWD} (i.e., PMB budget + budget contingency + fee), the TPD (PMB schedule + contingency), and the planned start date. The budget and schedule contingency percentage of the baseline should also be given. The text should be accompanied by a summary table of the key Total Project Definition elements, including a list of the Level 2 WBS elements (scope) and associated budgeted costs, schedule dates, and durations. The table should include overall budget, schedule contingency amounts, and baseline percentages in summarizing the TPC_{AWD} and TPD.

Table 3.5.3.1-1

Example of a Project Summary Table: Level 2 WBS with Costs, Schedule, TPC, TPD, and Assigned Responsibilities

WBS #	WBS Element Name	WBS Lead	Lead Institution	Budget	Schedule Dates and/or (Duration)
1	Project Name	Project Manager	INST 1	-	Start / End (Months)
1.1	L2 Element	Control Account Manager (CAM)	INST 2	$$	Start / End (Months)
1.2	L2 Element	CAM	INST 3	$$	Start / End (Months)
1.3	L2 Element	CAM	INST 1	$$	Start / End (Months)
	Performance Measurement Baseline Budget			$$$$$	Years/months
	Contingency Budget (% of Baseline)			$$ (%)	Years/months (%)
	Fee (if applicable)			$	
	Total Project Cost (TPC_{AWD})			$$$$$$$	Years/months

A time-phased funding profile for the financial resources needed to accomplish the project activities is detailed in this subcomponent. This is typically demonstrated in a table, with accompanying text that explains up and down ramps, along with unusually large peaks and low points. At a minimum, the table should include the time-phased project PMB commitment budget (spending plus obligation), the potential yearly contingency allocation amount, and the TPC_{AWD}. Other funding sources (i.e., non-NSF) should also be included as distinct, separate elements. An example is shown in Table 3.5.3.1-2. In the event NSF-managed Other Direct Costs or Management Reserve are a part of the TPC_{NSB}, consult with NSF on potential additional tables that may be presented in the PEP.[1]

[1] https://www.nsf.gov/bfa/rio/evm-gold-card

Table 3.5.3.1-2
Commitment and Funding Profile by FY Sample Table

Item	Year 1	Year 2	Year 3	Totals
Performance Measurement Baseline Budget	$15,350,650	$8,500,375	$34,560,180	$58,411,205
Contingency Budget	$2,302,598	$1,700,075	$5,184,027	$9,186,700
Total Project Cost (TPC_{EVM})	$17,653,248	$10,200,450	$39,744,207	$67,597,905

Good Practices and Practical Considerations

- It is good practice to include the responsible lead partner institutions in the project summary shown in Table 3.5.3.1-1, if any, and the assigned CAM if known.
- Some projects break the baseline budget in the project summary definition and funding profile tables down into cost categories to enhance understanding of the budget flow. For example, early project costs may be mostly equipment and materials and supplies (M&S) procurements, while later costs may be labor dominated. Commonly used cost categories include equipment, M&S, labor, and travel, or just labor and non-labor. Some projects may separate indirect and direct costs in the summary funding profile.
- Budgets and funding profiles should include escalation and inflation adjustments for all project costs in *then-year* dollars for the planned project spend date, which may be three to five years after a project proposal is submitted. The justification for all escalation assumptions and inflation factors may be included in the CEP and used consistently throughout the BOE.

3.5.3.2 PEP Subcomponent 3.2 – Scope

This subcomponent identifies and describes the baseline scope of the project via two key documents: a WBS and a WBS Dictionary. The WBS integrates and relates all funded activities (scope, schedule, and cost) and is used throughout the project management to identify and monitor project progress (see Section 4.2 Scope and Work Breakdown Structure for detailed guidelines on developing a WBS). Every project, regardless of type, size, or complexity, **must** have a WBS that includes at least specific Level 2 deliverables. Below that level, the details may be dependent on the project specifics. Summaries of these two documents are included in this PEP subcomponent.

> **Key Takeaway**
>
> A *deliverables-based* WBS should be used to organize the complete scope of the project.

Work Breakdown Structure. The full scope of the project is identified and listed in a deliverables-based WBS, where the deliverables are comprised of the project's products, results, and services. The project's WBS is an organized hierarchical listing by name or title of all scope in the project. If the complete WBS for the project extends to levels below Level 3, it may be too large for inclusion in its entirety within the PEP. In that case, the full WBS should be maintained in a separate document or appendix, and only the first few WBS levels should be displayed in the PEP. A statement should be made enumerating the number of levels and providing a reference to the full WBS as a supplementary document.

Note that the WBS structure should be tailored and scaled to the project and organization characteristics. Most, but not all, NSF projects are usually well matched to a traditional Waterfall framework, with a hierarchy of elements that sum up to higher levels. Traditional hierarchical frameworks are most common, but NSF allows other frameworks, depending upon the project characteristics. Software developers and other organizations accustomed to cyclical planning and management methods, for example, may be accustomed to an Agile framework.

If a Project Team elects to use a non-traditional WBS and management framework, it needs to present clear justification and description of the terms and methods to be used. For instance, Agile projects may equate *Stories* or *Epics* (see Section 5.9 Agile Guidance) with work packages in traditional project frameworks.

WBS Dictionary. A corresponding high-level WBS Dictionary summary is also included in this subcomponent. The WBS Dictionary defines and describes each element of the WBS. Like the WBS itself, the full WBS Dictionary is typically created as a supplementary document and referenced within the PEP. The WBS Dictionary that is included in this subcomponent is limited to the Level 2 or Level 3 WBS determined above. See Table 3.5.3.2-1 as an example.

Table 3.5.3.2-1
Illustration of High Level WBS Dictionary

WBS #	WBS Element Name	Element Description (Simplified WBS Dictionary Entry)
1	Project Name	
1.1	L2 Element Name	High-level deliverable description, including key subcomponents, significant exclusions, and other relevant high-level information necessary to describe the element clearly and unambiguously.
1.1.1	L3 Element Name	High-level deliverable description, including key subcomponents, significant exclusions, and other relevant high-level information necessary to describe the element clearly and unambiguously.
1.2	L2 Element Name	High-level deliverable description, including key subcomponents, significant exclusions, and other relevant high-level information necessary to describe the element clearly and unambiguously.
1.2.1	L3 Element Name	High-level deliverable description, including key subcomponents, significant exclusions, and other relevant high-level information necessary to describe the element clearly and unambiguously.

Scope Management Plan. A Scope Management Plan **must** be developed for Construction Stage projects (see Section 4.7.2.3 Scope Contingency), Mid-scale RI should develop one as part of their PEP. The Scope Management Plan should clearly and concisely describe the overall strategy and approach to managing scope. It should describe how scope is identified, defined, described, and documented in the WBS. The Scope Management Plan should describe specific roles and responsibilities for managing project scope. Further, since scope change opportunities may not be available throughout the life of the project, the Scope

Management Plan should define how scope is to be controlled over the course of the project, including the management of scope creep pressures. Finally, the Scope Management Plan should describe how and how often both de-scope and up-scope options will be identified, documented, and tracked, as well as how they will be considered, reviewed, and approved or rejected via Change Control and/or configuration management. Relevant information such as WBS area estimated cost and schedule impacts, time frames in which the de- and up-scopes are viable, priorities of these options, and how decision dates will be incorporated in planning (e.g., inclusion in the IMS) should be included.

If a Scope Management Plan is developed, it should contain the following, at a minimum.

- De-scope options that:
    - Are time-phased and identify the early, optimal, and latest date that each option can be implemented (trigger dates), and the associated project milestones. It should also note potential schedule impacts and considerations, such as whether it could be delayed or added later.
    - Identify the impact to science operations, including any affected KPP, minimum/threshold technical requirements or performance criteria, and technical objectives. Indicate the relative priority of options from least to greatest impact.
    - Include the expected cost reduction of the option and a basis for that amount.
    - For Major Facilities, per the No Cost Overrun Policy ([NCOP], see Section 2.6.1.1 Implementation of NSF's No Cost Overrun Policy), should total at least 10% of the baseline budget presented at PDR. This 10% is then confirmed at FDR and at the start of construction. If the Awardee does not consider this 10% total achievable without significant impact, or if options are only available early in the Construction Stage, then the Scope Management Plan should explain why and what other risk management alternatives might be available. For Mid-scale RI, this 10% of the baseline target is a good goal at the time of award, if a Scope Management Plan is proposed.
- Scope opportunities that:
    - Are time-phased and identify the early, optimal, and the latest date that each option can be implemented, and the associated project milestones. It should also note potential schedule impacts and any other considerations.
    - Are directly associated with the general construction project scope as determined by NSF.
    - Include the expected cost of the option and a basis for that amount.
- Define how scope contingency options relate to Quality Acceptance Criteria and Project Closeout Plans (see Sections 3.5.3.3 PEP Subcomponent 3.3 – Quality Acceptance Criteria and 3.5.9 PEP Component 9 – Project Closeout Plans).

Good Practices and Practical Considerations

- While task-based WBS are acceptable in some industries, a product-oriented WBS is preferred for NSF RI projects. That is, the WBS should capture only deliverables: products, services, and results. Associated tasks and activities are captured in the project's IMS, not the WBS. One simplistic way to think of this is that the WBS includes nouns while the schedule includes action verbs.
- The level of detail in the WBS should match the stage, size, and complexity of the project. The lowest-level elements of the WBS on any branch are called work packages. Work packages serve as the focus on corresponding activities in the IMS, that is, the activities in the IMS should be developed and organized around the provision and delivery of the work package scope. Similarly, work packages are used as the lowest level budgeting elements in the time-phased budget, that is, the cost BOE described below in PEP Subcomponent 3.5 – Time-Phased Budget are established at the work package level.
- In a hierarchical WBS, lower-level WBS elements roll up to higher levels such that each high-level WBS is the sum of the lower-level elements and work packages.
- When naming lower-level WBS elements, add identifiers that link to the higher-level WBS. For example, *Procurement* may occur many times in the WBS, but *Periscope Optics Procurement* will distinguish between the various other procurements and avoid confusion when viewing elements out of context.
- Control Accounts and CAM should also be identified for each high-level WBS element of scope to ensure proper management and oversight are provided.

3.5.3.3 PEP Subcomponent 3.3 – Quality Acceptance Criteria

This subcomponent describes the processes for determining and documenting the requirements and quality acceptance criteria and plans for the deliverables identified and included in the WBS. It describes how the key parameters and high-level science requirements summarized above in PEP Subcomponent – 3.2 Scope flow down to detailed science requirements, engineering requirements, and Quality Acceptance Criteria and plans. If all requirements or plans are not fully mature, it describes the process the project will follow to progressively elaborating documentation and planning.

Typically, requirements are captured in tabular format. One example of this type of table is shown below in Table 3.5.3.3-1; note, however, that the format of the table will depend strongly on the characteristics of the project. For complex projects with many cross-linked requirements, a database or multiple spreadsheets or tables with links to higher-level requirements may be needed to illustrate requirements' traceability. If the actual requirements documents are too large to include in the PEP itself, then this subcomponent should clearly describe the processes and linkages, and reference them as provided supplementary requirements documents.

Table 3.5.3.3-1
Traceable Flow of KPP to Science, Engineering, and Quality Requirements in Complex Projects

Key Performance Parameters (KPP)	Science Requirements Documents	Detailed Science and Engineering Requirements Documents	Quality Acceptance Plans
Key Parameter A	• High-Level Science Requirement A • High-Level Science Requirement B	• Detailed Science Requirements Document • Associated technical drawings, specifications, analyses	• Quality Control (QC) and Acceptance Plan for Component • QC and Acceptance Plan for Subsystem
Key Parameter B	• High-Level Science Requirement C • High-Level Science Requirement D • High-Level Science Requirement E	• System and Detailed Engineering Requirements for Subcomponent • Engineering Requirements for Subcomponent • Associated technical drawings, specifications, analyses	• QC Plan for Subcomponent • Acceptance Plan for Subsystem
Key Parameter C	• High-Level Science Requirement D	• System and Detailed Science Requirements Document • Associated technical drawings, specifications, analyses	• Testing Plan for Component

The quality acceptance criteria and requirements for all other lower-level scope listed in the full WBS should be included as supplementary documents and referenced from within this PEP subcomponent. Note: At the time of the award, not all Quality Acceptance Criteria documents, especially for lower-level elements, need to be completed. However, a plan for progressively elaborating, completing, and approving these requirements, including a timeline for accomplishing plan elements, should be described.

Good Practices and Practical Considerations

- Note that science requirements are related to the quality of the science, while engineering requirements are related to the details of the particular solution or approach to achieving the science goals.
- A good practice is to follow the SMARTTT criteria in determining requirements and acceptance plans: Specific (clear and unambiguous), Measurable (testable), Achievable (possible within project constraints and parameters), Relevant (suitable and germane to the project goals), Traceable (derived and flowed down from a higher-level requirement, KPP, or project objective), Tiered (numbered in a hierarchical [flow-down] manner), and Total (complete and standalone). For example, it is not sufficient to simply state that software will be robust.
- The use of compliance matrices is encouraged to track adherence to the acceptance

criteria, identify areas that are pending, and highlight specific requirements that have not been met. A good practice is to create a compliance matrix for every requirement document or set of specifications.

- A formalized process requesting waivers for requirements that cannot be met is encouraged during project execution. The plan for this process is described in PEP Component 7 – Project Control Plans. Depending on the magnitude of the scope impacted, some proposed waivers may require NSF review and approval, according to the established Change Control process.

3.5.3.4 PEP Subcomponent 3.4 – Integrated Master Schedule

This subcomponent describes the development of the baseline IMS, a management tool used for planning and executing work during implementation and Construction Stage projects. The IMS addresses both how and when the work is to be performed by identifying the activities needed to accomplish the scope of work and by time-phasing these activities with durations and schedule logic. Logical sequencing involves identifying the key relationships between activities to determine the proper sequence necessary to accomplish the work. The IMS is based on the WBS hierarchy and includes tasks and activities, project start and end dates, review dates, and other critical dates and key milestones. This subcomponent also includes a description of key assumptions, constraints, and other important information used as the basis of the IMS. Refer to Section 4.4 Schedule Development, Estimating, and Analysis for detailed guidance on the development of construction schedules and plans, including the Schedule Basis Document and NSF expectations associated with the GAO Scheduling Best Practices.

The following products are outputs of this subcomponent:

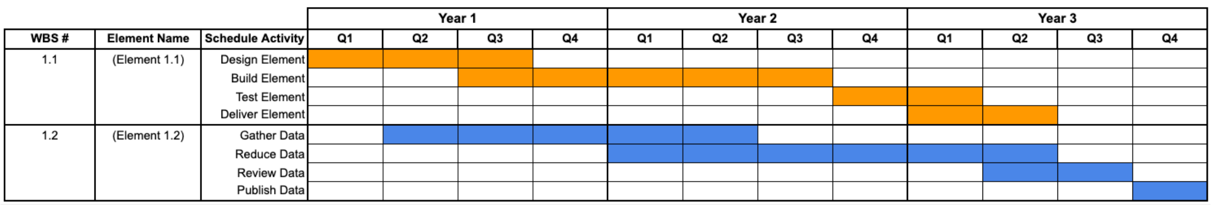
- **Schedule Basis Document.** Provides parameters and underlying assumptions used in developing the schedule for all project stakeholders' understanding (see Section 4.4.3.2 Schedule Documentation).
- **Schedule Management Plan.** A description of the policies, procedures, tools, and roles and responsibilities for developing and estimating the project schedule (see Section 4.4.3.2 Schedule Documentation).
- **Integrated Master Schedule.** A series of tasks, summary tasks, and milestones based on the WBS hierarchy. For the purposes of the *RIG*, tasks and activities can be considered equivalent terms.
- **List of Reporting Milestones.** A tiered table or list with the different levels of milestones that will be used to monitor and report progress.

The basis, plan, and milestones can be included in this PEP section if they are not too long. Otherwise, their key points can be summarized here with reference to either separate and complete documents or one combined document.

The IMS should be based on the WBS hierarchy, with each specific deliverable identified in the WBS accounted for in a series of tasks, summary tasks, and milestones. A complete IMS is typically too large to be included in the PEP document itself and is usually included as a supplementary document to the PEP. A summary view of the baseline IMS should be included in this PEP subcomponent, showing a high-level view of the project that corresponds to the high-level WBS deliverables listed above in PEP Subcomponent – 3.2 Scope. The scheduling approach, tools, and documents should be tailored to project complexity and characteristics. For very simple projects, the IMS may consist solely of a list of key activity and milestone dates or blocking in a spreadsheet or diagram, that can be updated as the project progresses to demonstrate task completion, and forecasts timeframes for remaining work. For most projects, however, a Gantt-type schedule that is created with commercial scheduling software is preferred. An example of a Gantt chart is shown below in Table 3.5.3.4-1.

Table 3.5.3.4-1

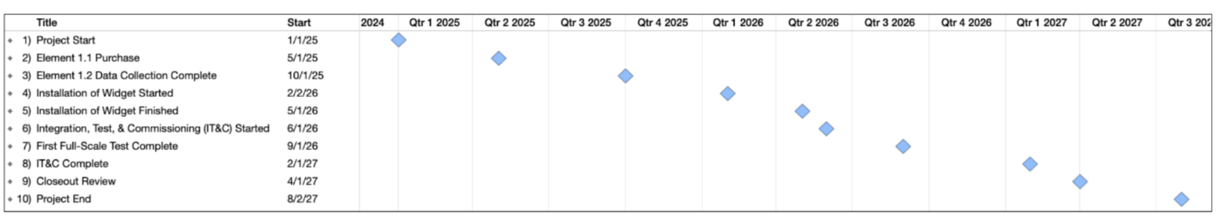
Sample High Level Schedule Gantt Chart



Projects need to produce a list of tiered tracking milestones based on the scheduled activities. At the highest level, this constitutes a short list of milestones that are reported to NSF. The milestones should be spaced at a frequency that will readily communicate how well the project is tracking the overall plan without being too inclusive of minor details. The second tier is typically used by project management to track progress, while lower tiers are used by CAMs, and work package leads track progress at lower WBS levels. Usually, only the key reporting and/or tracking milestones need to be displayed in the PEP, with lower levels referenced in separate supplementary documents. An example of a list of key milestones in graphical format is shown below in Table 3.5.3.4-2 below.

Table 3.5.3.4-2

Sample Graphical Representation of Key Reporting Milestones



A high-level view or description of the project's Critical Path should be included in this subcomponent. Ideally, this is represented graphically in the summary schedule (or milestone/task list for very simple projects) using color coding. Again, the full IMS with an identifiable Critical Path is typically included as a supplementary document to this PEP and updated throughout project execution. The Critical Path shown in the PEP should be a simplified high-level view that corresponds to the high-level WBS elements described above in PEP Subcomponent – 3.2 Scope.

Good Practices and Practical Considerations

- The IMS should be logically driven, with all activities and milestones driven by predecessors and successors. Specific deterministic dates (arbitrary start or stop dates not driven by related activities) are not good practice and should be avoided to the extent possible.
- The baseline schedule should not include built-in buffers or other forms of hidden schedule contingency, though allowances are allowed if adequately justified. Approved schedule contingency is held and managed separately from the baseline schedule, but it can be shown in the IMS as described in Section 4.7 Contingency Estimating and Management.
- The IMS should be resource loaded (labor and non-labor). For simple projects, this may mean assigning budget and staff to key milestones, tasks, or WBS elements. Projects using commercial scheduling software can use internal tools to add resources to the IMS.
- The number of Tier 1 tracking milestones per year will depend upon the project characteristics, but a good rule of thumb is at least one but not more than six.
- The TPD includes the baseline duration and schedule contingency, and the milestone table should reflect the difference between those dates.
- The project's IMS should adhere to the GAO Scheduling Best Practices as described in Section 4.4 Schedule Development, Estimating, and Analysis.
- The complexity of a schedule typically drives the needed experience level of the person(s) developing and maintaining the schedule and the selection of a scheduling software tool.
- The use of commercial schedule health evaluation tools, accompanied by explanations of any deviations from standards for quality schedules, is recommended.
- Level-of-Effort (LOE) tasks should be minimized to optimize the tracking of spending against budget and accomplishments against plan in the project's Performance Measurement and Management reports (see Section 3.2.1.3 Level-of-Effort Approach).

3.5.3.5 PEP Subcomponent 3.5 – Time-Phased Budget

The planned, time-phased budget necessary to execute the project is described in this subcomponent. The budget should be developed and aligned with the WBS deliverables described above in PEP Subcomponent – 3.2 Scope.

The following are the products of this subcomponent:

- **Cost Estimating Plan.** A description of the methodology, tools, and processes for developing and estimating the project budget, including key assumptions and constraints. The CEP describes how the costs are developed, documented, reviewed, approved, and managed, and may reference any organizational policies and procedures followed by the Project Team. Refer to Section 4.3 Cost Estimating and Analysis for detailed guidance on creating a CEP. The CEP should describe the expected cost-estimating methodology, maturity, and, if applicable, accuracy range (e.g., expert opinion, analogy, parametric, engineering build-up, historical data). It should also explain any ground rules, assumptions, and exclusions that apply broadly to the estimate, allowances, and other sensitive or significant factors or considerations, including their rationale and any references. The CEP should serve as guidance for the project estimators as well as inform NSF and reviewers. Planners should also discuss any methods used to validate the estimates, including Independent Cost Estimates (ICE) and reviews. The CEP should be tailored to the project's characteristics and may evolve over time as planning matures. Note that the CEP description within this PEP may only be high-level or an Executive Summary in nature; reference to and inclusion of a supplementary detailed cost estimating document is usual.

- **Cost Book and Basis of Estimate.** The collection of cost estimate worksheets is supported by detailed information on the basis of how each estimate was established. The Cost Book is a comprehensive and well-documented compilation of budget-related data for the total project scope that organizes and calculates project management information. The BOE provides supporting documentation outlining the details used in establishing project estimates, such as assumptions, constraints, and estimating methods, and referencing the technical information used. Consult Section 4.3 Cost Estimating and Analysis for detailed guidelines and requirements for creating a Cost Book and BOE. The Cost Book and BOE should be capable of being sorted and filtered to provide the cost estimate in multiple formats and reports in formats compatible with necessary reviews and analyses. The estimate structure should have clear traceability between WBS elements and the BOE correctly roll up to higher WBS levels and demonstrate compliance with the CEP. Because cost analyses assess the application of fringe, indirect, and escalation rates (among other things), there should be clear traceability in the application of all rates (e.g., with lookup tables and formulas). The budget should map into budget categories, including project-defined categories and, for financial assistance awards, NSF Budget Categories (as defined in the standard NSF Budget Form per Sections 1.3.1.1 Financial Assistance Awards – Grants and Cooperative Agreements and 5.6 NSF Budget Categories from the Proposal and Award Policies and Procedures Guide). The Cost Book and BOE should be progressively elaborated as project planning matures. For example, early estimates may be based on top-down comparisons to analogous projects, while mature estimates should be based on bottom-up estimates based on vendor quotes and other substantive sources.
- **Time-Phased Budget.** A map of the budget over time as a result of matching the budget estimates to the scheduled activities. Once the baseline budget has been established, it needs to be mapped to the schedule activities to create a time-phased budget that is the basis of the funding profile request and forms the target for cost

performance management as the project is executed. Mapping depends upon the scheduling tools and should be scaled to the project's needs. For example, a simple project may maintain a list of tasks or milestones as the schedule, in which case the budget would be mapped directly to each task or milestone. Most projects use commercial software that allows resource loading into the application, along with various codes and notes for sorting and filtering. Projects can scale the granularity of the mapping by controlling the level to which the budget is assigned: simple projects may map to WBS Level 2, while more complex projects may map at lower WBS levels or even at activity levels. A time-phased budget example is shown in Table 3.5.3.5-1.

Table 3.5.3.5-1

High Level Time-Phased Budget Report with NSF Budget Category Mapping Sample Table by Fiscal Year (FY)

Cost Category	FY1	FY2	FY3	FY4	Total
A, B, C – Personnel	$1,403,000	$5,598,400	$7,610,400	$5,229,700	$19,841,500
D – Equipment	$25,300	$4,296,000	$4,337,500	$2,777,700	$11,436,500
E – Travel	$3,500	$13,500	$13,500	$7,000	$37,500
G.1 M&S	$1,200	$132,500	$130,200	$110,600	$374,500
G.5 Subawards	$280,600	$1,120,000	$1,522,000	$1,046,000	$3,968,600
H – Indirect Costs	$155,300	$2,781,000	$3,001,600	$1,970,700	$7,908,600
Total PMB	**$ 1,868,900**	**$13,941,400**	**$16,615,200**	**$11,141,700**	**$43,567,200**
G.6 – Contingency	$262,000	$5,140,000	$6,950,000	$1,020,000	$13,372,000
Contingency %	14.0%	36.9%	41.8%	9.2%	30.7%
TPC	**$2,130,900**	**$19,081,400**	**$23,565,200**	**$12,161,700**	**$56,939,200**

Good Practices and Practical Considerations

- The project budget should adhere to NSF and GAO Cost Estimating Best Practices as described in Section 4.3 Cost Estimating and Analysis.
- All cost and budget estimates **must** utilize *then-year* United States dollars (USD) to include reasonable estimates of inflation, annual staff salary increases, and other escalation effects.
- Although justified *allowances* are permitted in the BOE (see Section 4.3.3.4 Uncertainty, Accuracy, and Allowances), the Performance Measurement Baseline budget should not include references to *reserves* or *contingency*. Only one method should be used to handle cost uncertainty. Employing both an allowance and an identified risk would result in double-counting and unnecessarily increase the proposed budget. Per NSF policy, budget contingency is held separately to manage known risks in aggregate and its use is addressed below in PEP Subcomponent – 4.3 Contingency Management Plan.
- Control Accounts and the assignment of CAM for managing the budget should be

considered both at the creation of the WBS and at resource loading of the schedule. Accounts may need to be readjusted based on the total dollar amount once the budget is established.

- During cost reviews, the application of negotiated fringe benefits, indirect cost rates, or algorithmic methods (e.g., 3% salary escalation) is frequently assessed. Clear demonstration and consistent application of such formulas and factors will greatly facilitate and accelerate the cost analysis.
- Note that Control Accounts should be assigned to a single WBS element; that is to say, a WBS can contain multiple Control Accounts, but a control account should be tied to a single WBS element.

3.5.4 PEP Component 4 – Risk and Contingency Management

What Does This Component Describe?

This component describes project risk management and the related Contingency Management Plans. Risk management includes a high-level overview of the risk management approach in the project Risk Management Plan, a list of identified risks (Risk Register), and an estimate of the project's overall risk exposure. An important aspect of any risk management approach includes the establishment and management of adequate contingencies that can be used to control project risks. Contingency management includes the estimation of those contingency amounts, supported by the project risk exposure estimates. These contingencies are part of the Total Project Definition that encompasses the Total Project Cost (TPC) and Total Project Duration (TPD). The Contingency Management Plan details how contingencies will be controlled and used to offset project risk and successfully complete the project within the TPC and TPD.

Why Is This Component Important?

A project's risk management approach identifies and analyzes potential risks, both threats and opportunities, that could impact the project's objectives. Identification then allows the project to take steps to minimize the probability and impact of threats, maximize the benefits from opportunities, and plan responses if those threats and opportunities are realized. An essential part of any risk management approach is the estimation of the overall project risk exposure, and the establishment of contingency amounts needed to support risk responses. Effective risk management can reduce project delays, avoid cost overruns, and help ensure the technical and scientific objectives of the project are met. Risk management also can lead to better decision-making and improved stakeholder confidence during the project. Performing systematic and effective risk and contingency management will greatly increase the likelihood of project success.

How To Develop and Write This Component

There are three subcomponents in PEP Component 4 – Risk and Contingency Management, as listed in Table 3.5.4-1 below:

- An overview of the risk management approach.
- Risk Management Plan, Risk Register, and an estimate methodology for total project risk exposure and the results.
- Contingency Management Plan that lays out the methodology to calculate and control contingency amounts.

Note that detailed guidance on creating both Risk Management and Contingency Management Plans, listed in the references in the table, should be followed when creating the plans.

The subcomponent plans and deliverables should be organized to align with the project's specific characteristics and agreed upon by both the Project Team and the funders. The plans should be tailored and scaled to the type, size, complexity, and characteristics of the project. Further, the plan should be developed in a progressively elaborated approach, as described in Section 3.2 Tailoring, Scaling, and Progressively Elaborating Plans.

Table 3.5.4-1

Risk and Contingency Management Subcomponents, Products, and Documents with References to Further Material and Related Topics

	Subcomponent	Documents/Products	References
4. Risk and Contingency Management	4.1 Risk Management Approach		
	4.2 Risk Management Plan	• Risk Management Plan • Risk Register • Estimate of Overall Risk Exposure	Section 4.6 Risk Management
	4.3 Contingency Management Plan	• Estimates of Cost, Schedule, and Scope Contingency Amounts • Contingency Management Plan	Section 4.7 Contingency Estimating and Management

3.5.4.1 PEP Subcomponent 4.1 – Risk Management Approach

This subcomponent provides a high-level overview of the project plans and approach for the management of risk. This subcomponent includes a description of the philosophy, commitment, and approach to risk management on the project, including any specific standards or institutional policies and procedures that will be followed. The subcomponent also describes how contingencies will be estimated and used to manage risk. The general risk tolerance of the Project Organization is also included in this subcomponent.

Good Practices and Practical Considerations

- If the plans and products expected in this component are not fully mature (e.g., still undergoing development before implementation), then explain the steps that will be taken to reach maturity (progressive elaboration).
- Every project is unique, so the plans, approaches, methods, and risk tolerances will vary from project to project. That said, the standard seven-step risk management process described in Section 4.6 Risk Management should serve as the starting point for planning risk management on most projects. If an alternative scheme or method is used, a justification for that approach should be included in this subcomponent.
- Contingency estimation and management guidelines can be found in Section 4.7 Contingency Estimating and Management.

3.5.4.2 PEP Subcomponent 4.2 – Risk Management Plan

This subcomponent includes the Risk Management Plan that should be used to identify and manage risks. The Risk Management Plan should identify the responsibilities for risk management and describe the risk management process that will be followed, including roles and responsibilities, procedures, criteria, tools, and techniques to be used to identify, analyze, respond to, and track project risks. The level of detail in the plan, and the scope, timing, and level of risk analysis should be commensurate with the maturity and complexity of the project and may evolve and change over time. A Risk Management Plan includes the processes that will be used during project execution to identify, manage, mitigate, and control risk.

In particular, the Risk Management Plan should describe the risk identification tool used to capture and document individual risks in a Risk Register. A view of the current Risk Register of the project should be shown, including all identified project risks with detailed descriptions and their quantified probabilities and impacts. The Risk Register should also include response strategies if risks are realized and should identify triggers for each risk. If the Risk Register is too large to include in the PEP document itself, provide a sample and attach the full Risk Register as a supplemental document. The Risk Management Plan should also describe the methodology used to estimate the aggregated total project risk exposure from threats. The current value of total project risk exposure in terms of cost and schedule should be supplied. The major risks that contribute most to risk exposure may also be identified. Detailed guidelines and information on creating Risk Management Plans, Risk Registers, and overall risk exposure estimates are covered in Section 4.6 Risk Management.

Good Practices and Practical Considerations

- Risk management should be started early in project development and, like budgets and schedules, be progressively elaborated to maturity before project execution. As an example, the creation of an early list of risks in a rudimentary Risk Register will support planning and allow projects to adjust plans to reduce or eliminate them by including mitigation plans in the baseline.

- Risk management includes managing both threats and opportunities. Project Team should include and monitor opportunities in their Risk Registers to enable timely actions to capitalize on and maximize the favorable outcomes opportunities can provide. (Note that most estimates of total risk exposure, however, do not include opportunities in the Basis of Estimate [BOE]).
- On simple projects, the entire Risk Management Plan may be described within this subcomponent. On larger projects, a summary and reference to an external detailed Risk Management Plan document should be provided.
- Methods for calculating total risk exposure may be tailored and scaled to the project characteristics. Simple, less risky projects may be able to use algorithmic methods that require less expertise and administrative overhead to be adequate for project needs. Note, however, that risk management requirements for Major Facility Construction projects require the use of Monte Carlo simulation to estimate the aggregated total project exposure. Additional details on tailoring Risk Management Plans are included in Section 4.6 Risk Management.

3.5.4.3 PEP Subcomponent 4.3 – Contingency Management Plan

This PEP subcomponent should describe the estimation and management of project contingency, which typically comprises three distinct types: budget contingency, schedule contingency, and scope/quality contingency. Contingency serves as a critical resource for managing the impacts of risks and uncertainties on project objectives. At least one type of contingency—and often all three—**must** sufficiently address relevant project risk. The Contingency Management Plan details how contingency is controlled, maintained, and reported, including usage and status updates (see Section 4.7 Contingency Estimating and Management for comprehensive guidance on requirements and considerations). The following additional points for each type of contingency should be addressed.

Contingency Estimation. The Contingency Management Plan should describe the methodologies for estimating the three types of contingencies and state the estimated amount for each one. An explanation of the BOE and justification of why the calculated contingency is sufficient should be included. The estimation methods should be tailored and scaled to match project complexity and other characteristics. Guidelines on contingency estimating methods can be found in Section 4.7 Contingency Estimating and Management.

Budget Contingency. Budget contingency is an amount of money which, when added to the baseline budget and any fee, sums up the TPC or award amount. Budget contingency is held separately from the baseline budget and is used to cover the monetary cost of realized risk, including cost impacts of schedule delays. Budget contingency should be estimated using a method that is appropriate for the type, size, and complexity of the project. Budget contingency can be estimated in a number of ways, depending on the nature of the project, its size and complexity, and the state of the project. Typical methods include simple percentage-based methods, summation of identified risk exposure (as captured in the project's Risk Register), risk-factored technical/cost/schedule methods, and Monte Carlo or other probabilistic methods performed on the Risk Register, the budget, and/or the schedule. Monte Carlo methods **must** be applied to combined cost and schedule analyses for Major Facility projects and should assume a confidence level between 70-90% for budget contingency.

Schedule Contingency. Schedule contingency is an amount of additional time beyond that of the deterministic (baseline) Integrated Master Schedule (IMS) project end date to obtain the risk adjusted project end date. Budget contingency is held separately from the baseline budget and is used to cover the schedule impacts of schedule overruns from realized risks. Schedule contingency should be estimated using a method that is appropriate for the type, size, and complexity of the project. Typical methods include expert judgment, comparison to other/similarly scoped projects that have been completed in the past, and statistical and/or probabilistic methods. For Major Facility projects, the amount of schedule contingency is determined by performing probabilistic risk analysis on the baseline IMS and selecting a commitment finish end date with a confidence level between 70-90%. Note that there may be costs associated with estimated schedule contingency. Risk managers should ensure that any such costs (e.g., labor during the extended project duration) are captured in the estimated budget contingency estimate.

Scope/Quality Contingency. Scope/quality contingency is comprised of elements within the Work Breakdown Structure (WBS) and/or Quality Acceptance Criteria that can be removed or reduced without affecting the overall project's objectives but that may still have an undesirable effect on the RI's performance or functionality. They are usually regarded as last resort actions when options that employ budget and schedule contingency while preserving project objectives cannot be used. Scope/quality contingency amounts for each reduction in scope or quality are based on the cost and schedule savings realized by the reduction in the baseline. The total amount of cost and schedule savings equals the sum of the individual scope contingency amounts. The total amount of contingency is time sensitive: it declines over time as opportunities pass their use-by dates without being exercised. Scope options are typically captured in a Scope Management Plan (see Section 3.5.3.2 PEP Subcomponent – 3.2 Scope), which may also include scope opportunities that can be exercised when budget and schedule allow. The project's Scope Management Plan should list all identified scope/quality contingency options, along with the estimated monetary value of each option, time-phased use-by dates, special requirements, and a description of the impact on science, performance, and/or functionality, operational costs, or sustainability of the RI. The process for defining when exploiting scope opportunities are allowable should also be defined in the Scope Management Plan. For Major Facility construction projects, identified scope/quality budget contingency should have a total value of at least 10% of the project's baseline budget until construction commences.

Good Practices and Practical Considerations

- To provide additional assurance of successful project outcomes, the scope contingency options **must** equal at least 10% of the Performance Measurement Baseline (PMB) at the start of the project. Major Facility projects have more specific guidelines (see Section 4.7 Contingency Estimating and Management).

- Scope contingency options should spread through as much of the project performance period as possible to avoid loss of flexibility too early in the project.
- Exercising scope contingency will often require NSF approval, so proposers should communicate and discuss the Change Request well before planned implementation dates.

Contingency Management Plan: Contingency Use Profile. In practice, all projects employ some sort of contingency, whether it is related to scope/quality, schedule, budget, or combinations thereof. The Project Team may create and maintain a potential contingency allocation profile that is reported in the funding profile provided in PEP Subcomponent – 3.5 Time-Phased Budget. Contingency allocation profiles should normally track an estimated time-phased risk exposure profile and usually do not track the commitment or spending profiles. For many projects, the highest use of both schedule and budget contingency occurs during procurement or contract award, and during the final commissioning/integration phases. A contingency allocation curve for such a project would be bimodal, with one peak for procurements activities and another for significant contingency amounts held back until the end of the project, even though the spending curve may be low near the end of the project. Although risk does reduce over time, there may be significant reworking of hardware, for example, needed as a result of knowledge gained during integration and commissioning activities.

Contingency Use and Change Control. The Contingency Management Plan describes how the Project Team uses the Change Control Plan, (see Section 3.5.7.4 PEP Subcomponent 7.3 – Change Control Plans) to assign contingency to specific WBS elements when risks materialize and how contingency is reallocated from WBS elements and returned to the contingency category when underruns occur. The NSF Program Officer (PO) needs to concur with all Change Requests exceeding negotiated thresholds for allocation of scope, schedule, or budget contingency, in accordance with the award terms and conditions. Contingency may only be used to support in-scope work for the approved project baseline or pre-approved scope opportunities in the Scope Management Plan (see Section 4.7 Contingency Estimating and Management).

All Change Control actions that affect the use of contingency – cost, schedule, or technical performance and scope – should link to an identified and documented risk and indicate the affected WBS elements. The Project Team should keep a log of all change actions such that contingency actions, including puts and takes, can be reported, and summarized. Adjustments to contingency should include taking advantage of opportunities to assign savings and underruns to contingency. Savings (projected cost under runs) should be left in associated WBS elements, shifted to other WBS elements, or moved to budget contingency in accordance with the terms and conditions of the award. However, all such changes **must** be made in accordance with the thresholds within the Change Control Plan. Budget made available through the implementation of planned de-scoping options should also be placed directly into contingency before being reallocated through Change Control actions.

Liens List: Forecasting and Opportunity Management. The Project Team should maintain a Liens List of likely future adjustments to contingency as a forecasting tool that tracks actions that have not yet been incorporated into the Budget at Completion or Estimate at Completion (EAC). The list may document items such as very high probability risks with trigger points for action, deferred scope held as contingency until a decision date, realized risks needing draws on contingency that require more definition for a Change Control action to be implemented, budget and schedule variances that will not/cannot be mitigated, and anticipated opportunities for returns to contingency. The Liens List acts as an escrow or staging account for planned or near-certain contingency allocations.

The list should include a description of the identified risk and the anticipated action, with estimates of budget and schedule impacts and anticipated decision date for any Change Control Board action. The affected WBS elements should be identified at the second level (or the first meaningfully specific level of scope description), where known.

Maintaining Adequate Contingency Levels. The Contingency Management Plan should describe the process for ensuring that the remaining amounts of budget and schedule contingency are adequate to cover the Risk-Adjusted Estimate at Completion (RAEAC) by periodically updating the EAC and the analysis of overall project risk exposure. As time goes by, risk exposure changes with risk mitigation, new knowledge, and new circumstances. The amount of remaining budget contingency fluctuates over time with assignments to risk mitigation and return of any savings. The Project Team should strive to ensure the remaining available contingency always equates to at least the difference between the TPC minus the EAC and any liens. If the remaining contingency is judged to be inadequate for project needs, steps should be taken to restore amounts to adequate levels (e.g., exercising de-scope options or returning underruns to contingency, or rebaselining the project).

Contingency Status Reporting. The Contingency Management Plan should describe the requirements for reporting contingency status, issues, and adjustments through the Change Control Plan in its interim reports (typically monthly reports). NSF generally sets reporting requirements for interim status. These typically include completed and anticipated Change Control actions involving the movement of contingency, obligated and authorized contingency balance, and a comparison of contingency amounts to the need indicated by the RAEAC.

Good Practices and Practical Considerations

- It is good practice to re-estimate EAC and risk exposure routinely, unless stated otherwise in the award terms and conditions. Specific dates may also be appropriate times for re-evaluation, such as at major milestones dates. The Project Manager (PM) should periodically assess the current risk status to identify and address any new risks that arise as the project progresses.
- Contingency is meant to be used when known risks become realized. Rather than preserving or protecting contingency funds for use late in the project, projects can appropriately use budget and schedule contingency to correct variances as long as their use is clearly documented in accordance with the PEP and the terms and

conditions of the award.

- If available budget contingency drops significantly below the remaining risk exposure such that confidence in on-budget completion is below 50%, the Project Team should take steps to restore contingency (e.g., this is typically done by exercising approved de-scope options listed in the Scope Management Plan. Moving budget to contingency due to other cost savings in the performance baseline should be done in accordance with the award terms and conditions
- Project Teams may opt not to request budget and schedule contingency but should always consider the use of scope/quality contingency plans (e.g., de-scope options).
- Scope quality/contingency can be used to address the remaining uncertainty between the cost and schedule estimates and the chosen calculated confidence levels of a risk analysis.
- De-scope options, when exercised, can be moved into up-scope (opportunity) options to be brought back into the baseline if resources are available later in the project.

3.5.5 PEP Component 5 – Acquisition Plans

What Does This Component Describe?

This component describes the planned processes, strategies, and methods that will be used on the project to acquire (i.e., create and provide) and implement the scope, as defined in PEP Component 3 – Performance Measurement Baseline. Additionally, it refers to plans for acceptance testing of the scope against the Quality Acceptance Criteria that are also specified in PEP Component 3 – Performance Measurement Baseline. Finally, it includes plans for determining, sourcing, and managing all the labor and non-labor resources required for acquiring and testing the scope.

Why Is This Component Important?

Pre-defining the expectations and approaches to creating the scope, testing it, and resolving non-compliance issues is necessary to understand the resources needed to carry out these plans and approaches, which are necessary for complete and thorough planning. Without a priori and complete consideration of acquisitions, accurate schedule development and cost estimation are impossible to achieve. A well-considered Acquisitions Plan also provides for the anticipation of potential challenges and bottlenecks, allowing for a complete review and assessment of risk. Finally, a complete and accurate Acquisitions Plan improves communication, minimizes misunderstandings (both with external stakeholders and Project Team members), and fosters a shared understanding of resource needs and procurement plans.

How To Develop and Write This Component

There are four subcomponents to be included in Component 5 – Acquisition Plans, as listed in Table 3.5.5-1 below.

The Scope Acquisition Plan should match the project characteristics and needs and should be agreed upon by both the Project Team and the funders. The plans should be tailored and scaled to the individual type, size, complexity, and characteristics of the project. Further, the subcomponents are typically developed in a progressively elaborated approach, as described in Section 3.2 Tailoring, Scaling, and Progressively Elaborating Plans.

Table 3.5.5-1

Acquisition Plans Subcomponents, Products, and Documents with References to Further Material and Related Topics

Component	Subcomponent	Documents/Products	References
5. Acquisition Plans	5.1 Overview of Acquisition Plans		
	5.2 Scope Acquisition Plans	• Scope Acquisition Plan	
	5.3 Systems Engineering and Quality Management Plans	• Systems Engineering Plan • Quality Management Plan	
	5.4 Resource Management Plans	• Resource Management Plan	

3.5.5.1 PEP Subcomponent 5.1 – Overview of Acquisition Plans

This subcomponent provides a brief, high-level description of the approach for acquiring the scope and ensuring it meets its Quality Acceptance Criteria. Acquisition Plans may include the approaches to any or all the following activities: development, design, analysis, site selection and permitting, prototyping, procurement, purchasing, construction, coding, assembly, integration, testing, commissioning, verification, and/or validation of the scope as defined in the Work Breakdown Structure (WBS). The Project Team should decide whether to build in-house, pursue subawards, subcontracts, or purchase commercially available components or services. The Acquisition Plan should also describe the high-level resource requirements (labor and non-labor) necessary to carry out the overall project plan and create, provide, and deliver the scope. Specific details of these topics are described in more detail below in the relevant subcomponents.

Good Practices and Practical Considerations

- When possible, sourcing from commercially available products or offerings can reduce project risk and increase confidence in cost and schedule projections.

3.5.5.2 PEP Subcomponent 5.2 – Scope Acquisition Plans

This subcomponent describes the plans for acquiring all the project scope. Elements to highlight in these plans should include the following.

Acquisition Approaches. All significant acquisitions should be listed, along with procurement approaches, subawards, and contracting strategies (e.g., vendor selection and management plans). This should be time-based and include explicit milestones for creation and provision of the scope. Also include the planned approval process for all significant acquisitions (e.g., those that require NSF review), with a year-by-year plan of approvals. The more detailed related documents (e.g., Request for Proposals, draft Contracts) may be referenced here.

Production-level Development and Design Work. All development and production-level design activities necessary for construction, acquisition, or implementation, including a time-phased plan for performing this work (i.e., schedule), may be included as part of the project scope. This may include specific pre-design, engineering and design work, prototyping, manufacturing validation, vendor qualification, modeling and simulation, creation of specialized acquisition plans, and the like, that are necessary for project success. Also, provide any estimated budget required to perform the development and design work, including specific NSF funding and any contributions from partners or outside sources.

High-Risk Acquisitions. Identify all high-risk acquisitions, including new or evolving technologies, single-source vendor situations, unique procurement concerns, such as long lead procurement items, and so forth. Describe the management approach to minimize risk of these and identify elements in the project Risk Register that are related to these acquisitions.

Site and Environment. Identify all required and/or special site selection criteria, provide a description of the selected site(s) for the Research Infrastructure (RI), and provide a plan to manage the associated site-related work. Provide a detailed list of all required site permitting, Environmental Impact Statements, site assessments, and any others that are required. The cost and time frame for performing the site selection and permitting activities should be described (and captured in the project budget and Integrated Master Schedule [IMS]).

Good Practices and Practical Considerations

- Within the Acquisition Plan, a defined list of major procurements (purchased items or services) with expenses and projected timelines can be included to facilitate award oversight and review. The list should include details of the procurement (e.g., sole source, fixed price, competitive bids).
- Every deliverable element included in the WBS should have a clear and unambiguous acquisitions approach identified and described herein this subcomponent. Often, the Acquisition Plans for so-called child elements in the WBS are contained at a higher parent level. Make note of these situations to ensure clarity of the plans.

3.5.5.3 PEP Subcomponent 5.3 – Systems Engineering and Quality Management Plans

This subcomponent describes the management plans and processes that will be used to ensure that all acquired scope will meet all specified Quality Acceptance Criteria. Systems engineering is a fundamental key to successful Acquisition Plans. The Systems Engineering Plan comprises a unique set of systems and subsystems with associated technical requirements and interfaces, both internal and external to the facility. Technical requirements and interface control documentation created during project planning and design assist in defining the inspection and test regimes necessary for commissioning and acceptance of the facility. Quality Management includes both Quality Assurance (QA) processes related to preventing quality issues and Quality Control (QC) processes related to products and deliverables assessment, testing, or evaluation plans and processes for reviewing and addressing non-compliant scope should be described herein.

This subcomponent should, where relevant, describe the project's Systems Engineering Management Plan, including roles and responsibilities and how requirements are to be developed, flowed down, tracked, and managed from high-level mission and science requirements through lower-level requirements. Examples of how requirements might flow from the mission statement to detailed engineering specifications are given in Figure 3.5.5.3-1. Additionally, this plan should describe how all internal WBS, and external interfaces are to be specified, documented (e.g., in Interface Control Documents), communicated, tracked, and managed.

Figure 3.5.5.3-1

Flow Down from Mission Statement to Individual Systems and Components

Project Mission Statement	**This is the overarching goal that defines the purpose of the project**. Example: • "To design, build, and commission a next-generation ground-based optical telescope capable of observing faint objects at high resolution to advance our understanding of the formation of galaxies and the nature of dark matter."
Key Performance Parameters (KPP)	**These are measurable science objectives that define success of the mission statement**. Example: • Angular resolution capable of resolving exoplanets orbiting stars with 100 light years. • Observing time in faint object operating mode more than 1000 hours/year. • Operating lifetime of observatory of 40 years.
Science Requirements	**These detailed requirements translate KPPs into specific capabilities needed for scientific observations**. Example: • The telescope must operate at wavelengths from ultraviolet (200-300nm) to near-infrared (1100-2500nm). • Observing resolution of 0.1 arc-seconds. • Science instrument achieving signal-to-noise ratios greater than 100:1.
System Engineering Requirements	**These requirements define the functionalities and performance of the deliverable.** Example: • The telescope optic train mirrors must each have a figure accuracy of less than 10 nanometers. • The telescope must be able to point and track celestial objects with an accuracy of 0.05 arc-seconds. • All telescope elements within 5m of the light path must maintain a stable temperature relative to ambient of +/0.5 degrees Celsius.
Detailed Engineering Requirements	**These are specifications for individual components and subsystems of the deliverable.** Example: • The primary mirror shall be 20m in diameter and manufactured from an array of meniscus types and low-coefficient-of-expansion glass. • The surface finish shall be polished to 20m peak-to-valley.

The Quality Management Plan should describe a clear, straightforward, achievable, and robust plan for the System Integration, Test, and Commissioning activities that are an essential aspect of complex RI projects. Successful completion of all inspections and tests provides validation that the facility meets the science flow down and technical requirements and therefore passes all acceptance criteria. Failure to plan or perform them well can lead to project cost and schedule overruns.

Relevant plans for the Integration, Test, and Commissioning of the RI should be described, including the following.

System Integration. How the various sub-elements and lower-level WBS items will be brought together and tested as a collective whole. Included in this is the identification of all physical and performance interfaces within and external to the RI deliverable components, including how they will be identified, combined, verified, and coordinated.

Testing. How compliance and fitness for the purpose of the deliverable will be assessed (i.e., verification testing) and documented (e.g., via compliance matrices) using the criteria established and documented (above in PEP Subcomponent 3.1 – Performance Measurement Baseline and Total Project Definition) to measure acceptable performance. Also, how non-compliance will be addressed and managed (e.g., via request for waivers).

Commissioning. How the capability of the RI to function and perform will be verified and validated, including how the various system components will be brought online sequentially and in simultaneous operations to study and affirm the interaction among subsystems.

Conditions for Acceptance. Specifying the expected condition of the facility, its performance attributes, the tests the Awardee will perform, and the data it will consider prior to accepting the facility or components of the facility and declaring it ready for operations and maintenance. In some cases, a phased approach to acceptance will be required.

Good Practices and Practical Considerations

- In some communities, the Integration, Test, and Commissioning activities are referred to as Assembly, Integration, and Verification/Validation.
- The ultimate goal of Quality Management is to ensure the RI is capable of performing/delivering the high-level science that is described above in PEP Component – 1 Project Overview, and that it is ready for handover to operations at the appropriate time. All activities and plans, from low-level scope production through high-level Integration, Test, and Commissioning activities, should be focused on achieving this goal.
- The Quality Management subcomponent should describe the plans for specifying the expected condition of the RI at the project conclusion, its verified performance attributes, all tests that will be performed, and the data that will be provided prior to accepting the RI and declaring it ready for the next life cycle stage (e.g., Operations). In some cases, a phased approach to acceptance may be required. For example, for distributed-but-integrated facilities or for facilities with complex instrumentation and equipment, it may be necessary to demonstrate performance and perform acceptance procedures for parts of the system prior to proceeding with construction and/or acquisition of other systems.
- On longer, more complex projects, it is common for some Quality Management Plans to change, evolve, or adapt as the project progresses. Further, some Integration, Testing, and Commissioning activities may overlap with the start of the next life cycle stage, such as the Operations Stage. How these adaptations and overlaps are to be managed should be described in this subcomponent. Typical questions that may be applicable to address include:

- Will the project have parallel periods of construction/acquisition and operations, with some components coming online earlier than others?
- What is the Project Team's strategy for facility acceptance, operational readiness review, site safety and security, and training of operational staff and members of the research community utilizing the facility?
- What are the project plans for transitioning staff from construction to operational support activities? Is there a plan to bring in personnel with the requisite technical skills to operate and support the facility at appropriate times? Have training needs been addressed?
- What risks to the project might result from contractor interference during periods of beneficial use or occupancy as construction activities conclude?
- What risks to the project might result from operations delays?
- What contracting strategies are employed to ensure that priority tasks are completed in a timely way and do not delay operational readiness?
- What are project plans for obtaining use and occupancy permits or satisfying other local regulatory criteria?
- Do the budgets reflect a proper allocation between construction/acquisition and operations?

Separate awards are generally required for operations activities because NSF Major Research Equipment and Facilities Construction (MREFC) funding does not support such costs. Where operational funding will be used for phased transitions to operations prior to project closeout, the Project Team should ensure that the budget justification clearly describes the changeover and that the earlier changeover is estimated and budgeted accordingly, per the Segregation of Funding Plan in PEP Subcomponent 7.5 – Business and Financial Control Plans.

- Projects should carefully consider issues of warranty, repair, and segregation of funding, especially when phased transition to operations results in operations activity overlapping with the implementation and Construction Stage of a project.

3.5.5.4 PEP Subcomponent 5.4 – Resource Management Plans

This subcomponent describes the Resource Management Plans necessary to successfully carry out both the Acquisitions Plans and the Quality Management Plans.

Staffing Plan. The project's Staffing Plan should include time-phased plans and expectations for project-specific job categories and correlation to scope deliverables. The requisite expertise and qualifications of key staff should be included. Hiring and Transition Plans should be included that clearly describe the schedule and requirements for hiring, training, onboarding, managing staff resources, retaining, and ultimately transitioning resources off the Project Team of all project staff.

Non-Labor Resource Plan. A Non-Labor Resource Plan identifies essential materials, tools, workspaces, equipment, software, and other non-labor resources required for the project.

This plan is integral to executing the Scope Acquisition and Quality Management processes. The Non-Labor Resource Plan outlines the necessary resources, while the Scope Acquisition Plan and Quality Management Plan manage and ensure the effective utilization of those resources

Good Practices and Practical Considerations

- Full Resource Management Plans for small, simple projects may be correspondingly simplified, e.g., the details of hiring and transition plans may be omitted if all staff are already employed by the Awardee organization.
- There are often risks associated with resource acquisitions (e.g., hiring for specialist roles with exacting technical or professional qualifications may require long lead times in the hiring process); these risks should be identified within the project's Risk Register as appropriate and included in the project schedule.
- Staff retention, especially towards the end of a project, can be difficult. Awardees should consider and plan for appropriate incentives to improve retention.
- Resource loading planning for the temporary transition of staff onto and off the Project Team can help to avoid any costs incurred (e.g., project management or engineering, non-labor resources) but can create challenges in retaining staff unless alternate assignments are available for those resources.

3.5.6 PEP Component 6 – Environmental, Safety, and Health Management

What Does This Component Describe?

PEP Component 6 – Environmental, Safety, and Health (ES&H) Management outlines the strategies, plans, procedures, protocols, and responsibilities for managing environmental, safety, and health risk aspects throughout the project's life cycle. It typically includes an assessment of potential environmental impacts, strategies for mitigating these impacts, and compliance with relevant environmental regulations. It outlines safety procedures, hazard assessments, and measures to ensure the physical safety of personnel and equipment during the execution of the project. The health subcomponent describes measures for promoting the physical and mental well-being of individuals involved in the Project Team, such as access to medical resources, acceptable ergonomics, and mental health support during project execution. The ES&H section also includes reporting mechanisms, emergency response plans, and ongoing monitoring to ensure that the Project Team operates in a manner that is environmentally responsible, safe, and supportive of the health of all parties involved.

Why Is This Component Important?

Incorporating ES&H considerations into project planning is of paramount importance. It helps ensure the safety, protection of human life and well-being by systematically identifying and mitigating potential safety hazards and health risks. The ES&H Plan safeguards the Project Team and demonstrates an organization's commitment to its employees and funders. Integrating environmental aspects into project planning helps mitigate negative impacts on the environment, fostering sustainability and compliance with environmental regulations, helping to prevent costly fines, legal issues, and damage to the Project Team's reputation. Addressing ES&H concerns from the outset of a project leads to better cost management by reducing the likelihood of accidents, rework, and delays, ultimately enhancing project efficiency and its probability of success. It also promotes a culture of responsibility, sustainability, and ethical practice. The inclusion of ES&H considerations in the PEP is not just a legal or moral imperative; it's a strategic move that contributes to project success, risk reduction, and the long-term well-being of both people and the environment.

How To Develop and Write This Component

There are four subcomponents to be included in this component, as listed in Table 3.5.6-1 below.

The ES&H Plans should match the project characteristics and should be agreed upon by both the Project Team and funders. The plans should be tailored and scaled to the individual type, size, complexity, and characteristics of the project. Further, the subcomponents should be developed in a progressively elaborated approach, as described in Section 3.2 Tailoring, Scaling, and Progressively Elaborating Plans.

Table 3.5.6-1

Environmental, Safety, and Health Management Subcomponents, Products, and Documents with References to Further Material and Related Topics

Component	Subcomponent	Documents/Products	References
6. Environmental, Safety, and Health Management	6.1 Overview of Environmental, Safety, and Health Management		
	6.2 Environmental Protection Management Plans	• Environmental Protection Management Plans	Section 5.4 Environmental Considerations
	6.3 Safety Management Plans	• Safety Management Plans	Occupational Safety and Health Administration (OSHA) Recommended Practices[1]
	6.4 Occupational Health Management Plans	• Occupational Health Management Plans	

3.5.6.1 PEP Subcomponent 6.1 – Overview of Environmental, Safety, and Health Management

This subcomponent provides a high-level description of the overall project approach to the management of ES&H. It describes over-arching policies and objectives, including a statement of the Project Team's commitment to ES&H. A description of the ES&H management structure is described, including roles, responsibilities, and the reporting structure of all personnel involved in managing ES&H on the project. Communications plans

[1] https://www.osha.gov/sites/default/files/publications/OSHA3886.pdf

relating to ES&H are described. Finally, ES&H emergency response plans should be discussed in detail or referenced if the supporting documents are too long to include. Specific details of ES&H management topics are provided and described in more detail below in the respective subcomponents.

Good Practices and Practical Considerations

- For simple projects, these plans may be aggregated into a single document. But, for larger, complex, or more specialized projects, there may need to be separate (larger) supplemental documents that are referenced from within the PEP.
- The project's ES&H Plans and approaches should adhere to relevant local, state, and federal regulations. It is the Awardee's responsibility to identify and adhere to all such requirements and regulations.
- The project's ES&H Plans and approaches should be tailored and scaled to the needs of the project but should also follow industry best practices as much as reasonably possible.
- If applicable, the project's ES&H Plans and approaches should refer to and draw upon any approved home/parent institution's ES&H Plans and policies.
- As a good practice and to minimize conflicts of interest, a project's safety management structure should be accountable to and report outside of the normal project management Organizational Breakdown Structure (OBS), that is, to avoid even the appearance of pressure from project management to maintain schedule and budget performance at the expense of ES&H. For example, on many projects, safety reports should be made to a level above the Project Manager (PM), for example directly to a Project Director (PD), Principal Investigator (PI), or other entity.
- As good practice, a project's ES&H Plans should explicitly empower all Project Team members to identify and report safety issues, extending to the point of being able to stop work that they deem unsafe.

3.5.6.2 PEP Subcomponent 6.2 – Environmental Protection Management Plans

This subcomponent describes specific plans and approaches for managing environmental concerns during the execution of the project. NSF's proposed funding for the construction or modification of RI facilities may constitute a federal action that triggers compliance with several federal environmental statutes designed to consider the proposed action's impacts on environmental, cultural, and historic resources as part of the federal decision-making process. Awareness of and strict adherence to all relevant environmental laws are extremely important considerations in the Planning, Construction, and Operation Stages of RI. These statutes include, but are not limited to, the National Environmental Policy Act (NEPA), the National Historic Preservation Act (NHPA), and the Endangered Species Act. While NEPA and the NHPA typically focus on proposed activities that take place within the United States, proposed activities that take place outside of the United States may also be subject to these federal statutes. In addition, there are international agreements and treaties that require consideration of potential environmental impacts. It is the responsibility of NSF to identify and comply with all relevant statutes, regulations, and laws prior to making a funding decision. If the project is funded, the Project Team may also have responsibilities during the Construction and Operation Stages to comply with applicable state, federal, tribal, and international legal authorities.

Typical topics covered in an Environmental Management Plan may include:

- **Environmental Regulations.** A list of all relevant environmental regulations and standards that the Project Team is subject to follow and will adhere to during execution.
- **Impact Identification.** Plans and approaches for the identification, assessment, and tracking of all relevant significant environmental impacts of the project, both positive and negative.
- **Mitigation Plans.** Plans and approaches for minimizing or mitigating all identified negative environmental impacts, including measures to protect local ecosystems and biodiversity, habitat preservation and restoration, reduction of the project's overall carbon footprint, reduction of electricity and other energy source usage, and the reduction of the overall greenhouse gas emissions of the project. Also include waste management plans, including recycling and disposal methods as appropriate.
- **Reporting.** Plans and approaches for reporting on environmental performance throughout the life of the project.

Good Practices and Practical Considerations

- The primary goal of a project Environmental Management Plan is to protect the environment during and after the execution of the project; this should be emphasized in all planning, procedures, and policies.
- For large and complex projects with significant environmental management concerns and implications, an external Environmental Management Plan with all the details defined and described may be required. For smaller and simpler projects, the Environmental Management Plan can be fully described within the PEP.
- It is common for projects to use a parent institution's environmental policies, plans, procedures, and protocols as a basis for ensuring environmental protection on a project. Every project is unique, with specific needs and requirements that will require modification, adaptation, and extension of any higher-level institution's policies.

3.5.6.3 PEP Subcomponent 6.3 – Safety Management Plans

This subcomponent describes specific plans and approaches to managing personnel and equipment safety during the execution of the project. Typical topics covered in a Safety Management Plan may include:

- **Safety Regulations.** A list of all relevant safety regulations and standards that the Project Team is subject to follow and will adhere to.
- **Hazard Identification.** Plans and approaches for the identification,

assessment/analysis, and tracking for all relevant safety hazards on the project.

- **Hazard Mitigation.** Plans and approaches for minimizing and mitigating all identified hazards and safety concerns.
- **Safety Facilities.** Plans for medical facilities, first-aid stations, emergency response protocols, and communication and transportation plans for injured personnel. Include plans for and use of personal protective equipment.
- **Documentation and Reporting.** Plans and procedures for monitoring, documentation, and reporting of safety status, including reporting of all safety incidents and responses. Plans and procedures for post-incident investigations and implementation of corrective actions as required.
- **Training.** Plans for safety training and awareness education of project personnel.

Good Practices and Practical Considerations

- The primary goal of the Safety Management Plan is to ensure the safety of workers and the protection of equipment during the execution of the project; this should be emphasized in all safety-related plans and procedures.
- For multi-site projects, the project lead may need to review, verify, and monitor ES&H the local plans and implementation at remote sites or partner organizations.
- It is common for projects to use a parent institution's safety policies, plans, procedures, and protocols as a basis for ensuring safety on a project. Every project is unique, with specific needs and requirements that will probably require modification, adaptation, and extension of higher-level institution’s policies.
- The PEP should also address plans for critical maintenance and inspection procedures that ensure the safe and efficient operation of RI elements during the project.
- For Design Stage proposed projects, the Safety Management Plan should address safety-by-design approaches to incorporate into the design and analysis process.
- If the project is subject to periodic reviews, the Safety Management Plan should ensure that safety is always discussed and included as a standalone topic during these events.
- Serious safety incidents, problems, or near-hits need to be reported to NSF, in accordance with the terms and conditions of the award.
- Documented and shared lessons learned from the execution of the project can inform and improve ES&H Plans over time.

3.5.6.4 PEP Subcomponent 6.4 – Occupational Health Management Plans

This subcomponent describes specific plans and approaches to managing personnel health during the execution of the project. Typical topics covered in an Occupational Health Management Plan may include:

- **Health Regulations.** A list of all relevant health regulations and standards that the

Project Team is subject to follow and will adhere to.

- **Identification, Assessment, and Mitigation.** Plans and approaches for the identification, assessment/analysis, and mitigation approaches for all relevant health risks on the project, including both occupational and environmental hazards. Include exposure control plans for hazardous materials.
- **Health Monitoring.** Plans and approaches for the ongoing assessment of the health of project personnel during the execution of the project, including ergonomic considerations, pre-project health screenings, and ongoing monitoring. Include protocols and procedures for managing occupational illnesses and injuries of project personnel.
- **Documentation and Reporting.** Plans and procedures for documentation and reporting, including reporting of health-related incidents and responses.

Good Practices and Practical Considerations

- The primary goal of a project Occupational Health Management Plan is to protect the health and well-being of workers during the execution of the project. This includes both physical and mental health and well-being. Therefore, stress management, work-life balance initiatives, and access to mental health resources and support should be considered and implemented as required.
- It is common for projects to use a parent institution's occupational health policies, plans, procedures, and protocols on a project. Every project is unique, with specific needs and requirements that will probably require interpretation of and specific guidance for suitable implementation of higher-level institution’s policies.
- Projects being implemented in remote areas or extreme environments should pay particular attention to health management and monitoring plans.

3.5.7 PEP Component 7 – Project Controls Plans

What Does This Component Describe?

This component describes the plans for Project Controls, the integrated system of tools and processes that collect, organize, and analyze project data to support understanding and control of the key project parameters: scope, quality, budget, schedule, contingency, risk, and resources. Through comparison of actual status against plans, analysis of trends and variances, and forecasting of future project requirements, Project Controls give managers the information needed to support decision making. Four major areas of Project Controls planning are addressed in this component:

- **Performance Measurement and Management (PMM).** Methods and approaches for assessing the state of the project during execution.
- **Change Control.** Methods for implementing modifications and changes during the course of the project.
- **Reporting and Documentation.** Ways of capturing and communicating the project status to key project funders.

- **Business and Financial Controls.** Methods and approaches that will be used to manage all project-related finances and accounting.

Why Is This Component Important?

Managing a Research Infrastructure (RI) project requires regular and accurate assessments of project status and predictions of future trajectory; it is impossible to successfully manage and guide a project unless one knows the current state and can forecast the path forward. Adherence to a defined control process also protects the plan against unauthorized and unplanned changes (e.g., scope creep) that place unanticipated demands on resources, budget, and schedule. The use of an integrated Project Controls Plan has been demonstrated to significantly improve a project's ability to successfully meet its objectives. When adjustments to the plan are necessary to keep a project on track, a transparent and systematic means of making appropriate decisions about the project baseline and/or the adjustment approach is necessary. Further, a consistent, clear, and accurate means of documenting and reporting the state of the project (i.e., project status, recent changes, outstanding risks, and forecasted trajectory) to the key funders (e.g., NSF) ensures maximum transparency and minimal surprises. Finally, the Project Team should follow its documented business and financial processes throughout the course of the project. Without sound, responsible, and appropriate Project Controls that address these factors, projects may miss goals, requiring unplanned time, money, and effort to return to the plan. In a worst-case scenario, a project may fail to achieve its objectives.

How To Develop and Write This Component

There are five subcomponents to be included in PEP Component 7 – Project Control Plans. These five are shown in Table 3.5.7-1 below.

Project Controls Plans should be structured in a manner that matches the project characteristics and is agreed upon by the Project Team and funders. This entire component should be both tailored and scaled to the type, size, complexity, and characteristics of the project. Further, the component should be developed in a progressively elaborated approach, as described in Section 3.2 Tailoring, Scaling, and Progressively Elaborating Plans.

Table 3.5.7-1
Project Controls Plans Subcomponents, Products, and Documents with References to Further Material and Related Topics

Component	Subcomponent	Documents/Products	References
7. Project Controls Plans	7.1 Overview of Project Controls	• Project Management Control Plan	
	7.2 Performance Measurement and Management Plans	• PMM Plan: Process and Tools	Section 4.5 Monitoring Progress Against Plan PEP Component 4 – Risk and Contingency Management
	7.3 Change Control Plans	• Change Control Plan • Change Log	
	7.4 Reporting and Reviews Plans	• Reporting Template(s)	Section 2.6.1.2 Construction Stage Reporting and Reviews
	7.5 Business and Financial Controls Plans	• Institutional Policies • Project-specific financial plans • Segregation of Funding Plan	

3.5.7.1 PEP Subcomponent 7.1 – Overview of Project Controls

This subcomponent serves as an Executive Summary and overview of this entire Project Controls component. The overview should briefly summarize the methods chosen for the other four Project Controls subcomponents: PMM, Change Control, Project Documentation and Reporting, and Business and Financial Controls. The overview should describe how the plans will be used to manage the project. It should also describe the tools (e.g., spreadsheets, databases, commercial software products) that will be used for the various Project Controls functions.

It should be noted that Project Controls form a subset of all project management functions; the two are not the same. Project Controls tools and processes focus on metrics, tracking, comparisons to plan, analysis of deviations, change management, and predictions of future needs and events. Project management serves a broader purpose that includes functions such as directing work, meeting scope and quality requirements, balancing resources, making decisions to keep the project on track and managing funder interactions and expectations. Effective Project Controls are closely tied to all aspects of project management so that they can inform and support these broader project management functions.

A flow chart of typical Project Controls elements and how they are connected is given in Figure 3.5.7.1-1. The figure shows how Project Controls are used during execution to compare actual project Status Inputs against the planned Total Project Definition and to inform management decisions and actions. The Total Project Definition includes the Performance Measurement Baseline (PMB) described in PEP Component 3 – Performance

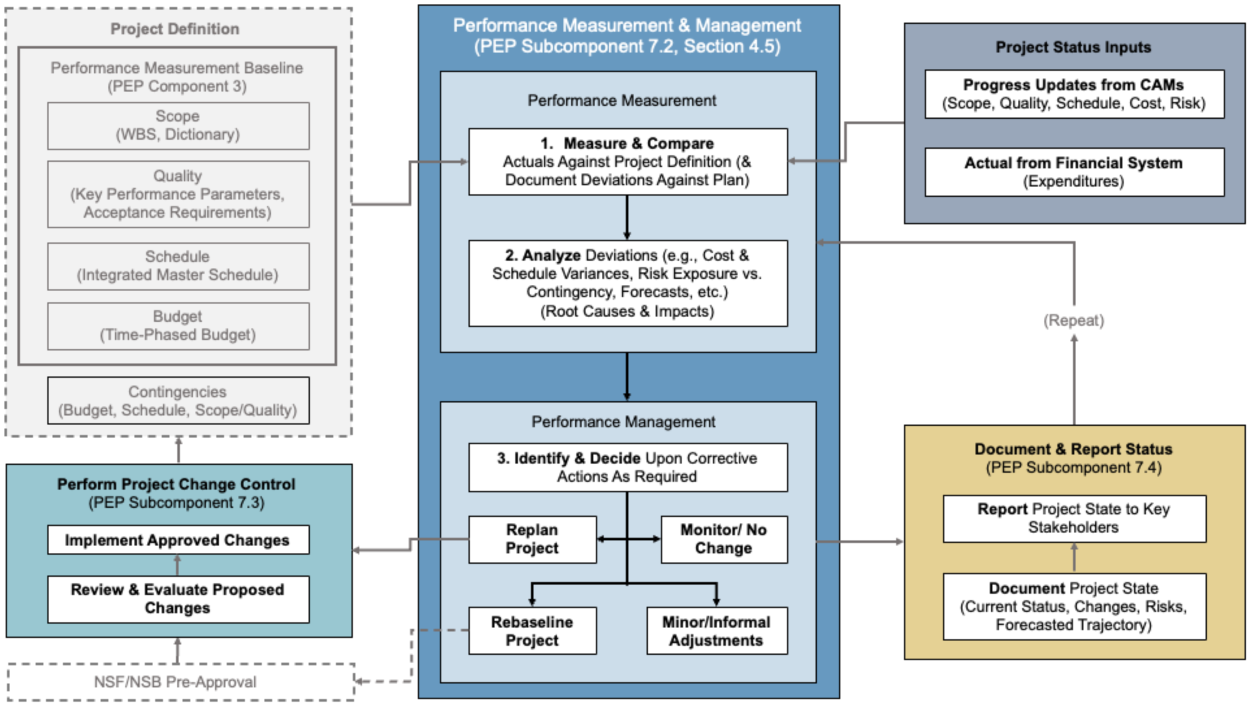
Measurement Baseline and the contingency amounts established in PEP Component 4 – Risk and Contingency Management. The Total Project Definition is established during pre-execution planning, using the appropriate tools used to create and document the elements of the definition (e.g., Work Breakdown Structure [WBS], Basis of Estimate [BOE], Integrated Master Schedule, etc.). During execution, project Status Inputs are updated and compared to the plan using the PMM tools and methods. Variances and identified issues are analyzed and used to inform management decisions and actions taken. Changes to the PMB or contingency amounts are managed according to the project Change Control Plan. Project status, variances, and changes are then documented and reported to funders, and the entire process is repeated for each reporting period. Although not shown in Figure 3.5.7.1-1, the institutional Business and Financial Controls ensure that funds are properly managed and that data on obligations and actual expenditures are correctly transmitted to the project as Status Inputs.

Good Practices and Practical Considerations

- Project Control execution and management requires dedicated time from Project Team members to report and update status, analyze the data, support decision-making, and carry out actions. The time and skills to perform various roles and responsibilities should be included in the consideration of assignments to project roles and in the calculation of hours and money spent in carrying out Project Controls functions. These costs should be folded into the budget and staffing/hiring plans.
- Care should be taken to make sure that the Project Team chooses tools to match its needs. Many commercial project software available for Project Controls (schedule platforms, PMM programs, risk managers, etc.) require expertise and experience to run the software as well as costs for licensing. Expert hire(s) may also be essential to support these applications.
- For large, complex projects, a supplementary standalone Project Management Control Plan document that describes all plans and expectations for Project Controls may be created and referenced from within this PEP. For less complex projects and/or nascent projects still under development, all details, and plans for the Project Management Control Plan can be contained within the PEP document itself.
- An illustration of standard operating procedures for the implementation of Project Controls is helpful in communicating the process used for monthly comparisons, analysis, management, and reporting in a format that speaks to the Project Team members and emphasizes project-specific details of the steps involved during each reporting period.

Figure 3.5.7.1-1

Project Controls Process Flow Chart: Interactions Among Subcomponents with Established Total Project Definition



3.5.7.2 PEP Subcomponent 7.2 – Performance Measurement and Management Plans

This subcomponent presents the project PMM tools and methods that describe how the project will be managed and controlled during execution using information from quantitative comparisons of status to the planned project. There are two major processes in a PMM Plan that need to be addressed, as shown in the PMM and Status Input boxes in Figure 3.5.7.1-1 above:

- **Performance Measurement.** Comparing and analyzing collected Status Inputs against the plans in the Total Project Definition.
- **Performance Management.** Making management decisions on actions to pursue based on the comparison analysis.

The selection of Project Controls tools depends upon the chosen PMM method, which should be tailored and scaled to meet project needs. For example, Major Facilities construction projects **must** use verified Earned Value Management (EVM) as the PMM method, which entails the use of tools such as EVM software applications and involves adherence to NSF Earned Value Management System (EVMS) guidelines. Simpler projects may find that scaled, non-verification EVM, or even simple spreadsheet comparisons of cost versus actual expenditures and milestone tracking, are adequate methods for comparison of plan to actual status. Further guidance on creating a tailored and scaled PMM Plan is given in Section 4.5 Monitoring Progress Against Plan.

The PMM Plan should describe how the following functions will be addressed:

- **Scope Assessment.** Describe how the delivery of scope will be formally assessed, compared to the WBS and the Quality Acceptance Criteria, and how variances will be documented. For example, the earned value rules outlined in the PMM Plan will provide a structured approach to assess progress against the WBS and Quality Acceptance Criteria.
- **Schedule Progress Assessment.** Describe how schedule activity progress inputs will be collected and formally assessed against the Integrated Master Schedule and how variances will be documented.
- **Budget Assessment.** Describe how expenditure inputs (actuals and estimated actuals) will be regularly collected (at the work package level) and assessed against the time-phased budget, as well as how variances will be documented.
- **Variance Assessment.** Describe how cost and schedule variances will be evaluated and how the Project Team will determine what corrective actions will be needed, if any.
- **Forecasting.** Describe the methods and frequency of updates to Estimate at Completion and Variance at Complete for cost and schedule.
- **Performance Management Process.** Describe processes, roles, and authorities for reviewing the performance measurement analysis and making decisions on which actions to take to keep the project on track.

Good Practices and Practical Considerations

- EVM is a commonly used PMM methodology for comparison and analysis of status to plan. If EVM is selected as the PMM comparison method, the Project Team should scale the processes and tools used to match project characteristics.
- For projects using EVMS, aligning the Performance Measurement and Management Plans to the applicable EVMS principles, processes, and guidelines can help demonstrate compliance and, for Major Facilities, facilitate the EVMS Verification Review.
- A means of qualitative assessment of project performance is encouraged. A good practice is for project leadership to regularly visit the work sites, talk to the staff doing the work, and assess progress first-hand, correlating it to the quantitative metrics gathered in parallel.
- Conducting both formal and informal status meetings with lead staff, Control Account Manager (CAM), and others doing the work is encouraged.
- The PMM Plans should note at what cadence PMM functions will be performed. Most quantitative PMM functions are conducted monthly. If the proposed cadence is longer or shorter than one month, explain why this is appropriate for the project.
- Identified variances by themselves are neither good nor bad; they are simply a form of information that requires analysis and interpretation. An appropriate means of systematically evaluating and assessing the significance of variances before corrective action is applied should be part of the PMM process.

- All variances, both positive and negative, should be communicated to funders to ensure a comprehensive and realistic understanding of project status and prospects.

3.5.7.3 PEP Subcomponent 7.3 – Change Control Plans

This subcomponent describes the project's Change Control Plan, which addresses how the project manages, controls, and reports changes to the Total Project Definition. There are two types of project changes addressed in the Change Control Plan:

- Change Control refers to changes to the PMB and movements/usage of contingencies (budget, schedule, and scope contingencies).
- Configuration Control applies to changes to the technical details (i.e., requirements and design).

Because of the unique and innovative nature of many NSF-funded projects, change is expected during the RI implementation and Construction Stage. In addition to normal adjustments that occur with all implementation projects that involve future planned work, RI projects typically carry significant risks that require adjustments to the plan if realized. When project performance begins to significantly deviate from the plan due to a risk occurrence that affects project objectives or the plan needs to change for other reasons, project management exercises the Change Control process to maintain the overall project trajectories. Once reviewed and approved, Change Control actions may involve adjustments as simple as the documentation of a straightforward schedule reorganization or as complex as a scope change involving changes to design and requirements, cost, schedule, scope, performance/quality, and contingency amounts.

Change Control Process. The Change Control Plan in the PEP should trace the path from submission of a Change Request, through the evaluation and approval processes, and end with implementation and reporting. It should be detailed enough that it can serve as guidelines for training and directing Project Team members responsible for delivering the project scope as planned and who are responsible for determining and implementing changes to the plan when necessary.

The Change Control Plan should include details of the following:

- The composition of the Change Control Board (CCB) and the roles and responsibilities assigned to Change Request submitters, reviewers, and approvers.
- The process for preparing and submitting Change Requests for evaluation.
- The process for analysis and review of benefits and impacts (e.g., review by a formal CCB).
- The thresholds and authorities needed for approval.
- Change documentation and archival of change materials (Change Requests, supporting documents, approvals, etc.).
- Reports and notifications to the Project Team, NSF, and other funders.

An example flow diagram for a Change Control process is shown in

Figure 3.5.7.3-1 below, tracing the path through the process for both Change Control and Configuration Change Requests. In this example, a single request form is used for both configuration and Change Control Requests, but they follow separate evaluation processes. A CCB (e.g., comprised of Project Managers [PM] and work package leads) evaluates changes to the Total Project Definition: baseline and contingency. A Technical Review Board (e.g., comprised of technical leads and Subject Matter Experts [SME]) evaluates changes to project configuration: technical scope, requirements, and design. The CCB makes recommendations on changes based on impacts versus benefits. If a recommended technical change involves changes to scope or requirements or affects cost, schedule, and/or contingency, it is transferred to the CCB for evaluation of the impacts on the PMB and contingency. If it is a request for a waiver of non-compliance for a completed part so that it can be accepted as still useful, it goes to the technical approver.

The CCB assesses the Change Request and makes a recommendation to approve or reject a Change Request based on the project-specific approval thresholds and authorities. The authorized approvers make the formal decision to approve, reject, return for adjustments, or place the request on hold. Generally, approvals progress from the lowest threshold level for CAM approval through higher levels in the project to the PM as the final approver. Others who may be included as approvers are Environmental, Safety, and Health (ES&H) officers or systems engineers. When NSF thresholds on project parameters apply, then NSF approval or concurrence **must** be sought, in accordance with the award terms and conditions.

If approved, the changes are implemented. Regardless of the approvers' decision, the Change Request Form is finalized and archived, and the Change Log is updated. The decision is communicated to funders who may be impacted (including other work package leads who may lose the opportunity to use remaining contingency or whose work may need to be adjusted). Finally, the outcomes of Change Requests are reported to NSF in interim progress reports and periodic submission of the Change Log.

The example process illustrated here should be modified by each project, keeping scaling in mind to match project needs. For example, on very simple projects with few WBS levels, the PM may act as a Change Request evaluator and approver without the use of a CCB. For more complex projects with many WBS levels, a deep hierarchy of leadership from CAM up to the PM and /or Program Director (PD), and a wide range of technical capabilities areas, CCB and Technical Change Board contribute a necessary depth of knowledge to the evaluation process.

Requirements and guidelines for creating and scaling Change Request Forms and Change Logs are described below.

Approval Thresholds and Authorities. In addition to internal approval authorities, the defined Change Control process generally includes provisions for seeking prior written approval from NSF (i.e., the Program Officer [PO] or higher) depending on the magnitude of the change and NSF policy. All actions that exceed these thresholds will also be included in the terms and conditions of the award. The approval thresholds are negotiated with the cognizant PO and award official before the award. In particular, the NSF PO will concur with all change actions exceeding thresholds defined in accordance with the award terms and conditions for use of scope, schedule, and budget contingency. Contingency may only be used to support the scope included in the approved Total Project Definition or Scope Management Plan (see Section 4.7 Contingency Estimating and Management).

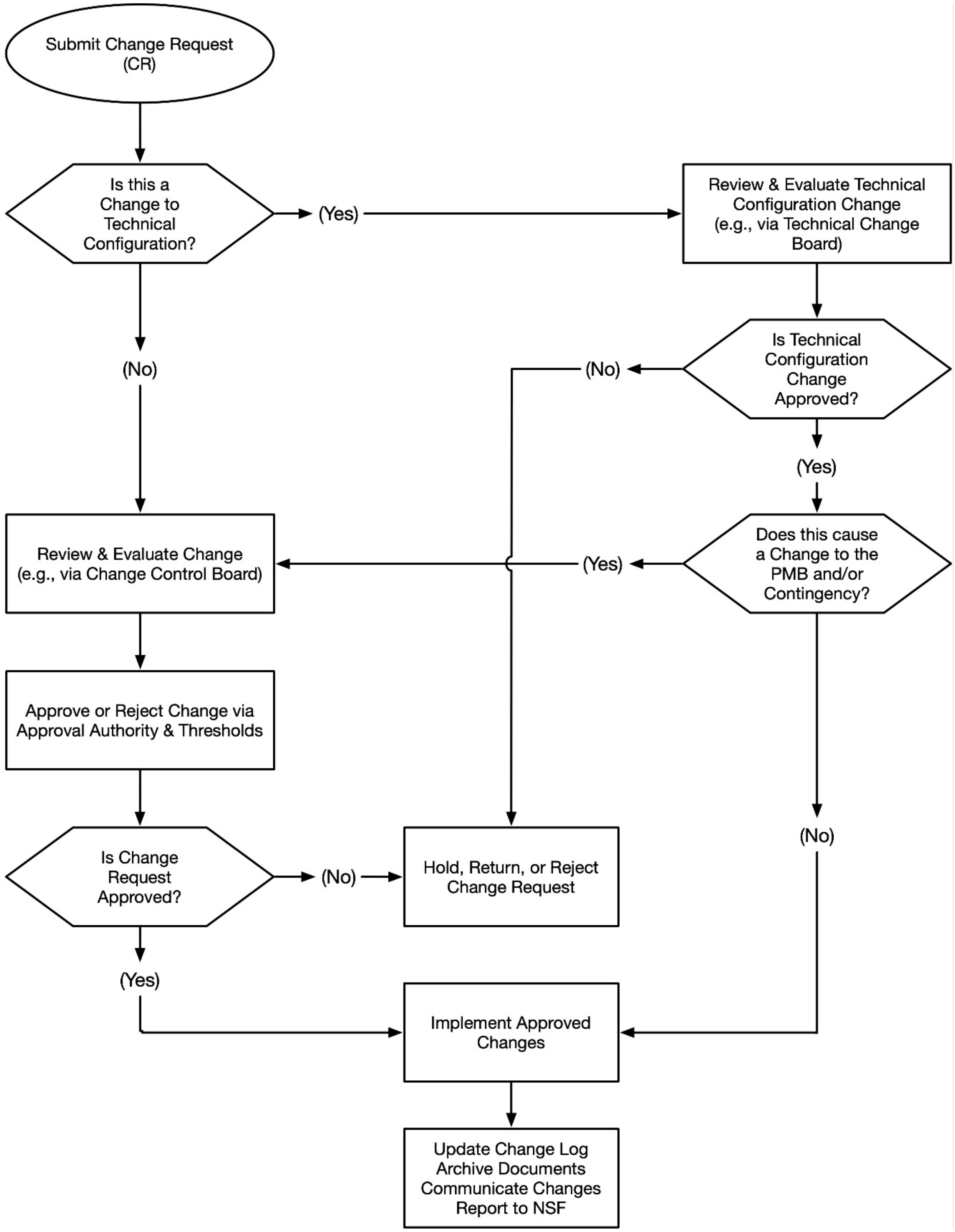
An example of a Change Control threshold table is shown in Table 3.5.7.3-1.

Table 3.5.7.3-1

Sample Change Request: Approval Thresholds and Authorities for a Medium Complexity Major Facility Project

Type of Change	NSF	PM	CAM
Key Science Objectives	Impact on Key Performance Parameters	Changes to science requirements	Changes to engineering requirements
PMB Budget (between WBS elements)	Budget changes above $250,000	Budget changes between $50,000 and $250,000	Budget changes between $5,000 and $50,000
PMB Schedule	Change in project end date	Change of two months or less to Tier 1 or 2 milestones	Change of one month or less to Tier 2 Milestones
Contingency (to/from contingency budget and PMB)	Greater than $100,000 or two months of schedule Exercising any scope option	Less than $100,000 or two months or less to project end date	Less than $25,000 or one month or less to Level 2 milestones

Figure 3.5.7.3-1
Example Flow Diagram for Change Control Process



Change Request and Change Control Log Formats. NSF requires projects to document and archive Change Requests and maintain a Change Log capturing all requests and outcomes for changes to project parameters. NSF does not have a specified format or template for a Change Request Form but does strongly encourage the inclusion of some common elements. For example, changes should be linked to WBS elements and schedule IDs, and all Control Accounts should be specified as impacted by budget or schedule changes. Any contingency adjustments **must** be linked to an identified WBS and risk ID in the Risk Register. In addition to these requirements, Project Teams should include the BOE data and calculations itemized by cost element (i.e., labor, materials, supplies, etc.) as well as before and after copies of the affected schedule and/or milestones. The final format for Change Requests, as well as the process and threshold approval levels for implementation, may be negotiated with NSF at the time of award.

The following is a list of the common elements included in a Change Request Form:

- Change Request ID, Title, Owner/Proposer, Date of submission.
- Summary of Motivation and Change Description, including change in risk to project objectives and any contingency adjustments.
- Links to impacted WBS elements and identified risks.
- Impacts on elements of the project PMB.
- Budget and schedule impacts, including proposed adjustments to contingency.
- Signatures of reviewers, if required.
- Acknowledgement of communication to impacted project leads.
- Project approvals according to authority and thresholds, with NSF approval if required.
- Project Controls acknowledgment of completed change implementation.
- Attachments: expanded schedules, BOE for impacts, technical reports, and any other pertinent information.

Figure 3.5.7.3-2

Example of a Change Request Form

<table>
<tr><th colspan="6">Change Request Form</th></tr>
<tr><td colspan="3">Change Request #</td><td colspan="3">Date</td></tr>
<tr><td colspan="6">Change Request Title</td></tr>
<tr><td colspan="2">Impacted WBS Elements</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="6">Associated Risk ID #s</td></tr>
<tr><td colspan="6">Award #</td></tr>
<tr><td colspan="3">Originator Name</td><td colspan="3">Originator Signature</td></tr>
<tr><td colspan="6">Other Personnel</td></tr>
<tr><td colspan="2">Summary change description and justification, and impact if change does not occur
(Include potential alternatives as appropriate)</td><td colspan="4"></td></tr>
<tr><td colspan="2">NSF Approval Required?</td><td colspan="4"></td></tr>
<tr><td colspan="2">Scope or Technical Impact</td><td colspan="4"></td></tr>
<tr><td colspan="2">Budget Impact</td><td colspan="4"></td></tr>
<tr><td colspan="2">Schedule Impact</td><td colspan="4"></td></tr>
<tr><td colspan="6">Project Acknowledgement and Concurrence</td></tr>
<tr><th colspan="2">Title/Name</th><th colspan="2">Signature (or attached email approval)</th><th colspan="2">Date</th></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="6">Budget Impacts by WBS and Control Account</td></tr>
<tr><th>WBS Element Level 2</th><th>Control Account (WBS Level 3)</th><th>Current Budget</th><th>Revised Budget</th><th>Change Amount</th><th>Change Description</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>WBS L-2 Subtotal</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">CCB Review Date (Can be bypassed for budget changes <$25K)</td><td colspan="3">Date</td></tr>
<tr><td colspan="6">CCB Review Results</td></tr>
<tr><td colspan="6">Change Approved or Rejected by PD?</td></tr>
<tr><td colspan="3">Project Director Signature
(Or attached email approval)</td><td colspan="3">Date</td></tr>
<tr><td colspan="3">Disposition</td><td colspan="3">Originator Signature</td></tr>
<tr><td colspan="3">NSF Program Officer Signature (required if >$75K)
(Or attached email approval)</td><td colspan="3">Date</td></tr>
<tr><td colspan="6">Comments</td></tr>
<tr><td colspan="6">Project Controls Implementation
(Description)</td></tr>
<tr><td colspan="3">Project Controls Staff</td><td colspan="3">Implementation Date</td></tr>
<tr><td colspan="6">Additional Documentation</td></tr>
</table>

It is compulsory for Project Teams to keep a complete list of all formal Change Requests, regardless of whether the Change Request was approved, rejected, or placed on hold, in a summary Change Log. The Change Log is submitted to NSF on a specified schedule. A list of the typical elements in a Change Log includes the following:

- Change Control document reference number, title, review date, and approval dates.
- Amounts of change in scope, schedule, and budget, labeled at WBS Level 2 or at the first meaningful level of technical differentiation within the project.
- Adjustments to contingency, both draws and returns.
- Running totals for baseline cost, budget contingency usage to date, and remaining obligated and authorized contingency.
- Running totals for project baseline duration, contingency usage to date, and remaining contingency.
- NSF approval and contingency obligation date if applicable.

Each project should tailor the Change Request Form and Change Log formats to the project needs. Projects may choose, for example, to use two separate forms for Change and Configuration Requests, where the information collected for configuration changes may be based more on test results and requirements compared to Change Requests focused on cost and schedule.

Change Log. It is essential that historical information be logged and maintained in a manner that allows NSF to systematically track the evolution of the PMB and the science objectives from the initial definitions at award through all subsequent changes. For example, PMB budgets should be traceable through historical records to the initial PMB release.

- All CCB Change Requests are to be documented and archived by the Project Team, regardless of the outcome.
- Subject to the terms and conditions of the award, Change Logs and Change Request documentation are usually provided on a periodic, pre-determined basis to NSF for review.

The Change or Configuration Change processes should reference the Contingency Management Plan for descriptions of considerations for managing scope, schedule, and budget contingency, including approval and notification thresholds, and how contingency will be added to/subtracted from the Total Project Definition. When a project approves a Change Control action that results in allocating or returning underruns to the contingency budget, the PMB budget will also change. Similar Change Control actions affect the PMB schedule; they revise the project PMB schedule and the available schedule contingency or float time - that is, the difference between milestones on the schedule's Critical Path and the expected completion dates for activities that lead to the accomplishment of those milestones. When a project exercises up- or down-scopes listed in the Scope Management Plan (see Section 3.5.3.2 PEP Subcomponent – 3.2 Scope), the PMB budget and schedule will change, and the contingency budget will either increase or decrease as a result. The Scope Management Plan will also change, with de-scopes removed from the PMB and documented in the Scope Management Plan. Up-scope options will involve adding to the PMB scope, schedule, and budget and retiring the option in the Scope Management Plan. All contingency requests **must** be supported by documentation demonstrating that the proposed amounts and changes to be allocated are considered reasonable and allowable and **must** reference the associated WBS elements and the previously identified risk (see Section 4.7 Contingency Estimating and Management).

Good Practices and Practical Considerations

- Modifications to the PMB that are within the defined scope and do not change the Total Project Duration (TPD) or Total Project Cost (TPC) are referred to as replanning. Replanning may be the result of adjustments or reorganization of the project plan and/or may signify that contingency is being used in an expected manner.
- Re-baselining occurs when the changes involve increases in the authorized TPC, an extension beyond the TPD, and/or major changes in scope or science goals. When the proposed changes reach the re-baselining level, the approval process involves NSF and may involve the National Science Board.
- Re-planning exercises are not requisite to address minor cost or schedule variances but may be warranted if there are substantive changes to the PEP during implementation or Construction Stage.
- Projects should include both threats and opportunities in the Risk Register from the very beginning of the project to allow both up- and down-scope actions during the implementation or Construction Stage.
- A single combined Change Log with both Change Request information and summary log inputs may be adequate to meet NSF requirements for simple projects and those with few or simple anticipated changes.
- NSF may request submission of native file formats (e.g., spreadsheets, not PDF files) to facilitate oversight.

3.5.7.4 PEP Subcomponent 7.4 – Reporting and Review Plans

This subcomponent describes how project status and progress will be periodically documented and reported. This description should address:

Interim Progress Report. At an interval that is specified in the project's award instrument, the Project Team will create and submit to NSF an interim progress report. At a minimum, the interim progress report should include:

- The current technical status of the project, including progress of scope production and adherence to quality acceptance criteria.
- Schedule status, including the current project's Critical Path, reportable milestones, and other significant information related to the schedule.
- Financial status, including the percentage complete, TPC, Budget at Complete, Estimate to Complete, and Estimate at Completion (if applicable). If EVM is not required, provide an objective means to monitor progress against the plan.

- Risk status, including current total risk exposure, response plans, realized risks, new/changed/retired risks, contingency status, and any other relevant information.
- The project status report and delivery format will be negotiated with NSF.

Annual/Final Project Report. As required by the project's Cooperative Agreement (CA), an annual report will be created and submitted to NSF. This report will generally contain the same type of information that is included in regular project status reports, but with a focus on the entire year's progress against the plan and plans for the next reporting period. Additional content may be requested by the cognizant PO or negotiated as part of the terms and conditions for the award, including documenting lessons learned.

Post-Award Reviews. After an award is made, on-going internal or external reviews of project plans, performance, or activities may occur. Some reviews will be pre-negotiated with NSF and specified in the terms and conditions of the award instrument (e.g., performance reviews) or arranged at the request of the Project Team (e.g., assistive reviews). Other review activities will be activities led by the Awardee (e.g., technical reviews, safety reviews, acceptance reviews). The number, frequency and type of reviews will vary depending on the nature and needs of the project. Depending on the specific details, NSF may arrange or attend such activities to ensure proper award oversight and maintain awareness of project status.

Good Practices and Practical Considerations

- The specific plans for progress reporting should be elaborated over time, starting with a summary of expected reporting elements based on information generated in the Project Controls Plan and ending with the actual details negotiated with NSF at the time of the award.
- In addition to supplying regular status reports in the terms and conditions of the award instrument, it is essential that project staff inform NSF in a timely manner of significant issues or significant changes in project status, such as a potential re-baselining, problems with partnerships, or surprising research and development results.
- For some projects, more frequent reporting and reviews may be beneficial. For example, quarterly reviews between Awardees and vendors or service providers may facilitate understanding of management topics, risks, or other performance aspects.

3.5.7.5 PEP Subcomponent 7.5 – Business and Financial Controls Plans

This subcomponent describes the award management and business, and financial procedures, policies, processes, and controls employed in executing the project. For projects involving partner institutions and/or other Subawardees, the host (award institution) acts as the central financial and accounting system for the project, collecting accounting information and invoices from the partners' financial systems.

The following elements should be described in this subcomponent:

- Identification of the roles and responsibilities for financial oversight, including decision authority, of proper allocation of expenditure if a question should arise during execution.

- Description of financial controls, including accounting practices, business controls, software tools, and/or award management practices.
- Stated references to institutional policies for subawards, procurements, and so forth.
- Description of accounting practices for collection and handling of financial data and actual expenses from internal and external subaward sources for input to the project PMM applications.
- Description of methods and responsibility for collecting various rates (salary, fringe, indirect costs, etc.) from the host and any partner institutions, including the process for incorporating rate changes and updates into Project Controls.
- System assessments and validations, such as audits passed and certifications.
- If relevant, a Segregation of Funding Plan describing accounting procedures used to properly delineate and separate expenses for construction activities from concurrent or related activities supported by other funding (e.g., Construction Stage awards from Operations or Design Stage awards).

Segregation of Funding Plan. A Segregation of Funding Plan is intended to establish internal guidelines to be used by the Awardee and to inform a mutual understanding between NSF and the Awardee of the Awardee's practices and responsibilities to determine the appropriate award when allocating expenses, particularly when construction and design or operations activities overlap in time.[1] The Plan describes the procedures the Awardee will use to ensure that costs and activities are expensed to the proper award by clearly defining the separation between the different sources of funding. Funds used on research facilities often come from sources such as existing ongoing operations, construction awards, operations start-up awards that include select commissioning activities, research grants, partner funds, etc. The Segregation of Funding Plan should include the following:

- Description of how work scope is defined and segregated according to funding source (e.g., project WBS, operations Annual Work Plan [AWP], design scope of work, etc.).
- Description of any contributions to the project from other funding sources and how these contributions are financially managed (i.e. separate job/cost accounting records).
- Provide a description of how the guidance in the plan will be articulated to all funders and project staff.
- Description of materials/services that benefit more than one award (i.e., Construction and Operations Stage awards) and methodology used to allocate expenses to the awards.

Various aspects of the Segregation of Funding Plan may be addressed in the Awardee's

[1] 2 CFR 200.413 "Direct Costs" describes the criteria Awardees must use when direct charging costs against a federal award. https://www.ecfr.gov/current/title-2/section-200.413

internal policies and procedures or addressed in other parts of the subject PEP. In these cases, the Segregation of Funding Plan should address these aspects by reference in lieu of duplicating internal documents or text from other components of the PEP.

Good Practices and Practical Considerations

- Typically, projects utilize the award or host institution's existing business offices (e.g., purchasing and contracting) and financial (e.g., accounting) services to execute the project. This subcomponent should describe any such framework or relationships, including how the project will be managed within the larger institution, roles and responsibilities, authorities, and other relevant information.
- A description of the institutional entities that provide oversight within the Awardee organization should be included. For universities and laboratories, this usually involves an Office of Sponsored Research, Grants, and Awards, a Vice President of Research, etc. For consortia or collaborative projects, representatives from several such groups may be managed as a committee. For contract awards, the corporate structure and NSF oversight details would define the relevant parties. These relationships may also be represented in PEP Subcomponent 2.3 – External Project Stakeholders.

3.5.8 PEP Component 8 – Cyberinfrastructure and Information Management

What Does This Component Describe?

This component describes the project's Cyberinfrastructure (CI) and Information Management Plans, which refer to the planned methods and processes for identifying, generating, gathering, organizing, storing, and sharing information within and external to the project. The CI described in this PEP component is distinct and separate from project deliverables for science purposes. When applicable to the project, CI and Information Management Plans should consist of five key areas of focus: CI, Information Assurance (IA), data management, documentation management, and communications management. CI, in this instance, is designed to efficiently connect facilities, data, firmware, software, computers, and people, with the goal of supporting project execution during the implementation and Construction Stage. IA includes cybersecurity and other methods to safeguard digital assets and project information during the planning, execution, and closeout of the project. Data management involves the handling of data produced during the project, including testing and prototype data, code development, and related matters. Documentation management involves the creation, tracking, storage, and retrieval of project documents such as contracts, plans, drawings, specifications, reports, and Project Control documents. Lastly, communications management involves planning, executing, and monitoring information flow and project communications.

Why Is This Component Important?

> **Key Takeaway**
>
> The CI described in this PEP component is distinct from any major computational equipment or resources that might be developed as a project deliverable.

Effective CI and Information Management ensures that needed information is available to the appropriate people at the right time. It enables informed decision-making using accurate, up-to-date information. It helps Project Managers identify potential risks and issues early, which can prevent costly delays and rework. Effective CI and Information Management promote collaboration and coordination while simultaneously preventing duplication of work, overlooked work, and general misunderstandings. It also helps maintain institutional knowledge both beyond the life of the project and with the departure of individual team members during the project. Effective CI ensures that project data is stored, available, reliable, and backed up. Effective IA protects against cyber threats, such as hacking, data breaches, and unauthorized access, ensuring confidentiality, integrity, compliance, and availability of project-related information (see Section 5.3 Information Assurance for additional detail). Effective documentation management ensures that project documents are accurate, up-to-date, and accessible to all relevant and appropriate stakeholders. Effective communications management ensures that information is routed to the correct people and that stakeholders are properly informed about project progress and issues.

How To Develop and Write This Component

There are six subcomponents to be included in PEP Component 8 – Cyberinfrastructure and Information Management, as listed in Table 3.5.8-1 below.

The Information Management Plans should be structured in a manner that matches the project characteristics and is agreed upon by the Project Team and funders. This entire component should be tailored and scaled to the individual type, size, complexity, and characteristics of the project. Further, the subcomponents should be developed in a progressively elaborated approach, as described in Section 3.2 Tailoring, Scaling, and Progressively Elaborating Plans.

Table 3.5.8-1
Cyberinfrastructure and Information Management Subcomponents, Products, and Documents with References to Further Material and Related Topics

Component	Subcomponent	Documents/Products	References
8. Cyberinfrastructure and Information Management	8.1 Overview of Cyberinfrastructure and Information Management		
	8.2 Cyberinfrastructure	• Cyberinfrastructure Plan	Section 5.2 Cyberinfrastructure
	8.3 Information Assurance Management	• Information Assurance Management Plan	Section 5.3 Information Assurance
	8.4 Data Management	• Data Management Plan	
	8.5 Documentation Management	• Documentation Management Plan	
	8.6 Communications Management	• Communications Management Plan	

3.5.8.1 PEP Subcomponent 8.1 – Overview of Cyberinfrastructure and Information Management

This subcomponent provides a high-level description and overview of the plans for the management of project information, which includes CI, IA, data management, documentation management, and project communications management. This subcomponent describes the overarching CI and Information Management policies and objectives, the management team structure, key roles and responsibilities, and other relevant high-level information. It serves as an introduction for the remainder of this CI and Information Management component, with specific details for each sub-area provided below in the relevant subcomponents.

Good Practices and Practical Considerations

- Projects are expected to maximize access, sharing, and transparency of project data (which is distinct from the scientific data resulting from use of the Research Infrastructure [RI]) while simultaneously safeguarding privacy, confidentiality, intellectual property, and cybersecurity. Striking the correct balance between these two competing goals should be jointly planned with the Project Team, the relevant science community that the project will serve, and NSF.
- Project budgets should include adequate resources for CI and IA and other Information Management activities, including personnel, infrastructure, services, and storage costs. Project Team members should also be trained in resource planning and budgeting.
- In the interest of transparency and as a general good practice as a steward of taxpayer-funded work, Project Teams should report on and share project activities and findings regularly via public outlets like websites, publications, conferences, etc.

- Project Teams should consult the NSF Brand Identity Portal for updated guidance on logos, signage, and acknowledgment of NSF support.[1]

3.5.8.2 PEP Subcomponent 8.2 – Cyberinfrastructure

This subcomponent describes the information to be included in the CI Plan that outlines the strategy and approach for CI during implementation or the Construction Stage. The CI Plan provides a structured approach for planning, implementing, and managing the CI aspects of the RI. Typical topics for a CI Plan include:

- Enabling the Scientific Mission
- CI Elements and Requirements
- Internal and External CI, Facilities, and Resources
- CI Implementation Approach
- CI Operational Approach

The CI Plan described in this PEP component is relevant only to implementation or the Construction Stage.

Good Practices and Practical Considerations

- Project Teams should consider options for geographically separated duplication of critical project data, documents, and other information resources to mitigate data loss resulting from catastrophic incidents.
- Training materials to support proper usage of project-related CI should be developed for use by relevant internal or external stakeholders.
- Wherever possible, project CI elements should be designed for rapid redeployment across different platforms or service providers if necessary.
- Project CI resource utilization assessment and benchmarking tests should be conducted regularly to ensure that system capacity matches workload and does not impede progress or waste resources.

3.5.8.3 PEP Subcomponent 8.3 – Information Assurance Management

This subcomponent describes specific plans and approaches for the management of project information during the Construction Stage or implementation. Guidance on the recommended elements of an Information Assurance Management Plan is provided in Section 5.3 Information Assurance. Topics covered in this subcomponent's plans should include:

Institutional Policies and Procedures. Reference to and compliance with a parent institution's cybersecurity management policies and procedures, if available. Identify the cybersecurity framework and control standard that has been chosen to guide the IA

[1] https://mediahub.nsf.gov/portals/dnmqqhzz/NSFBrandingPortal

program. Include compliance with NSF requirements and relevant laws and regulations.

Roles and Responsibilities. Identify roles, and responsibilities for planning and implementing the cybersecurity program. Include roles and responsibilities for responding to cybersecurity events.

Data and System Security. Plans, framework, and processes for data security, encryption, access controls, reporting, risk assessments, and security audits for all project websites, databases, servers, and other IT infrastructure. Includes plans for passwords, data encryption, multi-factor authentication (MFA), access control, and other security implementation practices. Include guidelines for software updates and security patching. Policies for the use of institutional and personal devices and accounts for funded activities.

Response Plans. Plans and protocols for identifying, reporting, and responding to cybersecurity events. Includes business continuity plans for critical systems, resources, and project activities. This includes identified individual team member responsibilities and response hierarchy.

Training. Policies and plans for cybersecurity awareness and implementation training for project staff. This includes training on phishing, password security, social engineering, and other means by which nefarious entities may gain access to the RI CI and data.

Good Practices and Practical Considerations

- Section 5.3 Information Assurance contains guidance on creating a rigorous Information Assurance Management Plan.
- Some NSF-funded institutions and projects have come under serious denial of service, ransomware, and other related attacks. It is the Project Team's responsibility to ensure that all appropriate means are applied to deter, minimize the likelihood of, and otherwise mitigate these attacks and ensure the integrity, security, and appropriate level of confidentiality for project systems and data.
- Projects utilizing cloud computing or third-party services should review all relevant security provisions, agreement terms, and potential risks posed by these entities. This includes interactions with allied facilities and data archives.
- The cybersecurity plans should be informed by risk analysis, emphasize data management best practices, include robust safeguards and regular vulnerability testing, and include software updates. Training is also very important and should be an essential component of any IA program.
- Cybersecurity risk management and incident recovery budgets should be included the project budget linked to the appropriate Work Breakdown Structure (WBS).

3.5.8.4 PEP Subcomponent 8.4 – Data Management

Plans and approaches for managing project information are included in this subcomponent. Topics covered in this subcomponent's plans typically include:

Institutional Policies and Procedures. The plan should reference and describe compliance with a parent institution's CI, IT, and/or data management policies and procedures, if available.

Roles and Responsibilities. Include plans for all IT support, including roles, responsibilities, and training to support project needs. Plans and processes for training and support to ensure project personnel are well-versed in using the project's CI, IT systems, and data management tools should be included.

Project Data. Policies, plans, protocols for the organization and control, documentation, and long-term preservation and archiving of project-produced data and models. For example, Earned Value Management (EVM) or procurement-related data would be covered in this subcomponent. Include plans for sharing and access to these data among project participants. Standards and meta-data requirements and expectations should be described. The project data referenced here is distinct and different from the science deliverables of the project.

Software and Code Data-Management Deliverables. Specific plans for software selection or development, deployment, coordination, benchmarking, documentation, code repositories, quality testing, version control, release, and issue tracking. Plans and expectations for key software and data analysis tools to be used during project execution should be included, along with details on licensing, installation, and other requirements.

Backup. Plans and methods for backup, reporting, and disaster recovery in the event of data loss or system failures during the execution of the project.

Good Practices and Practical Considerations

- Where possible, Project Teams should utilize existing and proven CI, repositories, archives, and community standards rather than developing custom solutions that are new and/or untried. Open licensing is also encouraged where applicable.
- Data governance and ownership need to be clearly defined and stated, including intellectual property rights and data rights for all relevant parties.
- Data quality assurance and control are key aspects of a Data Management Plan. Careful consideration, the implementation of best practices, and other means should be employed to ensure data quality, accuracy, and reliability throughout the execution of the project.
- Project Teams should have a comprehensive plan to manage digital assets, including code, software deployment recipes, hardware and network architectures, 3D designs, and the like. Management, access, and distribution of these project execution-related assets needs the same consideration as applied to scientific data and project deliverables.
- A digital asset inventory and associated points of contact can facilitate efficient management and oversight of all resources.

3.5.8.5 PEP Subcomponent 8.5 – Documentation Management

This subcomponent describes specific plans and approaches for managing project documentation. The Project Team is responsible for ensuring that a document management system is in place that provides for the retention and retrieval of essential and significant documentation related to the project. A robust document management system will help prevent miscommunications and misunderstandings and will ensure that future facility operators have the information required to maintain the facility. This plan should provide organized and straightforward access to project records as required for NSF oversight, audits, and post-award monitoring.

Awardees should retain financial records, supporting documents, statistical records, and other records pertinent to the award instrument employed for at a minimum of three years after submission of the Final Project Report. In addition, access to any relevant books, documents, papers, and records should be made available to the NSF Director, Office of Inspector General, and the Comptroller General of the United States, or any of their duly authorized representatives to make audits, examinations, excerpts, and transcripts in accordance with either the Uniform Guidance or Federal Acquisition Regulation (FAR) requirements, as appropriate.

Essential and significant documentation includes the record of any decision affecting the cost, schedule, or baseline. At a minimum, the following forms of documentation should be retained:

- Memorandum of Understanding (MOU) and any other project agreements or deals.
- Architectural, engineering, shop, and as-built drawings.
- Correspondence identifying problems, the resolution process, and the final decision.
- Contingency use log.
- Change Requests and approvals.
- System integration, commissioning, testing, and acceptance plans and results.

Topics covered in this subcomponent typically include:

Institutional Policies and Procedures. Reference to and compliance with a parent institution’s policies and procedures, if available, for document management, open access, intellectual property, and other relevant document control policies.

Documentation Development Plans. This plan should include processes for document creation, review, approval, access, and version control. Specify who is responsible for document generation, who reviews them, and the approval hierarchy. Include guidelines for document formats, templates, naming conventions, and styles to ensure consistency.

Document Storage Systems. Document management system(s) to be used for secure storage, retrieval/access, sharing and archiving documents, records, and data. Include repository retention, archiving, and backup plans.

Document Security Plans. Document security and confidentiality plans, including access and distribution permissions and restrictions for confidential or sensitive documents. These plans should be coordinated with and integral to the overarching cybersecurity plans described in PEP Subcomponent 8.3 – Information Assurance Management.

Good Practices and Practical Considerations

- Projects are encouraged to implement a document management system that is accessible via the Internet rather than paper-based, though some paper records may be necessary on certain projects. The documentation management system should aid in identifying the types of documents to retain and contain appropriate controls over official documents such as drawings to ensure that only the most recent drawings are being used and that only authorized personnel are able to access and modify them.
- NSF has specific requirements and expectations for documentation retention on projects they fund. It is the responsibility of the Awardee to determine the applicability and specific requirements for their project. This may include requirements for retention of financial, programmatic, and equipment records and documents post project. The Project Team is encouraged to work with representatives at NSF to determine and implement these requirements.

3.5.8.6 PEP Subcomponent 8.6 – Communications Management

This subcomponent describes specific plans and approaches for managing project communications. Communications can take a variety of forms, including regular all-hands meetings, regularly updated project websites, and team newsletters and blogs. Successful communication plans depend strongly upon interactions with project stakeholders, including NSF and other governmental representatives, Project Team members and partners, and the public. Awardees are recommended to put in place a stakeholder management plan that provides for the identification, analysis, and periodic review of project stakeholders, including an analysis of their needs and expectations. Topics covered in this subcomponent's plans typically include:

Institutional Policies and Procedures. Reference to and compliance with a parent institution's communication policies and procedures, if available.

Roles and Responsibilities. Plans for management and responsibilities for overseeing and implementing project communications, including any required approval hierarchies. Any single point of contact requirements (e.g., for press interactions, crisis management, etc.) should be identified.

Communication Strategies and Methods. The overarching strategies and specific methods planned for both internal and external (e.g., NSF) project communication. Specify items such as goals, target audiences, communication frequencies, formats, and other planned methods of formal and informal communication. The communication channels and methods to be used should be identified, such as emails, regular meetings, software, and social media platforms. Explain how each channel will be utilized.

Archiving. Plans for how project communications will be documented and archived, including the retention of emails, messaging apps, meeting minutes, website content, and other communication records, should be described.

Accessibility. Project Teams should ensure that they support accessibility standards for publications, events, and information releases.

Good Practices and Practical Considerations

- Awardees are recommended to put in place a stakeholder management plan that provides for the identification, analysis, and periodic review of project stakeholders, including an analysis of their needs and expectations.
- The Project Team should strive for clear, transparent, and unambiguous communications, both internal and external to the project.
- The Project Team should avoid siloing and compartmentalization of information within a project. Successful projects usually have systems in place to ensure vigorous and clear flows of information internal to the project to prevent issues related to siloing. Team members also should be encouraged to ask for project information, and project leadership is encouraged to freely disseminate such information to the maximum extent possible.
- Project Teams are encouraged to create websites, social media, signage, etc., to communicate project activities and outcomes to the general public during the course of the project. Project Teams should acknowledge NSF support in all such communications, publications, presentations, and press releases about the project using the language provided in the project agreement.

3.5.9 PEP Component 9 – Project Closeout Plans

What Does This Component Describe?

This component describes the plans for closing out the project. Closeout is the last phase of a project, when the Project Team verifies the completion of all scope contained in the Work Breakdown Structure (WBS), completes all the necessary tasks to validate the technical performance of the Research Infrastructure (RI), transitions all deliverables to owners/operations, and shuts down the project. This component comprises three elements that need to be considered when closing out a project: technical closeout activities, administrative closeout activities, and programmatic/award closeout activities.

Why Is This Component Important?

The closeout process is an essential part of any project. It ensures that all deliverables have been completed, key parameters have been met, major stakeholders are satisfied, and all unused resources have been returned to the funding agencies as required. The closeout process also provides an opportunity to evaluate the project's success and identify areas for improvement in future projects. By following a systematic and structured closeout process, the Project Team can be assured that all work has been completely addressed and all project objectives met.

How To Develop and Write This Component

There are four subcomponents to be included in this component, as listed in Table 3.5.9-1 below. Project closeout planning starts early in the project Design Stage and is factored into the baseline scope of work. Each specific closeout activity should be considered and incorporated into the Integrated Master Schedule (IMS) and included in the project budget as necessary. The Project Team should review and iterate plans with key project stakeholders (e.g., NSF and operations teams) early in the planning process to ensure all required activities are identified, planned, and budgeted. The key is to minimize surprises and to manage all stakeholders' expectations early and effectively.

The closeout plans should match the project characteristics and needs and should be agreed upon by the Project Team and funders. The plans should be tailored and scaled to the individual type, size, complexity, and characteristics of the project. Further, the subcomponents should be developed in a progressively elaborated approach, as described in Section 3.2 Tailoring, Scaling, and Progressively Elaborating Plans.

Table 3.5.9-1

Project Closeout Plans Subcomponents, Products, and Documents with References to Further Material and Related Topics

Component	Subcomponent	Documents/Products	References
9. Project Closeout Plans	9.1 Overview of Closeout Plans		In accordance with the award instrument used.
	9.2 Technical Closeout Plans	• Technical Closeout Plan • Transition to Operations Plan • Lessons Learned Document	In accordance with the award instrument used.
	9.3 Administrative Closeout Plans	• Administrative Closeout Plan	In accordance with the award instrument used.
	9.4 Programmatic/ Award Closeout Plans	• Programmatic/Award Closeout Plan	In accordance with the award instrument used.

3.5.9.1 PEP Subcomponent 9.1 – Overview of Closeout Plans

This subcomponent serves as an overview of the entire closeout component plans. It provides a brief description of the overall closeout approach and processes. It describes the high-level approaches for each of the three categories of closeout activities (technical, administrative, and programmatic/award). Specific guidance and details for each of these individual closeout categories should be covered in the three other subcomponents included in this PEP component.

Good Practices and Practical Considerations

- While closeout in this PEP guidance is described in terms of three distinct categories of closeout (technical, administrative, programmatic/award), it's important to recognize that many closeout activities are typically performed simultaneously.
- The process of closeout activities often begins well before the end of the project, particularly with respect to performance testing and verification of compliance with requirements.
- A project closeout checklist or compliance matrix can be a valuable component of the Technical Closeout Plan.
- Ideally, the details, procedures, documentation, and criteria for closing the project should be discussed and negotiated with NSF at the time of a received award.

3.5.9.2 PEP Subcomponent 9.2 – Technical Closeout Plans

This subcomponent describes the plans and approaches for the completion of all project scope. The primary goal of the closeout plan is to demonstrate how the Project Team will formally complete the project scope, verify compliance with requirements, prepare for, and finalize transitions, and document all final project deliverables, ensuring that they have been completed, meet their required quality acceptance criteria, and are ready for delivery/transition. Note that final validation (NSF or other federal or international partners) and formal acceptance of the project scope is not part of this subcomponent, that is, funder approval and acceptance are included as part of the programmatic closeout plans below.

While every project is unique, these technical closeout considerations typically include:

- **Product Scope Completion and Verification Plans.** Describe the plans for completing, testing, verifying, documenting, and handing over all scope deliverables that are included in the WBS. This may include activities such as plans for performing final acceptance tests, writing quality control reports, capturing test results, creating compliance matrices, processing requests for waivers against requirements, and creating, capturing, and processing all required as-built drawings and specifications. Specific procedures to accomplish the work for commissioning could be included as an appendix or separate document. The verification work is a precursor to validation and acceptance work described below.
- **Project Scope Completion Plans.** Describe plans for completing and documenting compliance with all other non-product-type project scope (e.g., services like project

management, systems engineering, safety management, etc., or a result such as the creation of a user group)

- **Transition to Operations Plan.** Describe the plans for determining operational readiness of the RI and completing the transition of the deliverables from construction to operations. This may include elements such as conducting an operational readiness review and/or operations demonstration. The plan should address verification of deliverables such as the provision of operations and maintenance manuals, staff training (if included in the proposal and authorized in the award), and other appropriate elements such as transfer of title/ownership, as well as operational readiness of the RI.
- **Project Lessons Learned Plans.** A lessons learned document is often included as part of the technical closeout deliverables of a project to improve a current or future project. The plans for creating and delivering this document should be described here.
- **Completion and Archival of Project Documentation.** Describe the plans for completing and filing/storing all relevant project documentation and communications.

Good Practices and Practical Considerations

- Commissioning verifies that the substantially complete facility operates over its full range of intended capabilities as specified in Key Performance Parameters (KPP) and science requirements. Once the commissioning planning is complete, an operations readiness review may be held to examine and comment on the plan. This can be conducted separately or as a component of one of the required project reviews.
- Project Teams should plan to gather, assess, and incorporate lessons learned during the entire course of the project, as well as analyzing and documenting those identified at project closeout. Feedback from NSF (e.g., the Program Officer [PO]) at the closeout should be included in the lessons learned document.
- Completing and archiving all project documentation and communications is often an overlooked project deliverable. It should be addressed in PEP Subcomponent 8.5 – Documentation Management. Systematically and regularly, using a well-structured and organized repository for key documentation during project execution will simplify the effort necessary to archive documents at project closeout. Note that financial records, supporting documents, statistical records, and all other records pertinent to the NSF award **must** be retained by the Awardee as described in accordance with the terms and conditions of the award.

3.5.9.3 PEP Subcomponent 9.3 – Administrative Closeout Plans

This subcomponent describes the plans and approaches that the Awardee institution will use to complete the closeout of all institutional administrative activities. Depending upon the characteristics of the project, this typically includes but is not limited to:

- **Closeout of Project Contracts, Agreement Commitments, and Legal Obligations.** Describe plans for ensuring all project obligations, contractual agreements, and other commitments are addressed and completed.
- **Financial Reconciliation and Return of Unexpended Balance.** Describe plans for reconciling all financial Control Accounts, including both budget and contingency. Describe plans for the return of any unspent/unused monies.
- **Release or Transfer of Labor Resources.** Describe plans for the release of project staff at the end of the project and/or transfer to another assignment or role (e.g., Operations). This may include the application of existing HR plans and policies but also may include project-specific plans and methods.
- **Return, Release, or Transfer of Non-Labor Resources.** Describe plans for the return, release, or transfer of non-labor resources (e.g., tools, equipment, computer hardware/software, office space, etc.). Specific property management policies and procedures should be addressed.

Good Practices and Practical Considerations

- Awardees should liquidate all obligations incurred under their awards as specified in accordance with the award instrument used (e.g., 120 days).
- NSF does not allow Awardees to keep any unspent money at the end of an award.
- Contractual obligations and commitments may not be considered fully complete until lien releases and/or over waivers have been received from external entities like contractors. The Project Team is encouraged to research and review specific requirements necessary to ensure that no persistent obligations, liens, or other commitments extend beyond the period of performance of the project.
- Project obligations on some RI projects may include environmental and regulatory commitments and requirements that should be formally completed, agreed to, documented, and closed out with all relevant parties. Formal documentation in these situations is critical to gather and include in the closeout documentation.
- The end of a project usually requires the release or transfer of key project personnel and staff from the project, and should be planned for in a professional, systematic, and graceful manner. It’s also good practice to celebrate success with the Project Team and recognize their contributions and hard work before the disbursement of these personnel.

3.5.9.4 PEP Subcomponent 9.4 – Programmatic/Award Closeout Plans

This subcomponent describes the processes and approaches for obtaining validation, i.e., the formal affirmation from NSF that all funded activities have been successfully completed such that the award may be closed. At an appropriate time approaching or following construction completion, NSF will typically conduct a Final Construction Review. This review is intended to assess the extent to which the required scope was delivered in accordance with the PEP and award terms and conditions. Depending upon the characteristics of the project, programmatic/award closeout usually includes but is not limited to:

- **Validation of Project Deliverables.** Describe the process for working with NSF to validate acceptance of the product scope delivery and formally acknowledge that all deliverables are complete and available, with no further action required on the part of the project.
- **Validation of Title/Ownership Transfer.** Describe the process to validate readiness to transfer title/ownership of deliverables to the appropriate entity and verify completion of the transfer.
- **Validation of Transition to Operations.** Describe the process to verify readiness for operation and validate completion of the transition.
- **Final Report(s).** Describe what Final Project Reports are required and will be provided by the Project Team to NSF at the conclusion of the project. These typically include but may not be limited to the Final Project Report and Project Outcomes Report for the General Public.
- **Closeout Review.** Describe the plans for conducting a close-out review (e.g., a Final Construction Review) with NSF at the conclusion of the project.
- **Agreement of Project Completion.** Describe the process for working with NSF to obtain formal written recognition that all funded activities are completed, project financials have been reconciled, and that the project award may be closed.

Good Practices and Practical Considerations

- In addition to the Final Project Report and Project Outcomes Report for the General Public, there may be other requirements contained in the original solicitation, the award agreement terms and conditions, Federal Acquisition Requirements, and/or Uniform Guidance (2 CFR 200 Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards the *Proposal and Award Policies and Procedures Guide*, and other oversight and requirements documents. The Project Team may work with NSF to identify all such requirements and ensure they are appropriately addressed.
- It is good practice to create an award terms and conditions compliance matrix that tracks and ensures all requirements have been met or achieved in order to facilitate the NSF Closeout Review.

3.5.10 PEP Component 10 – Post Project Plans

What Does This Component Describe?

This component encompasses the conceptual post-project plans that describe the expected activities and plans for deliverables after completion and addresses the feasibility and reasonableness of those plans. Such post-project activities typically include those undertaken during the operations and maintenance, and those adopted for the transition or closeout of the facility operation during a Disposition Stage. These plans are generally credible, high-level, conceptual estimates of the expected key activities, considerations, and costs that define the characteristics of these future life cycle stages. Note that these conceptual plans are not the same as the detailed operations Annual Work Plan (AWP) described in Section 3.6 Operations Stage Planning or Section 3.7 Disposition Stage Planning. NSF has separate proposal review and acceptance procedures for these life cycle stages. The creation of the final detailed life cycle proposals and plans for operations and disposition is the responsibility of the future life cycle operators/owners and is not the intention of these conceptual plans.

Why Is This Component Important?

There are a number of reasons the PEP includes the consideration of post-project activities. These include:

- Ensuring the feasibility and reasonableness of proposed operations, maintenance, and disposition programs and that the programs are not difficult or too expensive to accomplish.
- Ensuring that the operating plans take advantage of the Research Infrastructure (RI) capabilities and that access to the scientific capabilities and output of the RI meet stakeholder expectations.
- Alerting stakeholders, including NSF, to the expectations and assumptions that determine the necessary level of future support and responsibilities for the remainder of the RI lifetime.
- Raising awareness of any special considerations, including environmental, handling of human subjects' data, or other regulatory requirements that may impact the achievement of expectations and goals.

How To Develop and Write This Component

There are three subcomponents to be included in this component, as shown in Table 3.5.10-1 below.

The Post Project Plans should match the project characteristics and needs and should be agreed upon by the participants and funders. The plans should be tailored and scaled to the individual type, size, complexity, and characteristics of the project. Further, the subcomponents are typically developed in a progressively elaborated approach, as described in Section 3.2 Tailoring, Scaling, and Progressively Elaborating Plans.

Table 3.5.10-1

Post Project Plans Subcomponents, Products, and Documents with References to Further Material and Related Topics

	Subcomponent	Documents/Products	References
10. Post Project Plans	10.1 Overview of Post Project Plans		
	10.2 Concept of Operations Plans	• Concept of Operations Plan	
	10.3 Concept of Disposition Plans	• Concept of Disposition Plan	

3.5.10.1 PEP Subcomponent 10.1 – Overview of Post Project Plans

This subcomponent serves as an overview of the two plans included in this component, providing a brief, high-level description of each plan, and may describe how the plans will be created and elaborated during planning and how and under what circumstances they will be modified after the start of the project. Specific guidance and details for each of these individual Post Project Plans are covered in the two remaining subcomponents below.

3.5.10.2 PEP Subcomponent 10.2 – Concept of Operations Plans

This subcomponent describes the Concept of Operations (ConOps) Plan, which contains plans and expectations for the post project Operations Stage of the implementation and Construction Stage. The ConOps Plan is created early in project planning and is a high-level, conceptual view of expectations. The ConOps Plan is ideally matured by the time of award and does not need to be revised or modified unless new understanding or issues regarding key elements of operations and maintenance arise during project execution. The ConOps Plan is not the same as the Operations Stage AWP (see Section 3.6 Operations Stage Planning). The AWP is not the responsibility of the Project Team unless the entity executing the construction or implementation project is also the operator, and NSF has approved AWP as deliverables within the project scope. In that case, the AWP is treated as any other deliverable in the WBS and follows the requirements in Section 3.6 Operations Stage Planning, and it is not included in the ConOps Plan.

The ConOps Plan should:

- Describe the framework of how the RI will be operated and maintained, who the initial operator will be and for how long,
- Describe who has access to the scientific capabilities of the RI and how the output will be handled, distributed, or published such that operation plans satisfy stakeholder expectations.
- Give high-level estimates of the resources and budget needed for annual operations and maintenance (space, utilities, staffing, services, material/supplies, etc.), with analysis or justification for the Basis of Estimate [BOE] and reasonableness of assumptions. To the extent possible, the estimates should align with expectations for RI performance (e.g., expected uptime or reliability of subsystems).

- State the expected lifetime of the facility or operations after it becomes operational.
- Include a list of expected funding sources and contributors that will support operations activities and how much support each is expected to give (including any user's fees).
- A key part of a ConOps Plan for RI is a discussion of expected costs for future upgrades to instrumentation, including cadence of major expenditures (e.g., next-gen instruments).
- Include a description of any transition activities and costs that are not the responsibility of the implementation and Construction Stage (i.e., staff training, initial start-up).
- Describe any post project activities required to bring the facility to full science capability after the transition to the Operations Stage.

Good Practices and Practical Considerations

- If the plans for operations and maintenance include support and/or contributions from the operating or other institutions, then letters of collaboration from those institutions, stating the nature, duration, and level of support, are encouraged for creating a credible BOE.
- In some cases, particularly with distributed facility projects or when beneficial occupancy is allowed in construction, the transition to Operations may be staggered, with some deliverables moving to operations while others are still in the Construction Stage. Thus, the availability of operations and project funding will overlap in time. ConOps Plans should address how Operation responsibilities will be managed during the staggered transfers and how costs will be managed following the segregation of funding requirements covered in PEP Subcomponent 7.5 – Business and Financial Control Plans.
- For Major Facilities, the ConOps Plan, along with the Transition to Operations Plan (see Section 3.5.9 PEP Component 9 – Project Closeout Plans) and Segregation of Funding Plan (see Section 3.5.7.5 Subcomponent 7.5 – Business and Financial Control Plans) are reviewed during Conceptual Design Review (CDR), Preliminary Design Review (PDR), and Final Design Review (FDR). The plans are updated as needed during the Construction Stage. The plans should be updated and provided to NSF for review in a timely manner before commissioning activities commence.
- ConOps Plans for Mid-scale RI projects are typically reviewed during the proposal and award process as well as one year before commissioning or transitions to operations.
- For Design Stage proposed projects, separate guidance for follow-on plans for further design or implementation is described in the Design Execution Plan (DEP) outlined in Section 3.4 Design Stage Planning.

3.5.10.3 PEP Subcomponent 10.3 – Concept of Disposition Plans

This subcomponent describes the Concept of Disposition Plan, which provides a high-level description of the expectations during the Disposition Stage, the last stage in the RI life cycle. Disposition options may include the partial or complete transfer of a facility to another entity's operational and financial control, mothballing the facility so that operations can be restarted at a later date, or decommissioning. Decommissioning may include complete removal of the infrastructure and site restoration and remediation. The Concept of Disposition Plan is created early in project planning and is a conceptual view of expectations for divestment or disposition after NSF funding support is terminated. It typically reaches maturity by the time of the implementation and Construction Stage award and does not need to be revised or modified unless new understanding or issues regarding key elements of disposition arise during project execution. Concept of Disposition Plans are not as detailed or complete as the Facility Disposition Plan described in Section 3.7 Disposition Stage Planning. Detailed Facility Disposition Plans are usually produced after a period of operations to reflect circumstances that may change over time.

The Concept of Disposition Plan should:

- Describe the liabilities, expectations, and plans for transfer of the RI to another institution or entity, demolition and removal, site remediation, decontamination, and so forth.
- Provide a high-level estimate of financial liabilities and costs of disposition activities at the end of its Operational life or end of NSF support. List assumptions used in supporting the estimated costs.
- Describe plans, costs, and assumptions for all potential pathways to Disposition if more than one is likely.
- Note any known regulations, laws, permitting, or other requirements that are expected to be followed and/or adhered to during the Disposition Stage, including any binding agreements entered into during the construction planning and execution.

Good Practices and Practical Considerations

- The Concept of Disposition Plan is a pre-cursor to the Disposition Stage Facility Disposition Plan and should not include full and specific details, plans, and expectations for disposition; instead, it's a high-level, top-down overview that provides enough detail to ensure a broad but accurate understanding of the requirements by all stakeholders.
- For Major Facilities, the Concept of Disposition Plan is reviewed during CDR, PDR, and FDR. The plans are updated and reviewed as needed during the Construction Stage.
- The Concept of Disposition Plan for Mid-scale RI projects are typically reviewed during the proposal and award process as well as one year before commissioning or transitioning to operations.
- An explanation of the impacts of site or equipment contamination on disposition

planning is essential for a full understanding of the costs and administrative burdens.

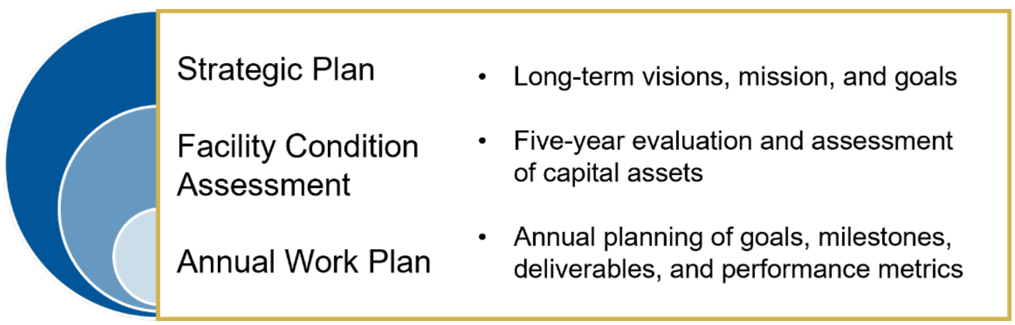
- Awardees should be aware of any legal liabilities for site restoration, remediation or other obligations that attend final asset disposition.

3.6 OPERATIONS STAGE PLANNING

Section Revision: TBD Early 2025
Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

Planning for the Science Support Program throughout the Operations Stage involves the provision of deliverables that address the planning and execution of operations of the Major Facility, including the Strategic Plan, the Facility Condition Assessment (FCA), and the Annual Work Plan (AWP), see Figure 3.6-1. The Strategic Plan communicates the overall vision, mission, and goals of the Science Support Program, with the other two components nested within. The FCA evaluates the capital assets that require significant expenditure for periodic replacement or refurbishment, which helps, in part, to inform upcoming AWP. The AWP presents the annual goals, milestones, deliverables, and performance metrics and indicators that are executed to meet the mission. The quarterly and annual reports outlined in Section 2.7 Major Facility Operations Stage complement the AWP by tracking performance against the AWP throughout the period of performance.

Figure 3.6-1
Three Main Deliverables Necessary for Operations Stage Planning and Execution



3.6.1 Strategic Plan

The Strategic Plan, or another comparable document, serves as a guided roadmap for the Awardee to communicate strategic goals, objectives, and activities to meet the mission of the funded Science Support Program. The Strategic Plan may be revisited as necessary, at least every five years, or at a cadence applicable for the period of performance in consultation with an external advisory body when appropriate. It serves as a foundational framework aligned with the objectives that enable the effective allocation of resources and program evolution.

Strategic Plans apply to any given program or a portfolio of programs that looks at the long-term evolution of capabilities enabled by the infrastructure. The document may include a mission statement, vision, or another high-level statement of the goals of the program that may be informed, in part, by goals outlined in appropriate level strategic documentation (such as National Academies of Sciences, Engineering, and Medicine, Decadal Surveys, etc.). Further, it may present a roadmap of how the facility will support the advancement of the research landscape and scientific discoveries, its contribution to workforce development, and the development and fostering of partnerships and collaborations. Strategic goals should be selected based on priorities for the award period and tailored to the type, size, complexity, and maturity of the Science Support Program. This document, along with the Asset Management Plan (see Section 3.6.2 Facility Condition Assessment of a Major Facility), serve as a base for the development of the AWP (see Section 3.6.3 Annual Work Plan).

3.6.2 Facility Condition Assessment of a Major Facility

An FCA evaluates capital assets requiring significant expenditures for periodic replacement or refurbishment and having a lifetime longer than the usual five-year award cycle. An Asset Management Plan, a strategic plan for dealing with these issues, accompanies the FCA and informs NSF and the facility management of anticipated major and infrequent maintenance expenses that cause a significant departure from the routine funding profile.

The Operations Stage for a Major Facility typically lasts 20-40 years. NSF expects that upgrades, refurbishment, and renewals of various components will be necessary over time in order to support the evolving scientific mission. The FCA assists with planning of these activities, including replacing obsolete instruments, refurbishment, or renewal of structural components, electrical and cooling systems or upgrading cyberinfrastructure (CI) and data storage/distribution networks.

As part of periodic Operations Stage reviews, NSF will use the outputs from the FCA process to evaluate the condition of each Major Facility to help inform long-term budgetary planning (see Section 3.6.2.1 Facility Condition Assessment Components).

An FCA, or equivalent assessment as discussed with the cognizant Program Officer (PO), **must** be conducted in accordance with the terms and conditions of the award. In general, they are conducted every five years, starting in year-five after the initial operations award and should encompass both critical support infrastructure and scientific components, including risks and mitigations associated with resilience to climate change and the resulting natural hazards. An FCA may be conducted more frequently based on risk and NSF's oversight needs.

3.6.2.1 Facility Condition Assessment Components

The FCA process includes two main components:

- **FCA Report:** A comprehensive evaluation of the condition of all capital assets requiring significant expenditure for periodic replacement or refurbishment. Capital assets include land, structures, equipment (including portable equipment such as vehicles, ships, and aircraft) and intellectual property (including software) that have an estimated useful life of two years or more, and/or exceeds the typical Operations & Maintenance (O&M) award duration.[1]
- **Asset Management Plan:** Elaboration of the proposed strategy for addressing the issues identified in the FCA Report specifying the corresponding timeline and

[1] Modifications and Supplemental Financial & Administrative Terms and Conditions for Major Multi-User Research Facility Projects and Federally Funded Research and Development Centers May 20, 2024, https://www.nsf.gov/bfa/dias/policy/cafatc/cafatc_modsandsup_mfandffrdc0524.pdf

resources needed.

The FCA Report and Asset Management Plan informs NSF and the Facility Management Team of anticipated major and infrequent maintenance expenses that may cause significant departure from the routine funding profile and should, therefore, be addressed proactively and sometimes separately.

The timely identification of needs, and subsequent planned renewal and modernization of capital assets is essential to supporting the scientific mission. Well-maintained Major Facilities have a positive impact on working conditions and reflect NSF's commitment to the scientific endeavor. Proper long-term maintenance can have measurable improvements in operational performance criteria such as ensuring scientific excellence, improving uptime, reliability, equipment availability, and downtime due to corrective maintenance. Renewals will also result in facility wide energy efficiency improvements and carbon footprint reduction, and associated reduction in annual operating costs.

Finally, a well-executed FCA process will contribute to the protection of the health and safety of employees and of members of the public from hazards and to minimize danger to life and property, including resilience to natural hazards.

The FCA Report and Asset Management Plan may be compiled using a priority ranking based on risks that include personnel health and safety, operations sustainment, and enhancement of the scientific mission.

3.6.2.2 Scope of the Facility Condition Assessment

In accordance with the terms and conditions of the award, and collaboration with the NSF PO, the FCA **must** include the federally owned/Awardee-titled property and capital assets necessary to support the Major Facility's mission under the award.

The FCA should use industry standard practices as appropriate, but should be tailored to the specialized technical nature of the Major Facility and cover both the supporting infrastructure (i.e., substructure, shell, interiors, HVAC, electrical, plumbing, site, etc.) and, if not addressed separately, the major scientific instrumentation.[1]

The specific scope of the FCA and the timing of the submittal, including submittal of any assessments conducted by other entities, will be determined in collaboration with the NSF PO to support agency oversight of the award.

3.6.2.3 Conducting Facility Condition Assessment

The steps to conduct an FCA are presented as follows:

List of Capital Assets: The Major Facility will provide a list of the capital assets to be included in the FCA process. For most Major Facilities these can be separated in three main categories:

[1] For example, ASTM standard E1557-09(2020)e1 Uniformat II Classification for Building Elements- classifying building specifications, cost estimating, and cost analysis. https://www.astm.org/e1557-09r20e01.html

- Science Support Equipment and systems
- Infrastructure (non-science equipment and systems; for example: specialized cranes and safety equipment, specialized environmental conditioning, vacuum systems, power conditioning, control, and communication systems).
- Buildings and building systems, including grounds, roads, fences, flood control etc.

Once negotiated with the PO, the list of capital assets will serve as a baseline for the FCA scope.

Establish Process to determine Asset Condition: The process to compile information for the FCA Report and Asset Management Plan will be established by the awardee and agreed by the PO. The process by which the Major Facility will conduct the FCA on the agreed list of capital assets could include:

- Gather information already available through regular inspection or monitoring reports conducted by the host institutions and local, state, or federal entities.
- Conduct on-site inspections and evaluations by qualified outside contractors.
- Conduct on-site inspections and evaluations by the Major Facility maintenance team.
- Have an independent entity evaluate the complete package of available information before submittal to NSF for review.

The FCA Report should use industry-standard practices, where appropriate, to break down the elements into major components common to most buildings and sites. Regardless of the standard used, a *systems approach* should be employed that uses a hierarchical structure of cost elements and assets.

The FCA Report and Asset Management Plan should provide documentation to include, but are not limited to:

- When the asset was put into service and estimated remaining useful life of the asset.
- The estimated full replacement cost of the asset.
- Current and projected maintenance requirements and effectiveness of past maintenance performance.
- A determination of requirements (i.e., an emergent scientific need or a deficient condition that should be addressed), including deferred maintenance, code issues, functional requirements, repair, partial replacement, full replacement, and/or capital investment or further in-depth study, analysis, or specialized inspection.
- A recommended action for each requirement, which is a remedy for the condition that includes itemized cost estimates.
- For each requirement, an asset-level estimation of annual asset repair or renewal or replacement funding needs projecting over the expected life of the Major Facility, or various components required to support the evolving scientific mission, and at a minimum covering the next five, ten and 15-year intervals.
- Estimate of energy efficiency improvements and associated reduction in annual

operating costs and carbon footprint associated with renewal and modernization of significant facility assets.

3.6.2.4 Creating the Asset Management Plan

The Asset Management Plan elaborates a strategy for addressing the issues identified in the FCA Report by specifying the corresponding timeline and resources needed. The Awardee can use data from the FCA Report for future maintenance management, capital planning, and budgeting and report generation.

The steps to create an Asset Management Plan are as follows:

- **Analyze and Prioritize Requirements.** The baseline FCA Report list assumes all requirements are equally important and have equal weight, so further refinement is needed to develop a meaningful plan. The items should be prioritized based on urgency and the need to be completed within specific timescales (i.e., in one, two-to-three, and five years).
- **Weigh and Rank Requirements.** With time priorities developed, refine a model that weighs and ranks requirements to be adjusted in alignment with the scientific mission of the Major Facility. Safety, impact on science mission, and sustainment of essential operational activities should have the highest weightings.
- **Develop Project Strategy.** The Facility Management Team will develop and mature a strategy for addressing the ranked requirements, specifying the corresponding timeline and resources needed. The strategy will be managed to de-conflict with science mission and essential operations.
- **Identify Funding Needs.** Identify the annual cost of executing the Asset Management Plan projecting over the expected life of the Major Facility and, at a minimum, covering the next five, ten, and 15-year intervals.
- **Determine Deferred Maintenance.** The Facility Management Team will keep an updated list of deferred maintenance. These are considered FCA requirements that still need to be projectized and scheduled.

The Asset Management Plan, along with the FCA Report and supporting maintenance documents, will be reviewed as part of regular external panel reviews so that priorities can be established, and potential funding avenues identified. The Program Office may choose to have the documents peer-reviewed and vetted by maintenance professionals from other Major Facilities.

Once agreed upon, the Asset Management Plan Work Breakdown Structure (WBS) element costs will have a sound, fully justified, and documented, and sufficiently detailed Basis of Estimate (BOE), and the planned refurbishment and preventative maintenance projects will be incorporated into the AWP, if funded through the Operations Stage award. The same level of detail will be provided if funded through a separate award.

3.6.3 Annual Work Plan

The AWP describes what the Science Support Program expects to accomplish in the upcoming period of performance. The Science Support Program for operations planning requires the annual submission of a forward-looking AWP (also known as a Program Operating Plan) that details the O&M, education and outreach activities and deliverables, as well as management activities necessary for a Science Support Program to fully perform to its intended scope for the upcoming period of performance. It may include annual technical, operational, managerial, and scientific goals, objectives, activities, milestones, performance targets, assumptions, and risks pertinent to the successful operation of the Science Support Program and its mission. The AWP may also incorporate activities with completion milestones in response to annual reviews and include a detailed budget for the upcoming period of performance.

The AWP serves as the baseline for assessing differences between planned and completed activities, and management thereof, within each program, laying out metrics and/or anticipated milestones and Key Performance Indicators (KPI), for the upcoming period of performance. The AWP enables planning for, and management of known operational risks.

The AWP is typically submitted annually for review and approval by the NSF PO in consultation with the Core Integrated Project Team ([IPT], see Section 2.1 NSF Staff Roles and Responsibilities for Award Management and Oversight). Submission of an AWP that satisfies the requirements articulated above, in part, informs NSF's release of annual funding increments.

The AWP is distinct from quarterly and annual reports (see Section 2.7 Major Facility Operations Stage) that are backward looking, and document progress against the AWP. Overall, the AWP should, in totality, describe how the Awardee will comply with the terms and conditions of the award, as well as describe their plans for the upcoming period of performance.

3.6.3.1 Assumptions

The AWP should be aligned with the strategic operations documents such as the Strategic Plan or the Concept of Operations Plan if transitioning from the Construction Stage. It should be developed in communication and consultation with the NSF PO. The following section provides an overview of typical components that may be included in the plan and should be used as a guideline for structure and content. It is not intended to be prescriptive.

When writing the AWP, the Awardee should ensure that it is tailored and scaled specifically to the type, maturity, and complexity of the Science Support Program, and progressively elaborated as the program matures (see Section 3.2 Tailoring, Scaling, and Progressively Elaborating Plans).

The period of performance may align with the government FY, the managing organization's FY, or some other time frame, depending on when the award was initiated. The priorities and initiatives should facilitate the delivery of the intended scope and align with the long-term Strategic Plan.

3.6.3.2 Components of an Annual Work Plan

The specific components of an AWP will be determined by the NSF PO in consultation with the Awardee. Recommended components of the AWP are as follows with detailed guidance on each given below. The applicability of the sections outlined in the AWP should be tailored and scaled to the needs of the award's type, size, complexity, and maturity, particularly as it relates to smaller-scale awards. The PO may also use the AWP outline to inform the most appropriate approach for award oversight.

1. **Overview**
2. **Program Management**
3. **Risk Management**
4. **Management Support Services**
5. **Science and Science Support**
6. **Cyberinfrastructure and Information Assurance**
7. **User Support: Community Education, Outreach, and Engagement**
8. **Proposed Budget and Financial Details**
9. **Performance Evaluation and Measurement**
10. **Operations and Maintenance Plan**

Depending on the scope, size, complexity, and maturity of the Science Support Program, not all the components may be appropriate for all Operations Stage programs. The Awardee is encouraged to discuss specific requirements with their NSF PO. Required sections will be specified in the funding announcement and subsequent award terms and conditions. Whenever possible, metrics or performance indicators to measure progress through the period of performance should be specified.

The AWP, informed by the Strategic Plan, should likely not change significantly from year to year other than providing updates as they relate to certain O&M requirements to maintain an operational program. For example, it may include:

- Work required to support and conduct research and educational activities.
- Data to demonstrate the facility is operating efficiently and cost-effectively.
- Small- and intermediate-scale technical enhancements when needed to maintain state-of-the-art research capabilities that reflect the continued relevance to the community of users.

This document is not intended to be onerous but to provide guidance and accountability for the RI investment.

1 – Overview

The Overview (or Executive Summary) provides an outline of the intended program outcomes for the upcoming period of performance and the planned objectives and associated activities to support them. These outcomes, objectives, and activities may be directly informed by the long-term Strategic Plan (see Section 3.6.1 Strategic Plan). Significant challenges, risks, and opportunities may be highlighted. Changes to organizational structure and major budget issues may also be summarized.

The goals and metrics will vary among programs and will be agreed upon between the Awardee and the NSF PO. The NSF PO will review the AWP goals to ensure they are aligned with the long-term scientific objectives of the program and meet the terms and conditions of the award. The annual goals of the Science Support Program should be outlined as they relate to the delivery of the intended scope, and presented as Specific, Measurable, Attainable, Relevant, Traceable, Tiered, and Total (SMARTTT) when possible. Milestones used to reach that goal and help manage the work, where possible, should be credible, visible, and have an accountability threshold.

2 – Program Management

Facility management concerns the management of scope, schedule, and cost of the Science Support Program's O&M. The AWP addresses management approaches to the following sub-components.

Management & Organizational Structure. Defining operations management and illustrating the organizational structure of the Science Support Program is an essential component of any AWP. This subcomponent may provide a brief description of the leadership and management team and highlight program management practices and overall oversight of operations. If appropriate, the methodology associated with allocation of staff in a matrixed structure where staff effort is shared across programs, should be described. Existing and new tools, processes, and procedures as well as changes and improvements the Awardee plans to implement in the upcoming period of performance may also be outlined.

- **Infrastructure and Human Capital.** A high-level overview of the primary physical infrastructure and human capital that enables the provision of science services to the community should be outlined and associated with the WBS. This sub-component includes milestones and anticipated outcomes regarding human capital management and physical infrastructure maintenance; however, an Integrated Master Schedule approach is not required. Operations management impacts on program budgets and delivery of science services, if any, should be specified.
- **Human Capital and Workforce Development.** This section should highlight current and future workforce-related needs of staff managing and operating RI, to enable completion of the funded activities, including efforts to develop the research and technical workforce. It should also articulate how the management team meets Section 5.7 Personnel and Competencies.
- **Physical Infrastructure.** This section should highlight the planned maintenance and

upgrades for the upcoming period of performance of the primary physical infrastructure (including facilities, RI, etc.), to support the funded activities of the Science Support Program.

Planned Procurements. Any major planned procurements should be noted in the AWP and be reflected within the WBS and budget line. It may be appropriate to include this section as an appendix. The Awardee may execute subcontracts and subawards in the upcoming period of performance that are above NSF approval thresholds given in the terms and conditions of the award.

3 – Risk Management

NSF expects Awardees to engage in routine risk assessment and management throughout the duration of the award to enhance program success by decreasing the likelihood of threats and increasing the probability of opportunities. The Awardee's approach to risk management should be summarized in the AWP, with top risks reported annually and, in some cases, quarterly (see Section 2.7 Major Facility Operations Stage) as determined by the NSF PO and required per the terms and conditions of the award. This description may be presented as a formal Risk Management Plan, developed in consultation with the NSF PO, and should be tailored and scaled according to the nature and complexity of the RI (see Section 4.6 Risk Management).

Risk management entails developing a reliable course of action to address known events that are likely to impact operations. Such planning is intended for responding to risks by reducing the negative impact of threats and increasing realization of opportunities during operations. Risk response planning entails selecting and applying appropriate methods that minimize the threat's likelihood and/or impact or maximize the opportunity's likelihood and/or favorable impact. After a risk has been realized, it becomes an issue and requires a different set of response plans to deal with the event. Issues are handled differently in the Operations Stage (see Section 4.6 Risk Management). Operations Stage awards generally use the following mechanisms to address the impacts of realized risks in the following order:

- Routine risk impacts are included in the BOE as part of the most likely cost.
- Re-budgeting authority is used by the Awardee per the award terms and conditions.
- The Awardee reduces the level of science support effort (with NSF approval if significant).
- The Awardee requests supplemental funding; assuming proper justification, availability of funds, and recommendation by the NSF PO.
- The Awardee requests contingency funding; assuming proper justification, availability of funds, and recommendation by the NSF PO and Awarding Official (AO).

A budget contingency separate from construction or implementation may be proposed for Operations Stage awards to handle identified risks documented in the Risk Register, in aggregate for either the entire award or components of the award by WBS. For example, a separate contingency budget may be advantageous if the AWP includes a significant upgrade that should be managed as a separate sub-project. That said, proposing budget contingency carries additional management and oversight responsibilities for the Awardee and NSF, respectively. Any request **must** utilize a formal risk management approach that is tied to a Risk Register and the WBS (see Section 4.7 Contingency Estimating and Management). If funded, and based on the type, size, complexity, and maturity of the program, thresholds for NSF approval on contingency use and periodic reporting may be given in the terms and conditions of the award including reporting actual costs against the draws on contingency by WBS. The award of budget contingency is subject to NSF approval. Given the additional requirements with developing and managing budget contingency, other mechanisms listed above may be sufficient to manage the impacts of known operational risks.

Funding and use of budget contingency should align with the award instrument used. In addition, since *contingency* has a specific meaning under the Uniform Guidance and the Federal Acquisition Regulation (FAR), and *management reserve* cannot be held by the Awardee under financial assistance awards, these terms **must not** be used by the Awardee in the BOE.

4 – Management Support Services

Performance Management. In consultation with the NSF PO, performance management activities planned to take place in the upcoming period of performance, including performance metrics, should be outlined. Processes in place to verify and validate systems requirements for the Science Support Program operations, including data product and service delivery to the user community, may be highlighted. These activities should be tailored and scaled to reflect the type, size, complexity, and maturity of the Science Support Program.

Asset Management. To preserve the long-term operational integrity of a Science Support Program, the Awardee should outline activities to be performed in the upcoming period of performance for tracking, maintaining, and maximizing the value of the Science Support Program's physical assets including preventative and predictive maintenance and technology refreshes (see Section 3.6.3 Facility Condition Assessment of a Major Facility).

Shared Business Services. Where applicable, the Awardee should describe any key administrative needs and services that are shared across multiple organizations, whether funded by NSF or other sources, which may be needed to complete the scope for the upcoming period of performance.

Environment, Safety, and Health. The Awardee should describe the execution, management, and compliance verification activities to ensure facilitation of Environmental, Safety, and Health in support of research. Based on the award type, size, complexity, and maturity, the Awardee may detail how they will comply with the award requirements for the upcoming period of performance as specified in the terms and conditions.

5 – Science and Science Support

Scientific Research. For Science Support Programs that have an embedded program that directly supports scientific research, for example if investigators at the facility undertake research activities using the RI that are funded through O&M, anticipated scientific highlights for the period of performance should be summarized, as appropriate. If Awardees scientific activities are supported by O&M funds, the processes used for review, selection, and prioritization of proposed activities should be described. Accordingly, the metrics and milestones being used to assess the scientific impact, i.e., KPI, of the Science Support Program described should be presented and used to track progress. Additional specific requirements that may be in place for the award should also be presented.

Science Services. Science support activities facilitate the collection and delivery of high-quality data and samples through the provision of services and support to science, engineering, and CI processes. Include activities implemented to meet the intended science services that will be delivered to the community in the upcoming period of performance. These could be detailed in the Asset Management Plan.

Research Support Services. Research support services facilitate the accessibility, usability, and interoperability of data and infrastructure delivered and provided by the Science Support Program. Any support services that will be available to the community in the upcoming period of performance, such as assignable asset or research support services programs, research coordination, instrumentation loans, etc. (if applicable and not described elsewhere in the AWP), should be briefly outlined.

6 – Cyberinfrastructure and Information Assurance

CI and Information Assurance (IA) are central components of most Science Support Programs. The Awardee may discuss any operations activities, and updates and changes to CI and IA that will be implemented in the upcoming period of performance to meet the scientific data management needs and maximize the production, delivery, accessibility, and usability of the Science Support Program infrastructure and data products and, ultimately, the scientific impact.

Performance metrics for data quality and delivery (such as completeness, conformity, validity, and integrity) should be outlined to inform O&M needs and outreach strategies and can be used to monitor the level-of-effort required to deliver data product delivery and supporting CI, at the discretion of the PO.

Cyberinfrastructure Management. Independent of the AWP, the Awardee **must** maintain a current and comprehensive CI plan, outlining the strategy and approach for CI management (see Section 5.2 Cyberinfrastructure). The AWP should articulate objectives and activities outlined in the plan that will be implemented in the upcoming period of performance. Data are vital to the missions of many Science Support Programs, and the CI Plan should refer as appropriate to the project's relevant documents addressing data-related requirements, design, and performance metrics. Relevant CI-related risks and issues should be carried forward from the Construction Stage and managed in the operations Risk Register per the Risk Management Plan, if applicable. If the Mid-scale RI is an upgrade to a Major Facility, it can leverage the Major Facility's CI Plan.

Information Assurance. Maintenance and development of IA objectives and activities to be implemented in the upcoming period of performance should be articulated in the AWP, including risks and issues to continue into operations from construction. Independent of the AWP, the Awardee **must** maintain a current and comprehensive plan for IA management, the Information Assurance Management Plan (IAMP), which should be summarized in the AWP – with updates to practices and procedures highlighted in the AWP (see Section 5.3 Information Assurance). If the Mid-scale RI is an upgrade to a Major Facility, it can leverage the Major Facility's IAMP.

7 – Community Education, Outreach, and Engagement

Community engagement, education, and outreach activities are designed to empower and value the community's role in using and understanding data products. It ensures diversity, equity, and inclusion in the accessibility and usability of the data products, services, and facilities. The Awardee should describe new objectives and activities to be implemented in the upcoming period of performance related to how they may monitor the community's scientific publications and users of the RI's data and infrastructure, the scientific productivity of the observatory, and the degree of community outreach, to ensure that data use is equitable across the user community. Performance metrics of the user support activities should be included, where applicable, and reflect the type, size, complexity, and maturity of the program. Performance metrics should include a record of facility use for research and education, including the name, affiliation, funding agency, award number, and annual award amount for each user. This description may be presented as a formal Community Engagement, Education, and Outreach Plan, developed in consultation with the NSF PO, and should be tailored and scaled according to the nature and complexity of the RI.

Education. The Awardee, where applicable, should describe ongoing and new educational objectives and activities aimed at the community and to be conducted during the upcoming period of performance, with performance metrics clearly articulated.

Outreach. Similarly, outreach activities with the scientific user community and the general public to be implemented in the upcoming performance period should be articulated along with the associated performance metrics. These initiatives and activities should include enhancing the usability of the data being collected, democratizing the science being served, increasing the diversity of the user base, and supporting historically underserved user communities.

Engagement. Additional engagement activities in the form of collaborations and partnerships, and long-term efforts to build sustainable relationships with the scientific and community at large should be highlighted along with the associated performance metrics.

Diversity, Equity, and Inclusion (DEI). Awardees should demonstrate prior experience and current capabilities in an effort to employ the best practices in broadening participation in science and engineering through effective DEI activities. Highlights of objectives and activities that will help comply with any award terms and conditions and demonstrate capabilities for broadening participation in the upcoming period of performance should be presented. Where applicable, reference should be made to practices for handling potentially sensitive demographic information.

8 – Proposed Budget and Financial Details

The Awardee should present the budget in a WBS format that is tailored and scaled to the type, size, complexity, and maturity of the Science Support Program to aid in NSF's evaluation of the proposed budget, monitor progress, and facilitate discussions with NSF on rebudgeting, if needed. The number of levels in the WBS depends on a program's complexity and risk. The WBS needs to be expanded to a level of detail sufficient for planning and successfully managing all the proposed activities as negotiated with the NSF PO, in consultation with the NSF IPT and in alignment with the terms and conditions of the award.

The AWP should include the approved budget amounts by WBS as required by the award instrument and in a budget format to facilitate obligation of funds. Any shared costs or matrixed services should be articulated, and indirect cost rates should be summarized, noting how these apply to program budgets. Any forecast for the carry-forward (residual funds) from the previous year **must** be clearly presented for ongoing operations to support discussions between NSF and the Awardee. A summary of how the carry-forward funds will be utilized **must** also be included in the AWP, as applicable (see Section 4.3 Cost Estimating and Analysis).

9 – Performance Evaluation and Measurement

The Awardee **must** have a process for evaluating and tracking their performance in delivering on program and scientific goals and objectives and in supporting and meeting the user community needs. The performance metrics outlined in the AWP should link to the goals outlined in the Strategic Plan and a Performance Evaluation and Measurement Plan, as appropriate, to inform the Science Support Program's forward-looking and retrospective annual reporting. While objectives and activities for the upcoming period of performance are not likely to change significantly from year to year, any proposed new approaches, initiatives, and efficiencies should be captured in the performance evaluation and measurement activities highlighted in the AWP to reflect the evolution of the Science Support Program.

Where applicable, updates to the performance evaluation and measurement activities should be captured annually in the annual progress report and be reviewed in conjunction with the AWP for the upcoming award year.

KPI and metrics should be clearly described in the performance evaluation and measurement activities and used to track progress in annual (and, if appropriate, quarterly) reports and reflect the intended goals and objectives of the Science Support Program. The metrics should be quantifiable (SMARTTT) whenever possible so the Awardee can track progress (such as operating time, and scheduled and unscheduled downtime, etc.). Current performance should be compared to the previous year's performance and, where applicable, historical performance, including historical record of costs related to maintenance (preventive, deferred, repairs, and/or emergency). All aspects of management and operations, scientific output, education, outreach, DEI, and workforce development efforts will be included where appropriate. This description may be presented as a formal Performance Evaluation and Measurement Plan, developed in consultation with the NSF PO, and should be tailored and scaled according to the nature and complexity of the RI.

10 – Operations and Maintenance

The O&M component of the AWP formally describes in-depth strategies and approaches used to operate and maintain the Science Support Program and ensure it delivers its intended scope. Typically, the plan includes the program's day-to-day operations, as well as planning, managing, and executing operations, maintenance, change management, and improvement needs. While the AWP is likely to remain mostly the same from year to year, it details the primary management components responsible for delivering the program activities funded under the award. The O&M description should be included as part of the AWP, even for awards with less complexity. This description may be presented as a formal Operations and Maintenance Plan, developed in consultation with the NSF PO, and should be tailored and scaled according to the nature and complexity of the RI. The FCA Report and the Asset Management Plan (see Section 3.6.2 Facility Condition Assessment of a Major Facility), based on the periodic FCA, may be included or referenced here.

3.7 DISPOSITION STAGE PLANNING

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Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

During the Operations Stage, NSF may recommend that a facility enter the Disposition Stage, which may involve divesting or transitioning Research Infrastructure (RI) or the non-renewal of the award (see Section 2.8 Major Facility Disposition Stage). Once a decision for disposition is made regarding the transition or closeout of the facility operation under an NSF award, the current operations management should start the preparation for the divestment. This preparation involves consulting stakeholders and the Program Office to appoint appropriate personnel or a management team responsible for overseeing the transition activities. The Awardee **must** develop and submit a Disposition Plan to the NSF Program Officer (PO).

The current operations management should be involved and integral to the Disposition Plan's development to ensure a smooth and successful transition. Below is an overview of the key components of a Disposition Plan. Project Teams should tailor and scale the Disposition Plan to meet the needs and nature of the disposition (see Section 3.2 Tailoring, Scaling, and Progressively Elaborating Plans).

- **Overview**. The overview of the Disposition Plan should identify the RI slated for disposition. The goal of the transition should be clearly defined, whether it involves establishing a new operation model under a different funding mechanism or decommissioning the facility. If transitioning to a new operation model, the Disposition Plan should describe the model, NSF's role, and the associated costs. A detailed handover procedure should also be included in the new management organization. For dispositions involving decommissioning, the Disposition Plan should outline the procedures and costs for proper equipment disposal and site remediation.
- **Scope**. The scope of the Disposition Plan should define the transition requirements, including engineering aspects and estimated costs (see Section 4.3 Cost Estimating and Analysis). The Disposition Plan should provide a comprehensive cost estimate for the transition, covering labor and material costs. The target date for completing the transition should be clearly indicated. If applicable, the Disposition Plan should also detail the procedures for properly disposing of equipment.
- **Roles and Responsibilities**. Partner organizations involved in managing the transition activities at each stage should be clearly described. Each organization's roles, responsibilities, and authority levels should be explicitly defined. It is essential to identify the individuals or management team responsible for overseeing the disposition activities and detailing their specific responsibilities. Additionally, consulting with stakeholders and the NSF Program Office is necessary to appoint the appropriate personnel to manage these activities effectively.
- **Risk Management**. A detailed description of the risk management strategy and its execution during the Disposition Stage should be included (see Section 4.6 Risk Management). Identifying and documenting potential risks associated with the

divestment transition is crucial. Additionally, it is essential to continuously monitor and update risks in the Risk Register and report these updates to NSF as determined by the cognizant PO.

- **Contracts and Award Management**. Describe the plan for resolving and closing contracts and sub-awards, including the review process for all existing contracts and sub-awards to identify terms, obligations, and termination clauses. Contractors and service providers should be notified about the disposition and potential contract and sub-award termination, with sufficient notice given to avoid penalties. Detailed records of all contract and sub-award terminations **must** be maintained, and contracts archived for future reference in accordance with the award terms and conditions and Awardee internal policies. Funders, including the NSF Program Office, should be kept informed about the status of contract and sub-award terminations, with regular updates and a final report provided. This systematic and legally compliant approach ensures smooth contract resolution and should be included in the Disposition Plan submitted to the NSF Program Office for review and approval.
- **Environmental Impact Analysis**. A comprehensive plan for evaluating and mitigating the environmental impact of the proposed transition activities should be addressed. It is essential to identify and consider all potential environmental impacts resulting from these activities. Additionally, the plan **must** determine the appropriate level of environmental review in accordance with the National Environmental Policy Act.[1]
- **Pension and Healthcare Responsibilities**. A detailed description of how pension and healthcare obligations post-divestment will be managed and funded should be included.

A comprehensive, well-documented Disposition Plan **must** be created to ensure transparency, accountability, and the successful execution of the RI disposition process. The Awardee should submit the Disposition Plan to the cognizant NSF Program Office for review and approval, ensuring alignment with NSF policies and guidelines.

[1] 42 U.S.C. § 4332. NSF regulations governing compliance with NEPA are found at 45 CFR § 640. NSF regulations supplement the Council on Environmental Quality's regulations, published at 40 CFR §§ 1500-1508.

4.0 FUNDAMENTAL ELEMENTS OF PROJECT MANAGEMENT

4.1 INTRODUCTION

This chapter offers in-depth insights into key project management components that Awardees should integrate during the Design and Construction Stages of Major and for design and implementation activities for Mid-scale RI. These elements are essential for upholding the principles set forth by NSF, facilitating effective planning, execution, and project completion. Unless otherwise noted in the funding announcement or the award terms and conditions, these principles should be used during the other life cycle stages only to the extent that project management principles would benefit the activities funded under the award.

4.2 Scope and Work Breakdown Structure. Involves defining project goals, deliverables, tasks, costs, and deadlines. Breaks down the project into manageable sections, facilitating detailed cost estimation, scheduling, and risk management

4.3 Cost Estimating and Analysis. Predicts financial resources needed for the project, covering all potential costs such as materials, labor, contingencies, and fees. Analysis ensures realistic budgeting, effective resource allocation, and financial planning, maintaining project viability and adherence to budget.

4.4 Schedule Development, Estimating, and Analysis. Develops a detailed timeline outlining activities, milestones, and deliverables. Guidance to ensure tasks are completed in an organized manner by understanding task sequences, durations, and dependencies.

4.5 Monitoring Progress Against Plan. Continuously monitors project progress against the initial plan. Uses key performance indicators and milestones to identify deviations and implement corrective actions, ensuring alignment with scope, schedule, and budget

4.6 Risk Management. Proactively identifies, analyzes, monitors, and reports potential risks throughout the project life cycle. It begins early and addresses uncertainties that could impact project success.

4.7 Contingency Estimating and Management. Includes estimating and setting aside resources to handle unforeseen events or challenges. Provides flexibility for the project to adapt and proceed despite disruptions, minimizing delays and cost overruns.

4.2 SCOPE AND WORK BREAKDOWN STRUCTURE

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Scope refers to the detailed description of a project's deliverables, objectives, boundaries, and requirements. It outlines what needs to be accomplished, the work that will be performed, and the specific outcomes or products the project will deliver. The scope defines the parameters and constraints within which the project will be executed and provides a clear understanding of what is included and excluded from the project.

The Work Breakdown Structure (WBS) is a hierarchical decomposition of the project scope into smaller, more manageable components called work packages. It organizes project work into a structured framework of components and deliverables, providing a systematic and visual representation of its scope and objectives. The WBS serves as a foundational tool for project planning, scheduling, resource allocation, budgeting, and control, enabling the Project Team to manage and execute project work effectively.

For Major Facility and Mid-scale RI projects, a Scope Management Plan and Change Control Plan should be included as part of the Project Execution Plan (PEP) to formally control scope (see Section 3.5.3.2 PEP Subcomponent 3.2 – Scope, Section 3.5.7 PEP Component 7 – Project Controls Plans, Section 4.7.2.3 Scope Contingency, and Section 4.7.3.1 Contingency Management Controls).

For projects in Design or Construction Stages, the WBS is a deliverables-based and hierarchical framework structure that provides specific, manageable, and schedulable work packages and may be composed of products, materials, equipment, services, data, and support facilities that the project should yield. See Table 4.2-1 for a WBS example of a project in the Design or Construction Stages. Level-of-Effort (LOE) tasks may be confined to only those tasks that are not easily definable as deliverables for better tracking of spending against budget and tracking of accomplishments against the plan.

Depending on the type of work, an operational WBS may be functional, activity, and/or deliverables based. See Table 4.2-2 and Table 4.2-3 for Operations WBS examples.

The WBS provides a consistent framework for planning, estimating costs, developing schedules, identifying resources, and determining where risks may occur. The WBS is a valuable communication tool and provides the means for measuring program status, e.g., via using Earned Value Management (EVM) for construction. WBS are developed at varying levels of detail but should typically include at least three levels. The number of decomposition levels varies depending on the project’s size and complexity, technical maturity, organizational constraints, acquisition and construction strategies, and management’s assessment of need.

A WBS Dictionary is a companion document to the WBS that provides detailed information about each work package or component of the WBS. It serves as a reference guide for understanding the scope, requirements, and responsibilities associated with each element of the WBS. The WBS Dictionary can include as much, or as little, descriptive information as required to fully and correctly plan and execute the project. It can also include requirements, exclusions, associated key schedule milestones and risks, and should name the person accountable for each element.

Guidance and examples of common WBS elements can be adapted from the Government Accountability Office (GAO) and other guidance and tailored for NSF projects, as depicted in Table 4.2-1 and Table 4.2-2. The intent of providing these typical WBS elements is to provide a standard format that is feasible to the vast array of different facility types while noting that additions and/or alterations to this list are likely due to the unique nature of each specific RI. The benefits of developing similar WBS across the portfolio of RI within an organization include:

- Consistent, clear, and familiar reporting structures and organizational relationships.
- Improved efficiency and effectiveness of NSF cost analyses.
- Better characterization of project scope, schedule, and cost.
- Ease of judging completeness and reasonableness.
- Enhanced collection and sharing of data and analysis methods across multiple contractors and projects to support future cost estimates.
- Better cost tracking over time and identification of major cost drivers and systemic problems across contractors and projects.
- Facilitate sharing of approaches, data, and best practices between Awardees and NSF.

Good Practices and Practical Considerations

- Deliverables-based WBS elements should be nouns, not verbs.
- Each high-level WBS **must** include 100% of the scope in the lower-level elements, and each element of scope should appear only once in the WBS.
- Generally, the number of levels employed should be sufficient to identify and measure progress towards achieving deliverables, assign responsibility, and enable effective management and reporting.
- The WBS Dictionary can also be used to define the boundaries of the work and what is excluded from the scope.

While all WBS aim to organize and structure tasks within a project or operation, they differ significantly in their focus, structure, and application.

Construction Deliverables-based WBS: This type of WBS centers on achieving specific deliverables or outputs within a construction project. It breaks down the project into a hierarchy of deliverables, sub-deliverables, and work packages. This approach is beneficial for construction projects where the focus is on tangible outcomes and specific deliverables, see Table 4.2-1.

Table 4.2-1
Example Format of a Construction Stage or Implementation Deliverables-based WBS

Deliverables-based WBS for the Construction Stage or Implementation
1.0 Project Administration and Management Office
1.1 Project Management Office
1.2 Site Office
1.3 Science Office
1.4 Education and Public Outreach
1.5 Safety and Environmental Assurance
2.0 Facility Infrastructure and Civil Construction
2.1 Sub-element X
2.2 Sub-element Y
2.3 Sub-element Z
3.0 Scientific Equipment and Instrumentation
3.1 Subcomponent X
3.2 Subcomponent Y
3.3 Subcomponent Z
4.0 Cyberinfrastructure and Information Assurance
4.1 Data Infrastructure
4.2 Data Products
5.0 Systems Integration, Testing, and Commissioning
5.1 Common Utilities and Support Equipment
5.2 Early System Assembly, Integration, and Testing
5.3 Acceptance Testing
5.4 Training
5.5 Science Verification

Operations Functional-based WBS: Emphasizes major functions or activities required to sustain operations, focusing on the work that needs to be performed, rather than the end products or deliverables. This type of WBS breaks down each function into smaller sub-functions or tasks, creating a hierarchical structure while clearly understanding the overall scope of work, see Table 4.2-2.

Table 4.2-2
Example Format of an Operations Functional-based WBS

Functional-based WBS for the Operations Stage
1.0 Project Director, Management, Administration Office
1.1 Director's Office
1.2 Project Management Office
1.3 Site Office
1.4 Education and Public Outreach
1.5 Safety and Environmental Assurance
1.6 Administrative Services
2.0 Science Operations
2.1 Research Planning
2.2 Experimental and Operations Support
2.3 Data Analysis
2.4 Calibrations and Data Quality
2.5 Special Projects
3.0 Significant/Important Infrastructure Modernization, Overhaul, Upgrade, Replacement, Expansion
3.1 Equipment
3.2 Facilities/Infrastructure
3.3 Computer Systems, Instrumentation
3.4 Information Technologies, Communications, Information Assurance
4.0 Facility and Equipment Operations, Maintenance, Engineering, and Support Services
4.1 Operations
4.1.1 Scheduling
4.1.2 Operating
4.1.3 Testing
4.2 Maintenance
4.2.1 Corrective Maintenance
4.2.2 Preventative Maintenance
4.3 Utilities
4.3.1 Energy (e.g., electricity, natural gas, central heating, central cooling)
4.3.2 Security
4.3.3 Water
4.4 Other/General Support Services
5.0 Contingency (if justified and supported by appropriate risk analysis and management)

Operations Activity-based WBS: This type of WBS details the specific tasks and activities needed to sustain operations, focusing on the sequence and interdependencies of activities rather than the deliverable. It breaks down the project into a hierarchy of activities, sub-activities, and tasks and is particularly useful for projects where the sequence and execution of activities are critical to the project or program's success, see Table 4.2-3.

Table 4.2-3

Example Format of an Activity-based Operations WBS

Activity-based WBS for Operations
1.0 Lab Directorate/Oversight
2.0 Lab Operations
2.1 Control Room
2.2 Detector Operations and Maintenance
2.3 Facilities Operation and Maintenance
2.4 Environmental, Safety, and Health
2.5 Cyberinfrastructure and Cybersecurity
2.6 Science Center
3.0 Data Science
4.0 Advanced Technology Research
5.0 Infrastructure Upgrades
6.0 Education, Public Outreach, Collaboration, and Community Activities

Each type of WBS serves its unique purpose, providing a structured approach tailored to different aspects of project and operations management.

4.3 COST ESTIMATING AND ANALYSIS

Section Revision: TBD Early 2025

Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

4.3.1 Introduction to Cost Estimating and Analysis Process

> **NSF Requirement**
>
> Awardees **must** adhere to the *GAO Cost Estimating and Assessment Guide*, while also complying with NSF policies and practices. They should tailor and scale the guidance to suit specific needs of their RI.

Section 1.3 Document Precedence and Award Instruments notes that award instruments can be financial assistance awards, such as grants and cooperative agreements (CA) or contracts. Unless otherwise noted, the guidance in this section applies to Major Facilities and Mid-scale RI at all stages, regardless of the award instrument employed. Proposed budgets **must** comply with the applicable federal regulations, in accordance with the funding announcement and the terms and conditions of the award as implemented by NSF, and any requirements associated with the particular award instrument. Section 1.4.4 Oversight Requirements notes that Awardees **must** follow the *GAO Cost Estimating and Assessment Guide* in accordance with the funding announcement and the terms and conditions of the award. Additionally, portions of GAO or NSF guidance may be tailored and scaled depending on what is relevant to the particular project or program. Accordingly, Awardees **must** note any departures from the *Research Infrastructure Guide (RIG)* and *GAO Cost Estimating and Assessment Guide* and explain their rationale in the Cost Estimating Plan (CEP).[1] Section 4.2 Scope and Work Breakdown Structure provides additional guidance on how to apply the relevant practices from the *GAO Cost Guide* and examples of potential deviations.

This section provides guidance on NSF expectations for the format, content, supporting justification, and good practices for Awardee cost estimates. It also explains the NSF cost analysis process and timeline. By following this guidance, Awardees should expect a more robust estimate and, therefore, a more efficient review by NSF, contributing to the likelihood of the science mission's success. The Awardee should consult the cognizant NSF Program Officer (PO) for existing awards.

NSF may use internal staff, outside experts, and panel reviews to analyze estimates. However, the NSF Awarding Official (AO) is responsible for the pre-award business and financial review process and making the final determination regarding costs estimated for the award. The Awardee's estimates **must** meet two sets of criteria that also serve as the basis of the NSF cost analysis:

- The cost principles associated with the award instrument used.
- The four GAO characteristics of a high-quality cost estimate, namely well-documented,

[1] Definition in Lexicon is adapted from AACE International Recommended Practice No 36R-08, Development of Cost Estimate Plans – As Applied in Engineering, Procurement, and Construction for the Process Industries, Rev. June 12, 2009.

comprehensive, accurate, and credible.

For financial assistance, the estimates **must** be allowable, allocable, and reasonable per the 2 CFR §200, Subpart E, and **must** be adequately supported in accordance with the standards set forth in the NSF Proposal and Award Policies and Procedures Guide.[1] NSF also considers cost realism important for all estimates. To meet the four characteristics of a high-quality estimate, proposers should develop them following the 12 steps of the *GAO Cost Estimating and Assessment Guide*, as appropriate (see Section 4.3.2 Characteristics of a High-Quality Cost Estimate).

As described in Chapter 2 NSF Life Cycle Oversight, Awardees will be expected to develop acceptable cost estimates for the design, construction, operation, and disposition of RI. It is understood that cost estimates will undergo progressive elaboration at each stage-gate review, and the materials required herein will evolve accordingly. NSF will review estimates at an appropriate level as the RI progresses through the various life cycle stages.

Figure 4.3.1-1 depicts the general NSF cost analysis process performed for construction and operations awards. The NSF PO, AO, Research Infrastructure Office (RIO) Liaison, and Cost Analyst from NSF's Cost Analysis and Pre-Award Branch conduct a detailed analysis of the Awardee cost estimate. NSF may also utilize Independent Cost Estimates (ICE) and cost estimate reviews done by external panels and independent contractors or agencies to inform the analysis. The AO and Cost Analyst review includes detailed sub-elements, NSF budget categories, and supporting Basis-of-Estimate (BOE).[2] The PO review includes the technical scope, risks, planned resources, schedule, and assumptions. The RIO Liaison supports the analysis of any risks and proposed contingency budget as well as compliance with the *RIG* and *GAO Cost Estimating and Assessment Guide*. The inputs from the various sources are integrated and addressed with the Awardee, potentially resulting in a revised cost estimate or additional documentation. The PO ultimately recommends the budget, funding profile, and internal and external sources of funds based on the project's technical scope and the funds' availability. The AO approves the Awardees' cost estimate, and ultimately, the proposal and approved budget are awarded based on the cost analysis results.

For construction awards, the NSF cost analysis is done at the end of each Design Stage phase, in conjunction with the Conceptual Design Review (CDR), Preliminary Design Review (PDR), and Final Design Review (FDR) to support stage-gate reviews. For operations awards, the NSF cost analysis is done on operations and management proposals for initial operations, renewal, and competition of awards. NSF may also perform cost analyses at other times, as necessary, based on a risk-based assessment. For example, cost analyses may be needed

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[1] Allowable costs are defined by federal guidelines and relevant cost principles. Allocable costs must be logically related to the particular award. Reasonable costs are what a prudent individual would pay in a competitive marketplace (i.e., costs are not too high). Cost realism defines whether the costs are realistic for the work to be performed, reflect a clear understanding of the requirements, and are consistent with the methods of performance and materials described in the Awardee's technical proposal (i.e., costs are not too low).

[2] See Sections 1.3.1.1 Financial Assistance Awards – Grants and Cooperative Agreements and 5.6 NSF Budget Categories from the Proposal and Award Policies and Procedures Guide.

during construction or operations to support significant scope, schedule, cost, risk, or complexity changes. These latter types of analysis may only require a review of targeted subsets of information for specific changes. NSF typically requires 90 to 180 calendar days to complete a full review and detailed cost analysis of a proposal budget before proceeding to the next design phase or before award for operations or construction. This time will vary depending on project scope, cost, risk, complexity, and relative importance. It will also depend upon whether revisions to the estimate due to errors or cost re-categorizations, for example, are needed.

If the information provided is incorrect, the PO, AO, RIO Liaison, Cost Analysts, and/or external or independent reviewers may require additional documentation, justification, and further interaction with the Awardee before completing the analysis. Communication among all parties and a sound initial BOE are essential for timely and successful completion.

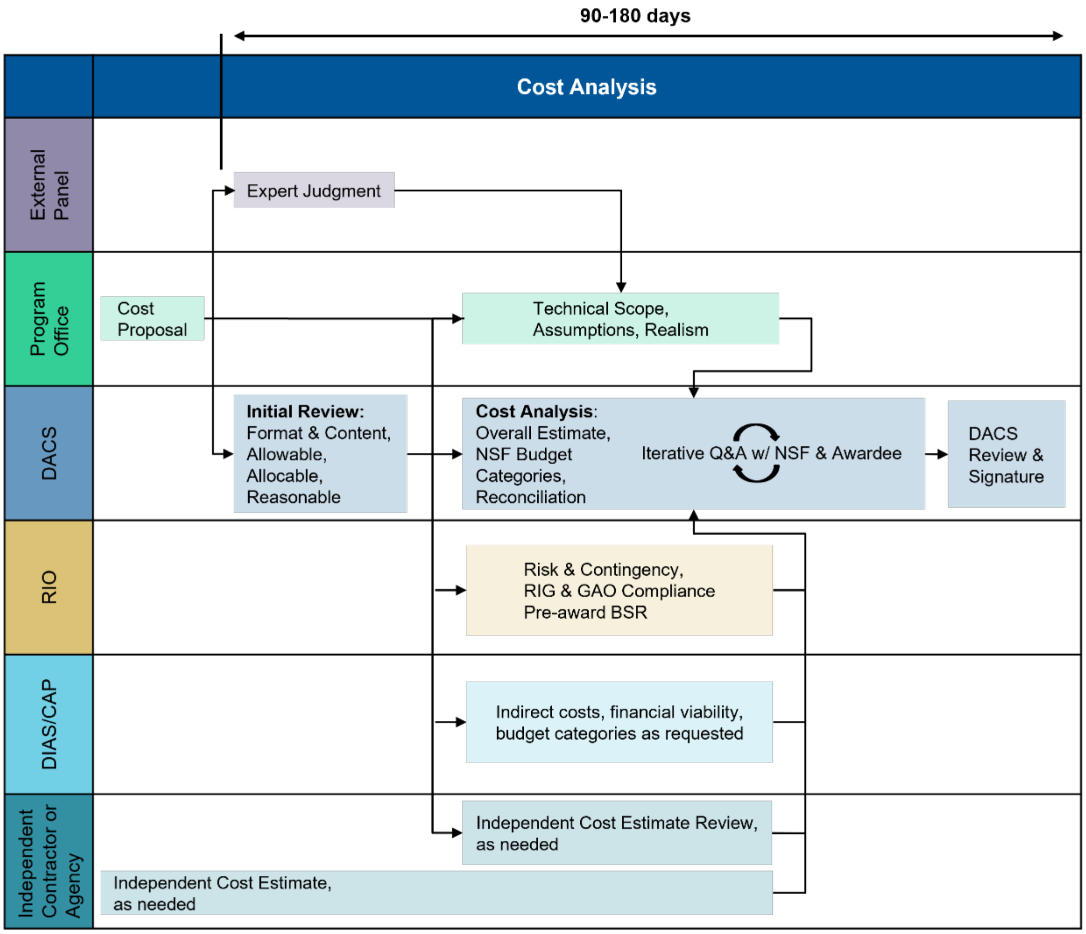
When submitting estimates for cost analysis, Awardees **must** submit the following, tailored and scaled to the project or program, as a minimum:

- A CEP per Section 4.3.3.3 Cost Estimating Plan.
- A WBS, as described in Section 4.2 Scope and Work Breakdown Structure.
- Cost Book, BOE, and supporting information.

For proposals that contain subawards, each subaward **must** include a separate budget justification.[1]

[1] See Chapter 8 Lexicon for the difference between a *subaward*, which transfers significant effort from the Awardee to another entity, and a *contract*, which involves the purchase of materials and supplies, equipment or general support services allowable under the award.

Figure 4.3.1-1
NSF Cost Analysis Process



4.3.2 Characteristics of a High-Quality Cost Estimate

The *GAO Cost Estimating and Assessment Guide* identifies four characteristics of a high-quality estimate – comprehensive, well-documented, accurate, and credible. Each of the 12 steps in the GAO cost-estimating process aligns with one of these four characteristics. Refer to the *GAO Cost Estimating and Assessment Guide* for details on each step, best practices, and mapping best practices to the characteristics.[1] NSF and independent reviewers use these GAO criteria, and other methods when analyzing Awardee cost estimates to determine whether to make an award. The application of the *GAO Schedule Assessment Guide* is discussed further in Section 4.4 Schedule Development, Estimating, and Analysis.

[1] See 2020 *GAO Cost Estimating and Assessment Guide* Chapter 16 (GAO-20-195G); Table 25 from the 2009 version (GAO-09-3SP) also provides a concise mapping.

4.3.2.1 Comprehensive

The cost estimate **must** completely define the infrastructure by WBS and reflect the current schedule and technical baseline. It is structured with sufficient detail to ensure that cost elements are neither omitted nor double-counted. Where information is limited and judgments should be made, assumptions and exclusions on which the estimate is based are reasonable, clearly identified, explained, and documented.

4.3.2.2 Well-Documented

Thorough documentation explicitly identifies the estimating methods, sources of the data, calculations, results, assumptions, and sources of the data used to generate each element's cost. The cost estimate **must** be well-structured, easily understood, and the data traceable.

4.3.2.3 Accurate

The cost estimate **must** be developed by estimating each cost element using the best methodology from the collected data, with appropriate escalation adjustments. Their underlying mathematical formulas, databases, and inputs are validated, and the resulting estimates contain few minor mathematical mistakes. Accurate estimates are based on a historical record of cost estimating and actual experiences from comparable programs. Finally, they are updated regularly to reflect significant changes in the program. Any variances between estimated and actual costs are documented, explained, and reviewed.

4.3.2.4 Credible

The cost estimate **must** discuss and document any analysis limitations, including uncertainty or bias surrounding source data and assumptions. The estimate's major assumptions are varied to determine how sensitive it is to changes. Credible cost estimates include an analysis of risk and uncertainty. In addition, high-value cost elements are often cross-checked with alternative estimating methodologies to validate results. Finally, the estimate can be compared with an ICE conducted by a group outside the acquiring organization.

4.3.3 Developing and Estimating Baseline Costs

4.3.3.1 Steps to Develop and Estimate Baseline Costs

Each of the GAO twelve steps are highlighted below to help show how they can be applied or tailored to RI, including potential deviations, and how they should be integrated with NSF processes.

Step 1 – Define the Estimate's Purpose

- The purpose should be clearly defined. There are typically two general purposes:
    - To help managers evaluate affordability and performance against plans and select alternative systems and solutions, including value engineering and scope management.
    - To support the budget and award processes by estimating the required funding.

- Defining the purpose helps clarify the intended use and package the estimate to facilitate review by various audiences, including managers and independent reviewers. Reviewers not familiar with the facility will need a standalone document with both the appropriate high-level perspective and the detailed CEP, BOE, and linkages via WBS so that someone unfamiliar with the program can understand and be able to determine if it meets the GAO's 12 steps and four characteristics of a high-quality cost estimate.
- Defining the purpose also helps determine its scope and level of detail, identify appropriate performance measures for benchmarking progress, address the benefits it intends to deliver, and link the estimate to NSF's mission, goals, and ideas.

Step 2 – Develop a Cost Estimating Plan

- A CEP **must** be developed and address the details described in Section 4.3.3.3 Cost Estimating Plan.

Step 3 – Define Program Characteristics

- Characteristics of the program being estimated should be defined for proposed design projects per Section 3.4.1 Design Execution Plan, for construction projects per the PEP in Section 3.5 Construction Stage and Implementation Planning and for operations awards per the Proposal and Work Plan in Sections 2.7 Major Facility Operations Stage and 3.6 Operations Stage Planning.

Step 4 – Determine Estimating Structure

- All estimates **must** be organized by the WBS described in Section 4.2 Scope and Work Breakdown Structure. Financial assistance awards **must** also organize the data by NSF budget categories, as described further in Section 1.3.1.1 Financial Assistance Awards – Grants and Cooperative Agreements.
- The estimate structure **must** have clear traceability between WBS, CEP, and BOE, correctly roll up to higher levels, and readily map between the WBS and NSF Budget Categories.
- The estimate is built up from the individual WBS elements and sub-elements. If the costs associated with each WBS element are binned into the appropriate NSF Budget Categories, data can be easily sorted and organized for different purposes. For example, costs can be coded with NSF budget format letters (Letters A–I per Table 1.3.1.1-1) to populate rolled-up NSF budget format summaries and the Cost Book organized by WBS.

Step 5 – Identify Ground Rules and Assumptions (GR&A)

- The ground rules (a common set of agreed estimating standards that provide guidance and minimize conflicts in definitions) and assumptions (a set of judgments about past, present, or future conditions) should be clearly defined and documented in the CEP, as described in Section 4.3.3.3 Cost Estimating Plan.
- The GR&A should be developed by estimators with input from experienced program and technical personnel, based on information in the technical baseline and WBS

Dictionary, vetted and approved by upper management, documented to include the rationale behind the assumptions, and backed up by historical data.

- GR&A may be global, which applies to the entire estimate and should be clearly and consistently used throughout. GR&A may also be program-specific or WBS element-specific, driven by the particular technical requirements.
- The potential impacts of changing GR&A should be considered when developing the sensitivity and risk analysis.
- GR&A often include schedule or budget constraints, acquisition strategy, participation of other agencies or governments, level of technology maturity, and required research and development (R&D). GR&A also often define what is included and excluded from the estimate, such as use of existing or multi-purpose equipment and facilities.
- Assumptions for escalation should be clearly defined. Awardees are not limited to using only broad and publicly available economic assumptions for cost estimates. NSF encourages organizations to use escalation information appropriate for known situations or a particular industry as long as they can be justified. For example, specialized data from the Department of Energy, Department of Defense, Bureau of Labor Statistics, industry metrics, and/or historical experience with similar items may be available. Escalation for raw materials and equipment in technological projects often runs higher than broad measures of inflation (e.g., the consumer price index) due to inelasticity in pricing (i.e., there are few or no substitutes available in the marketplace, and demand remains constant). The justification for all escalation assumptions and inflation factors (including the use of standard Office of Management and Budget [OMB] inflation factors) should be included in the CEP and used consistently throughout the BOE.

Step 6 – Obtain Data

- The estimating methods, level of detail, accuracy range, and availability of historical and current cost data will evolve and improve through the design phases and Construction and Operations Stages. Current data should be routinely collected, documented, and included in estimates.
- Data should be collected from multiple sources, normalized, and assessed for convergence and sensitivity. Cost drivers, trends, and outliers should be explored and carefully analyzed for reliability and relevance. Primary data sources, obtained from the original source and usually traceable to an audited document, should be used when possible. Backup data should be collected and used to help identify cost drivers and cross-check results.
- Awardees should carefully consider data sources and their applicability, potential limitations, allowances, risks, and uncertainty. This is especially true for NSF Major Facilities, where estimates often include research and development, prototypes, university work, software and cyberinfrastructure (CI), and unique, complex, new, and/or evolving technologies.
- The most appropriate estimating method should be chosen for each WBS element. The

following cost-estimating methodologies should be used, in order of preference, if the data exists:

  - Actual/historical data for the systems or operations being estimated.
  - Detailed engineering build-up.
  - Parametric data with adjustments to reflect differences (e.g., technical, size, weight, quantity, location, schedule).
  - Analogous data with adjustments to reflect differences.
  - Expert opinion, only if a secondary methodology is used to substantiate.
- Data sources, content, time, units, calculations, results, explanations for choosing a particular estimating method or reference, and circumstances affecting the data should be clearly documented in the CEP and Cost Book BOE.

Step 7 – Develop a Point Estimate and Compare it to an Independent Cost Estimate

- Awardees are encouraged to obtain an ICE and cost estimate reviews to help validate and improve the quality of the estimate before submitting proposals to NSF. Awardees should address this as part of the CEP, as described in Section 4.3.3.3 Cost Estimating Plan. Operations proposals do not typically warrant an ICE since analogous historical costs are readily available, or the BOE will typically not have the breadth and depth of technical and cost detail expected for a construction award.
- As noted in Section 4.3.1 Introduction to Cost Estimating and Analysis Process, NSF utilizes ICE and ICE Reviews from external panels and independent contractors or agencies. An ICE is required before construction awards. An ICE Review of some type is required of operations proposals before initial operations, renewal, and competition of awards. These ICE and ICE Reviews are used to validate the Awardee estimates, negotiate awards, check for compliance with GAO best practices and Uniform Guidance Cost Principles, and inform the NSF cost analysis. Far before reviews, the NSF PO, AO, RIO Liaison, and Cost Analyst determine the type, timing, scope, and team required. Awardees should be prepared to support these efforts, including consolidating all technical information, responding to questions, participating in reconciling proposals with ICE, and addressing any findings.

Step 8 – Conduct Sensitivity Analysis

- Done to test the sensitivity of cost elements to changes in estimating input values and key assumptions so that key cost drivers and the range of potential costs can be identified and highlighted for Awardee management and NSF, and a strategy can be developed to deal with them. Sensitive elements are those where small changes in variables can create the greatest changes in cost.
- Can be done rigorously and quantitatively by examining the effect of changing one assumption, ground rule, or cost driver at a time while holding all other variables constant to understand which variable most affects the cost estimate. The changes should not be arbitrary or subjective (e.g., +/-%) but rather determined by subject matter experts (SME) based on available data.

- Sensitivity analysis tries to isolate the effects of changing one variable at a time, while risk or uncertainty analysis examines the effects of many variables changing simultaneously. Therefore, the sensitivity analysis results can be used to help identify and quantify risks, which are then used in a probabilistic risk assessment to develop the contingency budget and confidence level.
- The sensitivity analysis results can also inform decisions when analyzing design, acquisition, construction, operations, and maintenance alternatives. Analyses can also drive actions to avoid, mitigate, transfer, or accept risk.
- For operations estimates that may consist largely of LOE work, a more qualitative sensitivity review could be performed, and justification could be provided that there are no particularly sensitive elements and, therefore, little or no potential impact.
- The major contributing variables within the highest percentage cost elements are the key cost drivers that should be considered in the analysis. They may be GR&A, especially those least understood or most at risk of changing. For NSF RI, sensitive elements may include electricity, fuel, major commodities, escalation specific to certain cost elements, requirement changes, location, domestic versus foreign sources/procurements, and acquisition strategy.

Step 9 – Conduct Risk and Uncertainty Analysis

- If a contingency is requested, risk management, Risk Register data, BOE, assumptions, and the detailed methodology used to calculate contingency budgets **must** be documented and provided (see Section 4.6 Risk Management).
- These analyses are not typically required for operations awards unless a separate contingency budget is requested for facility or instrumentation upgrades or replacement projects (see Section 4.2 Scope and Work Breakdown Structure). However, a summary of key operational risks and uncertainties, their potential cost impacts, and mitigation strategies may be beneficial to articulate as part of the proposal. These could also be handled as part of the sensitivity analysis described in Step 8 – Conduct Sensitivity Analysis.

Step 10 – Document the Estimate

- Described in Section 4.3.3.2 Estimate Documentation.

Step 11 – Present the Estimate to Management for Approval

- Described in Chapters 2 NSF Life Cycle Oversight and 3 Research Infrastructure Life Cycle Planning.

Step 12 – Update the Estimate to Reflect Actual Costs and Changes

- Described in this section and in the guidance on generating the Estimate to Complete (ETC) and Estimate at Completion (EAC) in Sections 4.4.4.2 Progress Schedule, 4.5.4 Earned Value Management, and 4.7.3.3 Contingency Management Forecasting. Typically, updating the estimate to reflect actual costs and changes is not required for operations awards, though work plans and budgets may be adjusted annually to reflect actual work done and updates to planned work.

4.3.3.2 Estimate Documentation

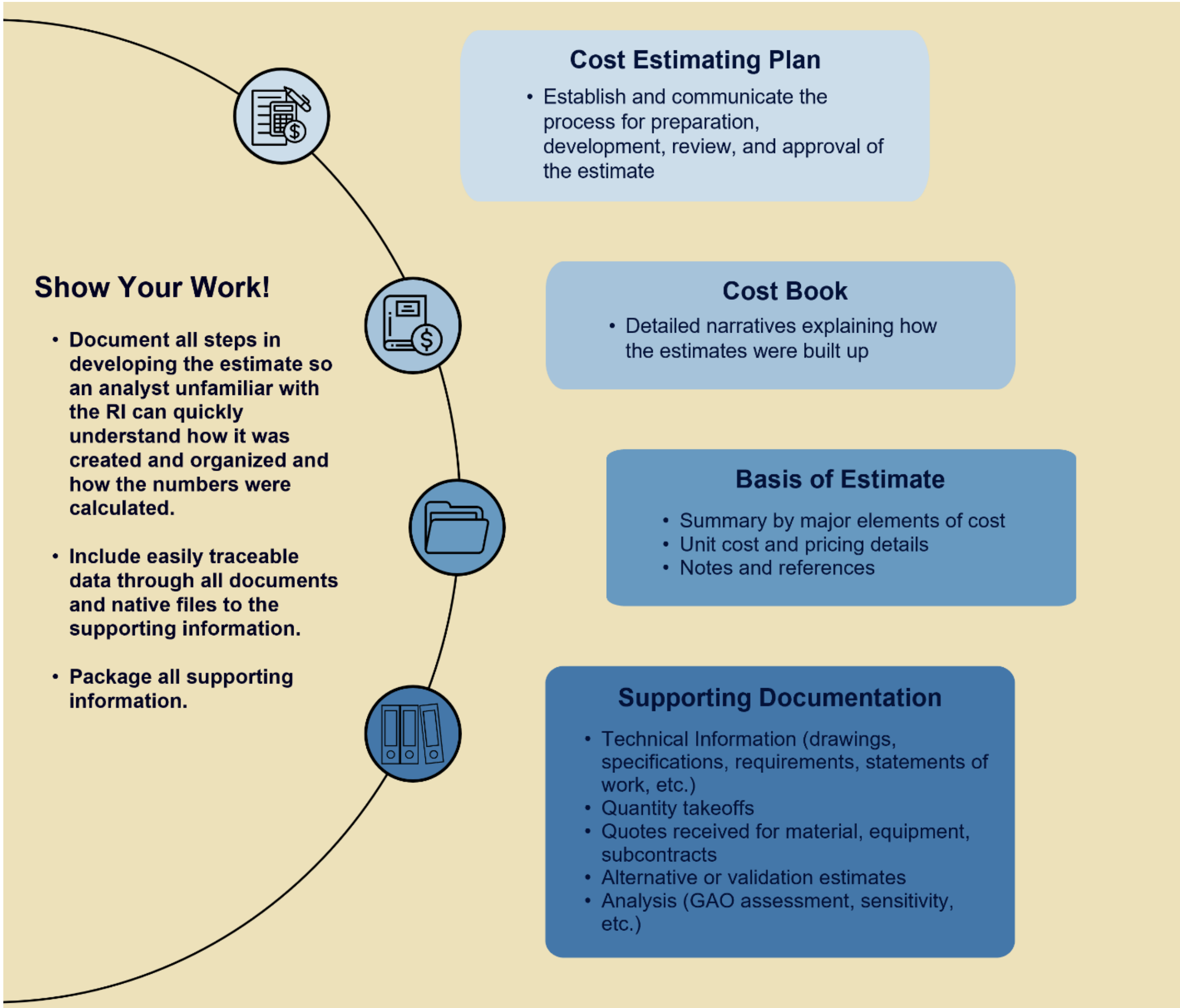
> **Key Takeaway**
>
> The four components of a carefully planned and justified estimate include:
>
> - CEP
> - Cost Book
> - BOE
> - Supporting documentation

This guidance supplements, not duplicates, the *GAO Cost Estimating and Assessment Guide* and industry good practices and standards. The four components of a carefully planned and justified cost estimate include a CEP, a Cost Book, a BOE and supporting documentation.

The CEP serves as a detailed framework that outlines and describes the major estimating steps, methods, and assumptions. It should be generated early in the estimating process to help ensure the estimate will meet NSF expectations and to avoid rework. This plan is crucial for setting the foundation of the cost estimate and ensuring that all necessary elements are considered and properly documented.

The Cost Book is the mathematical tabulation of cost data across all WBS elements and, for financial assistance awards, NSF budget categories, providing a comprehensive view of the estimated costs. Complementing the Cost Book, the BOE is the narrative explanation detailing how and why the Awardee determined the proposed Cost Book numbers. It provides context and justification for the figures presented, ensuring that the estimates are grounded in well-documented assumptions and methods. Supporting documentation includes all evidence required to justify the numbers and narratives, ensuring transparency and credibility in the estimating process. This comprehensive approach ensures that the cost estimate is not only accurate but also defensible and aligned with NSF standards.

Figure 4.3.3.2-1
Components of a High-Quality Estimate



4.3.3.3 Cost Estimating Plan

In accordance with the funding announcement and the terms and conditions of the award, Awardees **must** develop and submit a CEP for new construction and operations awards to establish and communicate how the estimate's preparation, development, review, and approval will be or was completed. The Awardee should consult with the PO regarding the CEP for existing awards. Ideally, the CEP will be developed and discussed with NSF far before submission (e.g., one year for Major Facility awards) to ensure that the Awardee's plans are aligned with NSF expectations and requirements outlined herein and sufficient time is available to collect and package data. The CEP is the cornerstone of the estimate, and it, the BOE, and supporting documentation are critically important for generating a high-quality estimate to facilitate management decisions and NSF cost analysis. Awardees may contact their NSF PO, AO, RIO Liaison, and/or Cost Analyst for more information or guidance.

The CEP **must** state the purpose(s) of the estimate and describe how the guidance will be or has been implemented. Awardees **must** note any departures from these NSF and GAO Guides and explain their rationale in the CEP. The CEP should also include the following, at minimum, to help ensure the estimate is well-documented:

- Outline the schedule of specific tasks, due dates, roles and responsibilities, practices, systems, and calculations used to develop the cost estimate.
- Describe the expected cost estimating methodology, maturity, and, if applicable, accuracy range at each stage or phase (e.g., expert opinion, analogy, parametric, engineering build-up, actual data).[1]
- Explain any ground rules, assumptions, and exclusions that apply broadly to the estimate (e.g., assumed work hours and days).
- Quantify explicitly any applied burdens, including the labor, escalation, indirect, and fringe cost rates that are used and explain why they are appropriate.
- Document where and how allowances are used and highlight any other sensitive or significant factors or considerations, including their rationale and any references.
- Discuss the ICE and reviews they are planning to validate the project estimate.
- Provide a detailed narrative explanation of how the estimate was built up and how to navigate through the files provided, from the supporting documentation through the BOE and Cost Book and any roll-ups into higher level documents (e.g., PEP). Assume the reader has no prior knowledge of the RI, organization, software used, etc. and explain in a way that is easily understood.
- Address specifically how the estimate will be well-documented through either:
  - Confirming the estimate will allow for mathematical checks of the proposal budget calculations and should contain actual formulas that allow manipulations to check calculations (i.e., the model should not display just the results of the application of formulas or be locked such that calculations cannot be verified in real-time), or
  - Providing a narrative explaining in detail how the cost estimating software performs calculations, including sample formulas for different elements of cost (e.g., labor, non-labor, travel), and provide examples tracing through documentation.

The CEP should be tailored to the stage of the RI life cycle and address the most relevant costs at that point in the life cycle stage. The CEP should explain how the cost estimate may evolve over time. For example, the CDR should initially identify the expected level of funding needed for the Operations Stage. Operating cost estimates should be refined and updated throughout the design and construction process, as further discussed in the Concept of Operations (ConOps) Plan, developed as part of the PEP described in Section 3.5 Construction Stage and Implementation Planning. The CEP presented in an operations

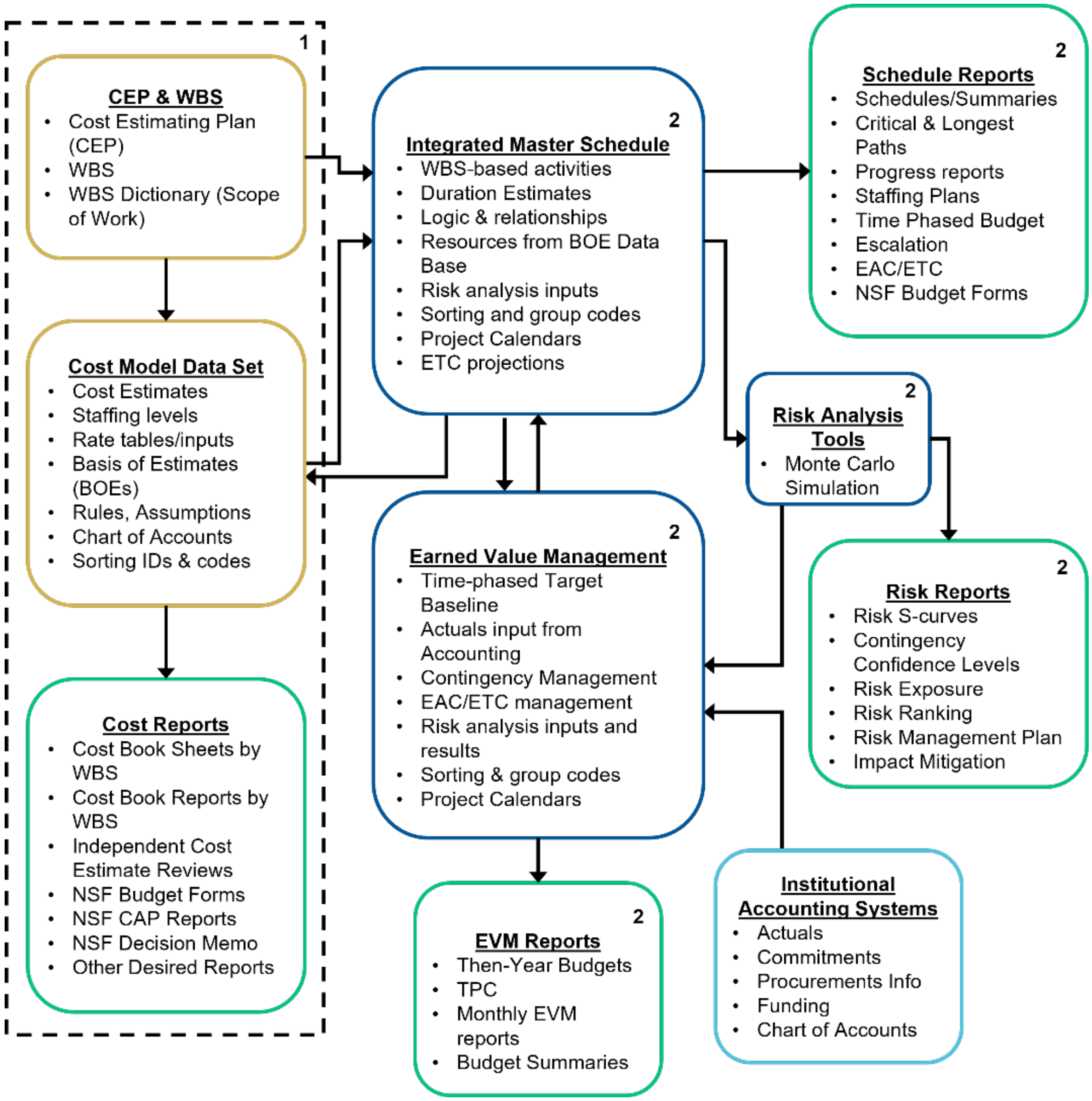
[1] For example, via classification levels in AACE International Recommended Practice No.18R-97, Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries, Rev. November 29, 2011

proposal, whether submitted by the Awardee of the construction award or by a separate entity, should be informed by appropriate excerpts from the ConOps Plan developed in the PEP or successor documents.

A Cost Model Data Set is the cost data used as input to software tools and/or project reports to organize, correlate, and calculate different management information. The CEP should explain how the Cost Model Data Set will meet the various needs of the RI. Figure 4.3.3.3-1 provides an example of how a Cost Model Data Set, WBS, and an Awardee's institutional accounting systems can be used as inputs in conjunction with scheduling, earned value, and risk analysis tools to generate various output reports for project purposes. The CEP is included as part of the PEP as described in Section 3.5 Construction Stage and Implementation Planning.

Figure 4.3.3.3-1

Sample Project Control Systems Relationship Diagram



Key

1. For construction and operations
2. For construction and Major Facility Upgrades funded through operations based on the technical nature of the proposed activity

4.3.3.4 Uncertainty, Accuracy, and Allowances

Definitions for uncertainty, contingency, allowance, as well as the application of accuracy, and precision requirements, can vary widely throughout industry and federal agencies, and some of the terms are often used interchangeably. The complete definitions applied to NSF RI are contained in Chapter 8 Lexicon, and brief explanations are provided in the text below.

Uncertainty. Uncertainty is the inherent variability in predicting the outcome of future events. Accuracy is a measure of correctness and specification closer to the true value. An accurate cost estimate predicts the final actual cost with little error. Precision is a measure of exactness and specification to more digits. A precise cost estimate is expressed to the nearest cent or dollar, whether it accurately predicts the true cost or not.

All cost *estimates* have *uncertainty,* as they are an *approximate forecast* of the most likely cost of future work based on information available at the time.[1] The *precise* costs will be *unknown* until the *actual* costs are realized.[2] The degree of uncertainty decreases for projects as the Project Definition matures, technical details are better defined, and engineering build-up estimates, and vendor quotes replace earlier rough estimates. This is often referred to as a cone of uncertainty, and correlations are available for the expected level of Project Definition and associated accuracy range at different design phases.[3]

Key Takeaway

Accurate and *credible* are characteristics of a high-quality cost estimate, not *precise*.

Accuracy Over Precision for Credibility. In cost estimating, accuracy holds greater importance than precision. It is preferable to be approximately correct rather than precisely incorrect. Excessive precision can undermine credibility, as it suggests a misleading level of certainty and exactness regarding costs and activities projected years into the future.

Credibility requires acknowledging the inherent limitations of future predictions, analyzing the uncertainty, risk, and sensitivity of data, and performing cross-checks and independent estimates using different methods to produce similar results. Considering all these factors helps to validate that the estimate is reasonable and realistic (neither too high nor too low), and believable.

Example:

Overly Precise: $1,239,876,543.21

Accurate and Credible: $1.25B, including a contingency budget at 90% confidence.

Below is a list of industry-trusted resources supporting the model that accuracy is more important than precision when estimating costs.

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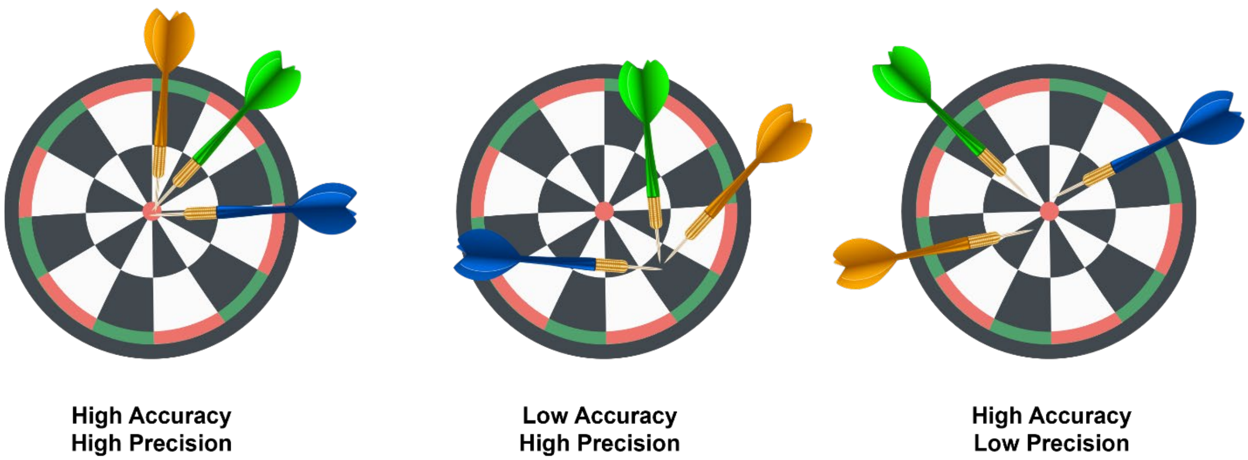
[1] Examples of uncertainty include inexactness and changes in quantities or durations, fluctuating prices, faulty assumptions, undefined details, requirement changes, economic factors, supply chain volatility, human error, bias, differences in individuals and organizations.

[2] Per *GAO Cost Estimating and Assessment Guide*, GAO-20-195G, March 2020: "uncertainty cannot be defined because of ambiguity… uncertainty is always present" and "because risks and uncertainty occur, there is always a chance that the actual cost will differ from the estimate. Thus, cost estimates are forecasts based on the best information available at the time." Per the *GAO Cost Estimating and Assessment Guide*, GAO-09-3SP, March 2009: "cost estimating is difficult. It requires both science and judgment. And, since answers are seldom if ever precise, the goal is to find a "reasonable" answer."

[3] For example, see Association for the Advancement of Cost Engineering International (AACEI) Recommended Practice (RP) 18R-97, Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries, August 7, 2020, which the Department of Energy correlates to their critical decision stage gates in DOE Cost Estimating Guide, DOE G 413.3-21A, June 6, 2018. Department of Energy's Critical Decisions 1, 2, and 3 are akin to NSF's Conceptual, Preliminary, and Final Design Reviews.

- Per *GAO Cost Estimating and Assessment Guide*, 2020:
  - "More detail, though, does not necessarily provide greater accuracy. Pursuing too much detail too early may be detrimental to an estimate's quality."
  - "Uncertainty cannot be avoided... Credible cost estimates clearly identify limitations resulting from uncertainty..."
- Per AACEI Recommended Practice 104R-19, Communicating Expected Estimate Accuracy, February 22, 2021: "every estimate presented as a single value of cost or duration will likely deviate from the final outcome (i.e., statistical error). In simple terms, this means that every base estimate value will likely prove to be wrong... a point value for an estimate... is in actuality just one point on a probability distribution curve that represents the range of potential cost outcomes."

Figure 4.3.3.4-1
Accuracy versus Precision



Allowances. Risks are differentiated from uncertainty as discrete events that have the potential to occur. The potential costs of risk and uncertainty can be accounted for in different ways, depending on the RI stage, complexity, and size. Specifically identified uncertainties can be included in the BOE for base costs. Broad, macro-level uncertainties can be included in the calculation of risk exposure and can also be covered with budget contingency, as discussed in Sections 4.6.2 Step 2 – Identify and Document Risks, 4.6.6 Step 6 – Assess Total Risk Exposure, and 4.7 Contingency Estimating And Management.[1]

Allowances are one way to estimate and account for uncertainty. A cost estimate allowance is an amount of money permitted for anticipated but as-of-yet undefined details or requirements. Allowances are a part of the most likely base costs and are included in the BOE. Allowances are often estimated from statistical correlations, discipline rule-of-thumb practices, predictive indices, or professional experience with past actual costs. Some

[1] RI that includes uncertainty in the budget contingency calculation must also explicitly include uncertainty in the Risk Register for tracking purposes to allow the use of contingency when encountered.

examples of common cost-estimating allowances include:[1]

- Design Development, Material Take-offs, Undefined Scope – when there is a lack of complete RI definition, or it might not be cost-effective to quantify and cost every small item.
- Overbuy, Scrap, Waste, Damage – e.g., concrete, plywood sheets, floor tiles.
- Services – e.g., inspection, testing, training, shipping.
- Custom Engineered Equipment – e.g., for tightening tolerances and changing finishes.
- Repair, Replacement, Preventive Maintenance, and Technical Refresh – routinely needed for operating RI.
- Other factors – e.g., potential increases in fuel costs, escalation rates, operating days.

For NSF, if appropriate, allowances could include uncertainties associated with cost estimating (as part of the BOE) in lieu of a defined risk, where the cost impacts would be held in aggregate as part of the budget contingency.

4.3.4 Specific Guidance for Major Facility Construction Estimates

4.3.4.1 Purpose and Process

As discussed in Section 4.3.1 Introduction to Cost Estimating and Analysis Process, NSF utilizes internal staff, outside experts, and expert panels at CDR, PDR, FDR, and during the Construction Stage to ensure that proposed construction budgets meet expectations, incorporate relevant GAO cost and schedule guides best practices, and are allowable, allocable, reasonable, and realistic. The CEP, Cost Books, and BOE should be updated through progressive elaboration during each phase in preparation for the reviews described in Section 3.4 Design Stage Planning. NSF documents all the cost analysis work, technical reviews, audits, etc., for cost analysis as part of its oversight and assurance roles.

The construction PDR estimate, and subsequent NSF analysis and independent reviews, are expected to be sufficient to give NSF confidence in the estimated Total Project Cost (TPC) that advances for National Science Board (NSB) authorization and potential inclusion in a future budget request. The FDR estimate and subsequent analysis are expected to be sufficient to give NSF confidence in constructing and commissioning the facility within the TPC and in adherence to NSF's No Cost Overrun Policy (NCOP) per Sections 1.4.7 NSF No Cost Overrun Policy and 4.7 Contingency Estimating and Management.

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[1] Many examples and associated percentage of other costs can be found in AACEI Skills and Knowledge of Cost Engineering, 6th Edition, 2015.

4.3.4.2 Construction Cost Book and Basis of Estimate Overview

Construction Cost Books and BOE are necessary at the CDR, PDR, and FDR, at minimum, to provide a comprehensive, consolidated estimate of construction costs.

The CEP, Cost Book, and BOE provide assumptions, calculations, and detailed information to support the proposed budget. The following additional high-level information should be provided as an overview and Executive Summary (see Section 3.5.3.5 PEP Subcomponent 3.5 – Time-Phased Budget to assist with the review process described in Chapter 2 NSF Life Cycle Oversight). Awardees should consult with the PO and AO as necessary to identify any other specific cost reports and content required to support the review.

- Overall high-level cost summary charts, tables, profiles, and reports depicting total and annual costs in *then-year* dollars, reported by WBS and in NSF budget format.
- A comparison of the current TPC to past estimates and an explanation of any major changes, including impacts on scope or design.
- Explanation of how project costs by WBS map to the NSF budget format, including detailed traceability or crosswalk matrix, described further below.
- Other reports, as needed, e.g., costs by resource types (subcontract, labor, materials, travel), cost profiles (total, labor, non-labor, by WBS sub-element), personnel profiles (full-time-equivalents by WBS sub-element).

4.3.4.3 Construction Cost Book and Basis of Estimate Additional Details

This section discusses additional detailed information needed for a high-quality Awardee cost estimate and NSF cost analysis. This information supplements the standard GAO best practices and industry standards.[1] The guidance aims to improve project execution, clarify NSF expectations, assist Awardees, facilitate NSF review with fewer iterative resubmissions, and prevent recurrent issues. It is understood that this information will be refined further as the design stage advances.

Presentation and Linkages. Individual WBS element costs should have a sound, fully justified, documented, and sufficiently detailed BOE. Figure 4.3.4.3-1 provides an example of a construction Cost Book sheet depicting the format and content typically needed to consolidate the cost model dataset and provide appropriate detail and BOE. This sheet includes the following information:

- WBS and activity codes and descriptions, per the WBS Dictionary, to index the cost estimate to a specific deliverable.
- Statement of Work describing the scope.
- Estimator Name and Date of Estimate.

[1] Examples: AACEI Recommended Practice No. 18R-97, Cost Estimate Classification System – As Applied in Engineering, Procurement, and Constructions for the Process Industries, August 7, 2020; and AACEI Recommended Practice No. 34R-05, Basis of Estimate, October 5, 2021

- Resource Descriptions.
- Cost Basis Codes describing the estimating methodology (e.g., expert opinion, analogy, parametric, engineering build-up, historical data).
- Direct Costs with Units and Hours.
- Associated Fringe and Indirect Costs.
- The NSF Budget Category Code corresponds to the budget categories described in Section 5.6 NSF Budget Categories from the Proposal and Award Policies and Procedures Guide, which allows mapping between WBS sub-elements in the Construction Cost Book and NSF Budget Categories on NSF Budget Forms.
- BOE source data, with a breakout of sub-elements, typically include direct input from technical experts in that area with calculations using material and labor quantities and unit prices, with clear assumptions and sources referenced.
- Supporting information associated with the use of allowances, if any (see Section 4.3.3.4 Uncertainty, Accuracy, and Allowances).

Estimates **must** have clear traceability, including the following, as appropriate, for CDR, PDR, FDR, and Construction:

- The total estimated cost should correlate to current drawings, specifications, and schedules to the maximum extent practicable.
- Lower levels of the WBS **must** correctly roll up to the higher levels, and the application of rates and factors **must** be consistent with the CEP, BOE, supporting rate agreements, and Awardee accounting practices.

Cost estimates may be directly linked to scheduling tools to allow automatic cost updates with schedule changes.

BOE Refinement Process. Because of the hierarchical nature of the WBS, it is possible, over time, to refine the level of detail at which the project scope, schedule, and task-based costs are captured. Throughout the Design Stage, the task and cost fidelity will increase, and eventually, during the project's construction, the plans should be fully detailed. As the project moves through the phases, detailed engineering build-up estimates using current quotes and prices should be collected to reduce the proportion of estimated costs based on expert opinion, analogy, or parametric estimates. As the Project Team finalizes plans for the start of construction, the BOE should include more vendor catalogs and quoted or proposed contract prices.

Direct labor rates, quantities, and skills mix should be justified, including information from subawards.

Cost estimates should include adequate project management funding, including the use of appropriate project management tools such as project management control software and associated staff support.

The Major Facility Construction Cost Estimate may include commissioning (i.e., integration, testing, acceptance, and operational readiness), including funding for staff to perform these activities and train the operations personnel. Roles change as a project progresses from construction through commissioning and eventually to operations; time and staffing requirements need to be carefully calculated in advance, with a clear demarcation between the construction-funded scope and the operations scope, as discussed in PEP Subcomponent 7.5 – Business and Financial Controls Plans.

CI technical requirements and costs (both the initial and continuing costs of hardware, software, maintenance, upgrades, and operations) should be carefully considered and periodically validated. Rapid advances in computing may require upgrades as often as every three to five years.

The cost of evolving technologies should be considered during budget development and acquisition planning. For example, it may be appropriate to include higher allowances in the BOE or higher impacts as part of the budget contingency development and plan for procurement late in the Construction Stage.

Figure 4.3.4.3-1
Construction Cost Book Sheet Sample Format

Activity Summary							**Year**		
Institution: WBS: Activity:	Equipment, Travel, Participant Support Costs Detail	Funding Source: WBS Description: Activity Description:	Materials, Supplies, Publication, Consultants, Computer Services, Subawards, Other Cost Detail	Estimated By: Date:					
Personnel Costs Detail (A + B + C) + I	(D + E + F) + I		(G1 + G2 + G3 + G4 + G6) + I	Total Base					
$0.00	$0.00		$0.00	$0.00					
Personnel Costs Detail (A + B + C) + I									
Exp Code	NSF Code	Resource ID – Price Group	Resource Description	Cost Basis	Labor Hours	Direct Labor	Fringe	Indirect Cost	Total Burdened Labor Cost
Cost Basis: CP – Catalog Price	CR – Cost Relationship	EE – Engineering Estimate	HD – Historical Data	VQ – Vendor Quote	VE – Vendor Estimate				
Equipment, Travel, Participant Support Costs Detail (D + E + F) + I									
Exp Code	NSF Code	Resource ID – Price Group	Resource Description	Cost Basis	Material Units	Direct Material	Indirect Cost	Total Burdened Material Cost	
Cost Basis: CP – Catalog Price	CR – Cost Relationship	EE – Engineering Estimate	HD – Historical Data	VQ – Vendor Quote	VE – Vendor Estimate				
Materials/Supplies, Publication, Consultants, Computer Services, Subawards, Other Costs Detail (G1 + G2 + G3 + G4 + G5 + G6) + I									
Exp Code	NSF Code	Resource ID – Price Group	Resource Description	Cost Basis	Material Units	Direct Material	Indirect Cost	Total Burdened Material Cost	
Cost Basis: CP – Catalog Price	CR – Cost Relationship	EE – Engineering Estimate	HD – Historical Data	VQ – Vendor Quote	VE – Vendor Estimate				
Statement of Work									
This activity includes									
Basis of Estimate									

4.3.5 Specific Guidance for Major Facility Operations Estimates

4.3.5.1 Purpose and Process

In addition to the specialized scientific expertise required for operations, award solicitations can include expectations for estimating budgets, business systems, and operational and financial reports. These systems and reports help ensure that the science mission can be met cost-effectively (see Sections 2.7 Major Facility Operations Stage and 4.2 Scope and Work Breakdown Structure).

NSF utilizes internal staff, outside experts, and panel reviews to ensure cost estimates and budgets meet expectations, incorporates relevant *GAO Cost Guide* best practices, and are allowable, allocable, and reasonable. The NSF Cost Analysis document is used as an award decision tool that captures all the cost analysis work, technical reviews, audits, etc., for cost analysis as part of its oversight and assurance roles. It is incumbent on NSF to plan and budget for effective research and educational use of facilities and the costs of operating and maintaining the facility in the long term. It is incumbent upon the Awardee to ensure their operations proposal is well-documented, accurate, comprehensive, and credible.

Operating budgets should include, when appropriate, resources to provide a continuing program of advanced R&D that will enable a facility to evolve and best meet the research community's needs. Funding for these kinds of upgrades may also come from separate equipment and/or instrumentation programs within the Directorate or Division.

4.3.5.2 Operations Cost Book and Basis of Estimate Overview

In addition to the guidance for the Annual Work Plan (AWP) described in Sections 3.6 Operations Stage Planning and 2.7.2 Operations Stage Awards, the PO or via the operations and management award solicitation may request additional information. Awardees should consult with the PO, AO, or CO as necessary to identify any other specific cost reports and content required to support the review.

Periodic plans may include an Executive Summary, narrative overview, strategic and annual objectives correlated to NSF mission needs, and an annual operating budget focusing on any significant changes from previous plans. Plans may also include expected scope, milestones, outcomes and impacts, developments, challenges, and opportunities.

Explanation of how program costs within functional areas are coded or otherwise related to the NSF Budget Categories depicted in Section 1.3.1.1 Financial Assistance Awards – Grants and Cooperative Agreements.

Other reports, such as annual cost by resource types (subcontract, labor, materials, travel), cost profiles (total, labor, non-labor, by sub-element), and personnel profiles (full-time-equivalents by sub-element).

4.3.5.3 Operations Cost Book and Basis of Estimate Additional Detail

This section discusses additional detailed information typically needed for a high-quality Awardee estimate and NSF cost analysis for Operations Stage award proposals. This information is intended to supplement the standard GAO best practices. The guidance should improve execution, clarify NSF expectations, assist Awardees, facilitate NSF review with fewer iterative resubmissions, and prevent recurrent issues. For existing awards, the Awardee should consult with the PO.

Multiyear budgets should take escalation into account, using factors discussed in Section 4.3.3.1 Steps to Develop and Estimate Baseline Costs, specifically step five, and documenting assumptions in the CEP. The Awardee should articulate the assumptions made to modify the LOE or science support capabilities for expected efficiency gains or for other adjustments if used to offset escalation.

The program should also explain the following:

- Key assumptions, sensitivities, risks, uncertainties, or other elements driving estimated costs, scope, and schedule.
- The associated potential impacts to science.
- Plans on how to routinely reassess cost drivers and actual costs and adjust at least annually.
- When power costs are significant and volatile, a strategy for dealing with price fluctuation should be developed as part of operations planning. Other examples of items that may require separate consideration are expendables – such as cryogens, gases, and spare parts – and ancillary equipment such as refrigerators and IT equipment.
- Separate funding sources and revenue streams (e.g., visitor center fees) should be clearly delineated.
- Education and Public Outreach costs should be explicitly identified and explained.

If contingency is requested, it **must** comply with Section 4.7 Contingency Estimating and Management.

4.4 SCHEDULE DEVELOPMENT, ESTIMATING, AND ANALYSIS

Section Revision: TBD Early 2025
Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

4.4.1 Introduction

A schedule is a management tool used for planning and executing work during any stage of an RI's life cycle. Schedules address both how and when the work is to be performed by identifying the activities needed to accomplish the scope of work and by time-phasing these activities with durations and schedule logic. Time-phasing involves identifying the key relationships between activities to determine the necessary sequence to accomplish the work.

A project schedule, also referred to as a schedule model, identifies the necessary activities with interdependencies along a timeline to complete a specific deliverable or defined scope of work with a beginning and an end. Project schedules are typically used to manage work during the Design and Construction Stages or implementation of an RI's life cycle. While NSF does not have a schedule overrun policy similar to the NCOP, a reliable schedule is critical for the Construction Stage or implementation. Schedules used for the Operations Stage of a facility's life cycle are generally performance goals defined as events or milestones on a timeline and may or may not have activities with identified interdependencies. An operation's Science Support Program may use separate schedules to manage upgrades or renewal projects.

The *GAO Schedule Assessment Guide* is intended to improve project schedules and identifies ten best practices associated with creating and maintaining reliable Critical Path Method (CPM) schedules.[1] Refer to the *GAO Schedule Assessment Guide* for a discussion of concepts associated with CPM and the specifics of each best practice. Awardees are required to utilize the *GAO Schedule Assessment Guide* in the development of Construction Stage schedules for Major Facility projects, regardless of the award instrument employed. Awardees should also tailor and scale the *GAO Schedule Assessment Guide* when developing schedules to manage design activities or for Mid-scale RI implementation, per Section 2.9 Mid-Scale Research Infrastructure Guidance. The GAO scheduling best practices have limited application to the schedules typically used for operations, such as bar charts or milestone charts, and are not required guidance for Operations Stage schedules.

The guidance in this section applies to the development of construction schedules for Major Facilities and Mid-scale RI projects and provides NSF expectations associated with the GAO scheduling best practices, considering NSF's policies and practices. This guidance also explains NSF's schedule analysis practices aligned with the Design stage-gate reviews discussed in Section 2.5 Major Facility Design Stage and the format and supporting justification for Awardee schedules. By following this guidance, Awardees can expect to

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[1] U.S. *GAO Schedule Assessment Guide*: Best Practices for Project Schedules (GAO-16-89G December 2015, or subsequent revision)

develop a high-quality and reliable schedule, enabling an efficient review by NSF.

Development of a construction schedule starts during the Conceptual Design Phase, evolves during the Design Stage, and is expected to be ready to support construction by the end of the Final Design Phase. For a Major Facility project, an activity-based Resource-Loaded Schedule (RLS) with network logic is required for advancement to the Construction Stage. This RLS provides the basis for the Performance Measurement Baseline (PMB) to be used to monitor the project performance and forecast future milestones during the Construction Stage (see Section 3.5.3.4 PEP Subcomponent 3.4 – Integrated Master Schedule). The RLS is also used to develop the time-phased construction budget plan during the Design Stage.

A high-quality and reliable schedule that is effectively controlled is a key element to successful project execution. A project's RLS is the foundation that integrates scope, schedule, and budget. Therefore, it is used to establish the budget and schedule contingencies, to develop the time-phased funding needs, and to measure and forecast performance. At the PDR, NSF requires a funding profile by fiscal year (FY) that includes the commitment and obligation of funds, plus anticipated contingency needs. The profile should be developed using the Construction Stage RLS and the quantitative assessment of risks and estimating uncertainties (see Section 4.6 Risk Management). Following the FDR, the RLS establishes the PMB and, when combined with schedule contingency and additional time for administrative purposes (generally six months), informs the award duration authorized by NSF.

Developing a high-quality and reliable schedule requires the knowledge and experience of both the activity owners and the project scheduler(s). Activity owners are responsible for managing the work, and the most experienced team members performing the work should be responsible for estimating the resources and identifying the interdependencies of the activities to execute the work. The complexity of a schedule typically drives the experience level of the person(s) developing and maintaining the schedule and selecting a scheduling software tool. A Construction Stage schedule for a Major Facility project usually requires a scheduler to be properly trained and experienced in CPM scheduling and the scheduling tool. Different scheduling software packages have different select features that require someone experienced with that software tool to ensure a reliable schedule. Various scheduling software packages use different terms to define a component of work performed during the course of a project – activity and task. The use of the term *activity* in this guidance is interchangeable with the term *task*.

4.4.2 Characteristics of a Reliable Schedule

The *GAO Schedule Assessment Guide* identifies four high-quality, reliable schedule characteristics: comprehensive, well-constructed, credible, and controlled. Each of the GAO ten Scheduling Best Practices (see Section 4.4.3.1 Ten Steps to Develop Baseline Schedule) aligns with one of these four characteristics. Various other industry scheduling good practices can also generally align with one or more of these characteristics. Refer to the *GAO Schedule Assessment Guide* for details on each of the best practices and the mapping of best practices to the characteristics.

As discussed in Section 1.3.1 Award Instruments, NSF does not directly construct or operate the facilities it supports. NSF's responsibility is to oversee the Awardee's performance. The Construction Stage schedules are developed and managed by the Awardee and do not include government activities. The discussion below provides NSF expectations associated with the GAO Scheduling Best Practices grouped by characteristic for Awardee-developed construction schedules.

4.4.2.1 Comprehensive

The schedule **must** include all the activities to complete the full scope of the project to be funded by an NSF construction award, if authorized, including all subaward and subcontract efforts. The schedule **must** be clearly aligned with the WBS. Section 4.2 Scope and Work Breakdown Structure provides guidance and examples for developing the WBS elements. The schedule shall be resource-loaded with all the labor, materials, equipment, and travel assigned to detailed activities and planning package activities. Detailed activities should be developed to allow discrete progress measurement. A planning package activity contains a defined scope of work, typically under the responsibility of one organization, without detailed schedule activities, and typically will occur in the distant future.

With the long duration of Major Facility projects, the use of planning packages in the RLS is an efficient method to ensure the budget is allocated for a work scope that doesn't yet have the level of information to define the detailed activities to perform the work. For example, at the beginning of a project, the scope associated with commissioning is commonly identified as one or more planning packages near the end of the schedule. As the project progresses, planning packages are broken into detailed activities. Incremental conversion of work from planning packages to detailed activities is commonly known as *rolling wave* planning. Increments for rolling wave planning may be event-driven (test, review, milestone, procurement) or time-based, such as every six months. If a project uses incremental planning, the process should be defined as managing and controlling the schedule.

The duration assigned to each schedule activity should be the most probable duration, factoring in the planned level of resources. Activities should have relatively short durations and be consistent with information provided in the BOE (see Section 4.3 Cost Estimating and Analysis). For activities that do not lend themselves to a short duration, it may be necessary to document the activity's scope in steps or use another measurement method to evaluate progress. Planning package activities will normally reflect longer durations until broken into detailed activities. Planning packages need to be of sufficient detail to establish a credible sequence of execution for the overall project. Duration of LOE activities, such as management and other oversight efforts, may be time-based or derived from the span of other discrete activities. The planning package and LOE activities should be identified in the schedule.

The schedule should include sufficient milestones to manage decision points and interfaces (internal and external) and monitor technical progress at different levels of the project.

External milestones may be associated with collaborative partnership efforts, reviews, funding, facility operations, etc. Typically, external milestones are constrained within the scheduling tool. The Awardee should consult with the NSF PO to identify programmatic milestones and high-level milestones for reporting to NSF. Lower-level milestones will facilitate more frequent tracking of the project's progress. Milestones should be coded to reflect their level of significance.

4.4.2.2 Well-Constructed

The attributes of a well-constructed schedule are primarily associated with the logic used to define the interdependencies of all the schedule activities and establish the Critical Path. The Critical Path is the longest path of activities between a project's start and its finish and is used to establish the PMB duration. Projects with multiple deliverables or collaborating with external partners may need to identify additional sequential activities considered critical to achieving project objectives and high-level milestones. All activities necessary to accomplish the project deliverables should be logically sequenced, typically with the predecessor activity finishing before its successor activity starts.

Minimize the use of constraints and lags to fix start or finish dates, as they reduce schedule logic clarity, complicate schedule management, and make it harder to provide accurate forecast dates as the project progresses. Schedule visibility tasks (SVT) or schedule calendars may be used to help minimize constraints and lags. SVT are schedule activities with no resources assigned, with a duration greater than zero, and typically represent external effort that is not part of the PMB. SVT may also be used to increase management visibility to items otherwise represented as lag or constrained milestones. Constraints and/or lags may be necessary to manage a project effectively based on the project parameters. The basis for constraints and lags used in a schedule should be explained in the Schedule Basis Document as discussed in Section 4.4.3.2 Schedule Documentation.

During schedule development, Awardees should perform schedule health assessments to analyze the integrity of the schedule. Schedule health metrics contain checks designed to indicate potential activity interdependency issues. At a minimum, a schedule health assessment should include missing predecessors-successors, relationship types, leads and lags, and hard constraints. Other potential checks to consider in the schedule assessment include logic density, high free float, Critical Path tests, path convergence, and resource rates. All schedule health assessment checks should be used to assess the construction quality of the schedule, optimize the schedule, and should not be used as a pass or fail test.

The activity durations and the logic sequences should be validated by activity owners and technical experts. A valid Critical Path is calculated by the scheduling tool, fully vetted, accepted by the activity owners and the Project Team, and aligned with the project execution strategy. The Critical Path represents the sequence of the activities that drive the earliest possible project completion date and establishes the PMB end date milestone. The Critical Path should include allowances for specific uncertainties as well as contain float, contingency, or margin. If the Critical Path runs through management activities, the schedule should be carefully examined to confirm the schedule logic.

Schedule contingency (see Section 4.7 Contingency Estimating and Management) is needed to provide time for uncertain activity durations and schedule impacts due to risks. Schedule contingency is typically estimated using statistical analysis or judgment based on past experience. The project end date is based on the PMB duration plus the established schedule contingency. The award end date is generally the project end date plus additional time for the closeout of the award. The award duration is less than or equal to the NSB-authorized duration. While NSF does not have a schedule overrun policy, Awardees are expected to exercise discipline to keep projects on schedule and follow the no-cost schedule extension practices in Section 2.6.2 Construction Award Extension and Close-out.

4.4.2.3 Credible

The schedule should align with the project execution approach and show how the work will be integrated to achieve project objectives, including activities performed by Subawardees and contractors. The schedule should clearly define the sequence of activities and be horizontally and vertically traceable through the activity relationship logic. If lower-level, more detailed schedules are utilized in addition to the project schedule (e.g., more detailed subcontractor activities may be bundled into the Awardee's higher-level Integrated Master Schedule [IMS]), milestone linkages should be established to show the vertical traceability between the project schedule and the lower-level schedule(s). The schedule should utilize milestones with predecessor activities to define the completion of major components and/or deliverables, hand-offs between different organizations, key events, etc. The NSF PO may define specific milestones for the Awardee to include in the project schedule.

For Major Facility projects, the amount of schedule contingency is determined by a probabilistic risk analysis and selecting a finish date with a confidence level between 70% and 90%. The schedule risk analysis shall be based on the project Risk Register, with identified schedule impacts and probabilities and activity duration uncertainty. In addition to the project end date, the total float or schedule margin for major deliverables should be reviewed and evaluated.

For further discussion on Risk Registers and schedule risk analyses, refer to Section 4.6 Risk Management. Before conducting a schedule risk simulation, the schedule should be assessed against GAO's comprehensive and well-constructed best practices and systematically checked to confirm the dependability of the risk analysis model. As noted in Section 4.6.6.3 Probabilistic Method – Monte Carlo Simulations, the risk analysis may use a summary schedule derived from the IMS if it has a large number of activities. The results from the schedule risk analysis, including the contingency amounts, method of calculation, project end date, and confidence level, should be documented in PEP Subcomponent 4.3 – Contingency Management Plan as articulated in Section 3.5.4.3 (also see Section 4.7 Contingency Estimating and Management). Schedule contingency is held separately from the PMB, and allocations of schedule contingency to and from the PMB are managed through formal Change Control.

4.4.2.4 Controlled

The baseline schedule used to establish the PMB is set post-FDR with the construction award. The RLS is the basis for the PMB. Every project will have changes to the plan as it is being executed; therefore, effective Change Control and disciplined schedule maintenance procedures are necessary. The baseline schedule logic changes due to detailed planning or re-planning should be managed through formal Change Control. This includes schedule changes that do not use budget and/or schedule contingency. The different levels of milestones used to monitor technical progress will typically correspond to approval thresholds in the Change Control Plan, as discussed in Section 4.7.3.1 Contingency Management Controls. As schedule contingency is used and placed into the baseline, the PMB end date is revised.

The schedule should be updated regularly to record actual project progress and forecast activity and milestone dates of the remaining work for comparison with the baseline schedule, typically referred to as the progress or status schedule. The projected milestone dates reported in the Construction Stage performance reports shall be generated using the progress schedule with the same logic as the baseline schedule, not arbitrarily constrained or adjusted. This comparison identifies the specific activities and events that are the source of current schedule variances or impending problems in meeting milestone dates. If lower-level schedules are utilized to manage the project scope, including major Subawardees and contractors, the project needs to establish a process to maintain vertical traceability and ensure consistency between the project schedule and the lower-level schedules.

The Project Team reviews schedule updates to verify and assess effects and identify actions as needed. The Awardee's Project Director reports the project status, including a narrative on accomplishments and challenges, to the NSF PO on a periodic basis. For Major Facility projects, the update period is monthly, and EVM is required (see Section 4.5 Monitoring Progress Against Plan).

4.4.3 Developing and Estimating a Baseline Schedule

The Total Project Duration (TPD) for the Construction Stage is set post-FDR and is defined in the construction award as two components: the PMB schedule duration and the schedule contingency. The construction award duration should be based on the TPD plus additional time for project closeout as determined by the AO. For further discussion, refer to the NSF EVM Gold Card, a guideline document that outlines key concepts for managing NSF-funded projects that require Earned Value Management System (EVMS). It helps measure project performance in terms of cost, schedule, and scope, allowing stakeholders and NSF to effectively monitor and control projects, ensuring adherence to established project goals.[1]

The development of the PMB is an iterative process as the PEP matures through the Design Stage. Developing a reliable schedule would generally follow the steps described below. First,

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[1] https://new.nsf.gov/bfa/rio/evm-gold-card

a project would select a schedule method, technique(s), and tool(s). For Major Facility projects, CPM, rolling wave planning, and Monte Carlo simulations are commonly used.

4.4.3.1 Ten Steps to Develop Baseline Schedule[1]

Step 1 – Define the total scope of work into deliverables and manageable parts or phases.

- The total scope of work is defined in the WBS and provides structure to the schedule. WBS are developed at varying levels of detail but should be at least to a level of manageable deliverables that can be assigned to one responsible organizational element. The WBS used in the schedule is the same as that used in the cost estimate. Refer to Section 4.2 Scope and Work Breakdown Structure.

Step 2 – Identify project goals and major internal and external interfaces.

- In discussions with the various project stakeholders, the Project Team identifies major internal and external interfaces and develops the project goals, including high-level milestones and target dates. If the NSF-funded project scope is a part of a larger overall project, the technical interfaces and the organizations of the overall project may affect how the NSF part of the scope should be executed. Equipment may be furnished by external entities, or there may be other *hand-offs* with external partners. There could also be interfaces and *hand-offs* of components between collaborating institutions within the NSF-funded scope. Operational facilities may have target dates for shutdown periods for facility modifications or a required sequence of deliverables to minimize impacts to operations. Establishing such interface milestones will provide clear visibility to the project's overall approach and ensure better project schedule management in execution.

Step 3 – Develop schedule activities and technical milestones.

- Schedule activities represent the specific actions to be performed to produce a specific scope of work. The level of detail of these actions becomes more defined as the project proceeds through the Design Stage. The Project Team works with the activity owners to ensure that all work scope has been identified at the appropriate level of detail. The use of long-duration activities to reduce schedule complexity needs to be balanced with the ability to manage the project and measure progress. The schedule should also include lower-level milestones that will facilitate more frequent project progress tracking. Milestones are also useful to track the progress of externally funded activities that are included in a project schedule.
- Planning package activities are commonly used for work in the distant future. Baseline schedules should have activities for the near-term work defined to a level to execute the work and measure progress. Projects that use planning package activities should

[1] Note these steps are slightly modified from GAO's sequencing in *GAO Schedule Assessment Guide*, GAO-16-89G, December 2015

be identified in the scheduling software and have a process to ensure they are promptly converted into detailed plans. For Major Facility projects, the conversion of planning package activities during the Construction Stage should be managed through the change control process established in the Design Execution Plan (DEP) or PEP.

Step 4 – Determine durations for each activity.

- Activity durations should be the most likely estimate considering the available or planned level of resources. Activity durations should not factor in risks or nonwork periods but may include allowances for specific uncertainties. Calendars in the scheduling software should be used to account for nonwork days and/or periods. The duration of planning package activities should be based on analogies to historical projects, experience, or productivity rates.

Step 5 – Logically sequence activities.

- The Project Team and activity owners identify the predecessor-successor logic relationships between activities and milestones utilizing three types of scheduling relationships (Finish-to-Start, Start-to-Start, Finish-to-Finish), along with required lead or lag times.[1] The majority of relationships within the schedule should be Finish-To-Start relationships. For reliable forecasting in progress schedules, planning package activities need to be detailed enough to maintain a proper sequence of work, and the use of lags should be minimized.

Step 6 – Define and assign resources to activities.

- Scheduling software broadly categorizes resources as either labor or materials and supplies (M&S). M&S is any cost other than labor and includes materials, procurements, contracted labor, subcontracts, travel, etc. A project may use a Resource Breakdown Structure to organize a list of the resources required to complete the scope of work. The RLS defines the PMB and reflects the activities' expected (planned) accrual or actual costs. An obligation baseline can also be created based on resource spreads or obligation activities. A fund obligation profile is only used to match time-phased funding when the PMB is established and is not used for earned-value analysis.
- The BOE and project cost estimates are the supporting documentation for the resources loaded into the schedule activities. The scheduling software may be used to *tag* resources and generate the cost data for the NSF Budget Format. For more information on the NSF Budget Categories and construction proposal formats, refer to the following sections
  - 1.3.1.1 Financial Assistance Awards – Grants and Cooperative Agreements
  - 4.3.4 Specific Guidance for Major Facility Construction Estimates
  - 5.6 NSF Budget Categories from the Proposal and Award Policies and Procedures

[1] Refer to *GAO Schedule Assessment Guide* (https://www.gao.gov/products/gao-16-89g) for additional information regarding activity relationships.

Guide

Step 7 – Perform schedule calculations.

- Schedule calculations are performed using scheduling software. Early and late dates, Critical Path, and activity float are determined. Calculations can be performed at various times during the schedule preparation to allow for preliminary reviews and resource leveling.

Step 8 – Review and analysis.

- The Project Team and the activity owners should actively participate in reviewing the results of the schedule calculations. The review should consider the project objectives, milestone completion dates, critical and near-Critical Paths, float values, and required resources (compared to resource availability) to determine the schedule's acceptability. Where alterations are required, changes are made to the schedule logic, resource allocations, and/or durations, and then the schedule is reanalyzed.

Step 9 – Assign risk-based schedule contingency.

- Part of the scheduling process includes the Project Team determining the risk-based schedule contingency that is derived from the estimated duration uncertainty and risks associated with a set of activities and/or the overall project. Schedule contingency, like budget contingency, is used to accommodate approved baseline changes and resultant schedule impacts without impacting overall project schedule objectives (see Sections 4.6.6 Step 6 – Assess Total Risk Exposure and 4.7.2.2 Schedule Contingency for more information on the development of schedule contingency).

Step 10 – Prepare schedule information.

- The scheduling software is used to produce various reports and graphics such as Critical Path, milestone summary, time-phased budget, and profiles of resources utilized over the project duration to confirm adequate resource-leveling. A summary of the baseline schedule and schedule contingency are part of the Project Definition and are included in the PEP (see Section 3.5.3.4 PEP Subcomponent 3.4 – Integrated Master Schedule or 2.6.1 Construction Award Management and Oversight for the specific schedule information to be provided in the PEP).

4.4.3.2 Schedule Documentation

The baseline schedule is accompanied by a basis document that provides parameters and underlying assumptions used in developing the schedule for all project stakeholders' understanding. A well-written Schedule Basis Document will also help oversight groups assess a schedule's validity and reliability. For Major Facility projects in the Design and Construction Stages, the Schedule Basis Document should include the following components at a minimum:

- General description of the overall approach to achieving the project goals that gives a high-level framework of the schedule network logic, the external dependencies, and key drivers of the Critical Path.

- Identify key dates used in the schedule development, such as life cycle, decision, hand-off, etc.
- A list of schedule assumptions, such as external constraints, procurement durations, construction calendar/seasons, operations integration requirements, funding parameters, any significant resource limitations, items excluded from the schedule, etc.
- Basis for the constraints, lags, leads, and open-ended activities used in the schedule.
- An explanation of how the Project Team followed the best practices in the *GAO Schedule Assessment Guide* to ensure the schedule meets the four characteristics of a reliable schedule from the *GAO Schedule Assessment Guide*.
- For the well-constructed characteristic, the assessment should include the results from a software quality assessment tool with explanations for elements that exceed standard metrics.
- Schedule contingency analysis and results.

A Schedule Management Plan or estimating plan typically describes the policies, procedures, tools, and roles and responsibilities to be used to develop and manage the schedule. It is not the same as the Schedule Basis Document but may include some similar components or be combined with it in one document. The following components could be included in the Schedule Management Plan that may be useful in an independent review of the Awardee's schedule:

- Identification of scheduling software options used, i.e., calendars, activity identifications (LOE, task-dependent, schedule visibility, planning packages, etc.), project-specific coding used, calculation of Critical paths, progress override contrasted with retained logic, progress updates with duration updates, etc.
- Method(s) used for resource-leveling – an explanation of how the project determined that the time-phased workforce requirements from the schedule are aligned with the project staffing plans.
- The process used to update the status and record progress of the project during execution.
- Provide a description of the process of converting planning packages to detailed packages or rolling wave planning, if used. This may be included in an EVMS Description Document.

4.4.4 Schedule Maintenance During Construction Stage

The baseline schedule used to establish the PMB maintains the original agreed-upon activities and milestone dates unless altered in accordance with the project's Change Control procedures. Work progress is measured regularly by the Project Team and maintained in a progress schedule, also referred to as a working forecast or status schedule. A comparison of the progress and baseline schedules indicates the extent to which the project is ahead of or behind schedule. This comparison also identifies the specific activities and events that are the source of current schedule variances or impending problems. If the earned value is used, the schedule status cycles **must** coincide with the accounting month's end used by the Awardee to ensure consistency of earned value calculations and reporting.

4.4.4.1 Baseline Schedule

During project execution, a baseline schedule is maintained to compare it against the progress schedule. The Project Team should document and approve all changes to the baseline schedule, including activity durations, logic, resources, etc. The Change Control process and approval thresholds should be documented in the PEP and/or the EVM procedures for Major Facility and Mid-scale RI projects.

The PMB end date is based on a technically driven schedule within funding limitations and does not include schedule contingency. The TPD establishes the project risk-adjusted end date. A project may want to use schedule buffers to manage or monitor interim milestones or external deliverables to the project, such as subcontract work. These schedule buffers should be identified as schedule margins with SVT instead of lags. If a schedule margin (buffer) activity is used in the baseline schedule, its duration should be zeroed out before running a schedule risk analysis. By doing so, the schedule analysis can be used to determine the margin durations needed to achieve specific milestones or deliverable requirements. The schedule margin activity should not drive the PMB end date. Schedule contingency amounts are not included in the PMB due to NSF's requirement that contingency is held and managed separately from the baseline. Allowances may be used in the schedule, as defined in Chapter 8 Lexicon, if adequately justified.

4.4.4.2 Progress Schedule

The progress schedule records the project progress status and forecasts activity and milestone dates of the remaining work. The PMB end date should be constrained to create float calculations and identify high-level milestones with negative float. If a delay is deemed significant, the Project Team should develop a plan to examine options for schedule recovery. If the negative float cannot be mitigated, the use of schedule contingency may be necessary to update the baseline milestone date.

The Project Team regularly reviews planned and completed activities to determine progress. Various methods are used to assess the status of different kinds of activities to ensure that progress is being determined objectively. Status information from the activity owners typically includes activity start and finish dates, percentage complete for ongoing activities, forecast completion dates, and milestones achieved. The Project Team should vet the progress schedule results and forecast dates before status reporting. It is important to note that progress information is not used to modify dates in the baseline schedule. The baseline dates, duration, resources, etc., are only changed utilizing the baseline Change Control process, including appropriate approval thresholds, as described in Sections 3.5.4.3 PEP Subcomponent 4.3 – Contingency Management Plan and 4.7.3 Contingency Management.

For work performed under subawards and contracts (referred to as subcontracts), the Project Team should identify appropriate reporting inputs to ensure objective progress measurement. Subcontracts may be based on milestones or require the subcontractor to develop a schedule that supports the project schedule. The Project Team needs to establish procedures to ensure accurate progress reporting and reliable forecasting from the progress schedule.

When progress schedule updates forecast significant changes in the schedule and cost to complete, associated revisions should be made to the ETC to develop a new EAC. Significant changes to ETC should be considered for a baseline change or, at a minimum, tracked as a lien against budget contingency. Prudent maintenance of the Control Account-level EAC ensures that the EAC reflects a valid projection of project costs. The EAC should be based on performance to date and new estimates for remaining work but does not include risks and opportunities within the project's Risk Register unless they are realized (see Section 4.7.3.3 Contingency Management Forecasting).

4.4.5 NSF Analysis of Construction Stage Resource-Loaded Schedules

NSF uses various oversight tools to assess the reliability of the Awardee's schedule and inform NSF stage-gate decisions. The discussion below describes at a high level how these tools are used to review the Awardee's schedule against the GAO Scheduling Best Practices and the documentation needed to conduct these reviews. Questions about these reviews should be directed to the PO and/or the relevant AO. Appendix II of the *GAO Schedule Assessment Guide* identifies qualitative information and key documentation that GAO Auditors use to assess a schedule.[1]

4.4.5.1 Schedule Review Component of Stage-Gate Reviews

The construction schedule develops as the project moves through the Design Stage to readiness for construction. Section 2.5 Major Facility Design Stage describes each stage-gate review and NSF expectations for readiness for a project to advance. Figure 2.3.3.2-1 illustrates the progressive phases within the Design Stage and NSF Decision Points. At the CDR, the schedule is high-level with key milestones and typically based on analogy with similar projects and/or experience of technical experts. At PDR, an RLS is required at a sufficient level to develop a time-phased budget and estimate contingencies. As the design matures toward FDR, the schedule is refined with more detailed activities to be ready for construction and to be baselined for the EVMS.

Based on internal guidance for PDR and FDR, the schedule should be reviewed for complete work scope (GAO Best Practice 1), sufficient resources and duration to execute the project (GAO Best Practices 3, 4, and 7), credible sequence of work (GAO Best Practices 2, 5, and 6), and appropriate schedule contingency for risks and estimating uncertainties (GAO Best Practice 8). The external panel provides expert experience to review the credibility of the

[1] https://www.gao.gov/products/gao-16-89g

schedule sequence, logic, duration, and resource requirements of activities. Based on the CDR and PDR results, NSF should provide guidance to the Awardee for implementation into the FDR schedule relating to the GAO Scheduling Best Practices. At the end of the Final Design Phase, the Awardee needs to have a reliable construction-ready schedule as defined by the GAO schedule characteristics to advance to the Construction Stage.

To support the schedule review at PDR and FDR, the Awardee should provide the following PEP subcomponents further defined in Section 3.5 Construction Stage and Implementation Planning:

- WBS Dictionary
- Full schedule sorted by the WBS - Gantt chart
- Critical Path and near-Critical Path schedule(s) – Gantt chart
- List of project milestones by WBS
- Schedule Basis Document
- Risk Register with schedule impacts identified
- Schedule contingency analysis and results

4.4.5.2 Schedule Review Component of Independent Cost Estimate Reviews

NSF may utilize independent cost estimates and cost estimate reviews, in some cases performed by independent contractors or other government agencies, to inform the NSF Cost Analysis (see Section 4.3 Cost Estimating and Analysis). In conjunction with an independent cost estimate review, NSF may include an independent review of the Awardee's schedule and schedule contingency analysis using GAO Scheduling Best Practices or developing an independent schedule and schedule contingency. NSF's selection of the type and scope for an independent cost estimate review should follow internal guidance.

An independent review of an Awardee's schedule would typically include an assessment of the GAO schedule characteristics, comprehensive (GAO Best Practices 1, 3, and 4) and well-constructed (GAO Best Practices 2, 6, and 7), in accordance with NSF expectations as described in Section 4.4.2 Characteristics of a Reliable Schedule. This review may also assess the methodology used by the Awardee for the schedule contingency analysis (GAO Best Practice 8). The external panel for a stage-gate review would usually provide expert experience in reviewing the schedule risks and associated impacts used in the schedule contingency analysis.

To support the development of an independent schedule and schedule contingency, the Awardee will need to provide the same detailed technical information that was used to develop the schedule, such as the following PEP subcomponents further defined in Section 3.5 Construction Stage and Implementation Planning:

- Technical specifications and requirements
- System design drawings and technology selections
- Key assumptions

- WBS
- Schedule Basis Document
- Schedule Management Plan, if used

To support an independent review of the Awardee's schedule and schedule contingency analysis, the Awardee should provide the following supporting files in addition to the stage-gate review PEP subcomponents further defined in Section 3.5 Construction Stage and Implementation Planning:

- Baseline RLS source file
- Schedule contingency analysis source file(s)
- Major subcontractor schedule, if applicable, and the associated terms and conditions

4.4.5.3 Schedule Review Component of NSF EVMS Verification Review

As part of NSF's EVMS verification review, discussed in Section 4.5.4.2 Verified Earned Value Management Systems, the Awardee's processes for maintaining a PMB schedule (GAO Best Practice 10) and updating the progress schedule (GAO Best Practice 9) are assessed per EIA-748 EVM guidelines for implementation of EVMS.[1] This review specifically addresses the status of the schedule and measuring performance, Change Control processes and documentation, and vertical traceability with lower-level schedules (i.e., subcontractor schedules) as applicable (GAO Best Practice 5). The EVMS verification review is informed by other NSF reviews, including the FDR stage-gate review for assessment of EIA-748 EVM guidelines associated with other Scheduling Best Practices such as complete work scope in the schedule (GAO Best Practice 1) and resources assigned to all the activities (GAO Best Practice 3).

To support an EVMS verification review, the Awardee should provide the following documents in addition to the FDR project documents for assessment of the GAO Scheduling Best Practices:

- EVM System Description
- Change Control process description
- Project Controls' schedule procedures for schedule progress and maintenance
- Baseline RLS source file
- Major subcontractor schedule, if applicable, and the associated terms and conditions
- Schedule Management Plan, if used

[1] https://www.ndia.org/-/media/sites/ndia/divisions/ipmd/division-guides-and-resources/ndia_ipmd_intent_guide_ver_d_aug282018

4.4.5.4 Schedule Review Component of NSF Cost Analysis

As part of the NSF Cost Analysis, conducted following internal guidelines, the Awardee's schedule will be assessed for alignment with GAO Scheduling Best Practices to determine if the schedule meets the four characteristics of a reliable schedule as discussed in Section 4.4.2 Characteristics of a Reliable Schedule. This schedule analysis will be led by RIO, will include a technical evaluation from the stage-gate review, and may include input from an independent schedule review and/or EVMS verification review (see Section 4.3 Cost Estimating and Analysis).

4.5 MONITORING PROGRESS AGAINST PLAN

Section Revision: TBD Early 2025

Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

Every RI project is required to undergo periodic and accurate assessments of its current state and forecasted trajectory towards the planned future state. These assessments are required to facilitate reporting to NSF and inform and facilitate sound decisions and changes necessary to ensure the project's success.

There are a variety of approaches to monitoring progress against a plan that may be appropriate to implement on a project. For example, a common and well-accepted method is the application of an EVMS. Major Facility projects are required to employ a verified EVMS (see Section 4.5.4.2 Verified Earned Value Management Systems). For Mid-scale RI, other monitoring methods may also be acceptable depending on the project type, size, and level of complexity.

NSF Requirement

- Major Facilities **must** use a verified EVMS to monitor progress against the PMB.
- Mid-scale RI **must** have an objective means to monitor progress against the plan.

Monitoring progress against a plan specifically focuses on tracking the actual progress of tasks and activities compared to a planned schedule, budget, or other predefined metrics. It involves regularly reviewing project performance data to assess whether the project is on track and identifying any deviations from the original plan. This process helps project managers and stakeholders stay informed about the project's status and make informed decisions to address any risks and issues that may arise.

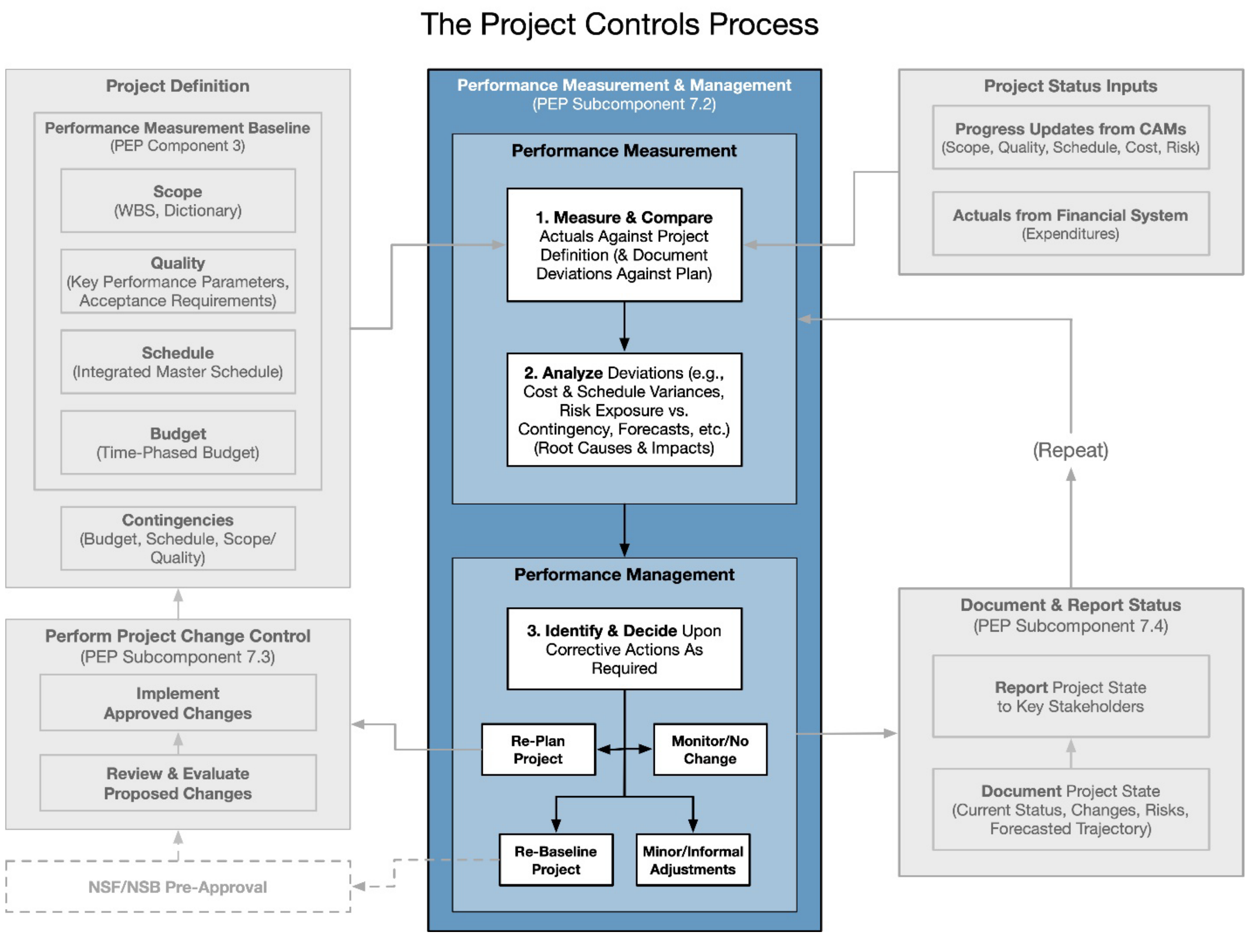
4.5.1 Performance Measurement and Management

Performance Measurement and Management (PMM) is a component of the broader Project Controls process (see Figure 4.5.1-1) and provides the framework for evaluating overall project performance. Monitoring progress against the plan is a specific activity within that framework focused on tracking the actual execution of tasks compared to a planned schedule, budget, or other metrics.

Performance measurement refers to measuring, comparing, and analyzing performance against the PMB, which monitors the progress of planned tasks toward specific predetermined goals and objectives. Performance Management involves monitoring the variances identified through performance measurement and then implementing corrective actions, as needed, to ensure the successful progress of the project.

Figure 4.5.1-1

Three-Step Framework for PMM Within the Context of Project Controls: Monitoring Progress Against Plan



Methods for monitoring progress against a base plan typically follow a three-step framework, as shown in the Project Controls Process figure above. These steps are:

1. **Measure and Compare Actuals Against the Total Project Definition**. The first step of any good progress measurement system is to gather inputs that reflect the current state of the project and compare these against the Total Project Definition (PMB + Contingency and Fees). For example, Actual Expenditures associated with a specific WBS element should be compared against the Time-Phased Budget profile of that element. The difference between the Actuals and the associated PMB element is a variance against a plan. Variances can be positive or negative, meaning the current state of the project is ahead or behind a plan.[1] Variances that should be measured include Scope Production Status, Adherence to Quality Acceptance Standards, Schedule Performance, Budget Performance, and Risk-vs.-Contingency status. Further, forecasted variances for future performance (such as an updated EAC) are

[1] Note that variances in and of themselves are neither good nor bad; they are simply information to be used to understand and make informed decisions.

also required. Finally, as part of this Measure and Compare step, all variances should be documented in a variance report (e.g., in a Cost Performance Report) at the appropriate level.

2. **Analyze Variances**. The second step in monitoring progress is to review and analyze the current variances (including trends from previous reporting periods). The goal is to understand each variance, including the root cause(s) of variance and the impact and/or expected ramifications if the variance is not addressed.
3. **Identify and Decide Upon Corrective Actions as Required**. The third step in monitoring progress is to identify and decide upon corrective actions for each variance that may be necessary to adjust the trajectory and ensure the project remains on track to a successful outcome. There are typically four actions that can be taken.
    - No change is required, and the monitoring should continue.
    - Minor plan adjustments that don't require formal change control.
    - Re-plan via formal project change control.
    - Re-baseline the project.[1] Every project should approach this step uniquely.

The specific processes should be defined within a management plan appropriate to the life cycle stage (DEP, PEP, or AWP). For example, this includes, but is not limited to, roles and responsibilities, the metrics, thresholds, and authorities to make decisions in place, required notification and approvals, documentation requirements, etc.

4.5.2 Essential Qualities of a Progress Monitoring System

Monitoring progress against a plan should not be viewed simply as producing static metrics or as a compliance report. Instead, the project's progress monitoring system should be implemented to provide the Awardee's management team with a reliable basis for objectively assessing performance against plan, identifying potential issues, forecasting future trends, and initiating corrective action. When selecting a PMM method for an RI proposed project or project, the following qualities and characteristics should be addressed:

- **Identified and Documented Process**. The selected progress monitoring method should be a recognized documented process with explicit and established procedures and plans and may include specific roles, responsibilities, and lines of authority.
- **Comparison of Actuals Against PMB**. The progress monitoring method should provide defined metrics and accurate assessments (i.e., variances) of Scope Production, Quality Status, Schedule Performance, Budget Performance, and Risk Exposure-vs.-Contingency Status.
- **Accurate Forecasting Predictions**. The progress monitoring method should allow for

[1] Re-Baselining is appropriate only when significant changes to the project are required. This includes increases in the NSB-authorized TPC, a schedule extension beyond the total project duration, and/or significant changes in scope. Re-baselining requires approval of NSF and may involve the NSB.

accurate predictions or forecasting of future project performance, providing early warning of potential issues.

- **Compatible Reporting**. The variance reports generated by the progress monitoring method should be compatible with NSF processes and organization (i.e., the plans and reports NSF expects to see).

4.5.3 Allowable Progress Monitoring Systems

All RI require an appropriately tailored and scaled progress monitoring method. The selected progress monitoring method should match the project's characteristics, size, and complexity, and should describe in detail how PMM will be conducted.

The selected progress monitoring method should be compatible with the chosen project framework (e.g., traditional, Agile, hybrid, etc.) Similarly, the method should be scaled to the size and complexity of the project. For example, on small, simple projects, the progress monitoring system may consist of simple metrics and comparison charts and spreadsheets of actual expenditures-vs-budget and risk-vs-contingency, milestone tracking and/or percentage complete charts for scheduled activities, and a basic compliance matrix for scope production. EVM is often the preferred approach for more complex projects. For Major Facility construction projects, a formal verified EVMS is required; see Figure 4.5.3-1.

Figure 4.5.3-1
Illustrative Example: Methods for Monitoring Progress Against the Base Plan

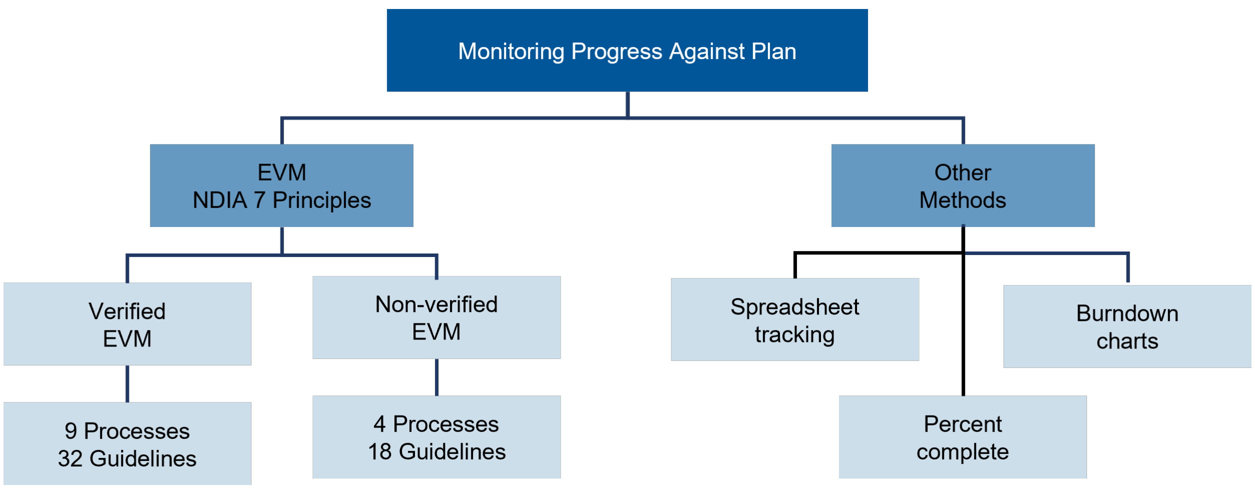


Figure 4.5.3-2
Burndown Chart Example: Contingency (Red Line) and Total Risk Exposure (Blue Line) Comparison, Emphasizing Best Practice

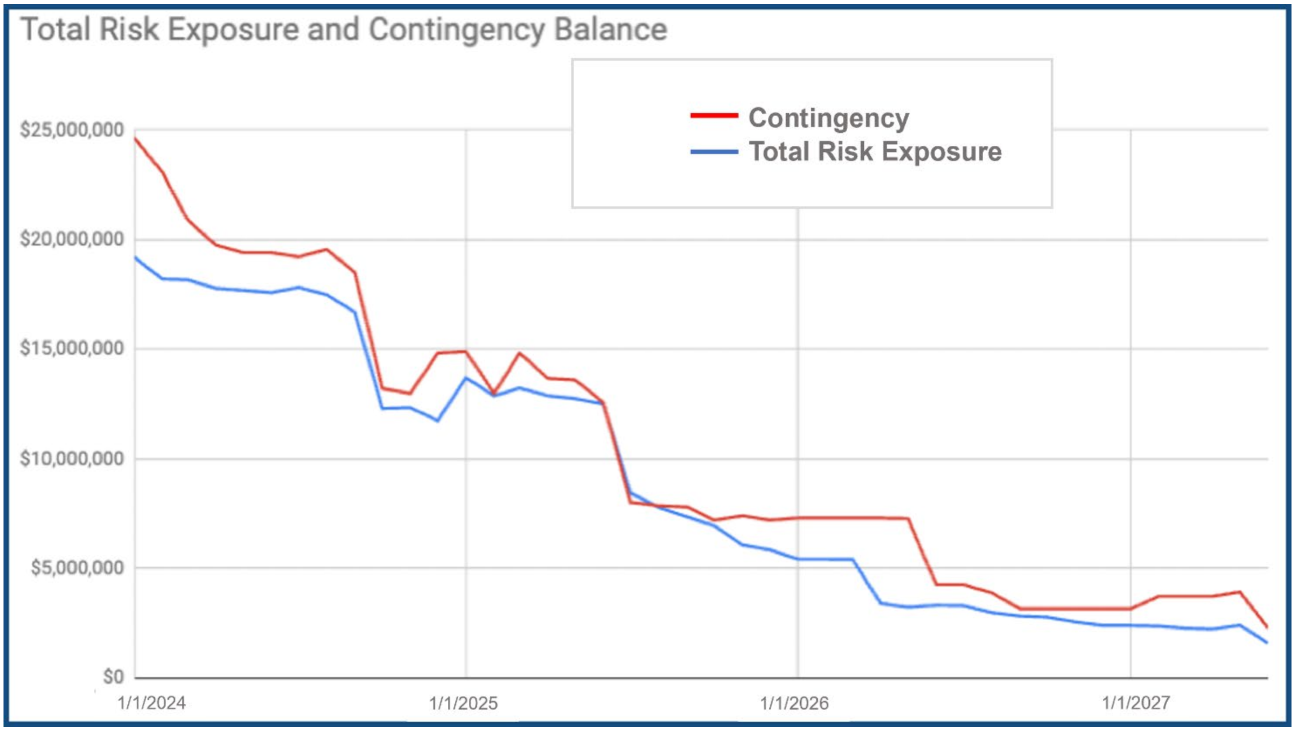


Table 4.5.3-1
Example of Level-1 Milestone Tracking: Comparison of Actual versus Planned Progress

Level 1 Tracking Milestones			
Activity (Milestone) Name	**Planned Date**	**Finished Date**	**Delta**
Utility Building Beneficial Occupancy Date (BOD)	19-Dec-24	16-Dec-24	3
Major Earthwork and S&O Foundations Complete	24-April-25	29-April-25	-5
Instrument Final Designs Complete	22-May-26	28-Aug-26	-98
Primary Mirror Blank – Polishing Complete	15-Nov-27	15-Oct-27	30
Enclosure Weather-tight, Ready for TMA	20-Jan-27	24-Feb-27	-34
TMA Installation Complete	2-Oct-28		
First Light Achieved	15-Jan-30		
Start of Operations	30-Sep-31		

If EVM is used as the progress monitoring method for a Mid-scale RI, it should be tailored and scaled to the project's needs (see Section 4.5.4 Earned Value Management). Regardless, the selected progress monitoring approach is subject to NSF approval before project execution activities commence.

All progress monitoring plans should be documented in a management plan appropriate to the life cycle stage, describing the details, approaches, and expectations of the system, including:

- Metrics and how measurable data will be gathered.
- How comparisons to the PMB and analyses will be conducted.
- The WBS level at which analysis will be performed.
- What specific variances and indices will be reported.
- What reports will be generated.
- The cadence of analysis and reporting.
- How corrective actions will be identified and decided upon.

4.5.4 Earned Value Management

4.5.4.1 Earned Value Management – The Seven Principles

EVM is a common methodology for progress monitoring. There are two levels of rigor for EVM used in RI efforts. For Major Facilities, NSF requires a fully verified EVM system compliant with EIA-748. For all other RIs, a non-verified version of EVM compliant with NSF requirements may be employed. The requirements for each of these EVM approaches are described below. Regardless of approach, however, all EVM systems should comply with the following seven principles:

1. Plan the project's scope to completion using discrete work packages and planning packages.
2. Break down the project work scope into finite pieces, assigning each piece to a responsible person or organization to control technical, schedule, and cost objectives.
3. Integrate project work scope, schedule, and cost objectives into a performance measurement baseline plan against which accomplishments are measured. Control changes to the baseline.
4. Use actuals incurred and performance attained in accomplishing the work performed.
5. Objectively assess accomplishments at the work performance level.
6. Analyze significant variances from a plan, forecast impacts, develop corrective actions, and prepare an EAC based on performance to date and the remaining work to be performed.
7. Use the EVMS information in the project's management processes.

4.5.4.2 Verified Earned Value Management Systems

NSF requires Major Facility RI Awardees to use a verified EIA-748 compliant EVMS for successful project planning and execution. To ensure that the Awardee’s EVMS data provide timely, accurate, and reliable performance information, NSF conducts RI EVMS Verification, Acceptance, and Surveillance (VAS) based on the processes recommended in the National Defense Industrial Association (NDIA) Earned Value Management Guides as part of the RI’s oversight and monitoring activities.[1]

As part of the VAS process, the Awardee should demonstrate it has a structured management process that follows the principles of EIA-748 EVMS standards and provides a sound basis for performance measurement, problem identification, corrective actions, and management re-planning activities as required. NSF's VAS process is intended to ensure that the implementation of EVMS is appropriately scaled and applied to the project's management needs. For the Awardee to utilize the full benefits of EVMS and aid the successful execution of the project plan, the EVMS should address all nine processes, and all 32 guidelines applied in a way that reflects the size, complexity, risk, and nature of the work, as noted in the NDIA EVMS Guideline Scalability Guide. NSF's verification and acceptance of an Awardee’s EVMS is not intended to be a certification of an Awardee’s EVMS. As a result, it should not be used by other government or contracting agencies, nor can it be extended to other NSF projects managed by the Awardee. If an Awardee has a current EVMS certification or equivalent verification from another federal agency, the NSF EVMS verification review may be modified. However, NSF acceptance will still need to be documented, and ongoing surveillance will be performed.

The award EVMS verification is performed through a Compliance Evaluation Review process (see Chapter 2 NSF Life Cycle Oversight). NSF strongly encourages projects to utilize EVMS to the extent practicable during the Design Stage to prepare for full implementation during implementation or the Construction Stage. NSF aims to complete the Compliance Evaluation Review before awarding construction funds. NSF also aims to accept the project's EVMS before actual physical construction or major acquisitions commence, based on acceptable resolution of the findings from the Compliance Evaluation Review.

RIO has responsibility for EVMS VAS process. After acceptance and during execution, periodical surveillance reviews may be conducted to ensure that the accepted EVMS is being maintained and followed and that the EVM data and information are being used to inform management decision-making. The frequency and focus of surveillance reviews are determined by the PO in consultation with the RIO via the RIO Liaison but are generally conducted as part of the annual construction review to minimize burden. The scope of the surveillance reviews can include all EIA-748 guidelines or concentrate on specific areas of interest. Targeted surveillance reviews may result from corrective actions, new procedures, and/or demonstration of practice.

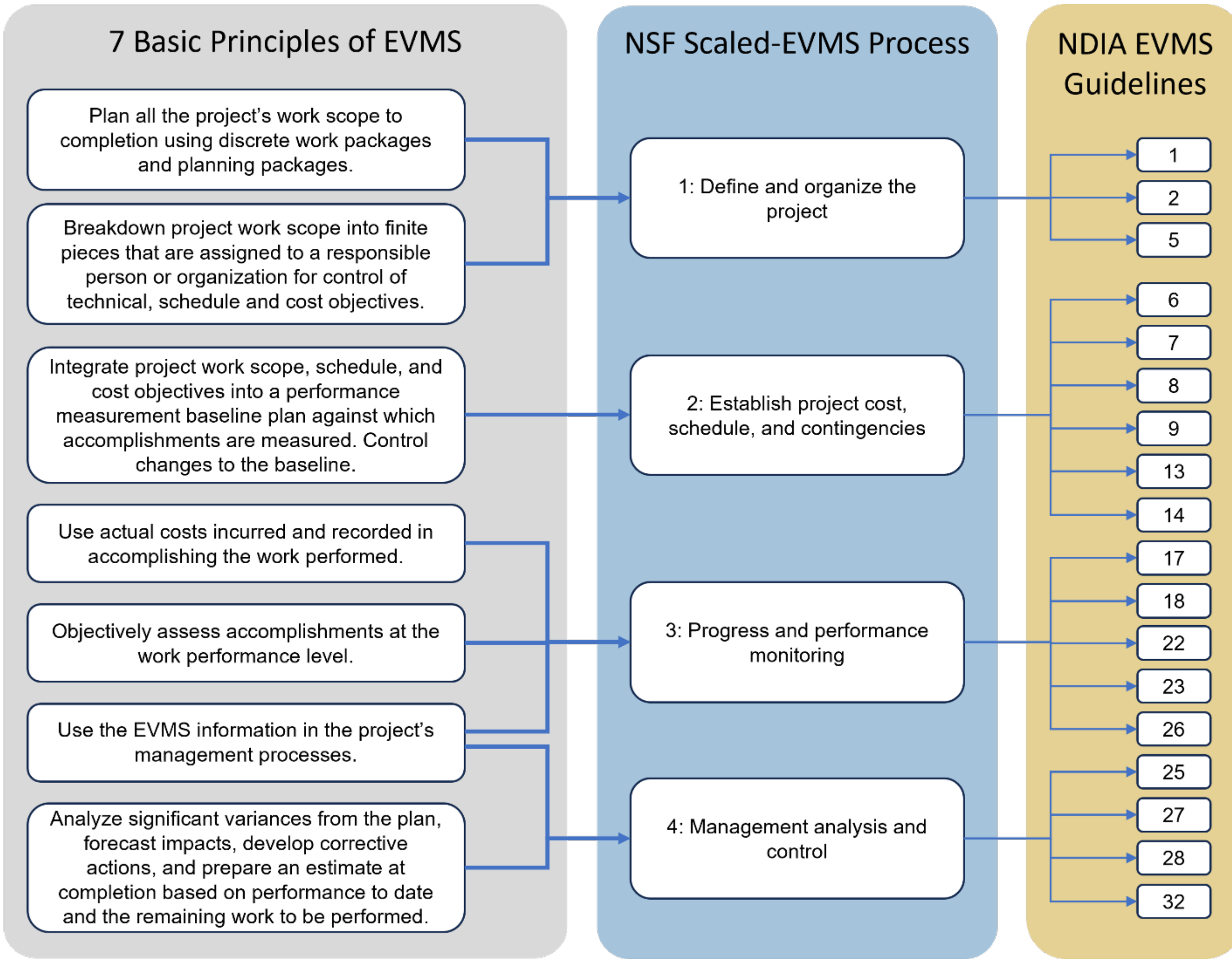
4.5.4.3 Non-Verified EVMS

NSF recognizes that a fully verified EVMS subject to VAS may add unnecessary administrative burden to Mid-scale RI. To allow the benefit of EVM without adding extra burden, NSF uses a more flexible EVM framework to assess smaller and less complex projects that encourages use of the seven key principles but only four of the processes and 18 specific identified guidelines. That is, a properly implemented EVMS should be no more complex than is

[1] https://www.ndia.org/divisions/ipmd/division-guides-and-resources

necessary to inform sound project management decisions and provide required reporting data to NSF.

Figure 4.5.4.3-1
NSF Scaled (Non-Verified) EVMS Process: Application of 18 of 32 EVMS Guidelines Aligned with the 7 Basic Principles of EVMS



Process 1 – Define and Organize the Project (Principles 1 and 2)

This process aims to ensure that the project scope is well-defined, and that responsibility is clearly assigned for each component. This will allow the organization of the project to meet EVMS Basic Principles 1 and 2. EVMS Guidelines 1, 2, and 5 are the primary reference guidance for this process, which is broken down into three key steps:

1. Define project scope in terms of WBS. Refer to Section 3.5.1.4 PEP Subcomponent 1.4 – Research Infrastructure Description for the explanation and guidance for WBS and an accompanying WBS Dictionary. The more detailed levels of WBS, the more details are required and need to be managed. The key to a properly scaled EVM is to set the WBS level details at a reasonably high level but detailed enough to provide sufficient visibility of the project's work scope for management control.
2. Define the project organization via an Organization Breakdown Structure (OBS). Refer

to Section 3.5.2.3 PEP Subcomponent 2.2 – Internal Project Organization for guidance on the project organizations. To ensure the project will benefit from EVM, the project's internal organization breakdown should link to the WBS, and the responsibility for each WBS element should be clearly identified.

3. Identify organizational responsibility for work, including significant subcontractors, for sufficient management/control. The Project Team should identify and assign the person or organization unit responsible for each WBS element's scope, schedule, and budget management. For efficient control, one group is typically responsible for the full scope at the lowest level of the WBS.

Process 2 – Establish Project Cost, Schedule, and Contingencies (Principle 3)

This process aims to establish the project's cost and schedule baseline against which the project's progress is measured during execution. This process ensures the project meets the expectations of the EVMS Basic Principle 3. In addition to setting the project's cost and schedule baseline, the budget and schedule contingencies should also be estimated. Project milestones should also be defined and identified in the project baseline schedule. EVMS Guidelines 6, 7, 8, 9, 13, and 14 are the primary reference guidelines for this process, broken down into four key steps.

1. Schedule the work with logical sequencing and task dependencies. Refer to Section 4.4 Schedule Development, Estimating, and Analysis for guidance in the development of an RLS as part of the project baseline. The level of detail should be suitable for the management control needed. For a less complex project using a non-verified EVM, the activity breakdown for scheduling can be less detailed, and summary-level activities/ tasks could be used when the measurement for progress is clear.
2. Identify technical milestones and/or other methods for progress measurement. Refer to Section 4.4 Schedule Development, Estimating, and Analysis for guidance on identifying milestones in the development of the baseline schedule. Technical milestones are important indicators for progress measurement. Milestones with assigned monetary value can be used in conjunction with summary-level tasks to calculate earned value. For some projects, appropriately time-spaced milestones can be sufficient for the sole progress measurement method.
3. Establish a time-phased budget by WBS and incorporate indirect costs. Based on the resource assignment for activities in the baseline schedule, a time-phased budget can be established for each WBS element. Refer to Section 4.4 Schedule Development, Estimating, and Analysis for more guidance on developing time-phased budgets.
4. Assess project risks and estimate uncertainties to establish budget and schedule contingency. The Project Team should identify technical, cost, and schedule risks and develop a Risk Register and Risk Management Plan to manage identified risks. The contingency estimates should be based on the total estimated project risk exposure. Refer to Section 4.6 Risk Management for guidance on developing a Risk Register and Section 4.7 Contingency Estimating and Management for establishing the budget, schedule, and scope contingencies. A probabilistic risk analysis is typically not used

on smaller scale and less complex projects.

Process 3 – Progress and Performance Monitoring (Principles 4, 5, 7)

This process aims to ensure the Project Team uses the EVM concept for quantitative measurement of progress and that the progress data is reliable and used by management to achieve project goals. EVMS Guidelines 17, 18, 22, 23, and 26 are the primary reference guidelines for this process, broken down into five key steps.

1. Define Control Accounts based on the project's WBS and Organization Breakdown Structure (OBS). The Project Team should set up Control Accounts at the appropriate level of WBS. The higher the WBS level for Control Accounts, the less earned value data detail. Proper EVMS sets the Control Accounts at the WBS level to suit the management control needs. Each Control Account should have a clearly assigned responsible person as the Control Account Manager (CAM) and the organization unit responsible for delivering the scope under this Control Account. This should be consistent with the OBS established in PEP Subcomponent 2.2 – Internal Project Organization. The CAM is accountable for completing the corresponding WBS element's work scope within the Control Account's planned budget and time duration according to the baseline.
2. Record and summarize actual costs by Control Accounts. After the Control Accounts are established, the Project Team should record monthly actual costs by Control Accounts. The actual cost should be reconciled periodically with the financial system's accounting statements. The Project Team should have a process to ensure the actual cost report includes estimated costs consistent with completed work to accurately compare actual costs to planned values.
3. Record task progress and summarize earned value for completed work by WBS. The Project Team should assess each work activity's progress to calculate the earned value for all activities and then summarize the earned value for each Control Account. The CAM is primarily responsible for providing input on the progress assessment for all activities.
4. Summarize schedule and cost performance at select levels of the WBS and perform variance analysis. Periodically, the Project Team should summarize earned value and compare it with the baseline plan and actual costs, which typically occurs in a Cost Performance Report. The Project Team should establish a variance threshold for the CAM to analyze variance, describe schedule, and cost performance variances, understand their root causes, and describe their impacts if left unchanged.
5. Management actions using information from variance analysis. Based on the information from the variance analyses, the Project Team should take corrective actions and mitigate threats to ensure the project execution meets the cost and schedule goals.

Process 4 – Management Analysis and Control (Principles 6 and 7)

This process aims to ensure the Project Team uses earned value data and forward-looking metrics to forecast the project's cost and schedule performance and to allow for early detection of potential issues. The forward-looking metrics are valuable input that EVM can provide, in addition to reporting on past performance. The Project Team should use forward-looking metrics to inform management decisions and make timely adjustments to the project planning necessary for its success. The changes to the project's PMB should be controlled to ensure the integrity of the baseline and the reliability of the earned value data. EVMS Guidelines 25, 27, 28, and 32 are the primary reference guidelines for this process, broken down into four key steps.

1. Incorporate major changes to the project plan with Change Control. When the Project Team makes major changes or adjustments to its plan, those changes should be incorporated into the PMB through an established Change Control Process (CCP). The Project Team should identify approval authorities and define thresholds for different levels of change and timely incorporate such changes into the baseline upon approval. The changes should be forward-looking and not be used to modify performance to date.
2. Periodically update estimates of remaining work. The Project Team should perform cost and schedule estimate updates for the remaining work, especially when new information is available. Depending on the task complexity and TPD, the Project Team can decide the frequency of such updates to suit the management needs. The process for updating the estimates for each WBS may also help identify potential threats and upcoming issues. The forecast and identified potential issues can be used to inform the management decision process. The Project Team should also forecast EAC based on the updated estimates for the remaining work and compare the EAC to the TPC. If the EAC exceeds the Total Project Budget, management may need to consider descope options.
3. Update risk assessment and assess the remaining contingencies. The Project Team should update the Risk Register, assess the total risk exposure, and evaluate the remaining contingencies against the remaining exposure.
4. Summarize project status and forecast milestones for NSF reporting. The Project Team should summarize performance narratively and provide earned value data, forecast EAC, and forecast milestones in a status report to NSF.

4.6 RISK MANAGEMENT

Section Revision: TBD Early 2025
Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

Risk Management includes the processes and methods used in planning, identifying, analyzing, responding to, monitoring, and reporting risks in an RI effort. This section provides information on risk management methodologies and strategies that can be adapted and applied by Awardees during all RI life cycle stages.

Risk is an inherent aspect of the unique, highly technical, and scientifically ground-breaking RI efforts supported by NSF. Ignoring risks or giving insufficient attention to proper risk management increases the probability that the RI effort may not meet its objectives. Successful risk management entails early recognition, proactive planning, and rigorous execution of all risk management processes. Ideally, risk management begins as early as the Development Stage of the RI's life cycle and continues during Design, Construction / implementation, Operations, and Disposition Stages.

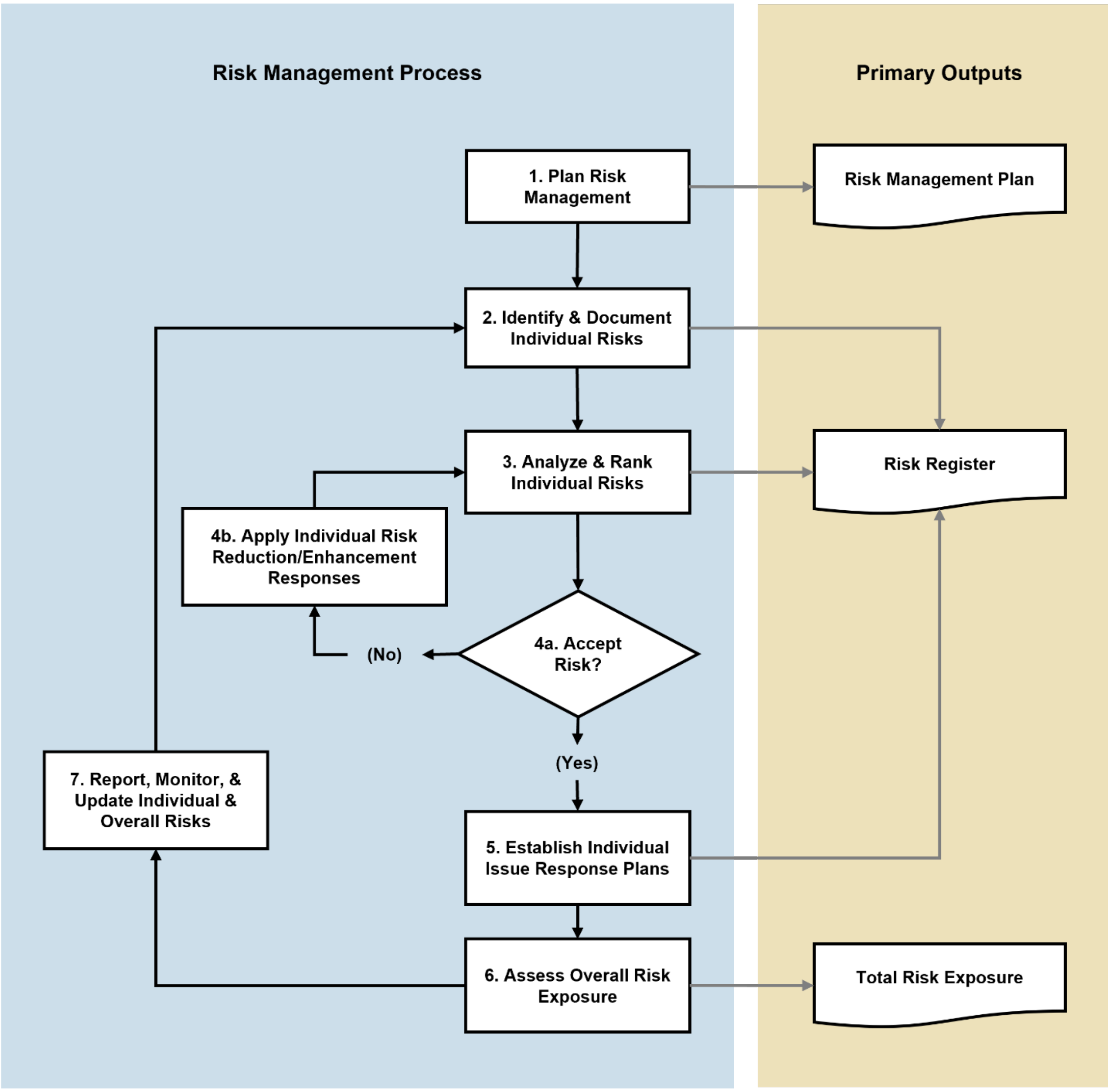
Table 4.6-1
Risk, Opportunity, and Threat per RIG Definition

Item	*RIG* Definition	Note/Comment
Risk	A potential event that, if it occurs, may have either a positive or negative impact on the objectives of an RI effort.	Contrary to our everyday idea of what *risk* means, a project risk could have either a positive or a negative effect on progress toward project objectives. There is also often confusion between risks and hazards; risks are programmatic concerns (e.g., impacting RI scope, schedule, or budget), while hazards are safety concerns (e.g., posing a physical danger to RI equipment or personnel.)
Opportunity	A risk that, if it occurs, may have a positive impact on the RI effort.	The goal of risk management is to enhance opportunities by increasing either their likelihood of occurring and/or their impact if they do occur.
Threat	A risk that, if it occurs, may have a negative impact on the RI effort.	The goal of risk management is to diminish threats by decreasing either their likelihood of occurring and/or their impact if they do occur.

The risk management strategy and process outlined in this *Guide* are based on standard project risk management principles adapted to NSF RI efforts. While many guides for risk management exist, the most effective approaches and processes are those that are tailored and scaled to the size, characteristics, organizational culture, structure, and circumstances of each RI. For example, risk management plans suitable for operations may differ from plans for construction of facilities. Simple, low-risk projects may use basic tools and methods implemented by Project Team members, while more complex, high-risk projects may require sophisticated tools and employ risk management experts. Further, risk management planning is often best served via a progressively elaborating approach: simple methodologies and procedures adopted early in the RI planning may be replaced with more sophisticated approaches as planning matures or as a need for new or changed approaches becomes apparent during execution of the RI effort.

The typical risk management process entails seven key steps and three key outputs, as shown in Figure 4.6-1.

Figure 4.6-1
A Typical Risk Management Process with Seven Steps and Three Outputs



The steps of the process are repeated at a regular cadence to ensure all relevant risks are captured, documented, analyzed, and appropriately responded to as the RI effort progresses.

A summary explanation of the seven steps of the risk management process is as follows. For more detailed information, see the seven respective sections below.

- **Plan Risk Management**. The primary output of this step is a documented Risk Management Plan. The Risk Management Plan lays out the overall approach to how risk will be addressed in the effort, including overall risk tolerance and strategies. The Risk Management Plan also describes the methods and processes to be used during the management of risk, roles and responsibilities, reporting cadences, etc.

- **Identify and Document Individual Risks**. The purpose of this step is to identify and document all relevant RI risks. The primary output of this step is the creation of a Risk Register that is populated with all relevant identified risks. The Risk Register is a living document used as a basis for all tracking, analysis, and reporting.
- **Analyze and Rank Individual Risks**. The purpose of this step is to assess each risk in terms of its current probability of occurrence, the impact that would result if the current risk were to occur, and the calculated exposure of the risk.
- **Apply Individual Risk Responses to Reach Acceptable Level.** The purpose of this step is to review the risk and determine if it can or should be accepted in its current state. If it can't or should not be accepted, then risk responses should be applied until acceptable. For negative risks (threats), response typically means avoidance, transference, or mitigation of the risk to decrease its likelihood and/or impact. For positive risks (opportunities), response typically means exploitation, sharing, or enhancement of the risk to increase its likelihood and/or impact. After risk reduction/ enhancement responses are applied, Step 3 is repeated to analyze the residual risk exposure and further reduce the threat (or increase the opportunity). The process is repeated until the risk is accepted.
- **Establish Individual Issue Response Plans**. This step develops initial response plans if/when individual risks are realized, i.e., if the risk occurs and changes from a potential event to an actual issue.
- **Assess Overall Project Risk Exposure**. This step assesses the residual risk exposure of all existing risks combined in the aggregate. This residual exposure should then be covered by RI contingency or some other source of means.
- **Report, Monitor, and Update Individual and Overall Project Risk(s)**. This step communicates the current risk status to key stakeholders (e.g., NSF). It also ensures regular monitoring of existing risks, identifies new risks, retires expired risks, and updates the status of all risks captured in the Risk Register.

The three key outputs or products of the risk management process that apply to NSF life cycle management plans are:

1. **Risk Management Plan.** A documented plan that describes the process by which the RI will follow to perform the seven risk management steps above.
2. **Risk Register.** A document used to capture all identified risks.
3. **Total RI Risk Exposure.** An estimate of the total cost and schedule vulnerability of the RI if/when identified risks are realized. This exposure estimate may then be used to quantify the necessary amount of contingency (budget, schedule, and/or scope/quality) necessary to allay and offset overall RI risk.

While recommended, complete risk management is not necessarily a requirement for every RI effort. For RI Awardees, the minimum risk management process step requirements for each individual life cycle stage are shown below in Table 4.6-2. The individual elements should be tailored and scaled to match the size, complexity, and nature of the RI effort. The elements should also be discussed and agreed upon with the cognizant NSF PO. Also note that if a budget contingency is included in the RI award, then the *recommended* elements in the table will become *required*.

Table 4.6-2

Seven Risk Management Process Steps Per RI Life Cycle Stage

Risk Management Process Per Life Cycle Stage					
	Development Stage	**Design Stage**	**Implementation or Construction Stage**	**Operations Stage**	**Disposition Stage**
1. Create Risk Management Plan	Recommended. E.g., a simple "1-page" Risk Management Plan.	Recommended. Tailored & scaled as appropriate for complexity of design.	Required. Formal Risk Management Plan that is placed under configuration control.	Required, if contingency is used, otherwise recommended.	Recommended. Tailored & scaled as appropriate for planned activities.
2. Identify & Document Individual Risks	Recommended. E.g., a written list of significant risks.	Recommended. Tailored & scaled as appropriate. E.g., simple Risk Register.	Required. Systematic risk identification and creation of Risk Register.	Required. Systematic risk identification and creation of Risk Register.	Recommended. Tailored & scaled risk capture document, as appropriate.
3. Analyze & Rank Risks	Recommended. E.g., qualitative *heat map* of all identified risks.	Recommended. Tailored & scaled as appropriate. E.g., estimated likelihood and impact.	Required. Likelihood (%) and Impact ($) calculated for each identified risk.	Required. Likelihood (%) and Impact ($) calculated for each identified risk.	Recommended. Tailored & scaled as appropriate, ranging from qualitative heat map to quantitative % & $.
4. Develop Risk Responses & Implement	Recommended. i.e., respond to significant (*red*) risks.	Recommended. i.e., respond to all appropriate risks as required.	Required. All identified risks reduced to *accepted* state.	Required. All identified risks reduced to *accepted* state.	Recommended. At minimum, respond to significant risks.
5. Develop Issue Responses	Recommended. Develop issue response plans for significant risks.	Recommended. i.e., develop issue responses as required.	Recommended. i.e., develop issue responses as required.	Recommended. i.e., develop issue responses as required.	Recommended. Develop issue response plans for significant risks.
6. Calculate Overall Project Risk Exposure	Not Required.	Not Required.	Required. Total risk exposure calculated and covered by contingency.	Required, if contingency used, otherwise recommended. Total risk exposure calculated and covered by contingency.	Not Required.
7. Report, Monitor, and Update Risks	Recommended. Update on appropriate cadence.	Recommended. Update on appropriate cadence.	Required. Risk status reported and monitored and updated on appropriate cadence.	Required. Risk status reported and monitored and updated on appropriate cadence.	Recommended. Update on appropriate cadence.

4.6.1 Step 1 – Plan Risk Management

The objective of Step 1 of the risk management process is to create a Risk Management Plan that describes an agreed-upon framework and approach the RI effort will employ during its execution. At a minimum, the Risk Management Plan should address each of the seven process steps outlined above. The development of a Risk Management Plan starts early during the planning stage of a life cycle. It is iterative and continuous, and the Risk Management Plan may need to be re-addressed and updated throughout the life of the RI.

A typical Risk Management Plan includes, but is not limited to, the following elements:

- **Introduction**. The introduction should summarize the purpose and scope of the Risk Management Plan and the goals and objectives of the Risk Management Plan. Also included is a discussion of the overall risk tolerance (i.e., *risk appetite*) of the RI effort and any other high-level considerations, such as the availability of contingency and how it will be managed.
- **Risk Management Organization**. This section includes a list of RI staff who will carry out risk management in the RI effort. A list of their roles and responsibilities is included, along with a corresponding organizational chart and/or Responsible, Accountable, Consulted, and Informed (RACI)-type matrix that describes who is responsible, accountable, consulted, and informed on risk activities during the RI effort. (See Table 4.6.1-1 Example Risk Management Roles and Responsibilities Table for typical risk management roles and responsibilities during an RI effort.)
- **Risk Management Framework**. The section describes and explains the approaches, methods, and tools that will perform the iterative steps of the risk management process (i.e., identification and documentation, analysis and ranking, risk responses, issue response plans, risk exposure estimation, and monitoring/updating/reporting).
- **Additional Sections**. This includes any additional information necessary to explain how risk management will be carried out during the RI effort. Depending on the characteristics of the RI effort, these sections may include appendices, templates, checklists, a glossary of terms and acronyms, and so on as required.

Good Practices and Practical Considerations

- Maintaining a Risk Register is a beneficial practice for all life cycle stages, even when contingency is not involved, and a formal Risk Management Plan is not required.
- When developing a Risk Management Plan, several factors should be considered, including how sophisticated and detailed the Risk Management Plan itself needs to be. The risk framework (methodologies and tools) should be tailored and scaled to the RI's characteristics, including scope, complexity, and overall *risk appetite* of the RI. For example, a major-scale construction project that includes several challenging procurements and complex in-house tasks may require commercial risk management software and the employment of a specialized risk manager, while a simpler operations-type RI effort that entails oversight of largely repetitive tasks may be adequately served by in-house spreadsheets and simple algorithmic or scaled

contingency estimations.

- After drafting and approval, the Risk Management Plan is typically kept under configuration management. The Risk Management Plan should be periodically reviewed but only formally revised as strictly necessary, such as during a project re-baseline or major change in project plans and assumptions. In contrast, a Risk Register is continuously updated to reflect the project's current status and evolving knowledge and understanding of the RI's risks.
- Good practice is to assign a single risk manager who is responsible for the Risk Management Plan and leads the ongoing execution of the risk management process. For smaller, less complex RIs, this assignment is typically given to an existing staff member with other duties and responsibilities (e.g., project manager or system engineer). In contrast, for large and complex RI, the risk manager may solely be responsible for risk-related duties and overseeing the Risk Management Plan. A focused risk management team may also be formed. Outsourcing or contracting risk management may also be preferred, depending upon the nature of the RI.
- Proper risk management is vital to RI's success. As such, the activities and associated costs related to risk management should be captured during planning and accounted for in the RI budget and schedule. These costs should include team member time focused on risk during the execution of the RI, as well as discrete costs such as commercial risk management software and licenses and the hiring or contracting of risk management experts.
- Proposed Design project Awardees should note that the Risk Register covering the design award activities is distinct from the Construction Stage Risk Register included in the PEP as a Design Stage deliverable. The risks in the Design Stage are not the same as those that will be encountered under a separate construction award.

Table 4.6.1-1
Example Risk Management Roles and Responsibilities Table

Position	Roles and Responsibilities
Project Management	• Encourage all levels of the project organization to participate fully and openly in the risk management process. • Make project decisions based in part on the results of risk analysis and authorize risk response implementation.
Risk Manager	• Oversee the Identification and documentation of new risks (threats and opportunities) in the Risk Register and assign risk ownership. • Oversee Project Team's analysis of risks and work with them to develop initial and remedial response plans. • Monitor and update risks and identify lessons learned. • Recommend and champion response implementation strategies to the Project Manager (PM) and/or Change Control Board (CCB) on behalf of the risk management team. • Maintain the Risk Register and report risk status to stakeholders. • Oversee Project Risk Exposure estimation.
Change Control Board Members	• Review and approve proposed changes to ensure alignment with project objectives and minimize risks to project success. • Provide input and guidance on change prioritization, resource allocation, and impact assessment to facilitate informed decision-making and effective change management. • Typically chaired by a senior project manager, project sponsor, or another high-level stakeholder with authority to make decisions regarding changes to the project.
Project Team Members	• Participate in risk identification, analysis, and response planning on a daily basis, as well as in risk workshops, status meetings, and interviews to provide risk data. • Assist the risk manager and risk owner with monitoring and updating risk status.
Risk Owner	• Assist the risk originator (project manager, risk manager, Project Team member, etc.) with the development of the risk descriptions, analysis, and development of risk response plans. • Implement or be responsible for the implementation of risk response plans. • Monitor assigned risk triggers and status and update the Risk Register as needed. • Attend project status and risk review meetings, as needed, and assist the PM with reporting risk status. • Contribute lessons learned.

4.6.2 Step 2 – Identify and Document Risks

The objective of Step 2 of the risk management process is to discover and formally capture all relevant risks (both threats and opportunities) that impact the RI's successful execution. Risk identification should follow a regular, logical, and systematic approach for ascertaining, describing, and documenting all relevant and specific events that might impact an RI's goals, constraints, and objectives (such as scope, schedule, budget, and performance). Note that the availability and use of NSF-awarded contingency depends upon the existence of a complete and accurate listing of risks, i.e. any Change Request that draws on contingency **must** be tied to specific identified risks in a Risk Register.

Risk management guidelines typically divide risks into identifiable discrete risk events and Estimate Uncertainties (EU). Discrete risks are unplanned events that are either threats (negative impact on project parameters) or opportunities (positive impact on parameters.) EU represent designers' and estimators' uncertainty in capturing all scope, completely understanding all the work required to execute the scope, and accurately predicting cost and schedule for work in the future. Unlike discrete risks, EU can be simultaneously potential threats or opportunities. As an example, the duration for completing a task is uncertain, ranging between 20 days and 50 days. If the Project Team uses 35 days as the most likely duration in the baseline schedule, then there would be a time savings (opportunity) if the task is completed in 25 days or a delay in completion (threat) if it takes 42 days. In contrast, an identified discrete risk event of late delivery of a key component from a vendor is always a threat. Some projects may choose to treat the EU as they treat discrete risks and include them as threats (ignoring the opportunity aspects) in the Risk Register and analysis as cost and schedule drivers. Others may choose to treat the EU via a different process and carry them separately (e.g., as allowances in the BOE, see Section 4.3.4.2 Construction Cost Book and Basis of Estimate Overview). The Risk Management Plan should describe how EU will be identified and managed (see Section 4.3 Cost Estimating and Analysis). Note that each risk in a Risk Register should have a single root cause; thus, EU captured in the Risk Register should not be conflated or bundled with discrete risks to create single group of similar risks, also called *omnibus* Risk Register entries, i.e., EU should be treated separately as standalone risks.

As risks are identified, they should be captured and documented in a Risk Register, which is an itemized listing of all identified threats and opportunities that currently exist within the RI life cycle stage. Depending on the nature of the RI, the Risk Register can take a variety of forms, ranging from simple lists to detailed spreadsheets to commercial database programs. Regardless, for each identified risk, the Register should capture at a minimum:

- **Unique Identifier**: A unique code or number for effective reference and tracking throughout the project life cycle. Once assigned, the identifier should never be changed for an individual risk, nor be deleted or re-used after a risk is retired. Example: 0045.
- **Risk Title**: A brief narrative-type name or title for risk. Example: Rocket launch weather delay.
- **WBS Element**: For RI efforts with a WBS, the risk **must** be associated with at least one WBS element.
- **Ownership**: Clear assignment of the individual responsible for assessing and tracking the risk and implementing any required responses. Example: Joanne Smith.
- **Risk Description**: A concise yet informative explanation of the potential issue, devoid of ambiguity, and usually includes an *if-then* statement. Example: If a storm with either nearby lightning or sustained winds over 25 mph occurs on the rocket launch day, then we will have to scrub the launch and reschedule, which will delay subsequent work and cost additional unplanned money.

Table 4.6.2-1
Sample Risk Register

Risk Description			Probability of Occurrence		Impact of Occurrence		Risk Exposure		Notes / Comments / History
Risk Status	Risk Statement	Trigger Date	Qual	Quan (%)	Qual	Quan ($)	Qual	Quan ($)	
Open	There is a possibility of inclement weather delaying transport of the widget to the construction site. If this happens, then it would delay installation of the widget into the facility, which pushes the project end date out, costing time, money, and stakeholder frustration.	June 1	Mod Likely	50%	Major	$300,000	High	$150,000	3/3/2026: We've reviewed this risk with Khalid, Sally, & Joe. We recognize we have no control over the probability of a weather event, and then impact is fixed by marching army costs. We also looked at accelerating the delivery, but the vendor assures us they can't finish before the scheduled FOB date in contract.
Open	There is a high likelihood the state-of-art widget will fail the first time we test it. If this happens, then it could clog the downstream equipment, causing a shut-down of the entire system.	July 9	Very Likely	90%	Minor	$10,000	Medium	$9,000	4/4/2025: This isn't a very serious risk, as the widget test is not on the Critical Path, and we have a lot of schedule float. This will need to be dealt with if it happens, so perhaps we can purchase a backup widget now, so impact is minimized.
Closed	There is a possibility the kazoo union will strike. If this happens, then it would shut down construction site until the situation is resolved.	Jan 15	Unlikely	10%	Major	$300,000	Medium	$30,000	10/4/2025: Union vote date is the trigger date. We will meet with the union rep and offer bonus pay. 10/22/2025: We met with union, and they expect low probability. 1/16/2026: Union voted not to strike. Risk can be retired.

Additional entries that are typically included in the Risk Register for each identified risk are described below in Steps 3, 4, and 5. Because the risk management process is iterative, new risks may be recognized over time, requiring immediate identification, assessment, and incorporation into the register. The Risk Register is thus a living document, meaning that it is continuously evolving in tandem with the RI's maturation and progress.

Note that not all risks are the responsibility of the Awardee. High-impact, difficult to predict, and rare events (unknown-unknowns) that are outside the control of a project may be noted if recognized, but they are not included in the risks under project management and control. Table 4.6.2-2 Known-Unknowns lists the different categories of risks and the responsible party, with examples of typical risks in each category.

Table 4.6.2-2

Known/Unknowns Risk Examples

Known/Unknown Risks			
	Known-Knowns	**Known-Unknowns**	**Unknown-Unknowns**
Definition	Established elements of the project scope, captured in the project WBS, scheduled, and budgeted, typically developed from bottom-up estimates. There may be some residual uncertainty tied to the estimates of these elements.	Recognized risks and uncertainties with unknown specific outcomes or details.	Significant threats to the project, which are either unknowable during the project planning process or are unreasonably too large to carry as a managed risk in the project's Risk Register.
Responsibility	Awardee	Awardee	NSF
Handled Through	Standard day-to-day management of the baseline (scope, quality, schedule, & budget).	Formal project Change Control implemented via use of budget contingency, schedule contingency, reductions in project scope and/or quality acceptance criteria.	Formal re-baseline process and the requested use of management reserve, project schedule extension, and/or significant project scope changes.
Example	A project to build a scientific instrument. Scope and quality requirements are developed by way of progressive elaboration by project subject matter experts (SME) and documented in WBS and technical specifications. Integrated project schedule and budgets are then developed bottom up. There is some uncertainty of cost and schedule estimates; these are included as specific line items in the project Risk Register and will be covered by use of project contingency if/as required.	A performance risk exists with an important aspect of the scientific instrument being built in-house: E.g., "If our team cannot meet the wavelength coverage requirements in time, then instrument will not be able to achieve full scientific capability." If this happens, the Project Team has a choice of issue responses, such as: write a Change Request to replan and hire an external vendor to expedite and improve performance; and/or write a Change Request to slip the project schedule to accommodate the delay while the team continues to work; and/or write a Change Request to change the technical specifications and accept the reduced science capability of the instrument.	An earthquake hits the construction site and knocks out the production of critical components of the science instrument. The vendor doing this work is a sole-source supplier, so there are no reasonable alternatives available. A major re-plan, extension of the project schedule, and/or cost increases would be required. As a result, a supplemental funding request would be submitted to NSF asking for management reserve monies and a formal extension of the award end date.

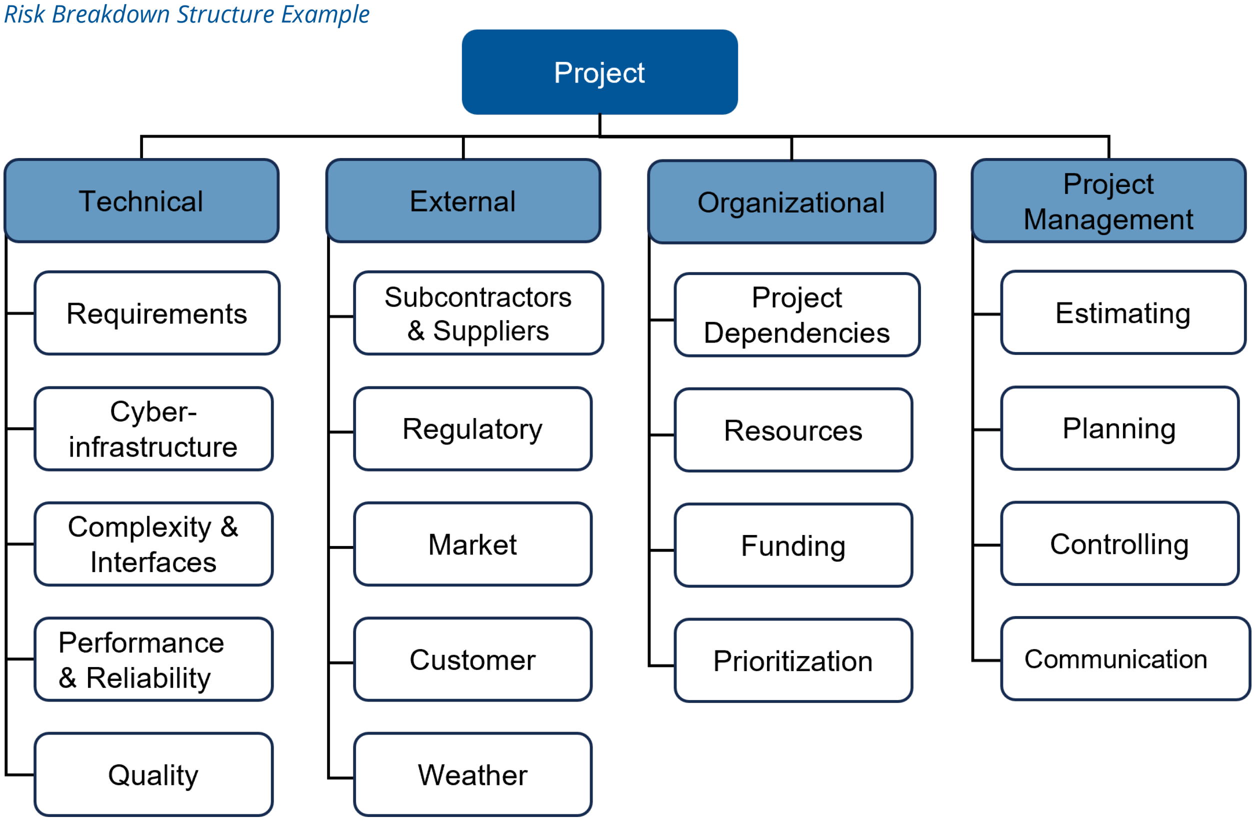
Good Practices and Practical Considerations

- Early in RI initiation and conceptual planning phases, risks that should be formally tracked are often hard to distinguish from less well defined and/or general worries and concerns. It may be enough to create a list of major concerns and consequences in a simple text document at the start of the RI and then transition to a formal Risk Register as planning matures.
- Maintain a single register, update it with the particulars of the current state of the risks (pre- or post-mitigation), and periodically archive to maintain a record of mitigation plans and risk management. Pre-mitigation impacts and probability are included until a risk reaches acceptance, at which point the Register should be updated to reflect the residual risk probability and impacts.

- If a risk passes its trigger threshold or is otherwise no longer applicable, then the risk is marked as retired but remains in the register for record keeping.
- A Risk Register should include only single root cause risks. If the risk is common to several unrelated project deliverables, the risk may be raised to a single, higher-level project management category risk or similar. If there are several root causes, the risks should be separately listed for each root cause.
- Stating and describing risks in very specific *if-then* formats with corresponding root causes should be emphasized and encouraged by all participants in the risk process, as it helps fully understand the likelihood and impact of each risk in clear, unambiguous terms.
- EU can be handled in a multitude of ways. For EU included as threats in the Risk Register, some projects use Maturity Level or Cost Estimate Classification tables to assign threat probabilities and impact levels to project elements based on design maturity and technical demands, while others use SME judgment. For Monte Carlo simulations, some projects assign EU to elements as 100% probable risks that retain their dual opportunity and threat natures, with a plus or minus range around the point estimate. The latter is most often used by large projects to include the cumulative impact from many low-level EU, while EU with high consequences is included in the Risk Register as impact drivers.
- It's a common mistake for RI teams to focus solely on the identification of threats, not opportunities. Opportunities, especially high-impact ones, may be low-hanging fruit that can provide significant benefit to the project, increasing its likelihood of success.
- A Risk Register should be readily available to be filtered and sortable by WBS, risk type, ID, owner, likelihood, impact, and other categories.
- Ideally, identification is performed by all RI personnel and available SME, the Awardee's director and manager, and external stakeholders. Additionally, the NSF PO and AO often have useful input to add that is based on their unique positions, perspectives, and experience.
- To ensure all relevant risks are identified, the RI team should adopt a multi-pronged approach. This may involve:
  - Facilitated brainstorming sessions; risk identification meetings; focused risk-based interviews; specialized strength, weakness, opportunity, and threat assessments; reviews of documented lessons learned on similar projects; leveraging historical data from analogous projects.
  - A structured review of key project stages, objectives, and WBS deliverables. Also, standardized Risk Breakdown Structure and/or classification/category lists and frameworks to ensure a comprehensive assessment, covering categories like technical, schedule, cost, resource, and external risks (see Figure 4.6.2-1). Note also that the OMB provides guidance on risk categories that can be used. See also the *GAO Cost Estimating and Assessment Guide*, GAO-09-3SP, Chapter 14.
- The RI Risk Register should generally be accessible to all RI team members (e.g., in read-

only access format). The primary objective of this is to keep the team thinking proactively about threats and opportunities, risk responses, and the like. Further, a means by which RI team members may readily comment on existing risks or submit new risks should be included in the Risk Management Plan.

Figure 4.6.2-1
Risk Breakdown Structure Example



4.6.3 Step 3 – Analyze and Rank Individual Risks

The objectives of Step 3 of the risk management process are to analyze each individual risk in the Risk Register, assign a specific likelihood and impact, and calculate the resulting individual risk exposure value. These values are then added to the Risk Register as additional related data for the risk. With this information, the risks can be ranked according to their consequences, providing a guide for strategically focusing resources and mitigation efforts on the most critical risks.

At the end of Step 3, each identified risk in the Risk Register should have the following information, with a supporting basis of estimate, added:

- **Likelihood Assessment**: A data-driven or expert-informed evaluation of the probability of the risk occurring. Example: Based on historical weather data, there is a 35% chance of bad weather on the launch day.
- **Impact Assessment**: A thorough evaluation of the severity of potential consequences if the risk occurs, usually expressed in time and/or monetary units. Example: The impact of a launch delay is calculated to be three months at a total cost of $1M.

- **Risk Exposure Assessment:** The mathematical expected impact value of the risk is the probability-weighted risk exposure, obtained by multiplying the risk likelihood and impact together. Example: The calculated risk exposure is 35% x $1M = $350K.
- **Trigger Date**: A date(s) on which the risk might occur. Sometimes also known as a *retirement date*, if this date is passed, the risk can usually be retired or removed from the Risk Register. Note also that risk trigger dates can inform contingency profiles required by the RI effort. Often, an explanatory description is included with the date. Example: Trigger Date - April 15. Per the weather service, historically this is the latest date in the year for significant winter storms to impact the launch area.
- **Risk Rank:** A subjective assessment of risk importance according to a ranking matrix.

Risk analysts may choose to start assessment with a completely qualitative analysis early in the planning by choosing to sort risks into subjective high to low bins for probability or likelihood of occurrence and impacts, without performing in-depth quantitative assessment of the bin boundaries or the value of the likelihood and impacts. Ranking is then accomplished by creating a matrix with likelihood on one axis and impacts to project parameters on the other. The choice of parameters should match the project characteristics, such as cost, schedule, and quality/performance impacts. The cells in the resulting risk ranking matrix or heat map are then subjectively ranked and labelled; assignments of high, medium, and low, for example, are typically used. Note that a qualitative ranking assessment carried out early in the project planning when probabilities and impacts are only roughly known can be useful in identifying which reduction and mitigation efforts will be most beneficial to the project and should therefore be included in the project baseline as planning progresses.

Once planning has advanced to a sufficiently mature stage, the bins boundaries can be determined, and the assessment of the likelihood and impacts narrowed to estimates backed by data and/or SME judgement. The number and assigned values in the ranges should have enough granularity to separate risks into meaningful ranking assignments. Again, the choice of parameters in this quantitative ranking should match the project characteristics. Some projects may choose to use the probability-weighted risk exposure as representative of overall risk importance and ranking, while others may choose individual impacts such as cost, schedule, and quality and performance impacts. The ranking values assigned to cells in the ranking matrix are based on subjective judgements by the analysists. The resultant heat map is a qualitative or subjective binning of quantitative inputs. Table 4.6.3-1 provides an example of a ranking heat map. The map inside the dark boundary is representative of a qualitative ranking analysis, while the entire map, with quantities assigned to the probability and impacts represents a thorough assessment of risk importance.

Table 4.6.3-1
Example Risk Matrix or Heat Map

Probability	Probability Value	Impact Ranking				
> 0.8	**Very High**	MEDIUM	HIGH	HIGH	HIGH	HIGH
> 0.6 and < 0.8	**High**	MEDIUM	MEDIUM	HIGH	HIGH	HIGH
> 0.3 and < 0.6	**Moderate**	LOW	MEDIUM	MEDIUM	HIGH	HIGH
> 0.1 and < 0.4	**Low**	LOW	LOW	MEDIUM	MEDIUM	HIGH
< 0.1	**Very Low**	LOW	LOW	LOW	LOW	MEDIUM
	Impact Value	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
	Cost Impact	< $20K	$20K to $100K	$100K to $250K	$250 to $1M	> $1M
	Schedule Impact	< 1 week	< 1 mon.	1 – 2 mos.	2 – 4 mos.	> 4 mos.
	Scope Impact	Negligible scope impact	Minor scope impacts	Significant scope impacts	Major loss of science	Loss of science mission
	Performance/ Quality Impact	Negligible impact on goals	Doesn't meet all desirable goals	Doesn't meet all essential goals	Doesn't meet key goals	End product effectively useless

Good Practices and Practical Considerations

- Good practice when performing quantitative analyses is to document assumptions, supporting data, and the estimate calculation itself as a basis of estimate. Besides validating the estimate, knowledge of the underlying assumptions and calculations will be helpful when impacts need to be re-evaluated over time. The probability that a risk may occur and the impact if the risk were to occur should be evaluated separately before combining the two parameters in a risk matrix. The idea that *the risk is unlikely so its impact will be low* confuses the two parameters of probability and impact. To mitigate this effect, SME should be asked to estimate the impact as if the risk had occurred.
- It is often useful to begin the assessment of a risk impact on separate project objectives such as time, cost, scope, or quality/performance impact ranges rather than creating a single, overall risk impact. Ranking levels are defined for each separate objective to ensure the full extent of the impact is captured. For instance, a particular risk can be judged to have a high impact on time but a moderate impact on cost and a low impact on scope. It is also important to note that the impact of a risk may have secondary or indirect consequences on other aspects of the RI that should be captured.

4.6.4 Step 4 – Determine and Apply Individual Risk Reduction / Enhancement Responses

The objective of Step 4 of the risk management process is to evaluate each identified risk documented in the Risk Register and determine whether a response action can or should be undertaken or whether the risk can be accepted as is. Note that in this context, the term *accept* means that no further actions are practical, possible, or should be applied due to excessive cost relative to the benefit that may be obtained. Actions taken in this step are called risk reduction/enhancement responses, or simply risk responses, for short.

A risk response is performed by selecting and applying appropriate methods that minimize the threat's likelihood and/or impact (or maximize the opportunity's likelihood and/or impact). After the determination and application of appropriate risk responses, the remaining risk is known as the *residual* risk. This residual risk state wholly replaces the previous information state of the identified risk in the Risk Register and is then tracked and managed accordingly, i.e., the Risk Register should always reflect the current status of each individually identified risk, either before or after a risk response has been applied.

All documented risks in the Risk Register should be responded to using three primary methods until the residual risk is *accepted*, meaning further responses are no longer necessary or beneficial. Risk response methods for reducing threats typically fall into three primary categories:

- **Avoidance**. These are actions taken to reduce the likelihood of the threat occurring. Example: Adjust the schedule of work activities to perform the launch when storms are less likely to happen and therefore delay the effort.
- **Transfer**. These are actions taken to shift the impact of a threat to a third party if the risk is realized. Example: Using a fixed-price contract transfers a portion of the risk to the vendor.
- **Mitigation**. These are actions taken to reduce both the likelihood and/or impact of a threat. Example: Development of efficient de-fueling processes and specialized storage equipment to speed the process if the launch has to be scrubbed.

Similarly, risk response methods for enhancing opportunities fall into three types:

- **Exploitation**. These are actions taken to increase the likelihood of an opportunity occurring. Example: Invest in early training to take advantage of new technology expected to come out that, if implemented, could cause an overall shortening of the project schedule.
- **Sharing**. These are actions taken to increase the overall impact of an opportunity by sharing the benefit with a third party. Example: Partner with Vendor X to increase the performance of a standard component they sell; the RI project benefits from the improved performance, while the vendor's development costs are reduced/shared with the RI effort.
- **Enhancement**. These are actions taken to increase the likelihood and/or impact of an opportunity. Example: Change the schedule to stage procurements in batches in order

to take advantage of volume discounts.

Good Practices and Practical Considerations

- Before applying any risk response, one should consider whether the cost of the response outweighs the benefit. Only when the benefit is greater than the cost of responding should it be applied. As such, risk thresholds and response trigger points need to be determined and factored into the decision to apply risk responses.
- Early in the RI life cycle, the monetary cost of a risk response can and should be added to the baseline budget, and the time required to implement the response is included in the RI schedule. Later, once the performance measurement baseline is set and the RI effort is underway, the cost of responses for newly identified risks will likely require the application of contingency, i.e., the earlier risks can be identified, analyzed, and responses planned, the less pressure on contingency will occur.
- The impact of an individual risk may be modest and still be considered a high or very high priority for mitigation. This is because the combined or aggregate impact of many moderate risks may be high. The Project Team may want to mitigate some low or moderate risks to reduce the combined threat from many risks.
- Project management literature typically includes four responses to both threats and opportunities, including *acceptance*. The guidance given here is based on the actual sequence of actions, employing the first three risk responses to bring the threat or opportunity to an acceptable level, followed by the *acceptance* response. All risks are accepted before applying the issue responses as necessary.

4.6.5 Step 5 – Establish Issue Response Plans

The objective of Step 5 of the risk management process is to establish plans for responding to issues, or realized risks, as they are also known. As its name implies, an issue is a risk that has come to fruition. A risk may or may not occur, while an issue is an event that has occurred. When a risk becomes an issue, it is addressed via an issue response plan.

Issue responses are commonly confused with risk responses, which address ways to handle potential risk impacts before the risk is realized. Issue responses are the steps that will be taken to address an unplanned event if and when it occurs.

Example: If a storm arrives at the site on launch day, we will de-fuel the rocket, move it to a safe location, and transition its state from launch mode to temporary storage mode. We will also need to move the team onto other work to keep them engaged while we wait for another launch opportunity, readjust the schedule, and release contingency monies to pay for these impacts.

The Risk Register is the central hub for documenting risks, assessments, and even risk response plans. Issue responses may also be contained within the Risk Register, or at a minimum, links to detailed issue responses can be included in the Risk Register.

Good Practices and Practical Considerations

- The value of developing issue responses should not be overlooked. Taking the time to consider potential scenarios and issue responses often will help inform risk reduction/enhancement responses as well. The details of the plans may change, but the planning is still indispensable.
- Developing issue responses also has the benefit of helping estimate the current impact of a risk, i.e., if the risk is realized, then a number of actions and results will need to occur, all of which have cost, schedule, and/or performance impacts.
- Issue and *what-if* planning also keeps risks at the forefront in the teams' mind, training them to always be in a problem-solving mode.
- When an issue does occur, a good practice is to document it in an issue log so that it can be tracked and managed. Transferring the realized risk from the Risk Register to the issue log may be necessary. The format of an issue log varies with the size and complexity of the RI effort but typically includes such things as issue number, name/description, associated risk ID, date of occurrence, impact assessment, status, assignee, and other/related information. Issue logs can also serve to inform any lessons learned documents at the conclusion of the RI effort.

4.6.6 Step 6 – Assess Total Risk Exposure

The objective of Step 6 of the risk management process is to estimate the total risk exposure, which is a measure of the entire vulnerability of the work effort to risk and estimate uncertainties. Estimated risk exposure can then be used as the basis for establishing an appropriate amount of contingency to be used to offset risk consequences. An allocated amount of continency that is equal to or larger than the total project risk exposure helps ensure that the work can be successfully completed within the TPC and TPD (see Section 4.7 Contingency Estimating and Management describes methods of calculating contingency). There is a large range of methods and techniques to calculate total risk exposure. This section should focus on demonstrating a selection of quantitative methods of analysis.

The method chosen by the Awardee should be tailored and scaled to the project characteristics and needs, the available tools, and processes available to the organization, and the capabilities and experience of the project Risk Managers. Simple projects and those considered to have low risk may obtain adequate risk exposure estimates using algorithmic or parametric methods that entail low overhead and effort (e.g., risk factor analyses). Complex and high-risk projects will likely benefit from more sophisticated probabilistic methods, such as Monte Carlo analysis.[1] Regardless of chosen method, the Awardee should ensure that adequate expertise and a thorough understanding of the project's characteristics are available and applied. For example, Monte Carlo methodologies generally require specialized risk management expertise to obtain reasonable results as project

[1] Major Facility construction projects are required by NSF to make use of probabilistic risk exposure methodology to determine risk exposure used as a basis for estimating contingency amounts.

complexity increases.

The following content describes some of the more common estimating methodologies, starting with algorithmic, progressing through parametric, and ending with probabilistic methods using scaled applications of Monte Carlo simulations.

4.6.6.1 Algorithmic Method – Risk Register Exposure Sum

If a Risk Register exists, the simplest algorithmic method of estimating total risk exposure is a summation of the individual calculated risk exposures in the Register from threats (excluding those from opportunities).[1] Note that estimate uncertainties can also contribute to total risk exposure. If these uncertainties are not included in the Risk Register (and therefore summed up along with other risks), accommodation needs to be included to factor their effect into the overall total risk exposure summation. Table 4.6.6.1-1 shows an example of overall project risk exposure determined by summing the individual risks exposures in a Risk Register.

The Risk Register exposure summation method can be used by simple projects for both the initial risk exposure calculation and subsequent updates as work progresses. More complex projects can use this method as an early planning tool before transitioning to more complex methods for establishing overall risk exposure as planning matures. The utility of the total risk exposure calculation with this method depends upon the statistics (>10 risk entries) and the thoroughness of the risk identification and analyses. Project Teams should be careful to ensure that correlations between risks are included as much as possible when estimating the total impact. For example, if the price of steel unexpectedly increases due to global market conditions for one procurement, then all similar future procurements involving steel will likely be also affected.

[1] This method is similar to Expected Monetary Value calculations used in business and economic calculations.

Table 4.6.6.1-1

Example Risk Register Exposure Summation

Risk ID	Risk Title	Risk Description	Estimated Risk Probability	Estimated Cost Impact	Estimated Schedule Impact	Cost Risk Exposure (Probability x impact)	Schedule Risk Exposure (Probability x impact)
001	Weather Event	If a severe weather event disrupts transportation, then delivery will be delayed, resulting in a schedule delay but no cost increase.	25%		4 weeks		1 week
002	Widget Failure	If the widget fails during testing, then a replacement will need to be found, resulting in cost and schedule increases.	10%	$50,000	12 weeks	$5,000	1.2 weeks
003	Gizmo Cost Estimate Uncertainty	Cost uncertainty estimated at 35% of baseline cost of $128,000, due to design maturity at conceptual level.	15%	$44,800		$6,720	
			Total Risk Exposure Sum			**$11,720**	**2.2 weeks**

4.6.6.2 Parametric Method – Risk Factor Analysis

Risk factor analyses to approximate mathematical calculation of total risk exposure have been successfully used in both Mid-scale RI and Major Facility efforts. These parametric analyses use historically derived look-up tables to estimate uncertainty factors for technical feasibility, cost estimate uncertainties, and schedule impacts on each element of an RI's WBS at a common level (e.g., Level 3 of the WBS). These uncertainty factors represent both discrete risk events and estimate uncertainties in a single risk exposure analysis. The factors are combined and multiplied by the cost estimate for each element of the WBS and then summed overall WBS elements. Note that this method results only in cost risk exposure since schedule exposure is converted to a monetary value, not a time or duration. Additional analysis with other methods should be used in tandem with risk factor analysis if an estimate of total schedule risk exposure is needed to support schedule contingency estimation.

See Table 4.6.6.2-1, below, for an example of a risk factor table. Risk managers need to adjust the table to suit the characteristics of the work at hand. Projects that are particularly sensitive to schedule delays, for example, may want to use a schedule multiplier of two rather than one, as assumed in the example table, or change the ranges or uncertainty factors for the number of days of slippage.

For example, imagine that a specific WBS element has the following attributes:

- **Technical**: The design of the WBS element is a new one that requires some research and development but does not advance state-of-the-art. The risk exists in both the design and the manufacturing areas of this item.

- **Cost**: The existing cost estimate was based on strong engineering judgement, i.e., an in-house estimate for required staff labor that was based on subject matter experience. This WBS item is almost entirely comprised of labor costs (i.e., no significant material costs are part of this item).
- **Schedule**: The activities associated with this WBS element are not on the project's Critical Path but would impact it if delayed more than a few days and will then cause an overall project slip.
- The overall cost estimate for this item is $10,000.

From Table 4.6.6.2-1 below, we see that:

- **Technical** Risk Factor: 8%; and Technical Multiplier: 4
- **Cost** Risk Factor: 4%; and Schedule Multiplier: 1
- **Schedule** Risk Factor: 8%; and Schedule Multiplier: 1

Therefore, the risk factored exposure percentage for this WBS item is: [(8% x 4) + (4% x 1) + (8% x 1)] = 44%. As a result, the specific risk exposure of this specific WBS item is: 44% x $10K = $4,400.

The overall risk exposure of the entire project is obtained by performing similar analysis on each subcomponent or WBS element and summing the results.

Table 4.6.6.2-1

Example of Risk Factor Tables Used to Calculate Total Project Cost Risk Exposure

Description of Area's Technical Type or Status	Technical Uncertainty Factor
No technical risk	0%
Existing, previoiusly built design that uses commonly-available off-the-shelf hardware	1%
Minor modifications to an existing design that has been previously built	2%
FDR-approved design	2%
Extensive modifications to an existing design	3%
New design within existing product line	4%
New design different from existing product line, using existing technology	6%
New design that requires some R&D but does not advance the state-of-the-art	8%
New design using new technology that advances the state-of-the-art	10%
New design far beyond the current state-of-the-art	15%

Technical Multiplier	Technical Multiplier
Not Applicable	1
Technical work is for Design or Manufacturing	2
Technical work spans both Design and Manufacturing	4

Description of Area's Cost Estimate Methodology	Cost Uncertainty Factor
No cost risk	0%
Firm-fixed price contract in place	1%
Off-the-shelf catalog item	1%
Vendor quote created from detailed SOW and/or Vendor quote from established drawings & specs	2%
Vendor quote from detailed drawings	2%
Vendor quote within 180 days, created from design sketches	3%
Professional estimator's estimate within past 180 days using established drawings, specs, designs	3%
Engineering judgement based on strong experience or recent history or by Subject Matter Expert (SME)	4%
In-house estimate with minimal experience	6%
Cost-plus contract in place	6%
Vendor quote that is 180-360 days old	6%
Vendor ROM estimate	7%
In-house estimate for item with minimal company experience or capability	8%
Vendor quote that is greater than 1 year old	8%
Top-down estimate from an analagous program or project	10%
Engineering ROM Estimate	15%

Cost Multiplier	Cost Multiplier
Cost Estimate covers either Material or Labor costs	1
Cost Estimate covers both Material and Labor costs	2

Description of Area's Schedule Estimate Methodology	Schedule Uncertainty Factor
No schedule risk	0%
No schedule impact on any other item or activity	2%
Slippage of this element would delay completion of another, non-critical path item (>120 days of float)	4%
Slippage of this element would delay completion of another, near-cp path item (<120 days of float)	8%
This item is on the project's critical path	15%

Schedule Multiplier	Schedule Multiplier
Schedule Risk	1

4.6.6.3 Probabilistic Method – Monte Carlo Simulations

Probabilistic risk analysis (e.g., Monte Carlo simulations) allows the analyst to estimate risk exposure based on many simulations of possible outcomes for selected project objectives.[1] The Monte Carlo simulation method relies on a model of the project objective data (e.g., a schedule, cost estimate, or a Risk Register) loaded into Monte Carlo software, along with input values for each objective. The software uses random sampling and statistical modeling to simulate possible outcomes for the project objectives.

The five steps in a Monte Carlo risk exposure analysis are the following:

- Determine the model and estimated outcome (e.g., a summary of WBS Level 3 schedule and projected project end date).
- Collect the inputs (e.g., threat probabilities and cost impact distributions).
- Load the model and inputs into the Monte Carlo simulation software tool.
- Run the Monte Carlo for a sufficient number of iterations.
- Analyze the results.

In its simplest form, inputs are a point estimate (or multiplier) for each element in the model (e.g. cost, duration, risk impact) and a probability or likelihood of the occurrence of that estimate. In the simulation, the Monte Carlo tool generates a random probability of occurrence for each element in turn and compares it to its input probability. If the input probability is less than or equal to the generated probability, the input point estimate is assigned as the output value for that element. Otherwise, the value is not included. The simulation builds an overall outcome for the model by summing the output values for each element in the model. By running many simulations (typically between 1,000 and 10,000 times depending upon the model complexity), a range of possible outcomes for the objectives is generated, e.g., a histogram plot of the outcome of each iteration for estimated total cost, finish date, and/or overall risk exposure. An S-curve of the cumulative frequency of output values returned by all iterations represents the confidence levels that the project will finish within the outcome values for the model. It can also provide an estimate of risk exposure and a basis for the selection of contingency amounts. As an example, Figure 4.6.6.3-1 shows the resultant plot and S-curve for the project end date for a Monte Carlo simulation on a schedule model. The difference between the baseline value and the highest output value in the histogram provides an estimate of the total schedule risk exposure to complete the project with 100% confidence. The 80% level indicated on the S-curve indicates that 80% of the iterations ended on or before the date at that point on the curve. The amount of schedule contingency needed to cover the risk exposure for that confidence level is the difference between the baseline end date and the end date at the 80% confidence level. Said another way, 80% is the confidence level that the project will successfully complete on or

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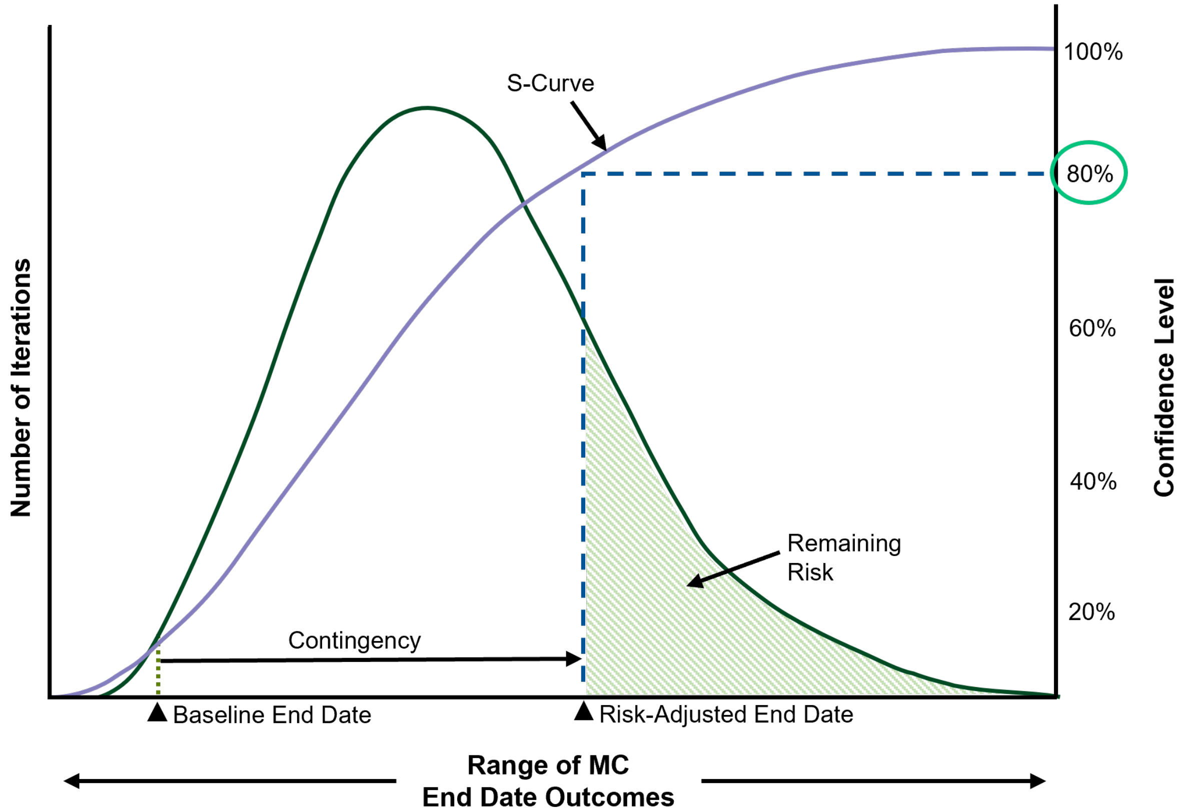
[1] Some risk management guides refer to probabilistic methods as *quantitative* methods while listing algorithmic and parametric methods as *qualitative*. This can be confusing to users since quantitative data is used in all these methods.

before that outcome end date if the estimated contingency amount is available.

Figure 4.6.6.3-1
Graphical Representation of Total Project Duration Using Monte Carlo Simulations Across Various Iteration Counts

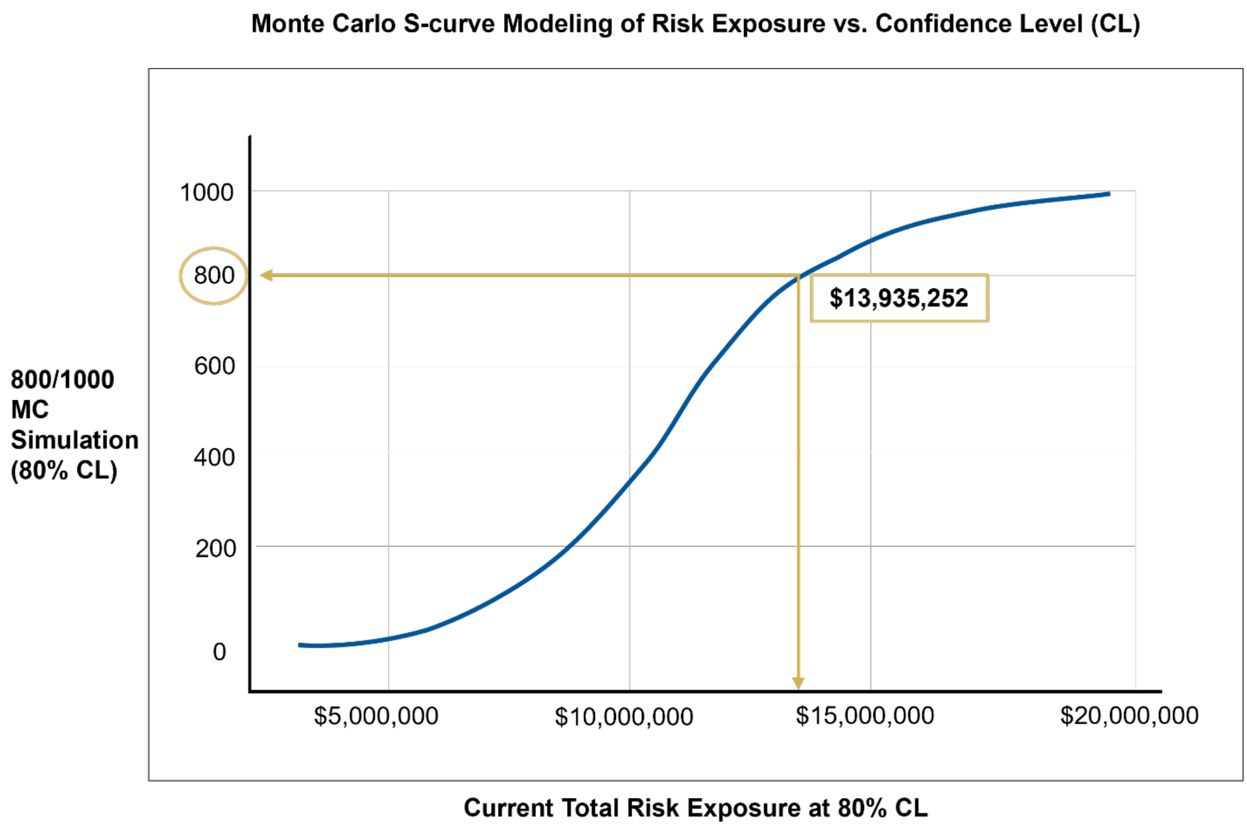


Scaled Monte Carlo Risk Exposure Analysis. The Monte Carlo method can be applied in multiple ways, scaled to match the complexity and/or maturity of project planning. This section should introduce some of the more basic concepts and methods of applying Monte Carlo analysis, but it is not an exhaustive exposition on all the nuances and methodologies that can be utilized. Because the quality of the results relies on the Awardee's understanding of the different types of risks, correlations between risk, the quality of the input data, and the benefits and limitations of various methodologies and tools, most projects will benefit from the involvement of risk management and risk Monte Carlo experts. For large, complex projects this may require hiring dedicated staff for the project duration. For small projects, it may mean obtaining training in-house staff or hiring temporary experts to direct the establishment of risk management tools and methods.

The model for probabilistic risk analysis is typically the project cost estimate, project schedule, or Risk Register. Since most cost estimates and Risk Registers are developed in a spreadsheet, a risk analysis of the project's cost estimate or risk exposure alone is often conducted in a spreadsheet or in a software package that simulates a spreadsheet model. Schedule risk analyses, on the other hand, simulate a project schedule, so software that is able to simulate schedules developed in the organization's preferred scheduling package should be used. Integrated cost-schedule risk analyses involve a good-quality integrated schedule loaded with the cost estimates attached to the activities they support. A few examples of Monte Carlo analyses are given below, progressing from simple applications to sophisticated analysis for complex projects.

Spreadsheet Model Monte Carlo Simulation. A common very simple method to estimate total risk exposure is to perform a Monte Carlo simulation on spreadsheet data, often on the Cost Book for budget (see Section 4.3.4.2 Construction Cost Book and Basis of Estimate Overview) or on the Risk Register for total risk exposure. The example given here is for total risk exposure estimated by using the Risk Register as the model. Inputs to Monte Carlo are the individual risk likelihoods/probabilities and their associated most likely impacts. The Monte Carlo output for each risk includes the impact if the risk occurs, based on likelihood. The total outcome for each Monte Carlo iteration is the sum of all the outputs, representing the aggregate or total project risk exposure for that iteration. A graph of how often each outcome value occurs, called a cumulative frequency or S-curve plot, yields the likelihood that the total risk exposure will be equal to or less than each value on the curve. See Figure 4.6.6.3-2 for an example of a typical S-curve output of a Monte Carlo analysis performed using the probabilities and cost impacts for threats listed in a Major Facility project Risk Register as inputs. In the example, 800 out of 1,000 iterations (80%) resulted in estimated total exposures equal to or less than $13,935,252. If the Project Team chooses that amount of contingency, then they have an 80% confidence level that the project can successfully complete within budget. A similar analysis can be done on the schedule risk elements in the Register to obtain the total risk exposure for the schedule.

Figure 4.6.6.3-2
Example of an S-Curve Output of Monte Carlo Performed on Risk Register



Software Model Monte Carlo Simulation. Monte Carlo analysis using complex models based in commercial software tools (e.g., scheduling applications) rather than spreadsheets take more effort and knowledge to set up and run. An added complication can be the use of distributions instead of point estimates as input values, such as estimate uncertainty ranges and/or schedule risk probabilities and impact distributions.

Point estimates can be used as inputs when the objective being analyzed is known to be an exact amount or for simple analyses that haven't yet been assessed for a range of impact values. They are commonly used for spreadsheet models, such as Risk Registers, as illustrated in the example above. Other distribution shapes (e.g., as normal/Gaussian, flat, triangular, Program Evaluation and Review Technique (PERT), and log-normal) may be used when a range of values is more representative of project characteristics and the Project Team understands the pros and cons of using them. Some of the easiest and therefore common distributions used are the triangular and PERT distributions, which are based on three estimates to define ranges - the best, most likely, and worst case possible for cost or schedule values. The most likely value is typically the baseline estimate or the estimated risk impact in the Risk Register, depending upon the Monte Carlo model being used. The best and worst values can be expressed in cost or duration units or as a percentage of the most likely value (*e.g., minus 15%, plus 25%)*. The range for risk impacts often relies on SME judgment, while EU are often expressed as plus or minus percentages taken from look-up tables based on the maturity and complexity of the activity/deliverable. The nuances of when one or the other method should be used are beyond the explanations included here.

The distribution ranges for EU often have a low-value tail (opportunity) compared to the most likely value and a high-value tail (threat), such as -5% and +10%. Asymmetries in the range of estimate uncertainty occur because it is often easier to overrun than underrun an estimated value. Also, note that the most likely value may not be the assigned value in the schedule or estimate. Hence a fairly typical uncertainty estimate range could be .95, 1.05, and 1.15 – the middle value implies that the estimator judged that the duration or cost is most likely 5% higher than in the baseline model. Activities that occur far in the future or that are less understood often can be addressed by allocating a wider range of uncertainty to durations or costs than to those assigned to better-understood activities occurring in the early years of the project. Discrete risks can be represented by assigning a risk to a cost element or schedule activity in the Monte Carlo analysis or by specifying a multiplicative factor to apply to the estimated cost (Risk Register method) or activity duration (risk driver method). For a discrete risk, the range of best and worst cases may depend upon the actual circumstances of the risk realization. If a component does not meet design requirements, the best case may just require changing out a subcomponent with little impact while the worst case may involve redesign, fabrication, and testing activities not in the plan. Examples of inputs for three-estimate schedule impact distributions are shown in Table 4.6.6.3-1.

Table 4.6.6.3-1

Probability Distributions of Schedule Risk Impact Durations Based on Best, Most Likely, and Worst-Case Duration Estimates

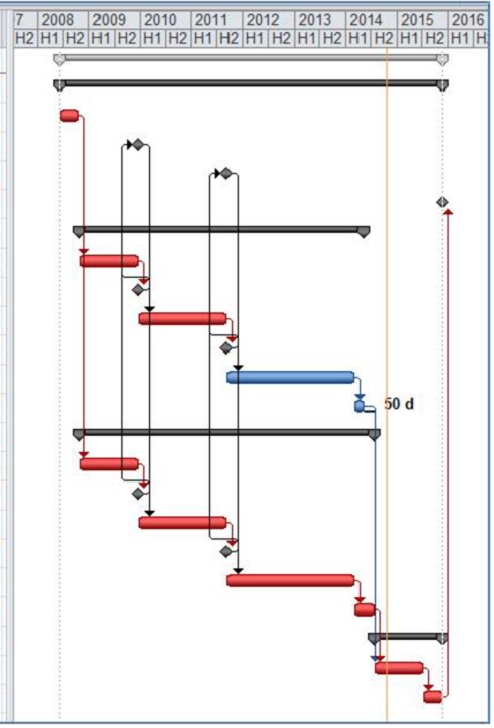
Risk Description	Probability of Occurrence	Best Case	Most Likely Case	Worst Case
Task risk of delay	35%	25 days	50 days	100 days
Estimate uncertainty on task duration	100%	-10%	60 days	+25%

Monte Carlo analysis of risk for models created in a schedule software application will be presented in this discussion to illustrate the methodology. An example of a logically driven schedule is shown in Figure 4.6.6.3-3. For this software-based application, the chosen Monte Carlo tool should be capable of loading the schedule data from the scheduling tool. Note that the full project schedule does not have to be used in all cases – many projects use summary schedules derived from the Integrated Master Schedule (IMS) with Monte Carlo inputs applied at the summarized levels. This may be because the schedule has not been fully developed, but the high-level outline has been established, or because an IMS with a large number of activities is too burdensome to troubleshoot and upload each time the schedule is updated or changed.

Figure 4.6.6.3-3

Example of a High-Level PMB Schedule for a Design and Construction Project

ID	Name	Duration	Start	Finish	Cost
0	**Spacecraft Integrat**	**1950 d**	**6/1/08**	**11/20/15**	**$651,599,953**
1	**Spacecraft Project**	**1950 d**	**6/1/08**	**11/20/15**	**$4,000,000**
2	Requirements De	100 d	6/1/08	10/17/08	$4,000,000
3	PDR Spacecraft	0 d	12/11/09	12/11/09	$0
4	CDR Spacecraft	0 d	9/2/11	9/2/11	$0
5	Ship to Launch Si	0 d	11/20/15	11/20/15	$0
6	**First Stage**	**1450 d**	**10/20/08**	**5/9/14**	**$331,599,994**
7	FS Preliminary De	300 d	10/20/08	12/11/09	$19,199,998
8	FS PDR	0 d	12/11/09	12/11/09	$0
9	FS Detailed Desig	450 d	12/14/09	9/2/11	$129,599,989
10	FS CDR	0 d	9/2/11	9/2/11	$0
11	FS Fabrication	650 d	9/5/11	2/28/14	$178,800,005
12	Test FS Engine	50 d	3/3/14	5/9/14	$4,000,000
13	**Upper Stage**	**1500 d**	**10/20/08**	**7/18/14**	**$261,999,984**
14	US Preliminary D	300 d	10/20/08	12/11/09	$19,199,998
15	US PDR	0 d	12/11/09	12/11/09	$0
16	US Detailed Des	450 d	12/14/09	9/2/11	$86,400,000
17	US CDR	0 d	9/2/11	9/2/11	$0
18	US Fabrication	650 d	9/5/11	2/28/14	$152,400,005
19	US Test	100 d	3/3/14	7/18/14	$4,000,000
20	**Integration**	**350 d**	**7/21/14**	**11/20/15**	**$54,000,005**
21	Integration	250 d	7/21/14	7/3/15	$45,000,002
22	Integration Testi	100 d	7/6/15	11/20/15	$9,000,000



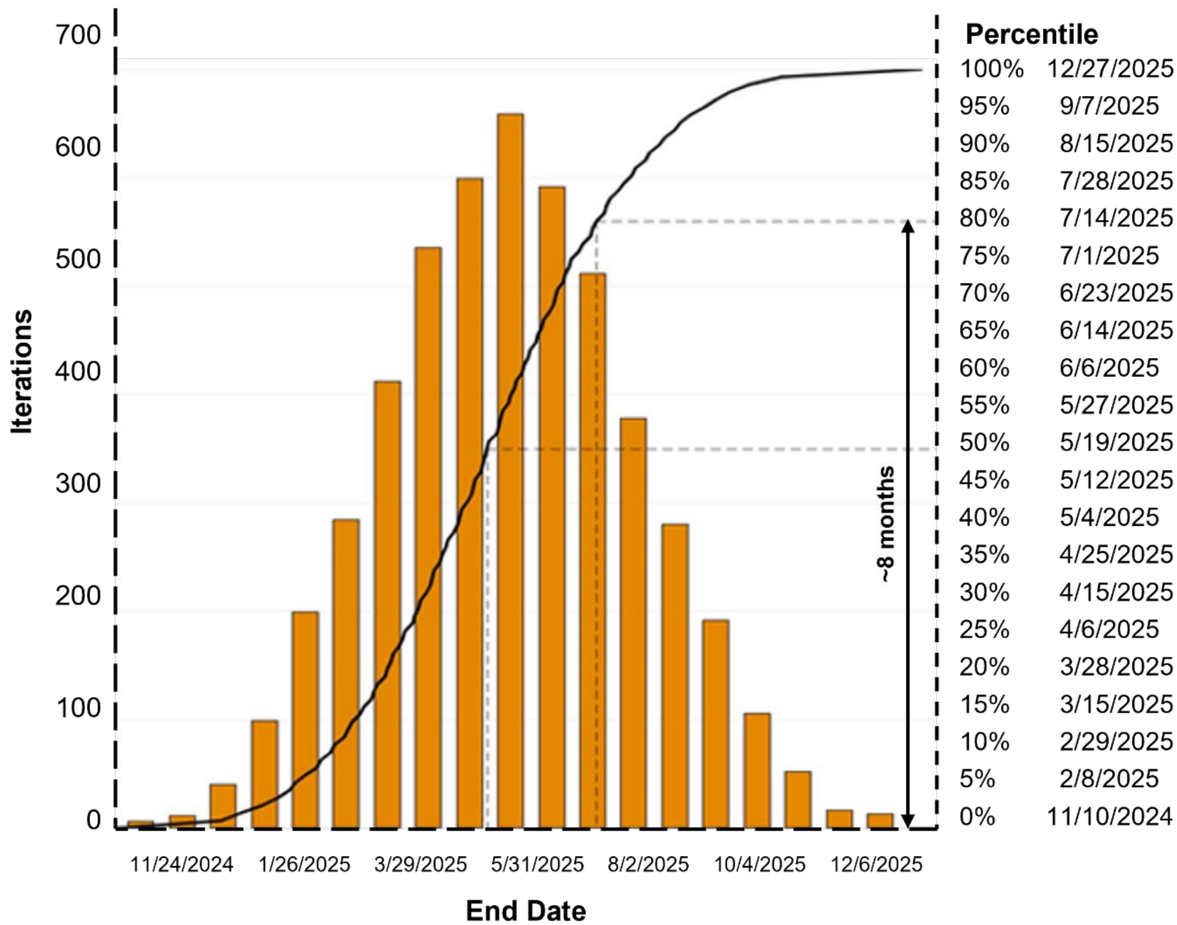
Once the schedule model has been determined and probability-impact distribution ranges have been assigned to each risk in the Risk Register, the risks are then assigned to the activities and resources in the Monte Carlo model and the simulation can be run for multiple iterations. Note that an activity can have more than one risk assigned to it and risks can be assigned to more than one activity. If a risk occurs for a particular iteration, the output durations of the activities in the schedule that the risk is assigned to will be randomly generated from the impact range according to the methodology used by the Monte Carlo application.

For example, assume a schedule impact distribution ranging from a best case of 10 days, worst case of 35 days, with a most likely duration of 20 days, is chosen for a risk assigned to the activity. If the probability of the risk occurring is assumed to be 40%, the Monte Carlo will generate a random impact value from the distribution range of 10 to 30 days for 40% of the iterations in the simulation. For the other 60% of the iterations, an output value of zero is assigned, indicating that the risk does not occur for those iterations.

In order to obtain an output value for the overall project end date for a single iteration, the Monte Carlo application will sum all the randomly generated output durations for each activity in the schedule. The output end dates for all iterations can be plotted as a histogram, which is then analyzed to determine the confidence level for completing the project by a selected end date. For the analysis, the histogram distribution is converted to a cumulative frequency curve representing the percentage of times in the simulation that all the work is completed by each generated end date. The stated confidence level for any end date is equal to the percentage of iterations completed by that date (i.e., 800 out of 1,000 iterations in a simulation represents an 80% confidence level). A representative Monte Carlo histogram and S-curve from a typical schedule Monte Carlo analysis for project end date is shown in Figure 4.6.6.3-4, where the 80% confidence level for 10,000 iterations supplies a basis for establishing schedule contingency to cover overall schedule risk exposure. The amount of schedule contingency required to ensure that the Project Team can deliver on time at the 80% confidence level is the difference between the baseline end date and the Monte Carlo generated end date.

Figure 4.6.6.3-4

Histogram from Monte Carlo Simulations Showing Schedule Risk Impacts on Project End Date with an 80% Confidence Level S-Curve. Baseline End Date: 11/10/2024; Projected End Date at 80% Confidence: 7/14/2025, Suggesting an Eight-Month Contingency Requirement



Combined Cost-Schedule Monte Carlo Analysis. The most thorough analysis comes from Monte Carlo simulations based on an integrated, RLS with costs loaded at the activity level, coupled with inputs from a comprehensive listing of the probabilities of occurrence and range of impacts for risks and uncertainties. NSF requires cost and schedule-integrated Monte Carlo analysis for Major Facility construction projects, starting with the Project Definition presented at PDR. Mid-scale RI projects and other life cycle stages may use scaled Monte Carlo versions described earlier in this section. Due to the complexities involved in running an integrated Monte Carlo combining cost and schedule, as well as the nuance required in interpreting results, it is recommended that the Awardee seeks expert advice to implement such analysis.

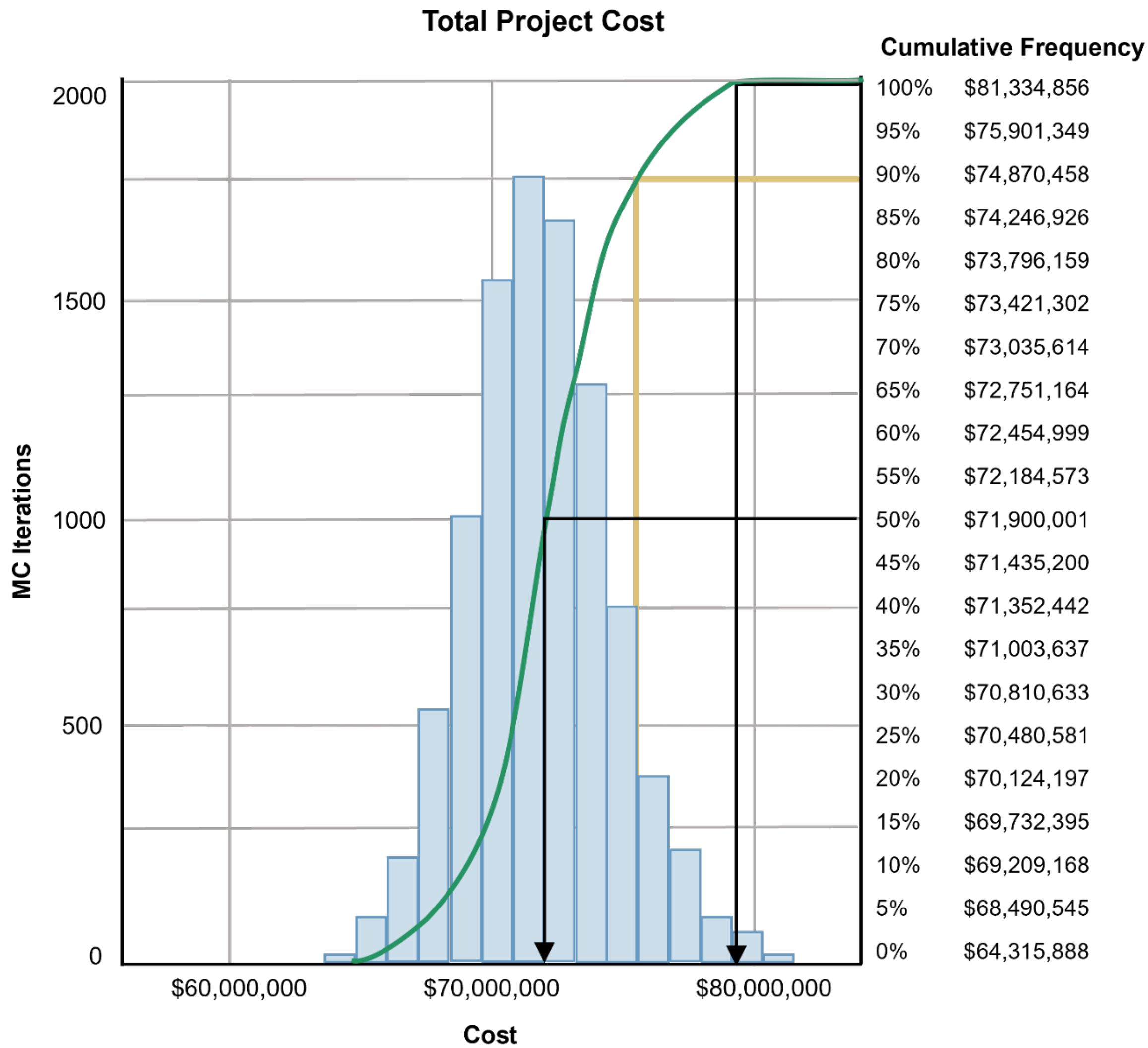
As mentioned above, an integrated cost and schedule Monte Carlo risk analysis requires an accurate, up-to-date, cost-loaded schedule that follows the project WBS, with established logic links, appropriate constraints, and a clear Critical Path. The baseline IMS, without schedule contingency or float, or a representative summary schedule modeling the project, may be used. Summary schedules are particularly useful during planning stage analysis performed before all work packages are fully developed or for a less burdensome frequent analysis during construction. The scheduling software should be compatible with the Monte Carlo software, as well as with other project control applications (see Section 4.4 Schedule Development, Estimating, and Analysis).

The PMB cost estimate used to load the schedule should be fully burdened for all WBS scope (see Section 4.3 Cost Estimating and Analysis). The baseline budget used in the Monte Carlo analysis does not have to be loaded into the schedule at the lowest detail level. Costs can be rolled up to higher WBS levels rather than being loaded at the IMS activity level.

A typical result of a Monte Carlo schedule risk analysis is a histogram of possible TPC from a combined cost and schedule analysis, which is shown in Figure 4.6.6.3-5. A similar plot for total schedule duration can also be extracted from the analysis. For the histogram below, the horizontal axis shows the range of possible total cost. The right vertical axis shows the confidence level for the cumulative S-curve. The solid lines on the plot represent the costs for which the confidence level for completion within that cost is 50% and 90% respectively. For this example, the PMB budget is $64.32M. If the Project Team elects to use the 90% confidence level, then the chosen project total cost is $74.87M, indicating that they need to mitigate or provide contingency for an additional $10.55M beyond the baseline budget.

Figure 4.6.6.3-5

Histogram of Total Project Cost from Integrated Monte Carlo Cost Analysis for Major Facility Construction. Total Cost: $74.87 M; Contingency: $10.55 M at 90% Confidence Level



The results of the analysis, including all risks and uncertainties, for the Major Research Equipment and Facilities Construction (MREFC) scope are as follows:

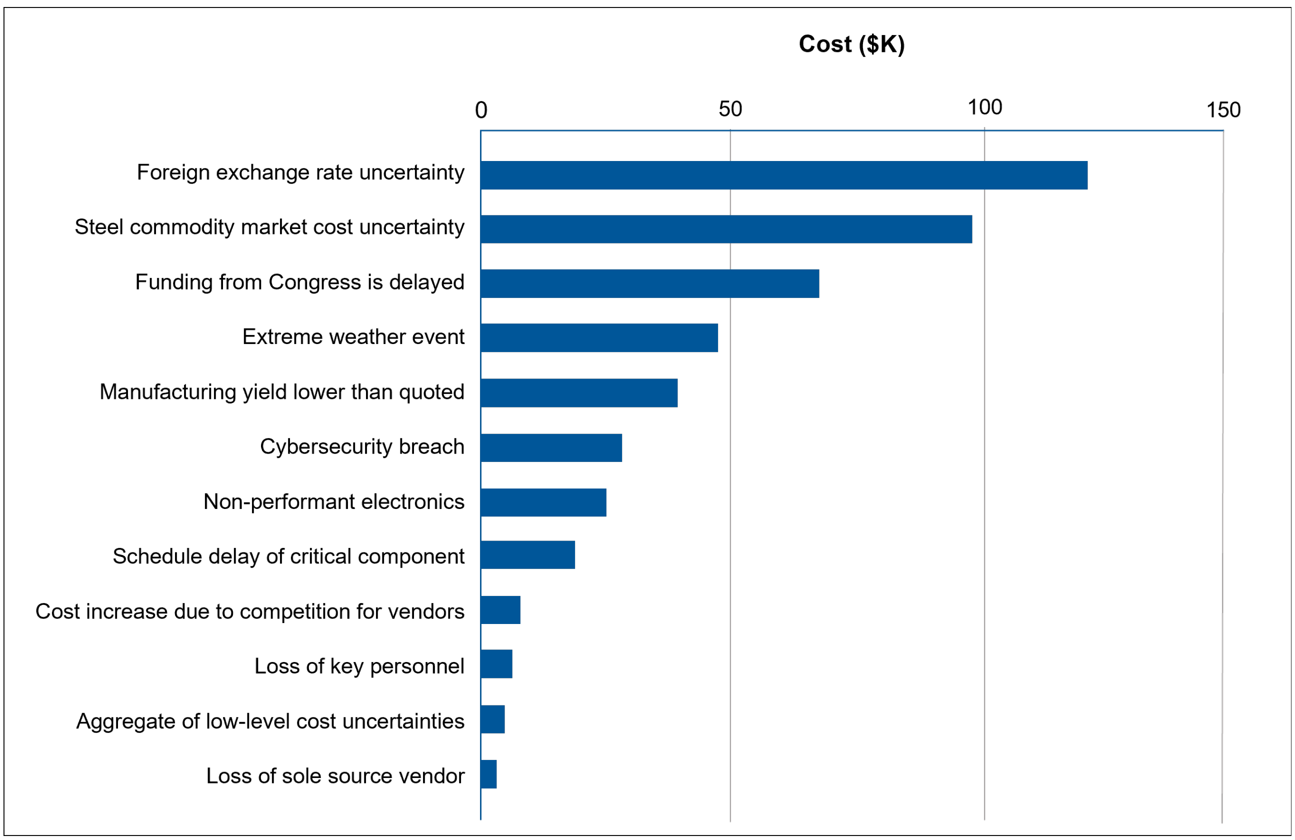
Project base cost (BAC = direct + indirect + escalation)	= $64.32M
TPC (BAC + contingency)	< $74.87M (at 90% Confidence Level)
Total contingency (TPC at 90% CL – BAC)	= $10.55M (at 90% Confidence Level)

An integrated cost-schedule risk analysis can also show the relationship between schedule and cost in a combined scatter plot. The scatter slope then indicates the positive relationship between time and cost.

Sensitivity Analysis / Tornado Chart. In addition to producing the likelihood of completion values, the Monte Carlo method can also identify the Critical Path and rank the main sources of risk in a sensitivity chart, often referred to as a tornado chart. The ranking is determined by removing the risks one at a time and rerunning the simulation to find which one has the largest impact on the project objectives. Deleting is accomplished by setting the probability to zero for the risk in question while including all the other risks. Once the highest-ranking risk is identified, it is excluded from further simulations, and the next impactful risk is identified by running through the sequence of dropping the remaining risks one at a time to find the next most important risk. The procedure is repeated until all the risks are ranked in priority order. This priority ranking is more indicative of a risk's importance than the Risk Register ranking because it considers correlations and knock-on effects of realized risks on other risks. Opportunities can be included in the sensitivity analysis, even if they are not included in the risk exposure simulations. This identifies which opportunity has the most beneficial impact on the project objectives if exercised. The sensitivity study thus provides information for making critical decisions on managing threats and opportunities. A sample tornado chart is shown in Figure 4.6.6.3-6.

Figure 4.6.6.3-6

Risk Sensitivity Analysis: Tornado Chart Depicting Contributions to Cost Risk Exposure from Individual Risks and Uncertainties



Good Practices and Practical Considerations

- In general, NSF expects Awardees to estimate and validate contingency requirements based on quantitative analyses of total risk exposure. In some cases, however, analogy, SME judgment, and general rules of thumb may be allowed when warranted and adequately justified.
- Scope contingency is an important element of good risk management. De-scope options can be used to recharge the budget and schedule contingency pools when needed. In a sense, they represent the additional contingency needed to fill the gap between the chosen Monte Carlo confidence level and the 100% possibility of success (see Section 4.7 Contingency Estimating and Management).
- The preparation work for a Monte Carlo simulation run can take significant time and effort. Project cost and staffing estimates should include the effort needed for software licensing and risk management resources, including hired SME, as well as project management and technical leadership efforts.
- The detailed project schedule is not always a good candidate for risk analysis input if it has a large number (thousands) of activities and is difficult to debug. A summary or analytical schedule may be used instead of a detailed schedule. This analytical schedule needs to represent all the work of the project and be validated against good schedule health practices.
- Projects often use algorithmic or scaled Monte Carlo methods for month-to-month risk management, saving the more labor-intensive Monte Carlo methods for establishing a new baseline or calculating an updated risk-adjusted estimate at completion (RAEAC).
- Managers should not assume that Monte Carlo analysis always represents the best analysis and is the final answer for decision-making. Good practice recommends the use of more than one method of estimating risk exposure. For example, Awardees may use algorithmic methods during early planning stages, graduating to scaled Monte Carlo methods with planning maturity. Equally important is the professional judgment and experience (*gut feelings*) of the project leadership team.
- Regardless of method(s) used, the RI team should always review the results and then, applying judgment, establish a risk exposure value, i.e., it is acceptable to override or modify the calculated risk exposure, provided an adequate explanation and justification is provided.
- Note that total risk exposure typically diminishes over time as risks are realized or retired. As a general rule, total risk exposure should always be less than or equal to the remaining contingency.
- If a risk factor method is used, Awardees are encouraged to review, change, and adjust the look-up table factors to meet their own project's unique characteristics. Further, analyses should occur at one consistent level or tier of the WBS, i.e., it's common to calculate contingency requirements with this method at Level 3 of the WBS cost estimates.
- Risk managers may want to explore some common advanced techniques not discussed

in these guidelines, such as the correlation between risks, risk driver methodology, manipulation of the sensitivity analysis, and the effects of risk sequencing. These topics are discussed in much of the available risk management literature.

- Monte Carlo analysis is a powerful method for understanding and managing risks in a project, but it does have limitations. First and foremost, the accuracy of the results depends upon the quality of the input data and the model. Poor assumptions or inputs can result in unreliable results (*garbage in, garbage out*). Secondly, the results can be problematic if the level of staff expertise does not match the complexity and nuances of the project risks and the tools themselves. Thirdly, the administrative burden for creating and maintaining Monte Carlo risk analysis increases with the complexity of the project itself and the chosen risk analysis methods and tools.

4.6.7 Step 7 – Report, Monitor, and Update Risks

The objectives of Step 7 of the risk management process are to ensure regular and consistent monitoring and updating of the RI risk status, as documented in the Risk Register. Completing this step facilitates proactive project management to maximize the RI effort's chances of success. Equally important, this helps ensure that the primary RI stakeholders (e.g., NSF) are kept apprised regularly of the current risk status, which helps planning within the Foundation.

Sound risk management requires continuous monitoring of project risks, and an iterative application of the risk process steps to keep the Risk Register current. Existing risks need to be monitored, controlled, and ultimately retired, while new risks should be identified as they arise and added to the Risk Register. The frequency, processes, and formats for reporting, monitoring, and updating project risks should be established in the project Risk Management Plan. NSF reporting requirements of risk status and management may be specific to each project and are typically included in the award instrument.

Good Practices and Practical Considerations

- Managers should avoid the practice of performing the first steps of the risk management process *only* at the start of the effort. Staying on top of the risk situation is critically important to success since new risks arise, existing risks evolve or become issues, and old risks retire during a project.
- One key aspect of risk management reporting (as is true of all project reporting) is the management of stakeholder expectations. This means open and transparent communication with NSF. A complete understanding of both threats and opportunities is required both within the RI team and at NSF. Risks are not bad things that are hidden from view but rather are simple realities of an RI effort that need to be communicated and addressed directly.

4.7 CONTINGENCY ESTIMATING AND MANAGEMENT

Section Revision: TBD Early 2025

Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

Contingencies are a necessary component of risk management for NSF-funded projects and provide the tools to manage known risks. They may be useful tools on proposed projects and Science Support Programs as well (see Section 4.7.2.5 Contingency Estimating for Major Facility Operations Stage for Operations and Maintenance [O&M] awards), but their use should be carefully considered due to the added administrative effort that comes with contingency estimating, management and oversight.

Contingencies fall into three distinct types: scope, schedule, and budget. At least one of these—and frequently all three—are used to cover relevant risk exposure sufficiently to allow the project to be completed at or below the authorized TPC or authorized award amount. The use of contingencies is managed through the formal Change Control Processes, as documented in Section 3.5.7.3 PEP Subcomponent 7.3 – Change Control Plans, to ensure robust oversight and administration.

4.7.1 Allowable Contingencies

The definition of contingency varies widely among project management practitioners and federal agencies.[1] Contingencies for NSF are defined below.

Scope Contingency. Deliverables (work products, outputs, and/or services) that are either: (1) included in the baseline definition and can be removed (*de-scoped)* without significantly affecting the overall objectives but that may still have undesirable effects on performance; or (2) may be added (*up-scoped* as a *scope opportunity*) if adequate funding becomes available, either through cost underruns or if the full amount of budget contingency is not needed to cover realized risks and their impacts. Both de-scoping options and scope opportunities should be included in the Scope Management Plan.

Schedule Contingency. A duration of time to allow for identified delays, conditions, or events for which the state, occurrence, or effect is uncertain at the time the schedule is developed and that experience shows will likely result, in the aggregate, in schedule delays. These *known-unknown* events are considered manageable by the Awardee.

This duration is held separately from the baseline schedule to help manage risk and uncertainty in aggregate. Schedule contingency may only be used when a risk, including uncertainty, from the Risk Register is realized. For projects, this is part of the TPD; also, see the NSF EVM Gold Card.

Budget Contingency. The amount of budget to allow for identified items, conditions, or events for which the state, likelihood of occurrence, or impacts are uncertain at the time of

[1] NSF terminology aligns with that of the Association for the Advancement of Cost Engineering International (AACEI), and of the Project Management Institute's (PMI) *Project Management Body of Knowledge (PMBOK Guide).* The NSF definition of contingency is consistent with both the Uniform Guidance (§ 200.433) and the Federal Acquisition Regulation (FAR).

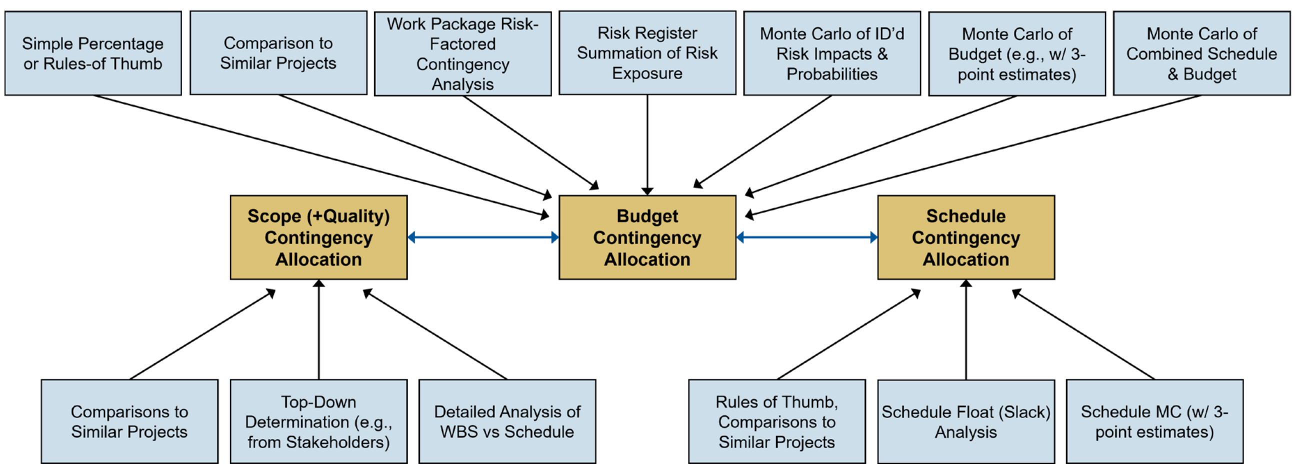
estimate and that experience shows will likely result, in the aggregate, in additional costs. These events are often referred to as *known-unknowns* and are considered manageable by the Awardee.

Budget contingency is held separately from the baseline budget to help manage risk and uncertainty in aggregate. Budget contingency is generally obligated to the award for the Awardee to manage based on justified need, however NSF can hold up to one hundred percent per NSF policy. It may only be used when a risk (including uncertainty) from the Risk Register is realized. Budget contingency is part of the TPC; also, see the NSF EVM Gold Card.[1]

In contrast, management reserve is a budget included as part of the authorized TPC to address unforeseen events or other uncertainties that are beyond the control of the Awardee or the agency. These events are often called *unknown-unknowns*; also, see the NSF EVM Gold Card. Management reserve is not allowable in the Awardee estimates per NSF policy.[2] The amount of management reserve, if any, is determined and managed solely by NSF and is based on agency risk tolerance and other factors. Once obligated to the award, it is allocated as either baseline, budget contingency or fee.

Figure 4.7.1-1

Methods for Determining Contingency Allocations



[1] https://new.nsf.gov/bfa/rio/evm-gold-card

[2] Per 2 CFR § 200.433 - Contingency provisions. “Reserves” are funds drawn down and held by the Awardee in anticipation of future need and are unallowable. As a result, the term “reserve” should never be used in the project documentation.

4.7.2 Contingency Estimating

4.7.2.1 Budget Contingency

The development of budget contingency starts with estimating the potential monetary risk exposure, as explained in Section 4.6.6 Step 6 – Assess Total Risk Exposure and depicted in Figure 4.7.1-1 above. The estimated risk exposure is intended to capture the potential cost impact of risk and uncertainty, if realized, which can have both direct cost impacts as well as the resulting costs for schedule delays. Risk exposure can be calculated in a variety of ways. A contingency budget is then selected to adequately cover this risk exposure while considering the project maturity, the technical nature of the project, risk tolerance, and the available de-scoping options, including the potential impacts to science if de-scoping has to be implemented.

> **NSF Requirement**
>
> Major Facility projects must use a combined cost and schedule risk analysis using Monte Carlo methods and select a value within the 70-90% confidence range.

Contingency can have a range of values and associated confidence levels and still complete the scope within the authorized TPC if the full suite of risk management tools is used in concert. The initial contingency budget should typically equal or exceed the calculated risk exposure. For Major Facility projects, the determination of budget contingency **must** include the use of a combined cost and schedule risk analysis using Monte Carlo methods and the selection of a value in the 70-90% confidence range at the time of the PDR. Later, at the FDR and the award for construction, it is confirmed that the confidence levels remain within this range when compared against the budget request and anticipated appropriations. During the Construction Stage, the confidence level is expected to fluctuate, but if it drops below 50%, de-scoping **must** be considered along with other risk mitigation strategies.

Higher risk projects with greater complexity and unproven or uncertain technologies often warrant higher contingency budgets and confidence levels. While it is prudent to be conservative in selecting a confidence level, professional judgment needs to be used in consultation with NSF. However, it is always better to deliver the full technical scope and finish under budget (returning unneeded funds to NSF) than to compromise science operability through de-scoping or be forced to request additional funding. Projects can never be 100% certain that the budget contingency alone will be sufficient and selecting a confidence level higher than 90% diminishes returns and sets unrealistic expectations.

It is not always realistic or even feasible to mitigate all anticipated risks. Risk acceptance is a normal part of risk management. However, it is also extremely unlikely that a project will encounter all the risks, or the full extent of possible consequences for each risk, that have been identified. The contingency estimate should be appropriate to manage only the aggregate risk, which is much more likely to occur than the sum of the individual risks. Therefore, a statistical approach like Monte Carlo produces a more likely estimate for the TPC than the overly conservative approach where CAM increases individual WBS elements to cover the risk.

Good Practices and Practical Considerations

- The risk exposure calculation methods identified in Section 4.6 Risk Management are rigorous bottom-up methods of analysis successfully used throughout government and industry. However, the overall results should always be scrutinized at the macro level and subject to a reality check to help ensure they are reasonable and credible.
- Supporting documentation should clearly articulate which risk elements were considered, the basis of the impacts and likelihoods, and how they were modified when making any adjustments to the model outputs when selecting the final contingency budget.
- Independent external reviewers and simpler top-down methods, such as percentage rules-of-thumb or comparison to similar projects, can also be used to help assess results. However, simple rules-of-thumb are not acceptable to estimate the budget contingency.
- Experience and sound professional judgment are essential. Results are subject to *garbage in, garbage out* where the quality of the output is dependent on the quality of the input. Project managers, risk professionals, and SME should always be leveraged to inform the process and the basis of determining potential cost and schedule impacts and likelihoods of occurrence.
- In some circumstances, if the overall contingency appears inadequate, it can be appropriate to adjust the inputs based on specialized knowledge of a particular technical area or market condition.
- Uncertainties in the cost range and schedule durations can be included in budget and schedule contingency calculations.
- Scope, schedule, and budget risks are correlated to some extent. A change in scope, for instance, usually means a change in cost and schedule as well. There are often trade-offs between the different contingencies, which can be balanced to cover risk exposure adequately. For example, projects with many de-scoping options (e.g., decreasing the number of individual detectors that are purchased) may warrant less budget contingency and vice versa. Risk analysis and budget and schedule contingency estimation methods should consider the degree of correlation in estimating an appropriate level of budget contingency.
- Developing a graphical timeline depicting available contingency-related trade-offs can help visualize available options when making management decisions. For example, the cost of available de-scopes and up-scopes can be graphed over the project duration, as can the estimated cost risk exposure over time, based on the most likely time of realizing risks or proportional to the baseline funding profile. When construction is underway, the available budget contingency can be added. See Figure 4.7.2.3-1.
- The timing of potential risk realization should be considered when determining budget contingency. For example, escalation of the cost impacts occurring in out-years can be

included, and the timeframe in which the project is exposed to different risks can help determine the appropriate funding profile. See Figure 4.7.2.3-1.

- Note that total risk exposure typically diminishes over time as risks are realized or retired. Generally, total risk exposure should always be less than or equal to the remaining contingency. If the remaining contingency is less than the risk exposure, recovery plans should be developed, and risk response methods should be revisited to decrease exposure and/or de-scoping to increase available contingency. See Figure 4.7.2.3-1.
- Even if all authorized budget contingency is obligated and used, the project may be completed under budget for other reasons, including final actual costs coming in below the estimates. Once project objectives are met, scope opportunities may be implemented, and any residual funds will be de-obligated and returned to NSF, at which time NSF may request possible re-allocation of those funds to other agency priorities. Obligated contingency is generally held by the Awardee through award close-out, where the final accounting is completed. Unused contingency funds may not be used to support initial operations or other out-of-scope activities. See Figure 4.7.2.3-1.

4.7.2.2 Schedule Contingency

Schedule risk exposure can be estimated using top-down approaches such as simple percentage rules-of-thumb or comparison to other projects, more rigorous bottom-up methods such as those described in Section 4.6.6 Step 6 – Assess Total Risk Exposure, or via a schedule float analysis. A schedule float analysis involves analyzing the available float in near-Critical Path activities and using expert judgment to determine or increase schedule contingency if there are many near-Critical Path activities with little available float and limited flexibility. The schedule contingency's total duration should usually equal or exceed the calculated schedule risk exposure.

The project end date is determined by the sum of the baseline duration and the selected schedule contingency amount. Schedule contingency is held separately from the PMB, and allocations of schedule contingency to and from the PMB are managed through formal Change Control (see Section 3.5.7.3 PEP Subcomponent 7.3 – Change Control Plans).

Good Practices and Practical Considerations

- As noted above for budget contingency, the overall results should always be scrutinized and subject to a reality check to help ensure they are reasonable and credible.
- The *cost* of schedule contingency should always be considered and factored into the estimation of budget contingency. For example, if a risk is realized that extends the overall duration of the project, any LOE personnel (e.g., project management or engineering) would usually be employed longer and increase costs. For simpler contingency calculation methods, the average daily cost for LOE personnel could be multiplied by the days of the schedule contingency.
- The Project Team should establish controlled milestones for the PMB and risk-adjusted end dates.

4.7.2.3 Scope Contingency

Project scope defines the boundaries and deliverables of a project, outlining what needs to be accomplished and the work that needs to be done to achieve the requirements and objectives, also known as Key Performance Parameters (KPP). Scope and quality are closely related, and project scope elements may vary in quality and associated costs. Quality is the standard (fitness for purpose) of something as measured against the requirements and specifications. Quality expectations for project scope elements are defined up front in technical documents and confirmed by defining acceptance criteria, which are checked via PEP Subcomponent 9.2 – Technical Closeout Plans. One element of scope contingency is adjusting the quality of a particular scope element, or the extent to which quality or performance is confirmed during construction or commissioning. This, of course, carries its own risks.

The term scope contingency will be used herein and may include the quality associated with certain deliverables. Depending on project risk performance and available budget contingency, scope contingency can be retained or removed to manage the project within the authorized TPC. Potential de-scope options are generally lower-priority items or tasks that can be delayed or dropped without a crippling impact on project objectives. The ability to de-scope, including targeted reductions in quality, varies widely, and the impact on the eventual scientific capabilities may also vary. The scope contingency should be well considered and strive to minimize negative scientific impacts since major reductions in scope would be considered a rebaseline. De-scoping may be used if the project forecast indicates that a cost overrun (including those driven by schedule extensions) is likely and/or risks are being realized with greater impacts than anticipated, and contingency may be significantly depleted.

Scope contingency should be identified in the Scope Management Plan (see Section 3.5.3.2 PEP Subcomponent 3.2 – Scope) and approved by NSF before the start of the Construction Stage. Since every risk may likely not be realized at its maximum impact, budget contingency may remain as the end of the project approaches. Depending on final forecasted costs, legal claims or other encumbrances, remaining contingency may become a significant consideration as part of the award close-out process.

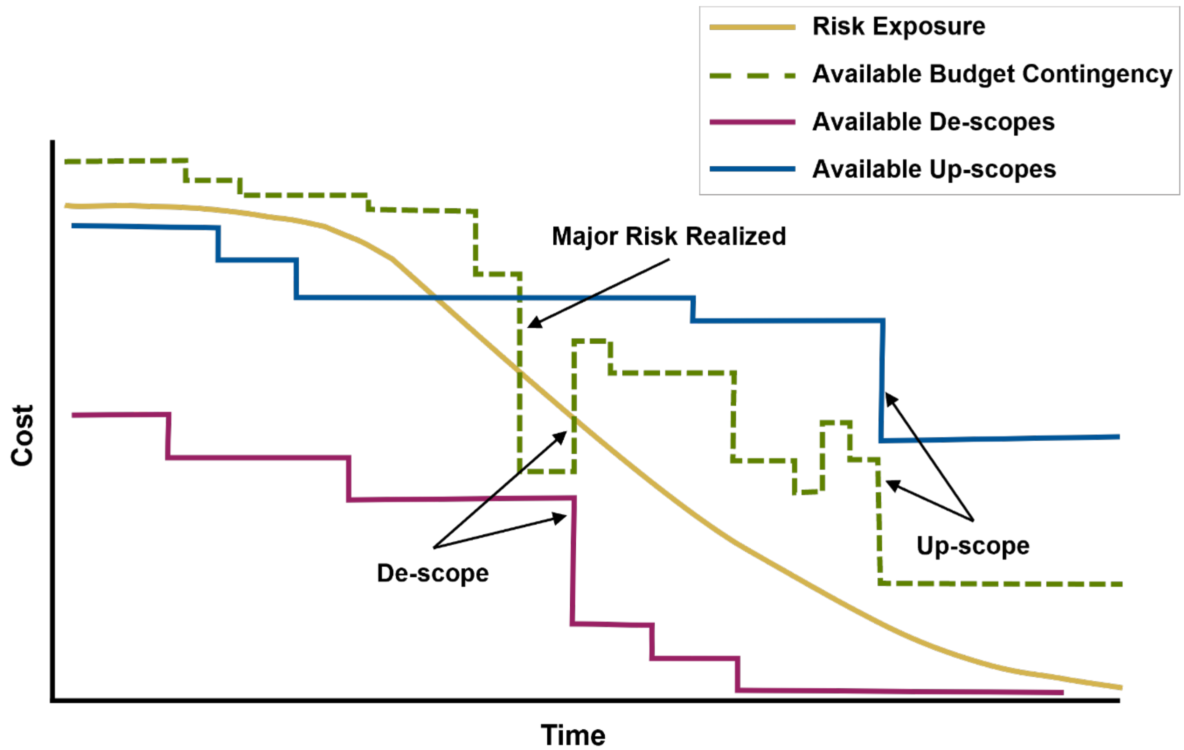
Identifying scope options may involve comparison to other projects, engaging stakeholders, and/or having the Awardee do a detailed analysis of the scope, WBS, schedule, and technical, science, and commissioning objectives and requirements (see Figure 4.7.1-1).

For a Major Facility in the Construction Stage, a Scope Management Plan **must** be developed and identify both de-scope options and scope opportunities. For other stages of a Major Facility, a formal Scope Management Plan is not required, but similar elements may be utilized in consultation with the PO. The Scope Management Plan describes each of the scope options, how they plan to be monitored and controlled, and how and when scope opportunities and de-scoping options might be implemented.

Good Practices and Practical Considerations

- As a project progresses through the Construction Stage, the risk exposure, available budget contingency, and de-scoping options continually decrease, as shown in Figure 4.7.2.3-1. Awardees should keep the following considerations in mind:
  - Having de-scope options available as late in the project schedule as possible is prudent. If many risks are realized and contingency is depleted, they may be the only option for staying within the authorized TPC.
  - During the Construction Stage, the confidence level is expected to fluctuate, but if it drops below 50%, de-scoping should be considered along with other risk mitigation strategies.
  - Maintaining de-scope options at 10% of the baseline ETC is not always possible over the project duration, particularly as the project nears completion and the options are past their last possible implementation dates.
  - Viable scope opportunities are more likely to be achievable late in the schedule as the risk exposure decreases and confidence in an on-budget completion increases. The likelihood of late decision points should inform the list of scope opportunities.
- Identify practical technical or project considerations related to scope contingency options. For example, on ship construction, adding or removing fixed scope, or major enhancements to capabilities could lead to potential rework, and impact weight and stability.
- The actual savings of executing de-scope options may not be as much as initially anticipated since the initial list of options may have been based on rough order of magnitude cost estimates and not considered all implications of the change.

Figure 4.7.2.3-1
Comparison of Risk Exposure to Available Contingency Over Time



4.7.2.4 Contingency Estimating for Major Facility Design and Construction Stages

The ability to estimate risks and uncertainties naturally changes over time as the design is refined, risks are mitigated, and the understanding of the project matures. During the Conceptual Design Phase, some form of quantitative risk analysis based on discrete risks and uncertainties should be developed to provide an adequate estimate of risk exposure. The use of probabilistic risk analysis to help establish a contingency budget at a specific confidence level is not required in the Conceptual Design Phase.

When the proposed project reaches the Preliminary Design Phase, the drawbacks of simpler quantitative analyses – the limited subset of risks, ignored correlations, and arithmetic sums of averages – do not allow an adequate portrayal of total project risk exposure. Awardees should transition to probabilistic Monte Carlo risk analysis to establish a credible risk-adjusted TPC at the time of the PDR.

At the PDR, NSF requires a funding profile by FY that includes the necessary funding obligations to meet scheduled objectives, plus that associate annual budget contingency needs. The profile should come from the current RLS to eventually be used for EVM reporting, even if resourced at a relatively high level. Since the outcomes of PDR potentially inform the budget request to Congress, this profile allows NSF to show not only the Year 1 request, but also future appropriation needs. The annual Congressional appropriation needs to be sufficient to accomplish the work proposed and provide the financial resources needed to manage the risks foreseen during that period, or the likelihood of exceeding the authorized TPC increases.

NSF requires the Project Team to refine its cost estimates following PDR, adding additional known risks, clarifying definitions, updating likelihoods and impacts, and mitigating risks where possible. At the FDR, the budget estimate should be based on externally obtained cost estimates (vendor quotes, bids, historical data, etc.) to an extent practicable. These are expected to result in an increase in the project's estimated Budget at Completion (BAC), or baseline cost, with an associated reduction in the budget and schedule contingencies. FDR confirms that the sum of the two remains at or below the budget request to Congress.

NSF may partner with other entities to design and construct a Major Facility or design and implement Mid-scale RI. The guidelines in Section 5.8 Partnerships should be considered when NSF funds a particular scope of work within a larger project. Risk assessment, contingency development processes, and contingency status reporting are to be applied to those WBS elements proposed for funding by NSF. NSF encourages the development of a unified risk management approach and a clear understanding of expectations between partners, for the planning and execution of the entire project scope.

An NSF Major Facility in Construction Stages is subject to NSF's NCOP (see Sections 1.4.7 NSF No Cost Overrun Policy and 2.6.1 Construction Award Management and Oversight for additional requirements and guidance related to contingencies).

4.7.2.5 Contingency Estimating for Major Facility Operations Stage

The processes and procedures for handling risk differ greatly between the Construction and Operations Stages. As with construction, operations have many inherent risks. However, the risks are markedly different in nature. Operational estimates are usually based on well-understood historical information and experience with routine risk exposures, which can be included in the BOE as part of the *most likely cost* for each operational WBS element. The work itself is based on the day-to-day activities of science support staff and required consumables rather than production, assembly, and testing of discrete deliverables associated with a new, one-of-a-kind, facility.

Although budget contingency may be requested and approved, Awardees of Operations Stage awards generally use, in approximate order, the following strategies:

- Routine risk impacts are included in the BOE as part of the most likely cost.
- Re-budgeting authority per the award terms and conditions.
- Reduce the level of science support effort (with NSF approval if significant).
- Request supplemental funding, assuming proper justification, availability of funds, and support from the PO.

In contrast, risk handling on Construction Stage awards uses the strategy per Sections 4.6 Risk Management and 1.4.7 NSF No Cost Overrun Policy.

Per Section 4.3.3.4 Uncertainty, Accuracy, and Allowances, explicitly identified allowances can be used and are generally more appropriate for Science Support Program budgets for repairs, replacement, and maintenance. Awardees should use a systematic program to identify the potential costs and operational impacts of both recurring and non-recurring events to develop these allowances and clearly articulate this information as part of the BOE. For NSF, if appropriate, allowances could include uncertainties associated with cost estimating (as part of the BOE) in lieu of a defined risk.

Any request for budget contingency **must** be justified and fully supported through a formal risk assessment process, including a Risk Management Plan. A separate contingency budget may be preferable when risks are better managed in aggregate, or if the award includes significant upgrades that should be managed as a separate sub-project. Added administrative effort for both the Awardee and NSF should be carefully weighed against the benefits, and the ability to effectively handle operational risks though the more common strategies listed above.

4.7.3 Contingency Management

4.7.3.1 Contingency Management Controls

Management of contingencies is described in the Contingency Management Plan (see Section 3.5.4.3 PEP Subcomponent 4.3 – Contingency Management Plan). In this plan, thresholds are established (based on the technical nature of the project) for those who have the authority to approve the use of contingencies. These thresholds are also documented in the terms and conditions of the award. Below these thresholds, the Awardee has the authority to manage and use contingencies accordingly, whether budget, schedule or scope contingency. Above these thresholds, approval from NSF is required, with the level of approval typically corresponding to the magnitude of the proposed change. A CCB may also be used to ensure certain experts concur (e.g., science advisors, other agencies, independent technical or cost reviewers).

NSF Requirement

Contingency use is subject to specific requirements to ensure accountability and transparency. Contingency use **must** be:

- tied to identified risks in the Risk Register that are realized.
- subject to NSF approved change controls with defined thresholds for approval and expectations for documentation.
- related to specific WBS elements.
- periodically reported to NSF.

De-scopes are a risk management tool, and the cost savings is normally handled as a *put* to the budget contingency. Underruns, once a WBS element is complete, could be added to the budget contingency, be allocated to another WBS element in accordance with rebudgeting authority in the award terms and conditions, or retained in the same WBS element until needed elsewhere or eventually de-obligated. Regardless of the method, it is important that the movements of budget are tracked, reported and follow the Change Control Process. See Table 4.7.3.1-1 for an example of baseline Change Control approval thresholds for a Major Facility in construction.

Table 4.7.3.1-1
Baseline Change Control Authority Levels

	Level 1 National Science Foundation	Level 2 Project Manager	Level 3 Control Account Manager
Scope	Any change that impacts Key Performance Parameters or execution of the Scope Management Plan.	Any change to scope that does not affect KPPs.	None
Cost	Any single change requiring utilization of more than $100,000 of contingency.	Use of contingency below a Level 1 cost change and above a Level 3 cost change	Any single cost change. <$10,000; not to exceed $30.000 in a month.
Schedule	Any Level 1 or 2 milestone change.	Any Level 3 milestone change that does not affect a Level 1 or Level 2 milestone.	None

The EVM framework for financial status reporting will eventually reflect contingency movement into the PMB budget (and an increase in BAC).

Key Takeaway

Like EVM itself, use of budget contingency is strictly a reporting (paper) exercise to show movement of budget, not a financial/accounting exercise. Budget contingency is never shown as an actual cost or expense.

While budget contingency is developed based on assessing risk exposure and the impacted WBS elements, once estimated and authorized, it loses its identification with any specific cost element. As stated above, it is a budget held separately from the PMB to manage known risks in aggregate. As a result, it is fungible throughout the project to manage the overall project risk. Only when a risk is realized does it get allocated to the impacted WBS elements which is strictly a reporting exercise (including NSF approvals in accordance with the award terms and conditions) to show movement of budget, not a financial/accounting exercise related to actual costs. Budget contingency is never shown as an actual cost or *expense*. To simplify processes and avoid unnecessary administrative tasks, it is recommended that Awardees manage PMB and budget contingency within a single internal account. This approach ensures efficient oversight and avoids the potential confusion or misperception that a separate reserve account is being maintained.

Controls in NSF's financial system prevent the cumulative Awardee cash draws from exceeding the obligated spending authority. All funds are retained within NSF's obligated award amount to be drawn down by the Awardee for allowable expenses once needed. NSF conducts various post-award monitoring activities, such as periodic external reviews (whose scope includes financial as well as technical status), site visits, and single and program-specific audits to monitor compliance.

NSF may request a recovery plan if the contingency budget appears inadequate to manage the remaining risk.

4.7.3.2 Contingency Management Documentation

Changes to the PMB budget through use of contingency and rebudgeting should be traceable through historical records to the initial PMB release. All CCP Change Requests are to be logged, documented, and archived by the Project Team, with the logs and documentation available to NSF for review in accordance with the PEP and the award terms and conditions.

Change Request Form. The CCB Change Request document, whether forwarded to NSF for approval or not, should have the following minimum content requirements (see the sample Change Control Request Form in Section 3.5.7.3 PEP Subcomponent 7.3 – Change Control Plans):

- Impacted WBS element(s) to allow technical differentiation.
- Risk identification number from the Risk Register.
- An analysis demonstrating that the proposed scope, schedule, and cost impacts are reasonable.
- Specify all Control Accounts that the budget is being allocated to or recovered from and tie to budgets itemized by cost element (i.e., labor, materials, supplies, etc.).

Change Request Log. The Change Request log, which summarizes all individual Change Requests and tracks available budget contingency, should include the following at a minimum:

- Change Control action title and document reference number.
- Change Level as defined in the CCP
- Awardee approval date.
- NSF approval date, if required.
- Risk Register ID number(s) and description for the risk(s) being addressed.
- WBS elements impacted by the change(s) at an appropriate level for technical differentiation, including the amounts of change in scope, schedule, and/or budget for each affected and identified WBS element.
- All *puts* and *takes* and schedule impacts.
- Remaining contingency balances against the total authorized amount and the amount obligated/allocated to date.

Budget Reporting. All awards with budget contingency require periodic reporting to NSF in accordance with the terms and conditions of the award. For Major Facilities in the Construction Stage, contingency use is generally reported monthly as part of the project status report.

The Change Requests and Change Log described above are intended to meet this requirement, and also track the use of schedule and scope contingencies.

Projected amounts of future adjustments to contingency in the Liens List (described further below) should also be periodically reported, generally within the monthly status report as well.

4.7.3.3 Contingency Management Forecasting

As a project progresses, the baseline cost estimate and schedule will evolve, contingencies will be used, and re-budgeting authority exercised. The project cost estimate should be revised periodically to reflect all new information, including actual costs and use of budget contingency, market changes, the learning curves for manufactured items from vendors, and lessons learned by the Project Team. Key forecasting terms and concepts include (see also NSF EVM Gold Card):

- The revised estimate of the cost of the remaining work is called the ETC.
- The Actual Cost of Work Performed (ACWP) + ETC equals the latest revision of the EAC.
- The EAC should equal the BAC only at the start of the project and after major changes to the baseline from replanning or re-baselining.
- The EAC should be compared to the BAC to identify potential new liens on the remaining contingency.

For NSF-funded projects, contingency amounts are not included in the ETC, EAC, BAC, or PMB due to the NSF requirement that contingency be held and managed separately from the baseline.

Risk exposure changes with risk responses and realization, new knowledge, and new circumstances as time passes. The remaining budget contingency also fluctuates over time with risk realization and the return of any savings, either from a risk being retired or work packages coming in below the estimated budget. There is often a lag between project actions such as risk realization and formal Change Control execution where the cost impacts are fully manifested. The Awardee should, therefore, maintain a Liens List of planned future adjustments to contingency as a forecasting tool that tracks actions that have not yet been incorporated into the BAC. The Liens List acts as an escrow or staging account for planned or near-certain contingency use.

The Liens List may document items such as very high probability risks with trigger points for action, deferred scope held as a form of contingency until the decision is made, realized risks needing draws on contingency that require more definition for a Change Control action to be implemented, and anticipated opportunities for returns to contingency. It can also be used to record the need for a contingency to cover budget and schedule variances that cannot be mitigated. It does not serve the same purpose as a *watch list* or major threats list from the Risk Register. The Liens List should include a description of the identified risk and the anticipated action, with estimates of budget and schedule impacts and anticipated decision date for any Change Control action. The affected WBS elements should be identified at the second level (or the first meaningfully specific level of scope description), where known.

At least annually, the Awardee should update the remaining risk exposure based on the quantitative risk analysis with current risks and uncertainties per Section 4.6 Risk

Management. For Major Facilities in the Construction Stage, a combined cost and schedule risk analysis using Monte Carlo methods in the 70-90% confidence range and liens should be included.

- RAEAC is the ACWP + ETC + remaining risk exposure (including liens). This RAEAC should be compared to the BAC plus the remaining available contingency budget. Note: The NSF EVM Gold Card refers to this as TPC_{EVM}.
- The total remaining available budget contingency should be compared to the remaining risk exposure (including liens) to determine whether the project has adequate funds to cover anticipated risks.
- If contingency was authorized to cover a variance but not added to the baseline, the sum of the EAC and liens should include variances (backward-looking actuals) and updated estimates (forward-looking forecasting) in the current plan, not the target baseline BAC.

If the RAEAC is greater than the TPC_{EVM}, de-scoping may be necessary. NSF may request a recovery plan if the contingency budget appears inadequate to manage the remaining risk, generally when the confidence level drops to 50%. The Awardee should also determine what percent confidence the remaining contingency provides and, if necessary, how much more contingency might be needed to get back to the desired 70-90% confidence range.

Good Practices and Practical Considerations

- Considerations for setting approval thresholds include:
  - A larger award amount may warrant the establishment of higher thresholds to lower the administrative effort for both the Awardee and NSF and potential schedule delays.
  - The complexity and risks associated with the technical nature of the project may warrant more NSF involvement and, hence, lower thresholds.
  - Past performance may help to indicate whether an Awardee's Change Control Process is adequate. Poor conformance to documented Change Control Processes would support a lower threshold.
  - The Project Team should ensure that safety protocols are not inhibited while the use of contingencies is under review.
- Once construction begins, the actual cost for specific WBS elements is likely to exceed the estimated cost. As stated above, the Project Team can choose to allocate contingency per the process defined in the PEP for Change Control. In other cases, the actual cost will be less than the estimates, and the Team may decide to transfer budget from the affected WBS elements to contingency using re-budgeting authority. In either case, whether it's a risk realized or a risk retired, the Change Control documentation should tie this transfer back to an identified risk in the Risk Register.
- Note that the use of contingency does not automatically require an immediate or additional change to the baseline. For instance, a Change Control action can authorize contingency to cover a cost overrun, which is tracked as a variance in the baseline BAC.

In such a case, the contingency can be incorporated into either the BAC or the EAC. In the first instance, the BAC is changed. In the second, the variance from the BAC remains and can be used for trending and other information, and the variance should be included in the Liens List.

- If needed, and at the appropriate time, cost underruns may either be assigned to contingency or re-budgeted following the Change Control Process. If approved, this may involve the AO increasing the contingency balance obligated through an award modification to ensure proper documentation by NSF in concert with the Change Control Log.
- For many projects, schedule and budget contingency use occurs during procurement and the final commissioning/integration phases. A contingency allocation curve for such a project would be bimodal, with one peak for procurement activities and another peak for significant contingency amounts held back until the end of the project, even though the spending curve may be low near the end of the project. Although risk generally decreases over time, significant reworking of hardware, for example, may be needed due to knowledge gained during integration and commissioning activities. Therefore, it is good practice to retain approximately 20% of the ETC in contingency throughout the project as a rule of thumb.

5.0 SUPPLEMENTAL GUIDANCE

5.1 INTRODUCTION

Section Revision: TBD Early 2025
Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

This chapter provides supplemental guidance on diverse aspects to ensure that the Research Infrastructure (RI) supported by NSF meets high standards regarding technological, environmental, human resource, and management considerations. It underscores the complexities of managing and overseeing research activities in the modern scientific landscape.

5.2 Cyberinfrastructure. Effective planning and oversight ensure cybersecurity, scalability, and alignment with scientific missions, safeguarding data integrity, ensuring reliability, and optimizing resource management.

5.3 Information Assurance. Rigorous measures protect against cyber threats and unauthorized access, ensuring the confidentiality, availability, and reliability of research data through a comprehensive program.

5.4 Environmental Considerations. NSF-funded RI **must** comply with federal environmental laws and regulations which help protect and minimize adverse impacts on environmental resources and reduce litigation risk.

5.5 Property Management. Defines responsibilities for Awardees and NSF throughout the life cycle of managing NSF-funded property.

5.6 NSF Budget Categories from the Proposal and Award Policies and Procedures Guide. Detailed guidance on budget justification for financial assistance aligning with NSF's *Proposal and Award Policies and Procedures Guide (PAPPG)*.

5.7 Personnel and Competencies. Emphasizes the importance of skilled professionals with diverse competencies to effectively manage Major Facilities and Mid-scale RI, as outlined by NSF.

5.8 Partnerships. Essential for Major Facility and Mid-scale RI, partnerships require careful planning, formal agreements, and early NSF notification to ensure compliance with legal and geopolitical considerations.

5.9 Agile Guidance. NSF supports Agile methodologies in projects, combining traditional and Agile approaches for effective management.

5.2 CYBERINFRASTRUCTURE

Section Revision: December 2024
Prepared by the Directorate for Computer & Information Science & Engineering (CISE)

Cyberinfrastructure (CI) is the ensemble of computational, data, control, and user-focused software and middleware, networking, and cybersecurity infrastructure and associated policies, standards, protocols, and staffing needed to accomplish the scientific mission for Major Facility or Mid-scale RI. CI elements may be embedded in the RI and leverage or interface with existing external CI resources.

CI associated with science deliverables is typically distinguished from information technology, i.e., the administrative- and staff-oriented IT systems and elements needed to conduct day-to-day operations of the facility itself and serve the staff, e.g., hardware/servers, personal computers, LAN, and facility security systems. By distinguishing CI from traditional IT, facilities can ensure that they allocate appropriate resources and support to both areas, thereby optimizing the overall efficiency and productivity of their operations and research activities.

Owing to the rapid pace of change of both CI technologies and associated user expectations, the approaches to development, deployment, and operation of CI can be dynamic. During operations, in particular, periodic refreshing and enhancement of CI capabilities is commonly needed to assure continued robustness, security, and scalability of the underlying technology infrastructure and that CI continues to be well-aligned with the RI's vision and science mission. This, in turn, necessitates well defined planning and oversight of CI across the RI life cycle.

5.2.1 CI Plan Requirements

NSF requires that all proposals for Major Facility and Mid-scale RI include a CI Plan that outlines the strategy and approach for CI across the life cycle of the proposed RI. If the Mid-scale RI is an upgrade to a Major Facility, it can leverage the Major Facility's CI Plan. The CI Plan should be tailored and scaled, and progressively elaborated as the RI advances through its life cycle stages as it aligns with the mission and objectives of the RI. Existing RI may also develop a CI Plan following this format based on requirements provided by the cognizant Program Officer (PO). For good practices on topics to address in the CI Plan, see the NSF Cyberinfrastructure Plan Outline on the Research Infrastructure Documents and Guidance webpage.[1]

5.2.2 CI Plan Purpose and Scope

A CI Plan provides a structured approach for planning, implementing, and managing the CI aspects of the RI. It also serves as a roadmap for the CI within a RI and thus helps ensure that NSF's expectations for CI are thoroughly included in the Development, Design, Construction/implementation, and Operations Stages. It serves as guidance for downstream

[1] https://www.nsf.gov/bfa/lfo/lfo_documents.jsp

oversight and review of the CI aspects of the infrastructure. Thus, the CI strategy and elements should be defined and planned for from the inception of the RI, be adequately resourced, including for periodic technology refresh, and evaluated for adequacy and performance throughout each life cycle stage. The CI Plan ensures that the complexities of the CI are well-documented and clearly communicated enabling effective management throughout the RI's life cycle.

Providing references to other planning and management documentation in the CI Plan is acceptable and the primary approach, as the CI Plan itself should not restate or specify new requirements or technical/operations design elements. Of note, since data are central to the missions of many RI, and thus often drive CI requirements, the CI Plan should refer as appropriate to the relevant data-related requirements and design documents. These may variously include the Data Management Plan, definitions of data products and data life cycle, requirements associated with open science and open data principles, such as FAIR (Findable, Accessible, Interoperable, and Reusable), and other emerging principles such as for data sovereignty, such as CARE Principles for Indigenous Data Governance (Collective Benefit, Authority to Control, Responsibility, and Ethics) and associated requirements and designs for data management, archiving, curation, and accessibility.

NSF acknowledges that various elements of the CI Plan may already be included in other RI plans and documentation. However, having a dedicated CI Plan is crucial as it ensures that all elements of CI are documented in one place that reviewers and RI team members can specifically reference and clearly understand CI components within the broader context of the entire RI life cycle.

The CI designs for RI, and thus the CI Plan, should include consideration of both internal systems within the scope that the proposing organization owns and operates, as well as any external CI resources that the proposing organization may not own or operate, but need to be leveraged and integrated into facility operations to accomplish its science mission, including, but not limited, to NSF-supported resources such as advanced computing, data and software infrastructure, resources, and networking.

5.3 INFORMATION ASSURANCE

Section Revision: TBD Early 2025

Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

> **Key Takeaway**
>
> IA encompasses cybersecurity, data protections, cyber risk management, and resilience.

Definitional Note: Information Assurance (IA) is used as the umbrella term inclusive of cybersecurity, data protections (including privacy), cyber risk management, and resilience. What was formally referred to as the *security plan* is now called the Information Assurance Management Plan (IAMP) to align the terminology with contemporary use and underscore the distinction between technical operations and program management (see Section 5.3.5 Information Assurance Management Plan). That is, the subject of IA is information, and not merely information systems.

5.3.1 Introduction

IA is fundamentally a program of risk management and is the responsibility of the management organizations of Awardees. Management organizations have significant leeway in how they choose to address IA. However, NSF remains committed to ensuring the mission of funded vital national assets are sufficiently protected from disruption, misuse, theft, or damage. In pursuit of this goal, NSF requires sufficient documentation and evidence that Awardees are performing good stewardship regarding IA. As discussed further in the section, NSF Major Facilities and Mid-scale RI Project Teams **must** develop and implement an IA Program and associated IAMP. If the Mid-scale RI is an upgrade to a Major Facility, it can leverage the Major Facility's IAMP. It should be appropriately scaled and tailored to the size, complexity and technical nature of the funded activities defined as follows:

- The IA Program is a set of measures that are taken together to protect and defend information and information systems.
- The IAMP is the high-level narrative summary of the IA Program.

It is essential for the Awardee and managing organization to recognize that it cannot address cyber risks merely through technical controls. Cyber-related threats evolve regularly, and prioritizing their mitigation should be done at the highest levels of RI management.

Accordingly, an IA Program should be managed in keeping with the principles that:

- A Major Facility or Mid-scale RI's IA Program should reflect its specific mission and goals.
- Cybersecurity attacks and defense are rapidly evolving areas of activity, and any such program should be similarly adaptive.
- IA requires a programmatic approach in contrast to a handful of transactional practices.
- IA within RI **must** support the goal of protecting vital national assets from cyber-attacks and data theft.

- Commonly recognized critical and impactful cyber hygiene controls should be fully implemented.
- IA Programs should include engagement with, and support of, managing organization leadership.
- NSF requires sufficient information about the planned and executed IA Program to meet oversight obligations.

Research programs differ from traditional commercial enterprises in many ways. From the location (traditional RI to airplanes, ships, and field work) to the technology (highly customized instrumentation, computational facilities, and data structures), to the people (students, faculty, remote collaborators), and, as such, IA Programs and specific cybersecurity practices should also be adapted to the needs of the research program. Be that as it may, many modern best practices, such as phishing resistant multi-factor authentication (MFA) for account protection, are generally applicable to every CI.

NSF expects facilities to strive for resilience. Resilience for a facility consists of:

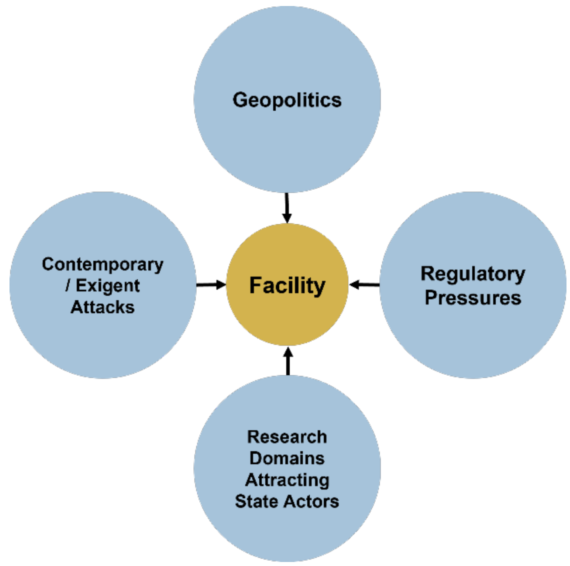
- Minimizing the likelihood of successful attacks in general, and unsophisticated, opportunistic attacks specifically.
- Minimizing the impact of even sophisticated attacks by constraining the impact or ability to spread throughout a facility.
- Minimizing the period of the disruption of scientific operations.
- Ensuring the integrity of scientific data and artifacts despite the occurrence of a cybersecurity incident.

An effective IA Program that builds resilience has several elements. While it is easy to focus on specific cybersecurity practices (e.g., strong passwords), the success of any IA Program is contingent on effective engagement with the NSF Program Office and facility management. As with any risk management program, cyber risk is rarely eliminated, rather it should be minimized where feasible and residual risk should be acknowledged and formally accepted by facility leadership. NSF, through its oversight processes, looks to see that cyber risk has been adequately managed and addressed.

5.3.2 Framing Information Assurance Risks in the Contemporary Threat Landscape

RI faces a wide array of threats and pressures that require attention. NSF expects RI to include cyber risks in the Risk Register which is discussed at length below. There are four areas detailed here to assist with the establishment of the cyber risk elements of a Risk Register and to provide both NSF PO and facility management with some situational awareness.

Figure 5.3.2-1
Threats to RI



5.3.2.1 Geopolitics

The state of the U.S. relationship with several adversarial countries directly impacts cyber-security operations. The goal of some state actors is not always focused on the theft of data or intellectual property; often the purpose is simply the costly disruption of operations. Countries on the Office of Foreign Assets Control sanctioned list or with International Traffic in Arms Regulations restrictions warrant special note in this context.[1] Both the Cybersecurity and Infrastructure Security Agency and the Federal Bureau of Investigation are effective partners in staying abreast of national security threats.[2,3]

5.3.2.2 Specific Research Domains

Facilities that work in specific domains or with nationally critical or emerging technology should recognize that this work may attract the attention of individuals or groups that are acting on behalf of a government or nation-state, also referred to as state actors. These domains include export-controlled data, research involving technology on the Critical and Emerging Technologies List, vaccine development, or defense related research.[4]

5.3.2.3 Regulatory Pressures

Regulations that address cybersecurity practices continue to be advanced by the federal government and many federal agencies. For example, the National Security Presidential Memo 33 and subsequent Office of Science and Technology Policy (OSTP) memos identify cybersecurity as a core component of research security program.[5] Dual use facilities may also be facing new Controlled Unclassified Information or other cybersecurity requirements

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[1] https://ofac.treasury.gov/sanctions-programs-and-country-information
[2] https://www.cisa.gov/resources-tools/services
[3] https://www.fbi.gov/investigate/cyber
[4] https://www.whitehouse.gov/wp-content/uploads/2022/02/02-2022-Critical-and-Emerging-Technologies-List-Update.pdf
[5] https://www.whitehouse.gov/wp-content/uploads/2024/07/OSTP-RSP-Guidelines-Memo.pdf

to engage in Department of Defense, or Department of Energy supported research. Finally, many of the newer privacy focused regulations contain their own data handling requirements as well as imposing specific cybersecurity controls. Facilities should monitor the activities of all agencies they interact with and examine these for potential impact on NSF sponsored programs. NSF's Office of the Chief of Research Security Strategy and Policy is a valuable resource for any facility.[1]

5.3.2.4 Other Attacks and Concerns

Finally, security professionals are faced with a variety of exigent and emerging attack types, some of short duration, others of a more enduring nature. Current examples include ransomware, supply chain management, and MFA fatigue.[2] Items such as these should be evaluated at least bi-annually, and mitigation plans developed or updated.

5.3.3 Awardee Obligations

There are several requirements relevant to IA for Awardees. These should be reviewed regularly and watched for updates or modifications.

- Uniform Guidance §200.303 states that the Awardee's internal controls, including technology infrastructure and security management, should be compliant with guidance published by the Comptroller General or Committee of Sponsoring Organizations of the Treadway Commission.[3, 4]
- The Cooperative Agreement Supplemental Financial and Administrative Terms and Conditions for Awardees of RI or Federally Funded Research and Development Centers requires an information security program and identifies a modest set of required components for the program.[5] These should be described in the IAMP.
- A tailored, scaled, and progressively elaborated IAMP is a required element of the Design, Construction/Implementation, and Operations Stages of a Major Facility or Mid-scale RI.
- In instances where a Major Facility or Mid-scale RI is funded through a contract, the Federal Acquisition Regulation (FAR) contains requirements for the Safeguarding of Covered Information Systems with FAR 4.1903 and FAR 52.204-21. Additional cyber-related requirements may also be included within the terms and conditions of the contract. All award documentation should be examined for IA-related terms.

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[1] https://new.nsf.gov/research-security
[2] MFA fatigue refers to the overwhelming attempts to log into an MFA protected account by a hacker resulting in the user accepting or approving the access out of fatigue from declining to approve it. See https://www.cisa.gov/sites/default/files/publications/fact-sheet-implement-number-matching-in-mfa-applications-508c.pdf for a discussion on preventing MFA fatigue.
[3] https://www.ecfr.gov/current/title-2/subtitle-A/chapter-II/part-200/subpart-D/section-200.303
[4] https://www.coso.org/
[5] https://www.nsf.gov/awards/managing/co-op_conditions.jsp

Key Takeaway

NSF expects to be provided with the following documentation pertaining to IA at all program reviews. These may also be requested after a reportable cybersecurity incident.

- The IAMP, what has been called the written summary of the security program or security plan.
- A current IA budget.
- A list of cyber related risks and intended mitigations as part of the Risk Register.
- An update on the status of the technical controls described below.

These are described in greater detail below.

5.3.3.1 IA Program Tailoring and Scaling

Because an IA Program should naturally reflect the nature and scope of a facility (facility type and Major Facility vs. Mid-scale RI), NSF presumes the materials provided describing such a program should similarly be tailored and scaled. Mid-scale RI, which commonly rely on institutional information security programs, may provide IAMP that largely refer to institutional resources and processes, primarily providing details for those elements local or dedicated to the RI. Major Facilities, that typically build their stand-alone security programs, will necessarily be considerably more comprehensive and rigorous.

Similarly, what can be said about an IA Program should also reflect the life cycle stage of the facility. Through the Design Stage, most proposed projects can only describe how cybersecurity plans to be integrated into the CI Plan, and what is intended for the future IA Program. However, NSF recommends that programs begin identifying and anticipating cyber risks as early as possible, allowing time for mitigations to be planned and resourced. **Table *5.3.3.1-1*** provides a general overview of the RI life cycle and IA activities.

Table 5.3.3.1-1
IA and RI Review Cycle

Phase/Activity	Development	Design					Construction/ implementation	Operations	Divestment
Cybersecurity		**Align cybersecurity architecture as design and infrastructure evolve**					Maintaining security plan alignment with exigent pressures. **Program implementation**	Maintaining security plan alignment with exigent pressures ---------------- **Security Ops**	N/A
Cybersecurity Plan Reviews		DEP Review		DEP Review		DEP Review	PEP Review	Largely driven by Risk Register	
Cybersecurity Performance Metrics		N/A	N/A	N/A	N/A	Identified	Update/ Monitor	Update/ Monitor	N/A
Risk Assessment/ Register		Initial		Updated		Update	Update/ Monitor	Update/ Monitor	N/A

Over time, the IAMP should be progressively elaborated to reflect the increasing maturity of the IA Program.

5.3.4 Cyber Risk in the Risk Register

Cyber risk should be included as a category in the Risk Register, if applicable (see Section 4.6 Risk Management) and systematically addressed through a Risk Management Plan. Note that cyber risks included on your Risk Register may be included in your contingency planning process. Cyber risks should be categorized or codified as such in the Risk Register to facilitate ease of organizing and extracting them for review. A review of cyber risks in the Risk Register should take place at least quarterly.

Cyber risks may be broken down into sub-categories, for example:[1]

- **Strategic Risks.** For example, relevant geopolitical flareups, reputational damage from cyber breaches, regulatory compliance, unmet budget, or staffing needs.
- **Exigent or Emerging Risks**. e.g., ransomware, supply chain, urgent and impactful vulnerabilities.
- **Operational Risks**. Unmet controls in any adopted standards, i.e., gaps in the baseline cybersecurity practices.

A reasonably complete set of risks requires input from facility management, scientists and researchers, and CI and cybersecurity professionals. Each of these groups will have different perspectives and concerns which should be captured in the Risk Register. Conversations with allied or similar facilities will also be helpful. Additionally, the Open Science Cyber Risk Profile was created specifically to assist with risk identification from the perspective of domain scientists.[2] It can serve as a framing device for tabletop risk identification exercises.

5.3.5 Information Assurance Management Plan

Created by the Major Facility or Mid-scale RI's IA Lead, the IAMP is the high-level management *runbook* for an IA Program.[3] The IAMP should codify an IA Program's scope, roles and responsibilities, governance, and controls. This contrasts with a collection of policy or procedural documents.

The IAMP is intended to be used as part of the RI management and the following elements should be included:

- **Statement of Cyber Risk Management Strategy.** A cyber risk management strategy is the process for identifying, assessing, and controlling cybersecurity risks. In

[1] This taxonomy is provided for the purposes of illustration only.
[2] https://trustedci.github.io/OSCRP/
[3] The IA lead, typically entitled an Information Security Officer, is the individual accountable for the entire execution of the IA Program. While it is ideal to have a dedicated, full time staff member in this role, it is also common to assign the duties of the information security officer to an existing staff member, typically a member of the infrastructure team. RI management should expect their IA lead to participate in cross-RI communities and programs. NSF recommends including the IA Lead on the executive management team.

addition to a brief narrative description of the cyber risk management strategy, this section should include:

- **A Cybersecurity Framework.** A cybersecurity framework refers to the approach taken to organizing an IA Program. This shapes the organization's IA Program (see Section 5.3.7 Building an Information Assurance Program).
- **Baseline Cybersecurity Control Set.** Specific practices and technologies the proposer or organization plans to commit to, or has committed to, implementing to manage cyber risks. A nationally or commonly recognized standard is recommended.

- **Scope and Boundaries.** A formal enumeration of network and service boundaries is particularly critical where resources or networks are shared or support dual-use situations. Include network, cloud, and data resources, as well as organizational resources.
- **Responsibility Model and Matrix.** Roles, responsibilities, and relationships among the IA and CI teams and critical partners. Include responsibilities for risk identification and acceptance (therefore include facility and program leadership).
- **Governance.** Any governance and advisory committees, working groups, and a description of their roles and decision-making rights regarding IA.
- **Risk Treatment Plans.** Describes how a critical risk, such as ransomware, is being mitigated. It typically includes a collection of individual technical, policy, and process controls, but aggregates them into a single summary document. Risk Treatment Plans are a useful tool for ensuring complex risks have been sufficiently addressed. Organizations are free to build Risk Treatment Plans that are topically appropriate to the facility.
- **IA Program Operations.** This section of the IAMP enumerates and describes core processes, functions, and responsibilities of the IA Program. It should include the following components.
  - **Programmatic Processes.** Systematic and structured approaches to managing various aspects of a program provide a framework for managing activities within the IA Program. Provide a description and activities to address processes such as inventory, policy exception handling, or compliance monitoring.
  - **Baseline Security Functions.** Establishes baseline security functions crucial for maintaining an organization's strong and resilient security posture and serves as fundamental building blocks for a comprehensive security strategy. Provides a description of and related activities to address functions such as (but not limited to) incident response, email anti-spam and malware protections, account management, MFA, vulnerability detection, and patching.
  - **Supplemental Responsibilities of the Security Program.** Supplemental responsibilities in a security program go beyond the foundational security functions and involve additional activities often specific to the RI's needs, industry regulations, and risk landscape. Provide a description of and related activities to

address supplemental responsibilities, such as regulated data contract/supply chain review and approval, security awareness, and training, if these are considered part of the IA Program.

- **Assessment Plan.** Regularly assessing the implementation of baseline security controls and overall success of the risk management strategy is crucial for ensuring that security measures remain effective over time. Describe how the controls plan to be monitored and assessed and consider engaging outside resources for a program assessment. Weaknesses identified during any assessment should become a component of the Risk Register (see Section 5.3.11 Program Assessment).

5.3.6 Critical Controls

Several cybersecurity controls have been identified as exceptionally impactful in improving the resilience of Major Facility and Mid-scale RI, as illustrated in Table 5.3.6-1. NSF expects these controls to be an integral part of the Awardee's management practices for each Major Facility and Mid-scale RI and to be targeted for prioritized implementation. These controls should be integrated into the design and construction of new RI, and phased into operational RI within a reasonable timeframe, as determined by the NSF Integrated Project Team (IPT).

NSF will continue to align cybersecurity requirements for Awardees with federal cybersecurity expectations as these evolve. Thus, Awardees are encouraged to accelerate implementation of their IA Programs and regularly engage with their cognizant NSF PO on the question of new or potential cybersecurity requirements.

To remain sensitive to the unique nature and workflow of each facility, compensating controls or novel approaches to addressing a control, and mitigating the targeted risk of a control, are welcomed, and encouraged. For guidance on interpreting these controls, refer to the National Institute of Standards and Technology (NIST) guidance for corresponding controls (suggested mappings to NIST standards are provided); NSF Subject Matter Experts (SME) are available for consultation through the cognizant NSF PO.[1]

[1] References are to the cited control families of NIST standard 800-53 revision5 (800-53r5) or 800-171. Thus, as an example, AC-6(4)(5), SC-3 800-53r5 refers to control family AC, controls 6(4)(5) and control family SC, control 3 of 800-53r5.

Table 5.3.6-1

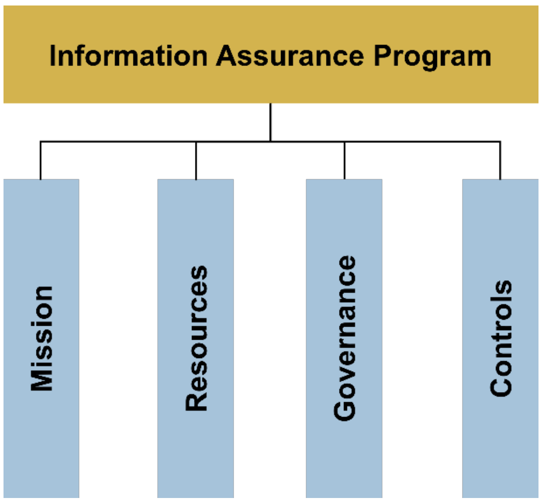
NSF Critical Controls Set

Control Key	Control	Description
NSF1	Require phishing resistant MFA for all privileged/ administrator accounts	Privileged and administrator accounts – accounts with system management privileges or the ability to change a system or an application's configuration. REF: IA-2(1), AC-2(7) 800-53r5
NSF2	Require phishing resistant MFA for all remote access	Protocols such as SSH, RDP (remote desktop), FTP, VNC, or VPN should require MFA. REF: IA-2(2), AC-17 800-53r5
NSF3	Limited scope administrative accounts	Privileged/administrative accounts should be restricted in scope (e.g., separate accounts for web servers, database servers, system management, network management). REF: AC-6(4, 5), SC-3, CM-7 800-53r5; 3.1.5 800-171
NSF4	Deploy and maintain anti-malware software	Deploy anti-malware software to systems capable of running such software. For a variety of reasons some systems (e.g. instrumentation, HPC, embedded systems, control systems) may not be able to run anti-malware software and are thus excluded from this control. REF: SI-3 800-53r5
NSF5	Anti-malware includes Endpoint Detection Response functionality	Modern anti-malware products include or can be supplemented with Endpoint Detection Response functionality. These greatly improve the ability to validate system integrity. REF: SI-3, SI-7(7) 800-53r6
NSF6	Immutable backups of systems	Backups of CI should be stored in a fashion as to be immutable from change, corruption, or deletion. REF: CP-4 800-53r5
NSF7	Immutable backups of essential research data	Critical research data should be backed up and stored in a fashion to be immutable from change, corruption, or deletion. REF: CP-4 800-53r5
NSF8	Regular tests of back up integrity and testing of restoration process	The backup program should include a step to test the integrity of and ability for large scale restoration of backups at least once a year. REF: CP-4, CP-10 800-53r5
NSF9	Collect and monitor all system logs	System and application activity logs for the CI should be centrally collected for the purposes of security monitoring and auditing. REF: AU-2, SI-4 800-53r5
NSF10	Network segmentation and isolation control	The network environment should be segmented thus reducing the ability of malware, such as ransomware, to spread. This may include any method of segmentation (e.g., network design and routing, internal firewalls, proxies, bastion hosts, etc.) sufficient to protect the infrastructure. REF: SC-7(13, 20,21,28,29) 800-53r5; 3.13 (various) 800-171r2
NSF11	Maintain and update an inventory of critical infrastructure	Maintain an inventory of critical infrastructure. Critical infrastructure are systems and devices that maintain and provide access to services (e.g., VPN, MFA, Identity and Access Management systems), network devices, and devices enabling core scientific capabilities. REF: RA-2, PM-5 800-53r5
NSF12	Defined process for identifying, tracking, and remediating vulnerabilities	A vulnerability management program is a framework for managing vulnerabilities in systems and software throughout the CI. REF: RA-5 800-53r5
NSF13	Hardening standards/processes for critical infrastructure	Create and implement a secure configuration standard applied to all systems under direct management. REF: CM-2, CM-6 800-53r5

Control Key	Control	Description
NSF14	Incident Response Plan and annual tabletop exercise simulating a major incident	Ensure the Incident Response Plan is documented and approved by Program and facility leadership. Run a regular tabletop exercise of it at least annually. REF: IR-2(1), IR-8, IR-3 800-53r5

5.3.7 Building an Information Assurance Program

Figure 5.3.7-1
Pillars of an IA Program



In the context of IA, a framework refers to the approach taken to organizing an IA Program. Typically, these are sets of policies, standards, guidelines, and best practices established to control information security risk. It is common for a complex organization to manage multiple frameworks as different regulatory bodies often impose particular frameworks. NSF does not require the use of any specific framework but requires Awardees to select one for their program and identify it in the IAMP. Map maintenance of the selected framework for federal or international frameworks, such as NIST's Cybersecurity Framework or International Organization for Standardization 27001 and 27002, is recommended.[1,2,3]

To help support facilities in establishing their IA Programs, four key elements upon which to build resilience have been identified.

5.3.7.1 Mission Alignment

Mission alignment requires understanding the scientific goals and workflows at a facility and considering the researchers' concerns in shaping the selection and implementation of practices. While identifying mission alignment is critical throughout the life cycle of a facility because it should guide the architecture of the facility's assurance program, it is critical that this is closely analyzed in the early planning and pre-implementation stages of a facility.

5.3.7.2 Governance

Oversight of IA is part of the overall facility governance process. Organizational roles, policies, the acceptance or mitigation of risk, and program assessment require engagement from the most senior administrators of a facility.

[1] https://www.iso.org/standard/75652.html
[2] https://www.iso.org/standard/27001
[3] https://www.nist.gov/cyberframework

5.3.7.3 Resources

IA Programs require adequate resources. The percent of budget that most Major Facilities devote to IA covers a wide range and is tightly coupled to the type of facility.[1] It is critical, however, for an organization to be able to line item the IA budget, thus surfacing the investment for explicit review by management.

5.3.7.4 Cybersecurity Controls

Every IA Program, within its IAMP, should identify a set of cybersecurity controls it plans to implement. In response to an analysis of historical incidents, NSF has identified a small set of essential security controls for prioritized implementation. These should be included as part of the identified baseline control set. These are detailed in Table 5.3.6-1.

To avoid investing resources in implementing and assessing low-impact controls, NSF recommends selecting a baseline standard that includes practices that are widely established and offer the broadest protection. Many organizations are now developing, or have produced, subsets of the comprehensive body of security controls, identifying those controls with the highest return on investment. A robust example of such a control would be MFA. Sample control sets include:

- Cybersecurity & Infrastructure Security Agency[2]
- Center for Internet Security[3]

Facility leadership may reasonably expect periodic updates on the implementation status for these standard and established practices. While a control assessment rubric can be as nuanced and sophisticated as desired, a simplified table is often more accessible for facility leadership.

5.3.8 Data Management and Curation

Historically, data management and the creation of the NSF Data Management Plan (see Section 3.5.8.4 Project Execution Plan Subcomponent 8.4 – Data Management) have been a parallel effort to cybersecurity and CI.[4] NSF recommends considering these topics holistically by reviewing access to data and data integrity concerns through the lens of cybersecurity.

When appropriate, RI should carefully monitor the work associated with the 2022 OSTP Public Access Memorandum and ensure that their Data Management Sharing Plan and budget address obligations for data retention that meets the needs and expectations of domain science, organizational, and sponsoring agency requirements, as well as federal

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[1] The security budget as a percentage of total budget for a ship, for example, may be wildly different than a monolithic computational facility.
[2] https://www.cisa.gov/cross-sector-cybersecurity-performance-goals
[3] https://www.cisecurity.org/controls/cis-controls-list
[4] NSF requires a Data Management Plan for all awards. To underscore the importance of open science, the Data Management Plan has been renamed the Data Management and Sharing Plan. Information on the Data Management Sharing Plan requirements can be found at https://new.nsf.gov/funding/data-management-plan.

requirements applicable to sponsored programs.[1] The sheer volume of data created at most large facilities (and many smaller research programs) far exceeds the capacity to store everything. Facilities should perform a close analysis with the researchers to identify data that should be retained, establish retention lifetimes, obtain digital object identifiers (DOI), target repositories, and identify data sets for which data integrity and provenance concerns are paramount.

Interfaces to data repositories should be examined as a possible entry vector for malicious activities and malware. Similarly, IA teams can help review the data pipeline between data collection to storage, identifying possible threats to data integrity or theft.

It is not uncommon for data that is ostensibly public to have elements requiring redaction or greater access limits. For example, geolocation information within data on endangered species has been used by poachers. IA staff can partner with domain scientists and data curation experts to make recommendations on secure data handling and access procedures and help evaluate the cybersecurity rigor of preferred data repositories.

5.3.9 Information Assurance and Cyberinfrastructure

It is useful when writing an IAMP to consider how IA and CI relate to one another. It is quite common to see IA referenced as a component of CI. This is because CI is itself secured through the application of IA practices. However, because IA is fundamentally a risk management function, it should not be seen as exclusively a subset of a CI Plan.

CI Plans may reference IA by addressing the question, *how is the CI described here secured and maintained?* directly, or by reference to the IAMP or the body of policies and practices enforced on the CI.[2] However, the management of risk – risk identification, assessment, mitigation, and acceptance – as a programmatic function sits outside pure CI. Strategies for cyber risk management should be articulated in the integrated risk program for the entire RI and referenced in the IAMP.

5.3.10 Cyberbreach Insurance

Increasingly organizations of every size, including Major Facilities, have obtained, or are pursuing, insurance to cover the costs associated with a cybersecurity incident. Typically, these packages do more than cover some of the expenses associated with a return to operations, but additionally provide access to expertise in the areas of forensics, crisis communications, breach notification, and legal counsel. NSF neither requires, nor takes a position on cyber breach insurance, however, NSF recommends this as a discussion topic with the cognizant NSF PO. NSF policy aligns with federal guidance and thus dictates that

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[1] https://www.whitehouse.gov/wp-content/uploads/2022/08/08-2022-OSTP-Public-access-Memo.pdf
[2] The Trusted CI framework provides an excellent starting point with templates for major policy documents, https://www.trustedci.org/framework.

award funds may not be used to pay ransoms, nor cyber insurance's ransom coverage.[1]

5.3.11 Program Assessment

NSF expects a RI leadership or the managing organization to annually assess the effectiveness and progress of its IA Program in the context of reportable events and support of its mission. This is essential not merely to ensure the effective use of resources dedicated to IA but to keep an IA Program aligned with and resourced to meet the changing demands of the ever-evolving cybersecurity landscape. This can be achieved using internal or external assessors.

During program review, Major Facility and Mid-scale RI can expect evaluation across three dimensions:

- Is sufficient progress being made in implementing the baseline controls set? That is, are gaps in compliance with a chosen cybersecurity compliance standard being filled?
- Are the mitigations identified in the Risk Register successfully implemented? Are high priority risks getting addressed?
- Have any significant, reportable, incidents been avoided?[2]

[1] It is important to note that 2 CFR 200.447 speaks to insurance as an allowable cost for grant Awardees. In particular, however, the FBI discourages the paying of ransom or extortion demands, and payments may threaten US national security, foreign policy interests and may violate Office of Foreign Assets Control regulations. https://www.ic3.gov/CrimeInfo/Ransomware

[2] RI leadership should note that a cybersecurity incident does not in itself indicate the failure of an IA Program. It does warrant a serious review of one's program to ensure leadership support and resourcing is adequate to meet the expectations of the RI and NSF.

Table 5.3.11-1
Simplified Sample Posture Rubric

Control	Fully Implemented (+10)	Partially Implemented (+5)	Not Implemented (-5)	Score
Require MFS for laptops/workstations	X			10
Require MFA for all applications		X		5
Deploy and maintain anti-malware software		X		5
Immutable backups of systems		X		5
Immutable backups of essential research data			X	-5
				20/50

No IA Program is perfect or complete. Over the life cycle of a Major Facility or Mid-scale RI, the IA Program should show a steady improvement in maturity as measured using one of the commonly established methodologies. It may be useful to note that most of the assessment frameworks in common use assume an enterprise or industrial context.[1] However, if an IA Team has expertise in a specific assessment approach, consider leveraging that capability.

[1] Such as the NIST CSF framework https://www.nist.gov/cyberframework or the DOE's C2M2 https://www.energy.gov/ceser/cybersecurity-capability-maturity-model-c2m2.

5.4 ENVIRONMENTAL CONSIDERATIONS

Section Revision: XX Fall 2024

Prepared by the Research Infrastructure Office and the Office of the Chief Officer for Research Facilities.

RI supported by NSF **must** comply with all relevant international (when applicable), federal, state, and local environmental requirements. Certain environmental compliance requirements, such as review under the National Environmental Policy Act (NEPA), **must** be addressed prior to a funding decision, and is NSF's responsibility, though the potential Awardee may provide input to NSF's review. The Awardee may have other environmental compliance requirements after the funding decision is made, such as permitting and implementation of required environmental mitigation measures.

5.4.1 Environmental Considerations prior to NSF Funding Decision

NSF funding for the construction, implementation, operation, modification, or change in disposition of a Major Facility or Mid-scale RI constitutes a federal action that triggers NSF's compliance with federal statutes and regulations that require NSF to consider impacts on environmental, cultural, and historic resources as part of its decision-making process. These legal authorities include, but are not limited to, the NEPA, the National Historic Preservation Act, and the Endangered Species Act. While NEPA focuses on activities proposed to take place within the United States, activities that are proposed to take place outside of the United States may be subject to review under Executive Order 12114 and relevant international agreements and treaties.[1]

Environmental review **must** be completed prior to the issuance of an NSF decision (e.g., award and/or approval for use of funds). Failure to take necessary compliance steps can cause undue delays in the schedule, significant cost escalation, and potential federal litigation.

Segmenting a proposed funding action into smaller component parts in such a way that obscures potentially significant impacts is not allowable. However, NSF funding of planning and conceptual design activities typically does not have the potential to result in environmental impacts and, therefore, they are not anticipated to trigger environmental compliance requirements. Subsequent proposed actions that might adversely affect the quality of the human environment are, however, subject to environmental review and NSF approval. There is no special source of funding within NSF to pay for the environmental compliance process; the cost is normally borne by the program using Research and Related Activities (R&RA) funds.

[1] https://www.archives.gov/federal-register/codification/executive-order/12114.html

5.4.1.1 NSF's Role in Conducting Environmental Review

NSF's NEPA implementing regulations found at 45 CFR § 640 supplement the Council on Environmental Quality's NEPA regulations published at 40 CFR §§ 1500-1508. PO, as required by NSF's regulations, are responsible for evaluating potential environmental impacts that may result from the implementation of a proposal and determining the appropriate level of environmental review required. The PO is encouraged to consult the NSF Office of General Council Environmental Compliance Team when determining the extent of compliance requirements. NEPA compliance may require the preparation of environmental documentation, such as an Environmental Assessment in cases when significant environmental impacts are not anticipated, or an Environmental Impact Statement when significant impacts are anticipated.

Compliance with NEPA may require NSF staff to engage with the public on issues such as potential environmental impacts and ways to avoid, minimize, and/or mitigate adverse impacts. In addition, NSF will evaluate whether the proposed activities may impact communities with environmental justice concerns. This would include impacts such as adverse effects on communities disproportionally affected by climate change, energy costs, pollution, and historical under-investment in infrastructure. In conjunction with, or independent of, its NEPA compliance, NSF may be required to initiate consultations with interested parties, including Tribal Nations and Native Hawaiians, pursuant to the National Historic Preservation Act, and/or initiate informal or formal consultation with the National Oceanic and Atmospheric Administration Fisheries, and/or the U.S. Fish and Wildlife Service under the Endangered Species Act.[1] The PO may need to rely on and maintain close communication with the potential Awardee when preparing complex environmental documentation and during various environmental compliance processes and Tribal Nation consultation, as described below.

5.4.1.2 Potential Awardee Role in Supporting NSF's Environmental Review

The potential Awardee may be requested to submit supplemental post-proposal submission information to NSF in order that a reasonable and accurate assessment of environmental impacts by NSF may be made. The types of information that may be requested are exemplified in the NSF Environmental Impacts Checklist.[2] Potential Awardees may choose to consider environmental criteria as appropriate, when selecting potential sites and developing conceptual-level design features, to avoid unnecessary environmental impacts from any future construction and operation of the RI, should it be funded. Further, given the need for NSF to evaluate potential environmental justice concerns, RI proposals may benefit from the potential Awardee's early consideration of, and/or engagement with (e.g., through culturally appropriate co-design processes), such communities when considering potential site locations and design features. If the proposed activities are anticipated to impact Tribal Nation resources or interests, and financial assistance is used, the potential Awardee **must**

[1] https://www.fws.gov/program/endangered-species
[2] https://www.nsf.gov/bfa/dias/policy/papp/pappg17_1/environimpacts_checklist.pdf

follow the requirements set forth in the *PAPPG*, related to seeking and obtaining permission from the potentially impacted Tribal Nation(s) in accordance with the directives of each Tribal Nation.

There may be cases where the Awardee is authorized to prepare an Environmental Assessment or Environmental Impact Statement, or to conduct activities in compliance with other environmental statutes, on behalf of NSF, consistent with 40 C.F.R. 1506.5; in such cases, consistent with 40 C.F.R 1507.3(c), NSF will review and approve the purpose and need section and the range of alternatives evaluated within the document and independently evaluate the document.

5.4.2 Environmental Considerations Following NSF Funding Decision

If the Awardee identifies any unexpected or actual environmental impacts while performing the work required by the award, they **must** promptly inform NSF, in accordance with the award terms and conditions. The Awardee **must** halt any work causing these impacts until NSF has had time to evaluate the situation, complete necessary compliance activities, and give further instructions. The Awardee is also responsible for implementing post-award mitigation measures or fulfilling reporting requirements determined during the environmental review process. These requirements may be the responsibility of the Awardee (e.g., to hire a Tribal monitor during ground disturbing activities) and/or NSF (e.g., to provide training to facilities staff on how to deal with the presence of a listed species).

Permitting is typically the Awardee's responsibility and may be obtained after a funding decision is made. Municipality-issued construction permits, and state or federal agency-issued collections permits are examples of environmental permitting.

Good Practices and Practical Considerations

- It is recommended that the PO contact the NSF Office of General Council Environmental Compliance Team early in the Conceptual Design Phase to seek guidance on specific requirements for compliance. The time required to complete environmental compliance can take one to two years (or more) depending upon the level of impacts associated with a proposed project.
- The potential Awardee may be prepared to submit supplemental information to assist NSF with determining potential environmental impacts, preparing environmental documentation, and completing various environmental compliance processes and consultations.
- It is extremely important that the PO and the Project Team get cost estimates for the compliance process and factor these into the proposed project's scope, schedule, and budget early in the design process.
- The cost drivers associated with these activities (their impact on the proposed project construction cost) need to be well understood by Preliminary Design Review (PDR) since the PDR budget and risk assessment provide the basis for the construction funding request.

5.5 PROPERTY MANAGEMENT

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NSF retains ownership of the property it funds, such as equipment (personal property) or real property, as specified in the terms and conditions of the award which will vary by award instrument type. Under financial assistance, title resides with the Awardee unless otherwise stated in the award terms and conditions since one purpose of such awards is to “transfer a thing of value to the non-federal entity.” In some limited cases, NSF will retain title to the property (i.e., keep as federally owned property) based on operational considerations and other award or program-specific circumstances. These determinations are made at the time of the award or periodically during the award period of performance when the property is acquired. At the end of the award, NSF may choose to invoke its *conditional interest* in NSF-funded property to take title or transfer it to another organization in support of the broader science program.[1] Under FAR, the government retains title to all property until properly disposed of, since the primary beneficiary of the activities under the award is the federal government. These title and disposition determinations are necessary to protect the public’s substantial investment in these unique research facilities.

Given the extent and value of these investments, it is incumbent on the Awardee to understand their responsibility under the award and maintain a sufficient property management system and supporting policies and procedures.

The Awardee’s policies and procedures governing the management of federally funded property should include:

- Acquisition and procurement processes.
- Financial records retention processes (physical and electronic) necessary for property audits or award close-out.
- Inventory management processes, including custody, marking and identification, location, use, and disposition.
- Routine and preventative maintenance processes, as appropriate.
- Security and protection processes (during use, storage, or transit), as appropriate.

[1] *PAPPG*, Part II, Chapter IX.E. and 2 CFR 200.313

5.6 NSF BUDGET CATEGORIES FROM THE PROPOSAL AND AWARD POLICIES AND PROCEDURES GUIDE

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This section discusses types of detailed additional information typically needed by financial assistance Awardees to justify the estimates based on the required NSF Budget Categories. This information is intended to supplement the standard guidance for the NSF Budget Categories from the *PAPPG* (see Section 1.3.1.1 Financial Assistance Awards – Grants and Cooperative Agreements).[1] It is intended to clarify NSF expectations, assist Awardees, facilitate NSF review with fewer iterative resubmissions, and prevent recurrent issues.

All Personally Identifiable Information should be removed from the documentation. Awardees may contact their NSF PO, Awarding Official (AO), Research Infrastructure Office (RIO) Liaison, and/or Cost Analyst for a Master Labor Schedule template spreadsheet that can be used to compile all labor data to ease estimating and justifying labor costs.

A – Senior Personnel

- Awardees should verify the actual salaries paid for any named senior personnel. Salary rates should be based on actual costs per current rate paid by payroll register, W-2s, or appointment letters. Awardees should note Academic Year (nine to ten months) versus Calendar Year (12 months) appointments or time available to conduct independent research if such appointments provide it. The Awardee should also provide sufficient justification for NSF to determine the cost reasonableness for the salary rate paid, such as salary rate surveys, salary comparators, Human Resource Department analysis, or other information.

B.1 – Postdoctoral Scholars; B.3–Graduate Students; B.4–Undergraduate Students; B.5–Secretarial – Clerical

- Awardees should provide an average salary rate or rate range for postdoctoral students in the organization's field of science. Actual payroll data may not be available as these may be to-be-hired positions.

B.2 – Other Professionals, Technicians, Programmers, Etc.

- Since the NSF budget format poses this as a total number of individuals for a total number of months, additional explanation is generally required to disaggregate the total for cost analysis. The Level-of-Effort (LOE) will likely need to be obtained by an individual or by position for salary calculations. Awardees should also provide a spreadsheet with the budget justification that includes name or position number, location, Work Breakdown Structure (WBS), title, salary rate and period, level of effort as a percentage or in person-months, and amount calculation for each award year.
- Awardees should provide supporting documentation for justification and

[1] *PAPPG*, Part I, chapter II.D.2.

determination of the salary rates of the proposed technicians, programmers, and other professionals. For these types of positions, NSF recommends using Bureau of Labor Statistics (BLS) Standard Occupation Classification Codes by position title and referencing their positions to BLS salary rates to gather information of proposed salary rates. BLS data is also available by region or city. Other salary rate survey data may be used, and larger Awardee organizations may already have established salary ranges and qualification bases internally through their Human Resources Departments.

C – Fringe Benefits

- Fringe benefits proposed shall follow the Awardee's established written policies, law, or organization-employee agreements in accordance 2 CFR 200.431.

F – Participant Support

- Justification should include the number of participants, stipend amount, travel cost estimate, and subsistence costs per participant.[1] Awardees should also provide the number of days or weeks of the training activities to provide a basis for determining the proposed payments.
- Participant support costs may not be used for personnel at the Awardee institution.

Other Direct Costs

Note: All contracts for procurements or services necessary to carry out the work must be categorized under the appropriate budget activity: G.1 – Materials and Supplies, G.2 – Publication, Documentation, Dissemination, G.3 – Consultant Services, G.4 – Computer Services, or, if none of these apply, G.6 – Other. All contracts **must** follow 2 CFR § 200.317 – 326, including price and cost analysis, competition, contracting with women-owned, small, and minority businesses, and contract provisions. The micro-purchase threshold for supplies or services is $10,000 (based on the micro-purchase threshold as amended by Sec. 207 of Pub. L. 114-329, codified at 41 U.S.C. § 1902 note). **Contracts must not be listed in G.5 - Subawards.**

To assist Awardees in determining the difference between a subaward and a contract, please refer to the Subawardee vs. Contractor Checklist developed by the Association of Government Accountants.[2]

G.3 – Consultant Services

- For each consultant identified, the Awardee should justify the proposed pay rate.

G.4 – Computer Services

- Where it is established institutional policy to charge computer services directly, the Awardee may justify and include such costs in the budget. Generally, such re-charges

[1] See 2 CFR 200.1
[2] https://www.agacgfm.org/Resources/intergov/SubrecipientvsContractor.aspx

should be based on established internal institution usage rates. Awardees should provide a supporting institutional statement or policy document and rates by units of actual usage.

G.5 – Subawards[1]

- Awardees of cooperative agreements are expected to conduct a pre-award risk review of the subawards, including cost and price analysis, to identify risk as outlined in the Uniform Guidance, 2 CFR § 200.331.
- Awardees should provide NSF with their pre-award analysis of each of the proposed subawards when submitting for approval of each subaward. Such Awardee pre-award analysis should include a determination of subaward risk. This should include an assessment of financial capability and ensuring the Subawardee is not on any federal government *do not pay* listing. The Awardee should also have carried out a price or cost analysis of the Subawardee's proposed work to ensure the reasonableness of costs.

G.6 – Other

- When applicable, budget contingencies should be presented as part of the total amount of Other Direct Costs under category G.6 on the standard NSF budget form.

I – Indirect Costs

- When the Awardee has a Negotiated Indirect Cost Rate Agreement (NICRA) established with a cognizant federal agency, the rate and base in that agreement should be used to compute indirect costs. A copy of the NICRA should be included in the Cost Estimating Plan.
- When an Awardee does not have a NICRA, the Awardee should provide a calculation and an indirect cost rate proposal. The Awardee should ensure that indirect costs are in accordance with the *PAPPG*, Chapter II.D.2.f.(viii), Indirect Costs. Awardees should provide a clear description of rates and application bases. Awardees should also provide a spreadsheet calculation of rates or rates by year clearly showing exclusions such as subcontracts greater than $50,000, equipment or capital expenditures, and participant support. If an Awardee has different indirect cost rates across NSF budget categories, these rates should be clearly identified and justified. Any deviation from an Awardee's normal rate should also be justified.

K – Fee

- Fee can be proposed if it is not disallowed by solicitation but is always subject to negotiation. The amount of Fees will not exceed the statutory limitations of cost contracts set forth at 41 U.S.C. 3905, notwithstanding that the Fee is provided through

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[1] A subaward is for the purpose of carrying out a portion of a federal award and creates a federal assistance relationship with the subawardee. See 2 CFR § 200.92 Subaward. Characteristics which support the classification of a subawardee versus contractor can be found at 2 CFR § 200.330. See also *PAPPG* II C.2.g (vi)(e).

a Cooperative Agreement.

- The payment of fee may be authorized for Major Facility construction and operations awards, unless otherwise prohibited in specific circumstances by NSF. Fees will be evaluated for reasonableness by the AO. Awardees that receive fee **must** comply with the award terms and conditions on the use of fee, such as the inappropriate uses of fee (e.g., including but not limited to not using fee on alcoholic beverages or lobbying as set forth at 2 CFR § 200.450 and 48 CFR 31.205-22). NSF will reserve the authority to review the Awardee's actual use of fee. Accordingly, Awardees will be required to separately track and account for uses of fee provided under NSF awards. NSF will consider reductions in future fees if an Awardee's actual use of fee is in contravention with the guidelines on inappropriate uses.

5.7 PERSONNEL AND COMPETENCIES

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Successful execution of construction projects and ongoing programs of the scale and complexity typical of NSF's Major Facilities requires skilled people who collectively possess a broad range of professional competencies. The minimum set of competencies that NSF considers essential for managing a Major Facility is detailed in Section 5.7.3 Competency Assignment Guidance for Major Facility Management and addresses all the life cycle stages. It is expected that fulfillment of these competencies will be achieved differently by each managing organization. Mid-scale RI Awardees should consider this guidance and form their Project Teams based on the complexity and technical nature of the project or program.

From NSF's perspective, there are two categories of personnel that are involved with managing a Major Facility throughout its life cycle. One category is Key Personnel (KP) and the second is the Project Team as given in Section 5.7.1 Key Personnel and 5.7.2 Project Team below, respectively. The objective is that some combination of individuals identified as either KP or Project Team members possess the full breadth of necessary knowledge, skills, and experience to manage the Major Facility. How this is achieved is up to the Awardee but is subject to NSF review.

5.7.1 Key Personnel

KP are individuals from the managing organization who are considered essential to successful project or science support program execution and are named specifically in the original proposal and, ultimately, in the award terms and conditions.[1] For Major Facility and Mid-scale RI awards funded through financial assistance, NSF requires identification of a Principal Investigator (PI) or Project Director (PD). Major Facilities may have both and they will automatically be considered KP. In addition to the PI and PD roles, KP positions appropriate for a Major Facility project may include a Project Manager (PM), Deputy PD, Associate Directors, or similar senior staff members.

Other than the PI and PD, it is the managing organization's responsibility to propose any additional KP. For example, in addition to the positions mentioned above, acquisitions and contract management may be deemed so crucial for success that the organization assigns a dedicated Procurement Officer and includes this position as KP. The competencies fulfilled by KP should be identified and maintained over time, as detailed in Section 5.7.3 Competency Assignment Guidance for Major Facility Management.

Under both the Uniform Guidance and FAR, NSF has approval authority over KP that are identified and named in the original proposal and any subsequent changes to KP named in the award terms and conditions.[2] Following award, any proposed substitutions, or

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[1] Major Facilities use the term *Key Personnel* as opposed to *Senior Personnel* on other NSF awards to maintain consistency with terminology used in Major Facility award documents.

[2] The ability to approve other KP is based on specific requirements detailed in the governing NSF award documents.

replacements, to KP **must** be submitted in advance, with all necessary supporting documentation to assess competencies, to the cognizant NSF PO for review and approval. No changes may be implemented without prior formal written notification by an NSF AO.

If NSF deems certain personnel who were not listed as KP in the proposal to be nonetheless essential to the Science Support Program, then NSF may require that these individuals be listed as KP in the award instrument (e.g., cooperative agreement). Similarly, if restructuring of the facility's management chain is recommended (e.g., by NSF or by an external review) or proposed by the Awardee during the period of performance, then the list of KP should be updated accordingly in the Award instrument.

The following descriptions include general expectations of these roles in executing a Major Facility or Mid-scale RI implementation project or program:

- **Principal Investigator**. Under financial assistance, this position is responsible for the scientific, technical, and budgetary aspects of the award and is generally the individual responsible for submitting the proposal to NSF. The PI is ultimately responsible for all aspects of successfully executing the project and/or Science Support Program, including ensuring that it meets its scientific and technical objectives and interfacing with NSF and the broader science community. For the purposes of this *Guide*, PI/co-PI is interchangeable with PD/co-PD if not proposed as separate positions.
- **Project Director (may also be the PI).** The PD is typically responsible for the day-to-day management of the activities funded under the award, generally reports to the PI (if proposed as a separate position) and may be named as a co-PI. This position may transition from Design to Construction, or from Construction to the Operations Stage to help ensure continuity once the prior Stage is complete.
- **Project Manager or Operations Manager**. This position is responsible for managing the proposed project's design activities or project's construction activities on a day-to-day basis. For construction projects, this would include major deliverables, the project's schedule, budget, and earned value metrics to monitor project progress against the current plan. The PM is essential in the Construction Stage of a Major Facility project, but is optional in the Development, Design, Operations, and Disposition Stages, depending on the planned activities. The PM may also serve in other capacities, such as deputy PD. For facilities in the Operations Stage, the Operations Manager could be considered an analogous position to PM. PMs can also be hired for upgrade projects that take place during the Operations Stage. NSF would have approval authority if this position were identified as KP or otherwise required in the award terms and conditions.

5.7.2 Project Team

The Project Team comprises additional managing organization staff who are often spread across different organizational units. The Project Team may comprise any combination of individuals or organizational units, such as an Office of Sponsored Research or the institution's IT support office. NSF approval of Project Team members is not required, but the Program should be notified when significant changes occur that might influence the activities funded under the award.

Project Team members should be identified in the proposal, Design Execution Plan (DEP), Project Execution Plan (PEP), or Annual Work Plan (AWP) where the Awardee discusses the organizational structure and fulfillment of the necessary competencies.

This documentation allows NSF, via proposal and annual reviews, to assess whether competencies are adequately covered by the KP and Project Team.

5.7.3 Competency Guidance for Major Facility Management

The knowledge areas listed in Table 5.7.3-1 are considered necessary for effective project and program management of a Major Facility and are based on the project and program management standards developed as part of the Program Management Improvement Accountability Act (PMIAA), Public Law No. 114-264. While PMIAA is only applicable to federal staff, the competency requirements nonetheless apply to most Major Facilities. Under NSF Major Facility awards, the Awardee typically performs many of the management roles normally done by federal project/program managers at other agencies. As given in Section 2.1 NSF Staff Roles and Responsibilities for Award Management and Oversight, NSF's role is to oversee activities performed by the Awardee, including the proper use of federal funds.

Table 5.7.3-1
PMIAA Areas of Program Management Standards and Principles

Knowledge Areas	
Change Management	Performance Management
Communications Planning, Stakeholder Engagement, and Coalition Building	Portfolio Management
Contracting and Acquisition Management	Process Improvement
Customer Service	Project Management
Evaluation	Requirements Development and Management
Financial Management	Risk Management
Human Capital Management	Strategic Planning
Information Management	

The competencies listed in Table 5.7.3-2 are derived from these knowledge areas and are tailored to reflect the characteristics of NSF Major Facility projects.

While there is no one-for-one mapping between these knowledge areas and the competencies in Table 5.7.3-2, there is a close alignment to align with federal standards under PMIAA and increase the likelihood of successfully executing the project or Science Support Program.

It is the responsibility of the managing organization to identify the KP and Project Team that collectively fulfill the suite of competencies listed in Table 5.7.3-2. All competencies **must** have at least one resource assigned; however, the same resource may be assigned to fulfill more than one competency. Some competencies are required to be assigned to KP as indicated in the Assigned Resource columns in Table 5.7.3-2. Fulfillment of other competencies may be provided by the Project Team.

It is important to note that not all competencies are necessary for each stage of the Major Facility life cycle. In some life cycle stages, there is no requirement for one or more competencies to be fulfilled, and the competency requirement is designated in Table 5.7.3-2 as Optional. The managing organization should make the decision whether a particular competency is considered essential based on the nature of the proposed activities under the award. For example, if an operations award includes a major upgrade, Project Management, and Earned Value Management (EVM) competencies may be beneficial if the project has a significant budget or a long duration or would otherwise benefit from the implementation of project management good practices.

The managing organization should submit documentation (e.g., resume) substantiating the assigned resource's expertise and qualifications for each assigned competency based on the funding announcement, as part of a periodic NSF review, or proposing a change in KP or Project Team members in accordance with the terms and conditions of the award. As stated above, NSF approval is only required for KP. While NSF does not approve Project Team members, substantiating documentation relating to competencies may still be requested when changes to the Project Team are made. This method allows NSF to confirm that competencies are adequately covered even though NSF does not have approval/concurrence authority over the individuals.

If a competency is assigned to an individual KP or Project Team member, then the substantiating documentation should include a resume, certification, or similar document(s) describing the individual's expertise and qualifications relating to the assigned competency. If a competency is assigned to the Project Team via an organizational unit, the applicable training or certification requirements for individuals to work within that organization may be provided rather than those of the individuals themselves. This method allows NSF to confirm that the competency is addressed by the organizational unit even though NSF does not have approval/concurrence authority over individuals within the unit. Likewise, if an external contractor provides a specific competency as an individual, the qualifications should be specific to that individual, whereas if the contractor is fulfilling the competency as an organizational unit type, the applicable training or certification requirements required for the individuals within the organization may be provided.

Table 5.7.3-2

Competency Assignment Guidance for Major Facility Management

Competency Assignment Guidance					
	Assigned Resource per Life Cycle Stage				
Competency	**Development**	**Design**	**Construction**	**Operations**	**Disposition**
Project Management	Optional	KP	KP	Optional	Optional
Program Management	Optional	Optional	Optional	KP	Optional
Earned Value Management	Optional	Optional	KP or Project Team	Optional	Optional
Risk Management	Optional	Optional	KP or Project Team	KP or Project Team	Optional
Cost Estimating	Optional	KP or Project Team	KP or Project Team	KP or Project Team	Optional
Business Process Reengineering	Optional	Optional	Optional	KP or Project Team	Optional
Compliance	KP or Project Team	KP or Project Team	KP or Project Team	KP or Project Team	KP or Project Team
Contracting and Acquisition	Optional	KP or Project Team	KP or Project Team	KP or Project Team	Optional
Financial Management	Optional	KP or Project Team	KP or Project Team	KP or Project Team	Optional
Data Management	Optional	Optional	KP or Project Team	KP or Project Team	Optional
Information Technology	Optional	KP or Project Team	KP or Project Team	KP or Project Team	Optional
Workforce Management	Optional	Optional	KP or Project Team	KP or Project Team	Optional
Stakeholder Management	Optional	KP or Project Team	KP or Project Team	KP or Project Team	Optional

A general description for each of the listed competencies in Table 5.7.3-2 is provided in Table 5.7.3-3. These descriptions are intended to be general and reasonably in alignment with the guidance established in PMIAA and are not considered a fully authoritative set of definitions.

Table 5.7.3-3

Competency Descriptions

Competency Descriptions	
Competency	**Description**
Project Management	• Demonstrates general and specialized knowledge of the principles, methods, and tools for project management, with project defined as a temporary endeavor with a defined scope, cost, and completion date. A project may be part of a larger program or portfolio. • Demonstrates knowledge of the strategies, techniques, and processes used to plan, monitor, and control project scope, including collecting requirements, defining scope, creating a work breakdown structure, validating scope, and controlling scope to ensure project deliverables meet requirements. • Demonstrates knowledge of the strategies, techniques, and processes used to plan, develop, and control project schedules and track project milestones, activities, and deliverables, including timeframes and assigned resources. • Demonstrates knowledge of the principles and methods for identifying, soliciting, analyzing, specifying, designing, and managing requirements and is able to systematically assess how well a project is working to achieve its intended outcomes. • Skilled in the use of project management controls to analyze project budget and schedule information and to generate reports with the primary focus of answering two fundamental questions: o How much will the project cost at completion, and will the project finish within budget? o How long will the project take, and will it finish as scheduled? • Knowledge of the principles, methods, and tools of Quality Assurance, Quality Control, and reliability to ensure that a project, system, or product fulfills requirements and standards. • Skilled at recording and controlling changes to the performance baseline (scope, schedule, and budget). • Able to identify and align project needs to the science mission and goals. • Skilled in satisfying internal and external customers through successful project execution; able to communicate and report progress to the NSF PO.

Competency Descriptions	
Competency	**Description**
Program Management	• Demonstrates knowledge of the principles, methods, and tools for the coordinated management of a program, including oversight of a set of programs, projects, contracts, and other work that supports scientific goals. • Able to provide oversight of multiple projects, integrate dependent schedules and deliverables, and conduct related activities, for example, benefits management, life cycle management, and program governance. • Able to plan for and manage capital assets and develop budgets, cost/benefit analyses, and investment decision documentation to evaluate and justify program costs. • Demonstrates knowledge of the strategies, techniques, and processes used to plan, monitor, and control the level of scientific support; includes collecting requirements, defining scope, creating a Work Breakdown Structure, validating scope, and controlling scope to ensure program deliverables meet requirements. • Demonstrates knowledge of the strategies, techniques, and processes used to plan, develop, and control program schedules and track major sub-project milestones, activities, and deliverables, including timeframes and assigned resources. • Skilled in implementing Continuous Process Improvement initiatives to leverage organizational strategy and performance management data to identify and eliminate waste, reduce variation, and satisfy customer needs. • Skilled in long-term planning, implementing actions needed to realize scientific goals, and mitigating likely challenges and barriers to achieving the desired outcomes. • Demonstrates knowledge of the principles and methods for identifying, soliciting, analyzing, specifying, designing, and managing requirements and is able to systematically assess how well a program is working to achieve intended outcomes. • Knowledge of the principles, methods, and tools of Quality Assurance/Quality Control, and reliability to ensure that a project, system, or product fulfills requirements and standards. • Able to identify and align program needs to the science mission and goals. • Demonstrates knowledge of change management principles, strategies, and techniques for effectively planning, implementing, and evaluating organizational change. • Skilled in satisfying internal and external customers through successful program execution; able to communicate and report progress to the NSF PO. • Demonstrates knowledge of the principles and methods for evaluating program or organizational performance using financial and nonfinancial measures, including identification of evaluation factors such as workload and personnel requirements, metrics, and outcomes, addressing both the science and operations.
Earned Value Management	• Demonstrates knowledge of the Electronic Industries Alliance-748 on Earned Value Management Systems and how to use it as an integrated management tool for successful project planning and execution. • Able to apply the 32 guidelines described in Electronic Industries Alliance-748 when developing and implementing the project Earned Value Management System. • Skilled at scaling the guidelines based on the size, complexity, and type of work effort needed to manage the project successfully.
Risk Management	• Demonstrates knowledge of principles, methods, and tools for risk management. • Skilled in identifying, evaluating, mitigating, managing, and overseeing risks and opportunities within a project or program. • Able to remedy potential issues and implement improvements to reduce risk, including through the development of Risk Mitigation Plans.

Competency Descriptions	
Competency	**Description**
Cost Estimating	• Demonstrates knowledge of the principles and methods of cost estimating, including the best practices (twelve steps) identified in the Government Accountability Office Cost Estimating and Assessment Guide. • Able to develop a Cost Estimating Plan and Cost Book that reflects NSF and Government Accountability Office guidance.
Business Process Reengineering	• Demonstrates knowledge of methods, metrics, tools, and techniques for restructuring and improving business processes.
Compliance	• Skilled in ensuring the award is managed in compliance with applicable federal laws, regulations, and guidance.
Contracting and Acquisition	• Demonstrates knowledge of the process and procedures for soliciting, executing, monitoring, and closing contracts and other award instruments in compliance with Awardee organization procurement policies.
Financial Management	• Demonstrates knowledge of procedures for assessing, evaluating, and monitoring programs or projects for compliance with federal laws, regulations, and guidance, including Office of Management and Budget Uniform Guidance (2 CFR § 200), relating to financial management. • Able to prepare, justify, and/or administer the budget for project or program areas. • Able to plan, administer, and monitor expenditures to ensure cost-effective support of programs and policies, e.g., through financial controls and audits. • Skilled in assessing the financial condition of a project or program.
Data Management	• Demonstrates knowledge of data management principles, procedures, and tools, such as modeling techniques, data backup/recovery, data mining, and data standardization processes. • Able to plan/budget for, manipulate, and control access to information/scientific data during the project or program's life cycle.
Information Technology	• Able to manage cyberinfrastructure and information technology resources, such as personnel, equipment, software, etc., that support the project or program. • Demonstrates knowledge of the four pillars of information assurance programs (Mission Alignment, Governance, Resources, and Controls) and how to develop and manage a robust information assurance program.
Workforce Management	• Able to manage workforce requirements to meet organizational and program goals within budget constraints and to ensure employees are appropriately recruited, selected, appraised, and rewarded.
Stakeholder Management	• Demonstrates knowledge of the concepts, practices, and techniques used to identify, engage, influence, and monitor relationships with stakeholders; able to collaborate across organizational boundaries and engage in partnerships and team building.

5.8 PARTNERSHIPS

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For both Major Facility and Mid-scale RI, partnerships are an essential consideration – beginning with initial development and extending through disposition decisions. Partnerships can take many forms, but often include coordinated funding from states, other federal agencies, non-governmental entities, and foreign funding agencies.[1] International partnerships are generally the most complex given geopolitical considerations and differences in lexicons, funding mechanisms, and project management practices.

Regardless of the nature of the partnership, care should be taken to ensure that all parties have a common understanding of expectations, roles and responsibilities, and schedules. In most cases, this understanding should be formalized in writing and agreed to by personnel with authority to commit the partner(s) to the specified arrangement. It is also wise to notify the cognizant NSF PO of plans to enter into partnership arrangements.

International partnerships present several important challenges to which the Awardee and PO need to give timely and careful attention. Cultural differences in approaches to the emergence of science and engineering projects, project management approaches, risk management, and project oversight should be considered and addressed. Thus, NSF should be notified of the partnership to facilitate governance and other agreements prior to NSF making an award. Partnerships being considered post-award also require NSF notification. Prior to entering formal arrangements with foreign collaborators, Awardees **must** provide written notification to the cognizant PO according to the terms and conditions of the award. Early notification allows the PO to coordinate with the appropriate NSF units, particularly those associated with research security, to ensure that potential international partnerships are compliant with U.S. law, NSF policy, and geo-political considerations.

[1] See “Best Practices for Federal Research and Development Facility Partnerships,” IDA Science & Technology Policy Institute, IDA Paper P-5148 Log: H 14-000676, for guidance or models on forming interagency federal partnerships.

5.9 AGILE GUIDANCE

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Agile is a project management approach that uses cycles of design, implementation, evaluation, and process improvement to reduce risk and improve the quality of the produced scope. It comes in many forms, including Scrum, Kanban, Extreme Programming, and Lean Development, among others. Agile can apply to many different kinds of scope, and it is commonly used for developing software.

While there is extensive industry guidance related to Agile management techniques, this section contains NSF guidance specific to Agile methodologies. This section is designed to be a starting point on how to integrate Agile into NSF projects and is not intended to provide instruction on Agile methodologies.

This section explains how Agile systems can satisfy NSF expectations for project management and identify any unique processes and documentation necessary to support NSF review. Existing Government Accountability Office (GAO), Project Management Body of Knowledge (PMBOK), and National Defense Industrial Association (NDIA) Agile guides can provide general Agile guidance.[1,2,3]

[1] The GAO Assessment Guide: Best Practices for Agile Adoption and Implementation (GAO-20-590G) may be used as a general guide to Agile implementation on RI effort but should be modified and tailored to the needs and requirements of the NSF. https://www.gao.gov/products/gao-20-590g

[2] The Project Management Book of Knowledge (PMBOK 7th edition)/Agile Practice Guide (2021) Project Management Institute (PMI). https://www.pmi.org/pmbok-guide-standards/practice-guides/agile The agile practice guide is often included with the PMBOK 7th edition. Fees or membership in PMI are required to access these documents.

[3] An Industry Practice Guide for Integrating Agile and Earn Value Management on Programs, NDIA December 9, 2022 Version 1.4 https://www.ndia.org/-/media/sites/ndia/divisions/ipmd/division-guides-and-resources/2023/ndia_ipmd_agileandevmguide_version_1-4.pdf?download=1

Figure 5.9-1

Agile Development Methods Versus Traditional Development Methods: Emphasized Elements; Graphic adapted from GAO Agile Assessment Guide Figure 5 (GAO-20-590G)

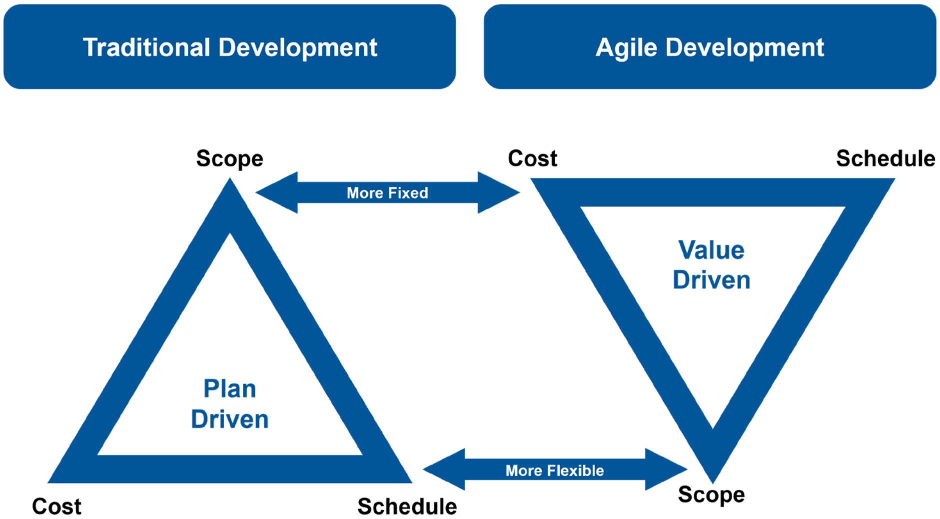


Figure 5.9-1, which has been modified from one found in the *GAO Agile Guide*, identifies the differences between Traditional and Agile Development. Traditional Development is plan-driven where cost and/or schedule are more likely to be adjusted to support scope. Agile Development tends to be value driven where scope may encounter adjustments to support a more fixed development team (cost) and schedule. NSF awards, like other government procurements, have disciplined methods which limit scope (and other driver) flexibility and often require additional documentation and reporting (see Section 2.1 NSF Staff Roles and Responsibilities for Award Management and Oversight). NSF does not allow unconstrained flexibility in scope (i.e., baseline scope changes without executed change order or other methods documented in the award PEP).

The general project management guidance in this *Guide* applies to all projects with an Agile component. Traditional methodologies that are important in an Agile environment may include but are not limited to the following:

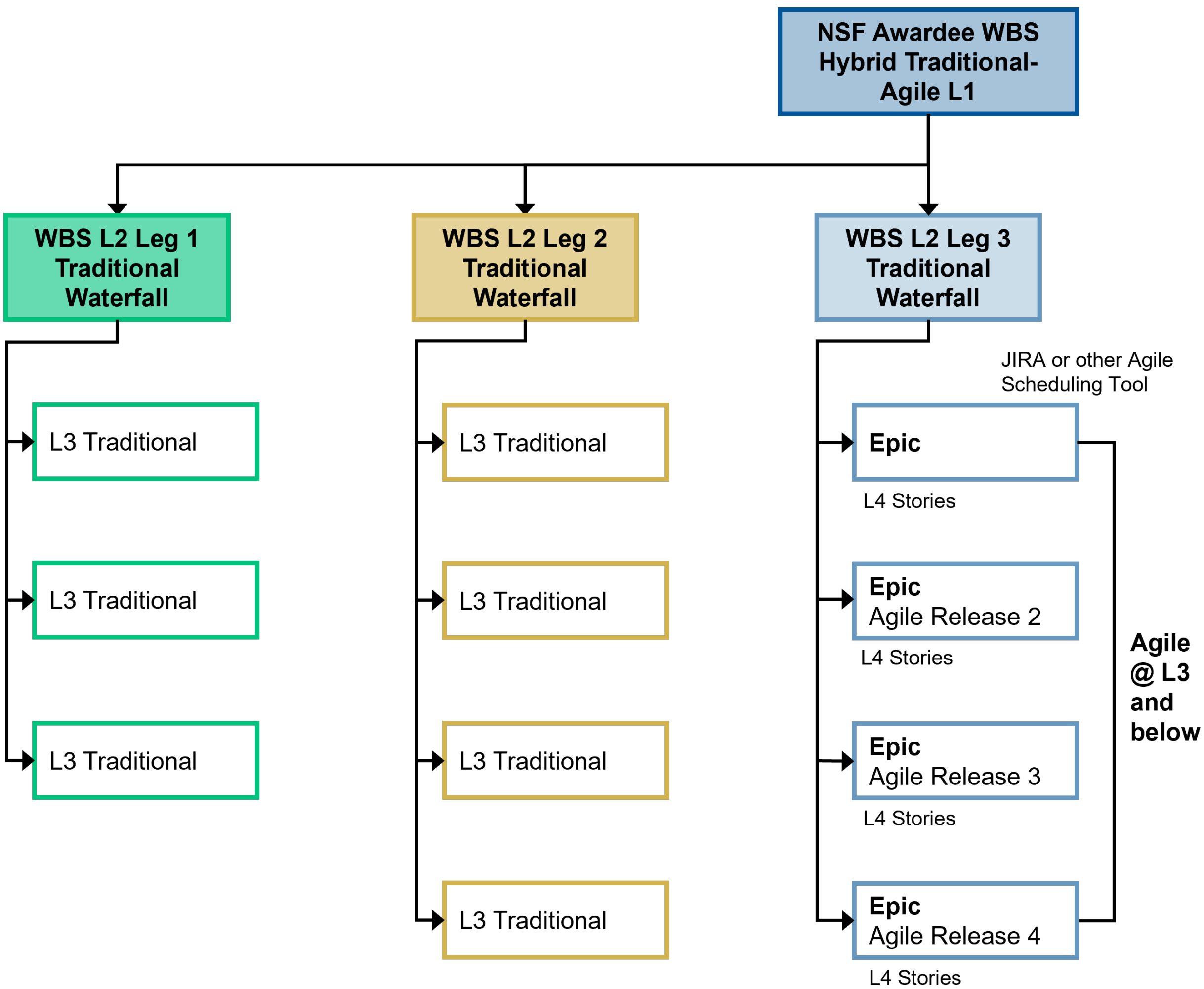
- The life cycle stage of the project.
- The need for a well-defined and comprehensive Work Breakdown Structure (WBS).
- Having all scope assigned to the appropriate accountable individual (Control Account Manager [CAM]).
- Appropriate use of a project schedule.
- Appropriate use of a Change Control Plan for significant scope, schedule, and budget changes.
- Appropriate use of risk management scope, schedule, and budget contingency.

5.9.1 General Agile Guidance

NSF supports projects that use Agile methodologies via a hybrid approach that combines traditional project management methods with Agile methods. NSF expects the use of a hybrid WBS when utilizing the Agile methodology. This hybrid method unifies two different methodologies via the award's WBS. Traditional project management methods are required at WBS Levels 1 and 2. An Awardee may elect to extend traditional methods to lower levels of the WBS, but Levels 1 and 2 are considered essential. Figure 5.9.1-1 shows the WBS that uses a traditional methodology for WBS Levels 1 and 2 and the Agile methodology below. Note that some WBS legs utilize only traditional methodology, and Agile is confined only to the blue leg.

Figure 5.9.1-1

Traditional / Agile Hybrid Project Example WBS



5.9.2 Agile Documentation

If Agile methodology is utilized, the following needs to be documented in the PEP:

- A WBS that clearly illustrates the traditional elements and those that are using Agile.
- An expanded WBS Dictionary with Identifying and mapping linkages between traditional and Agile terminology. The WBS Dictionary should define all significant Agile terminologies the Awardee elects to use.
- Identified type of Agile methodologies used; any are allowable if documented in the PEP.
- Identified reporting methods, levels of rigor, and frequency for Agile components.
- Traditional-Agile Data Flows:
  - Planning. Include a flow chart that shows how the Performance Measurement Baseline (PMB) refines itself downward from higher traditional WBS levels to detailed Agile planning (From WBS Level 1 to the most detailed Agile level).
  - Executing. Illustrate how Agile performance data flows upward from the lowest Agile level to the traditional WBS levels and reports. Agile practitioners are free to utilize common and acceptable Agile methodologies and definitions. Methodologies and definitions are not restricted to a single set or those used in *Research Infrastructure Guide* examples. However, the above terminologies and processes used should be documented in the PEP.

5.9.3 Specific Agile Guidance

Traditional waterfall methodology guidance is included throughout this *Guide* and are not repeated in this section. The following are specific Agile expectations:

- The initial budgetary and schedule estimation requires at least a planning package level for the Agile scope for the entire performance period.
- Agile utilizes rolling wave planning which involves detailed planning (work package or equivalent) for near-term efforts and more summary-level planning (planning packages or equivalent) for subsequent attempts. Planning packages need enough detail to provide a credible estimate of schedule and cost.
- Agile PMB budget/schedule estimates may be calculated via Agile sizing techniques. The detailed PMB should include performance measurement milestones at the appropriate detail level for Agile near-term scope. For example, budgeted Stories may be assessed periodically, giving credit for completion, and summarizing cumulative performance (percent complete).
- WBS elements that are identified as Agile may utilize non-Agile methods for support effort. For example, quality management, program management, and other non-coding (non-development) support activities may be utilized as an LOE within an Agile WBS element.
- Agile scope progress should be calculated at the lowest level of the WBS on a

percentage basis using a chosen metric.

- Rolled-up expenditures (i.e., actual costs) should be reported and measured against assigned budgets, which may be executed at the work package level or the Agile equivalent.
- A forecast of detailed Agile budgets and actual costs may exceed (or be forecasted to exceed) the overall work package (may be called Epic) budget. In this case, the Awardee either realizes an over-run or moves scope, schedule, and budget via the award's change management system (same process as with other project management methods).
- Agile should utilize the Change Management Plan for scope, schedule, and budget changes and as well as identify any changes handled within the Agile process Defined in the PEP what changes use change management and what changes are handled within detailed agile processes. Appropriate change management thresholds should be defined in the PEP.

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7.0 ACRONYMS AND ABBREVIATIONS

Acronym or Abbreviation	Full Spelling
AACEI	Association for the Advancement of Cost Engineering International
ACWP	Actual Cost of Work Performed
AICA	American Innovation and Competitiveness Act
AO	Awarding Official
AWP	Annual Work Plan
BABA	Build America, Buy America
BAC	Budget at Completion
BFA	Office of Budget, Finance, and Award Management
BLS	Bureau of Labor Statistics
BOE	Basis of Estimate
BSR	Business Systems Review
CA	Cooperative Agreement
CAM	Control Account Manager
CARE	Collective Benefit, Authority to Control, Responsibility, and Ethics
CCB	Change Control Board
CCP	Change/Configuration Control Process
CDR	Conceptual Design Review
CEBOK	Cost Estimating Body of Knowledge
CEP	Cost Estimating Plan
CI	Cyberinfrastructure
Co-PI	Co-Principal Investigator
CO	Contracting Officer
ConOps	Concept of Operations
COR	Contracting Officer’s Representative
CORF	Chief Officer for Research Facilities
CPM	Critical Path Method
DACS	Division of Acquisition and Cooperative Support

Acronym or Abbreviation	Full Spelling
DEI	Diversity, Equity, and Inclusion
DEP	Design Execution Plan
DOI	Digital Object Identifiers
EAC	Estimate at Completion
ES&H	Environmental Safety and Health
ETC	Estimate to Complete
EU	Estimate Uncertainties
EVM	Earned Value Management
EVMS	Earned Value Management System
FAIR	Findable, Accessible, Interoperable, and Reusable
FAR	Federal Acquisition Regulations
FCA	Facility Condition Assessment
FDR	Final Design Review
FFRDC	Federally Funded Research and Development Center
FY	Fiscal Year
GAO	Government Accountability Office
GR&A	Ground Rules and Assumptions
IA	Information Assurance
IAMP	Information Assurance Management Plan
ICE	Independent Cost Estimate
ICEAA	International Cost Estimating and Analysis Association
IMS	Integrated Master Schedule
IPT	Integrated Project Team
ISO	International Organization for Standardization
IT	Information Technology
KP	Key Personnel
KPI	Key Performance Indicators
KPP	Key Performance Parameters

Acronym or Abbreviation	Full Spelling
LAN	Local Area Network
LFO	Large Facilities Office
LOE	Level-of-Effort
M&S	Materials and Supplies
MFA	Multi-factor Authentication
MMFWG	Major and Mid-scale Facilities Working Group
MOU	Memorandum of Understanding
MRE	Major Research Equipment
MREFC	Major Research Equipment and Facilities Construction
MRI	Major Research Instrumentation
NCOP	No Cost Overrun Policy
NDIA	National Defense Industrial Association
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NICRA	Negotiated Indirect Cost Rate Agreement
NIST	National Institute of Standards and Technology
NSB	National Science Board
NSF	National Science Foundation
NSPM	National Security Presidential Memo
O&M	Operations and Maintenance
OA	Other Arrangements
OA/T	Other Arrangements/Transactions
OBS	Organizational Breakdown Structure
OM	Operating Manager
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
OT	Other Transactions
P/PM	Project and Program Management

Acronym or Abbreviation	Full Spelling
PAPPG	Proposal and Award Policies and Procedures Guide
PD	Project Director
PDR	Preliminary Design Review
PEP	Project Execution Plan
PERT	Program Evaluation and Review Technique
PI	Principal Investigator
PM	Project Manager
PMB	Performance Measurement Baseline
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PMIAA	Program Management Improvement Accountability Act
PMM	Performance Measurement and Management
PO	Program Officer
QA	Quality Assurance
QC	Quality Control
R&D	Research and Development
R&RA	Research and Related Activities
RACI	Responsible, Accountable, Consulted, and Informed
RAEAC	Risk-Adjusted Estimate at Completion
RAM	Responsibility Assignment Matrix
RI	Research Infrastructure
RIG	Research Infrastructure Guide
RIO	Research Infrastructure Office
RLS	Resource-Loaded Schedule
SMARTTT	Specific, Measurable, Achievable, Relevant, Traceable, Tiered, Total
SME	Subject Matter Expert
STEM	Science, Technology, Engineering, and Mathematics
SVT	Schedule Visibility Task

Acronym or Abbreviation	Full Spelling
TPC	Total Project Cost
TPC_{AWD}	Award Amount to Recipient (PMB + contingency + profit/fee)
TPC_{EVM}	Total Project Cost Earned Value Management
TPC_{NSB}	National Science Board Authorized Total Project Cost
TPD	Total Project Duration
USD	United States Dollars
VAC	Variance at Completion
VAS	Verification, Acceptance, and Surveillance
WBS	Work Breakdown Structure

8.0 LEXICON

8.1 LEXICON PREFACE

This lexicon contains definitions of project and program management terms used in this *Guide* specifically tailored for use in NSF Major Facilities and Mid-scale Research Infrastructure (RI) context. It combines specialized terms defined by the NSF with widely used professional project and program management terminology. A selection of common project management terms, compatible with NSF usage, has been adopted from the *Project Management Institute Inc.'s Lexicon of Project Management Terms* (2017). Entries italicized are directly from PMI's Lexicon, while those marked with an asterisk (*) are slightly modified versions for NSF purposes.

The purpose of this lexicon is to establish a common set of standard terms and definitions to enhance communication and understanding among stakeholders in documents and correspondence related to Major Facility management. The term *project* in this lexicon refers to elements of project and program management across all life cycle stages unless specified otherwise.

Please note that the terms and definitions included are in development and may be updated in future versions.

8.2 TERMS AND DEFINITIONS

JUMP TO: A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

A

Acceptance Criteria. *A set of conditions that is required to be met before deliverables are accepted.*

Accuracy. The degree of correctness, exactness, and reliability of project-related information, data, estimates, and measurements. It involves ensuring that project activities, plans, forecasts, and evaluations reflect the true state of affairs and are free from errors, bias, or distortion.

Activity. *A distinct, scheduled portion of work performed during a project.*

Actual Cost. *The realized cost incurred for the work performed on an activity during a specific period.*

Allocation. The assignment and distribution of resources to various tasks, activities, or project phases or stages.

Allowance.[1] An amount of money or time permitted for anticipated but as-of-yet undefined details or requirements and is included in the basis of estimate for base costs or activity durations in the schedule. May be used when the level of RI definition may not enable certain costs or durations to be estimated definitively or times when it is simply not cost effective to quantify and estimate scope, but reliable correlations are available. If appropriate, allowances could include uncertainties associated with cost estimating (as part of the Basis of Estimate) in lieu of a defined risk, where the cost impacts would be held in aggregate as part of the budget contingency.

Approval. The act of officially accepting an idea, action, or plan.

Assistance. The act of giving support or help; making it easier for someone to do something or for something to happen.

Assumption. *A factor in the planning process that is considered to be true, real, or certain, without proof or demonstration.*

Assurance. To give a strong and/or definite statement that something will happen or that something is true; to give confidence.

Authorized. The total amount approved by NSF, but not necessarily obligated and allocated by NSF.

Award instrument. An agreement between NSF and an Awardee with the terms and

[1] Definition adapted from: AACEI RP 10S-90: Cost Engineering Terminology, September 30, 2021; AACE International Skills and Knowledge of Cost Engineering, 6th Edition, 2015; International Cost Estimating and Analysis Association (ICEAA), Cost Estimating Body of Knowledge (CEBoK), Glossary of Terms, 2013

conditions set forth in (cooperative agreements, contracts, etc.).

Awardee. The organization receiving the NSF award to manage and conduct the day-to-day operations and maintenance of the Major Facility.

Awardee-titled property. Any federally funded property in the custody of the Awardee where the government has not retained ownership, but the property is still subject to established obligations and conditions. Awardee-titled property is held in trust for the beneficiaries of the project or program (generally the science community) under which the property was acquired or improved. This arrangement is otherwise known as the "property trust relationship." Generally, the Awardee may not encumber (i.e., place a lien on) the property and must follow the award terms and conditions on use, management, and disposition of the property. Only following disposition decisions at the end of the award, would ownership potentially transfer to the Awardee.

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***Baseline.** The approved cost and schedule plan for a scope of work, used during planning. For NSF, contingency is not included in the baseline but is held and managed separately. A planning baseline may or may not be under change control. Once a baseline has been approved, is under change control, and is used as the basis for monitoring progress against the plan, it is referred to as the Performance Measurement Baseline (PMB).*

***Basis of Estimate (BOE).** Supporting documentation outlining the details used in establishing project estimates such as assumptions, constraints, level of detail, ranges, and confidence levels.*

***Bottom-up Estimating.** A method of estimating project duration or cost by aggregating the estimates of the lower-level components of the work breakdown structure (WBS).*

***Budget at Completion (BAC).** The sum of all budgets established for the work to be performed. For NSF projects, contingency amounts are not included in the Estimate to Completion (ETC), Estimate at Completion (EAC), BAC, or PMB due to the NSF requirement that contingency is held and managed separately from the baseline.*

Budget contingency. A budget held to allow for identified items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in the aggregate, in additional costs. These events are often referred to as "known-unknowns" and are considered manageable by the Awardee. This amount is held separately from the baseline budget as part of the Total Project Cost to help manage risk and uncertainty in aggregate and obligated to the project for the Awardee to manage based on need per NSF policy. Contingency may only be used when a risk (including uncertainty) from the risk register is realized. In short, budget contingency is a budget held separate from the baseline to manage known risks in aggregate.

C BACK TO TOP

Change control. *A process whereby modifications to documents, deliverables, or baselines associated with the project are identified, documented, approved, or rejected.*

Change Control Board (CCB). *A formally chartered group responsible for reviewing, evaluating, approving, delaying, or rejecting changes to the project, and for recording and communicating such decisions.*

Change Request. *A formal proposal to modify any document, deliverable, or baseline.*

Closeout. The process by which the federal awarding agency or pass-through entity determines that all applicable administrative actions and all required work of the federal award have been completed.

Conceptual Design Phase. The first phase of the Design Stage, after passing the gate from the Development Stage, that advances the definition of the scope and requirements, determines feasibility, and produces updated drafts of most elements of the Project Execution Plan (PEP), including parametric cost and schedule range estimates and a preliminary risk analysis.

Conditional interest. The government's right to invoke a transfer of Awardee-titled property, including to the government or to another Awardee.

Contingency. See Budget, Schedule, and Scope Contingency.

Constraint. *A limiting factor that affects the execution of a project, program, portfolio, or process.*

Construction Stage. The period in which funds are obligated for acquisition and/or construction of a facility that fulfills the terms and conditions set forth in an award instrument between NSF and the Awardee(s). This Stage ends with the start of the Operations Stage.

Contract. A contract is for the purpose of obtaining goods and services for the non-Federal entity's own use and creates a procurement relationship with the contractor. All contracts over $250,000 require written prior NSF authorization.

Control account. *A management control point where scope, budget, actual cost, and schedule are integrated and compared to earned value for performance measurement.*

Corrective action. *An intentional activity that realigns the performance of the project work with the project plan.*

Cost Book. A compilation of Cost Book Sheets, typically used to present baseline or Total Project Cost (TPC) but may be used to present rolled-up costs for smaller elements or sub-elements.

Cost Book Sheet. A compilation of related information from the Cost Model Data Set, used to define and present the cost estimate for a particular element or sub-element of a deliverable- based work breakdown structure for construction or a functional, activity, and/or deliverable based work breakdown structure for operations.

Cost-loaded. A project schedule or WBS that includes the associated costs for each task or activity and financial resources required for the completion of each task are identified and assigned, allowing for comprehensive cost management and control throughout the project.

Cost Model Data Set. The cost data used as input to software tools and/or project reports to organize, correlate, and calculate different project management information.

Cost Performance Index. *A measure of the cost efficiency of budgeted resources expressed as the ratio of earned value to actual cost.*

Cost Variance. *The amount of budget deficit or surplus at a given point in time, expressed as the difference between the earned value and the actual cost.*

Critical path. *The sequence of activities that represents the longest path through a project, which determines the shortest possible duration.*

Critical path activity. *Any activity on the critical path in a project schedule.*

Critical path method. *A method used to estimate the minimum project duration and determine the amount of scheduling flexibility on the logical network paths within the schedule model.*

Current plan. The project cost and schedule plan reflecting the status of progress to date and updated estimates for completing remaining work that is compared to the approved Performance Measurement Baseline (PMB), as part of Earned Value Management.

Custody. Protective care or guardianship responsibilities of the Awardee over federally funded property.

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Decomposition. *A technique used for dividing and subdividing the project scope and project deliverables into smaller, more manageable parts.*

Deliverable. *Any unique and verifiable product, result, or capability to perform a service that is required to be produced to complete a process, phase, or project.*

De-scoping options. See Scope Options.

Design Stage. The life cycle stage for detailed planning for projects approved by the NSF Director at the end of the Development Stage and funded under the formal Major Facility planning process. It is divided into the Conceptual, Preliminary, and Final Design Phases; with a formal and rigorous review gate at the end of each phase to show readiness for advancement to a higher level of refinement regarding scope, cost, and schedule.

Development Stage. The facility life cycle stage in which initial high-level ideas are developed and a consensus built for the potential long-term need, priorities, and general requirements for a large research facility of interest to NSF and the broader research community.

Disposition Stage. The stage in the facility life cycle encompassing disposition of the facility starting after the NSF Operations Stage ends and funding for disposition begins. Disposition options may include partial or complete transfer of a facility to another entity's operational and financial control (with or without reduction in project scope), "mothballing" the facility so that operations can be restarted later, or decommissioning. Decommissioning may include complete removal of the infrastructure and site restoration.

Divestment. The final transfer of property ownership, including relinquishing any conditional interest, from NSF to another entity. Divestment can occur for the entire Facility, a component of the Facility, or other capital assets.[1] Divestment can also be accomplished through the decommissioning and deconstruction of a Major Facility or component in cases where those actions are necessary to complete the transfer of ownership or meet environmental obligations. If the assets remain operational under the new entity, NSF may still fund individual investigators separately to utilize those assets for research. Following divestment, the asset(s) is no longer considered an NSF-funded Major Facility or part of an NSF-funded Major Facility.

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Earned Value. *The measure of work performed expressed in terms of the budget authorized for that work.*

Earned Value Management (EVM). *A methodology that combines scope, schedule, and resource measurements to assess project performance and progress.*

Effort. *The number of labor units required to complete a schedule activity or work breakdown structure component, often expressed in hours, days, or weeks.*

****Estimate at Completion (EAC)****. The expected total cost of completing all work expressed as the sum of the actual cost to date and the estimate to complete. For NSF projects, contingency amounts are not included in the ETC, EAC, BAC, or PMB due to the NSF requirement that contingency is held and managed separately from the baseline.*

****Estimate to Complete (ETC)****. The expected cost to finish all the remaining project work. For NSF projects, contingency amounts are not included in the ETC, EAC, BAC, or PMB due to the NSF requirement that contingency is held and managed separately from the baseline.*

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Facility. Shared-use infrastructure, equipment, or instrument - or an integrated network and/or collection of the same – that is either acquired or constructed to collect, analyze, and provide necessary data and information in support of research having a major impact on a broad segment of a scientific or engineering discipline.

Federally funded property. Any property acquired, fabricated, or improved in whole or in part with federal funds, whether funded by NSF or any other federal agency.

Federally owned property. Any federally funded property in the custody of the Awardee

[1] Excess or sale of property is a form of divestment. This is more typical for capital assets or components of Major Facilities that are removed as part of routine upgrades.

where the agency has retained ownership. The Awardee is subject to use and disposition requirements in accordance with the award and must submit to NSF annually an inventory listing of Federally owned property in its custody.

Final Design Phase. The third and last phase of the Design Stage, after a successful Preliminary Design Phase, that further refines the project definition and the Project Execution Plan (PEP) and demonstrates that project planning and management meet requirements for readiness to receive funding. The Final Design Phase ends in a potential NSF approval to obligate construction funds.

Finish-to-Finish. *A logical relationship in which a successor activity cannot finish until a predecessor activity has finished.*

Finish-to-Start. *A logical relationship in which a successor activity cannot start until a predecessor activity has finished.*

Float. *Also called Free Float. The amount of time that a schedule activity can be delayed without delaying the early start date of any successor or violating a schedule constraint.*

Funding announcement. A formal notification to invite researchers, institutions, and organizations to submit proposals for financial support of research and educational projects and provides detailed information about the funding opportunities available, including the objectives, eligibility criteria, application procedures, evaluation criteria, and deadlines.

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Gantt chart. *A bar chart of schedule information where activities are listed on the vertical axis, dates are shown on the horizontal axis, and activity durations are shown as horizontal bars placed according to start and finish dates.*

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Independent Cost Estimate (ICE) Review. An objective and unbiased review of a cost estimate by an independent entity outside of the acquisition chain that may be used by NSF to help validate the Awardee's estimate. It may include reconciliation of an ICE with the Awardee's estimate and detailed reviews of the schedule, Risk Register, and contingencies.

Information Assurance (IA). The umbrella term inclusive of cybersecurity, data protections (including privacy), cyber risk management, and resilience.

Integrated Master Schedule (IMS). A detailed schedule that is based on the WBS hierarchy and includes tasks and activities, project start and end dates, review dates, and other critical dates and key milestones

Issue. A point or matter in question or in dispute, or a point or matter that is not settled and is under discussion or in dispute between project stakeholders.

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Key Performance Indicator (KPI). A measurable value that indicates how effectively an organization, project, or individual is achieving key business or science objectives. KPIs measure performance in specific areas that are important for achieving strategic, operational, and scientific goals.

Key Performance Parameter (KPP). Critical, measurable characteristic, attribute, or requirement that a project, system, or process must meet that are used to ensure that essential performance criteria are met. Failure to meet a KPP typically means the project cannot achieve its intended purpose and may be considered a failure.

Known-unknowns. Recognized risks and uncertainties with unknown specific outcomes or details.

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Lag. *The amount of time whereby a successor activity is required to be delayed with respect to a predecessor activity.*

Late finish date. *In the critical path method, the latest possible point in time when the uncompleted portions of a schedule activity can finish based on the schedule network logic, the project completion date, and any schedule constraints.*

Late start date. *In the critical path method, the latest possible point in time when the uncompleted portions of a schedule activity can start based on the schedule network logic, the project completion date, and any schedule constraints.*

Lead. *The amount of time whereby a successor activity can be advanced with respect to a predecessor activity.*

Lessons learned. *The knowledge gained during a project which shows how project events were addressed or should be addressed in the future for the purpose of improving future performance.*

Level-of-Effort (LOE). *An activity that does not produce definitive end products and is measured by the passage of time. (Note. Level of effort is one of three earned value management [EVM] types of activities used to measure work performance.)*

Liens list. A list of expected adjustments to project scope, budget, and schedule contingency amounts that are waiting for implementation, including formal change control actions for planned baseline modifications, scope contingency options held for decision, realized risks, and coverage of variances.

Life Cycle Stage. The sequence of steps or stages that characterize the lifetime of a facility from beginning to end. For NSF**,** the stages include Development, Design, Construction, Operations, and Disposition.

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Major Facility. A science and engineering facility project that exceeds $100,000,000 in construction, acquisition, or upgrade costs to the Foundation.[1]

Management. The act of controlling and making decisions about an operation, organization, or project; the act or process of deciding how to use something; the judicious use of means to accomplish an end.

Management Reserve. An amount of money or time included as part of the Total Project Cost (TCP) estimate to address unforeseen events or uncertainties that are beyond the control of the Awardee or the agency. These events are often referred to as "unknown unknowns." The amount of management reserve (if any) is determined based on agency risk tolerance and managed exclusively by the agency. Similar "reserves" are not allowable in Awardee estimates per the Uniform Guidance.

Mid-scale Research Infrastructure (RI). RI that currently have a TPC between $4 million and $100 million.

Milestone. *A significant point or event in a project, program, or portfolio.*

Monte Carlo simulation. A computational technique that utilizes random sampling and statistical analysis to model the probability of different outcomes in a process that involves uncertainty, such as cost or schedule. Project managers use this technique to gain insights into the likelihood of various outcomes, aiding with making more informed decisions about resource allocation, scheduling, and risk management.

Most likely duration. *An estimate of the most probable activity duration that considers all the known variables that could affect performance.*

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Near-critical path. Activities with minimal total float that can quickly become part of the critical path if delays occur. These tasks require close monitoring because any delay can potentially affect the entire project.

No Cost Overrun Policy (NCOP). NSF policy requiring that a Total Project Cost (TPC) estimate established at the Preliminary Design Phase have adequate contingency to cover all foreseeable risks. However, NSF conducts its oversight of projects against the Total Project Cost (TPC) authorized by the National Science Board (NSB) following Final Design Review (FDR).

Non-renewal. The decision not to recreate a legal relationship between NSF and the current managing organization by replacing an old award with a new one. It generally applies in situations where NSF does not have property ownership or any conditional interest in the capital assets or other property but only funds the managing organization to operate the

[1] https://www.congress.gov/116/plaws/publ283/PLAW-116publ283.pdf

asset. Following non-renewal, the asset(s) are no longer considered an NSF-funded Major Facility or part of an NSF-funded Major Facility.

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Obligation. A definite commitment that creates a legal liability of the government for the payment of goods and services ordered or received, or a legal duty on the part of the United States that could mature into a legal liability by virtue of actions on the part of the other party beyond the control of the United States.

Off-ramps. Decision points where a proposed project can be canceled or no longer supported to move forward.

Operations Stage. The life cycle stage that succeeds Construction and includes the day-to-day work to operate and maintain the facility and to perform research. Operations may also include activities to transition from construction to operations, replacement or upgrade activities, technology research and development, and activities that support planning and staging for the Disposition Stage.

Opportunity. *A risk that would have a positive effect on one or more project objectives.*

Organizational Breakdown Structure (OBS). *A hierarchical representation of the project organization, which illustrates the relationship between project activities and the organizational units that will perform those activities.*

Oversight. Watchful and responsible care of something or some activity; regulatory supervision.

Ownership [Owned]. The ultimate and exclusive rights and control over property.

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Parametric estimating. *An estimating technique in which an algorithm is used to calculate cost or duration based on historical data and project parameters.*

Path convergence. *A relationship in which a schedule activity has more than one predecessor.*

Path divergence. *A relationship in which a schedule activity has more than one successor.*

Percent complete. *An estimate expressed as a percent of the amount of work that has been completed on an activity or a work breakdown structure component.*

Performance Measurement Baseline (PMB). The approved cost and schedule baseline for accomplishing project work scope used as a basis of comparison for Earned Value Management. The PMB is typically approved and established at the time of the construction award, in the terms and conditions of the award instrument, and is under formal change control for the life of the project. (For NSF projects, contingency amounts are not included in the PMB due to the NSF requirement that contingency is held and managed separately from the baseline.)

Planned Value. *The authorized budget assigned to scheduled work.*

Planning package. A component of work within the WBS with budget and duration but without detailed schedule activities (work package). A planning package should be converted to work package(s) when the lower-level details of the work are defined and prior to start of the work.

Portfolio. *Projects, programs, sub-portfolios, and operations managed as a group to achieve strategic objectives.*

Portfolio management. *The centralized management of one or more portfolios to achieve strategic objectives.*

Predecessor activity. *An activity that logically comes before a dependent activity in a schedule.*

Preliminary Design Phase. The second phase of the Design Stage, after the Conceptual Design Phase, further advances the project definition and the Project Execution Plan. It produces a bottom-up scope, cost, schedule, and risk analysis of sufficient maturity to allow determination of the Project Total Cost and Duration for a stated future start date and to establish the construction budget request.

Probabilistic Risk Analysis. A quantitative risk analysis that uses probability distributions to represent the uncertainty usually present in the cost of a deliverable or the duration of a scheduled activity and discrete risks, to obtain a range of outcomes for overall project cost and finish dates that support selection of contingency amounts as part of risk management. Many commercial probabilistic risk analysis applications employ Monte Carlo simulations of project cost and schedule.

Program. *A group of related projects, subprograms, and program activities that are managed in a coordinated way to obtain benefits not available from managing them individually.*

Program management. *The application of knowledge, skills, tools, and techniques to a program to meet the program requirements and to obtain benefits and control not available by managing projects individually.*

Progress schedule. Also called a forecast schedule. A detailed plan that tracks the advancement of tasks, activities, and milestones within a project and provides a timeline for the completion of project elements, helping to monitor progress against the planned schedule.

Progressively elaborating. *The iterative process of increasing the level of detail in a project management plan as greater amounts of information and more accurate estimates become available.*

Project*.* The activities associated specifically with the Construction Stage for Major Facilities and Mid-scale RI implementation, even though elements of project and program management may be associated with other life cycle stages.

Project definition. A clearly defined scope, schedule, and cost that is formulated before the project begins and is the foundation for project execution. See also Total Project Definition.

Project end date. The projected date for the completion of all the project baseline schedule activities plus use of all schedule contingency. (Note that this date may be earlier than, but no later than, the end date of the award instrument.)

Project life cycle. *The series of stages that a project passes through from its initiation to its closure.*

Project management. *The application of knowledge, skills, tools, and techniques to project activities to meet the project requirements.*

Project Management Control System. The software tools for development of the project databases and the processes and procedures needed to organize and manage the project; schedule and optimize project resources; compute and track Earned Value and document project risk factors; and manage the change process by evaluating the effects of alterations to the baseline on the project's planned budget and schedule.

Project Management Office. *A management structure that standardizes the project-related governance processes and facilitates the sharing of resources, methodologies, tools, and techniques.*

Project Manager (PM). *The person assigned by the performing organization to lead the team that is responsible for achieving the project objectives.*

Project schedule. *An output of a schedule model that presents linked activities with planned dates, durations, milestones, and resources.*

Project scope. *The work performed to deliver a product, service, or result with the specified features and functions.*

Project Team. A group of individuals with specific roles, skills, and expertise, assembled to collaborate on the planning, execution, and completion of a project. The team is responsible for managing project resources, schedules, risks, and deliverables, working cohesively to ensure the project meets its objectives on time, within scope, and on budget. Members contribute to decision-making, problem-solving, and ensuring the project's overall success through clear communication and coordinated efforts.

Property. Consists of both real property and personal property. Generally, real property includes land and things built on land that are not typically moveable, such as buildings. Personal property is all other property whether it is tangible (having a physical existence) or intangible (i.e., intellectual property and other financial instruments). Personal property includes "equipment" which is any tangible property with a useful life greater than one year and typically a per-unit purchase cost of $10,000 or more unless the Awardee sets a lower value for financial statement purposes. Equipment can range from the very small to the very large as long as it is moveable, in principle.

Property trust relationship. The arrangement where the Awardee has custody of federally-funded property for the beneficiaries of the project or program subject to established obligations and conditions.

Puts and Takes. Adjustments made during the planning or execution phase to balance resources, timelines, budgets, or scope and are often used when discussing budget reallocations needed to stay on track with project goals. Puts are a positive adjustment, takes are negative adjustments.

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Quality Acceptance. The process of confirming that a project deliverable, product, or service meets the specified requirements and fulfills its intended purpose. It involves assessing whether the output being assessed aligns with the expectations of stakeholders and complies with the defined quality standards and criteria.

Quality Assurance (QA). The systematic activities and processes used to ensure that project deliverables meet defined quality standards. QA focuses on the process of producing deliverables, ensuring that proper methodologies, standards, and procedures are followed to prevent deficiencies and ensure continuous improvement.

Quality Control (QC). The process of detecting and correcting defects, errors, or variances to assess performance against the desired quality level in project deliverables or processes. QC focuses on identifying deficiencies or variances in the final product or service, using tools like inspections, tests, and reviews.

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Re-baselining. A modification to the Total Project Definition that results in a change that is outside the terms set forth in the award instrument for any of the following: 1) Total Project Cost (TPC); 2) Total Project Duration (TPD); or 3) project scope, except for approved options in the scope management plan. The initial TPC and award duration are part of the NSB authorization for the Construction Stage and Mid-scale RI implementation and inform the terms of the award. Re-baselining actions require special review and approval by NSF beyond those of the typical change control approval process for re-planning actions.

Re-planning. A normal project management process to modify or re-organize the Performance Measurement Baseline cost and/or schedule plans for future work without impacting Total Project Cost (TPC), Total Project Duration (TPD), or overall scope objectives, or the implementation of approved scope management options. Formal change control processes are followed for all baseline changes. Retroactive changes to past performance should not be included in re-planning.

Recipient-titled property. Under financial assistance, any federally funded property in the custody of the Awardee where the government has not retained ownership, but the property is still subject to established obligations and conditions. Awardee-titled property is held in trust for the beneficiaries of the project or program (generally the science community) under which the property was acquired or improved. This arrangement is otherwise known as the “property trust relationship.” Generally, the Awardee may not encumber (i.e., place a lien on) the property and must follow the award terms and conditions on use, management, and disposition of the property. Only following disposition decisions at the end of the award, would ownership potentially transfer to the Awardee.

Recovery Plan. A formalized plan of corrective actions to address negative cost and/or schedule trends for return of the project to within the project definition. The plan should be based on a comprehensive analysis of the variances and establish a timeline for actions and recovery.

Requirement. *A condition or capability that is required to be present in a product, service, or result to satisfy a contract or other formally imposed specification.*

Research.gov. (Replaces the now decommissioned FastLane) Used by potential Awardees for proposal preparation, submission, proposal file updates, and budgetary revisions.

Research Infrastructure (RI). Any combination of facilities, equipment, instrumentation, computational hardware and software, and the necessary supporting human capital.

Resource Breakdown Structure. *A hierarchical representation of resources by category and type.*

Resource leveling. *A technique in which the start and finish dates are adjusted based on resource constraints with the goal of balancing demand for resources with the available supply.*

Resource-loaded. A schedule or plan that includes not just tasks and their dependencies, but also the allocation of resources required to complete those tasks, including personnel, equipment, materials, and any other necessary inputs.

Responsibility Assignment Matrix (RAM). *A grid that shows the project resources assigned to each work package.*

Review and Recommend. The act of carefully looking at or examining the quality or condition of something AND then suggesting that someone act or do something.

Risk. *An uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives.*

Risk acceptance. *A risk response strategy whereby the project team decides to acknowledge the risk and not take any action unless the risk occurs.*

Risk-adjusted Estimate at Completion (RAEAC). The expected total cost of completing all work expressed as the sum of the actual cost to date, the estimate to complete, and the project’s remaining risk exposure.

Risk avoidance. *A risk response strategy whereby the project team acts to eliminate the threat or protect the project from its impact.*

Risk Breakdown Structure. *A hierarchical representation of risks that is organized according to risk categories.*

Risk category. *A group of potential causes of risk.*

Risk exposure. Quantitative impact of risk for a single event, quoted in currency or time, and typically estimated from probability of occurrence and a likely impact or consequence. Overall project risk exposure results from an accumulation of individual risk impacts for the work to be completed, typically determined by applying probabilistic analysis to the set of individual risks.

Risk mitigation. *A risk response strategy whereby the project team acts to reduce the probability of occurrence or impact of a risk.*

Risk Register. *A document in which the results of risk analysis and risk response planning are recorded and managed.*

Risk transference. *A risk response strategy whereby the project team shifts the impact of a threat to a third party, together with ownership of the response.*

Rolling wave planning. *An iterative planning technique in which the work to be accomplished in the near term is planned in detail, while the work in the future is planned at a higher level.*

Runbook. A documented compilation of procedures and operations related to the ongoing management and maintenance of systems that is an essential tool for ensuring consistent execution of tasks, especially during incident management or routine operations. Key features may include detailed, step-by-step instructions, guidelines on procedures, incident management, roles and responsibilities, and standards to ensure uniformity and consistency.

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Schedule basis document. A written document to describe the schedule at a high-level including dependencies, key dates, assumptions, and the project team's assessment of the schedule integrity and quality using GAO schedule characteristics.

Schedule contingency. A duration of time to allow for identified delays, conditions, or events for which the state, occurrence, or effect is uncertain, and that experience shows will likely result, in aggregate. These events are often referred to as "known-unknowns" and are considered manageable by the Awardee. This duration is held separately from the baseline schedule as part of the Total Project Duration to help manage risk and uncertainty, in aggregate.

Schedule margin. An activity with duration and no resources used to manage risk associated with specific interim milestones or external deliverable requirements. A schedule margin activity should not be on the critical path that establishes the performance measurement baseline (PMB) duration nor used in the schedule risk analysis to establish the schedule contingency. Schedule contingency amounts are not included in the PMB due to the NSF requirement that contingency is held and managed separately from the baseline.

Schedule model. *A representation of the plan for executing the project's activities, including durations, dependencies, and other planning information, used to produce a project schedule along with other scheduling artifacts.*

Schedule Performance Index. *A measure of schedule efficiency expressed as the ratio of earned value to planned value.*

Schedule Variance. *A measure of schedule performance expressed as the difference between the earned value and the planned value.*

Schedule Visibility Task (SVT). Schedule activities with no resources assigned whose duration is greater than zero. SVTs may be waiting periods such as concrete curing timing or equipment delivery within the PMB or may be used to represent external effort that is not part of the PMB. SVTs may also be used to increase management visibility to items otherwise represented as lag or constrained milestones.

Science Support Program. The suite of activities related to operations and maintenance (O&M) conducted under the award as negotiated with an NSF Program Office for all Major Facilities and Mid-scale RI.

Scope contingency. Scope either (1) included in the Scope Baseline that can be removed ("de-scoped") without affecting the overall project's objectives, but that may still have undesirable effects on facility performance, or (2) may be added to the project baseline ("up-scope" or "opportunity") if budget contingency is not needed to cover realized risks and remaining risk exposure. De-scoping options and scope opportunities are included in the Scope Management Plan. Scope opportunities cannot be added after start of the Construction Stage. For Major Facility construction projects, identified scope contingency should have a value equal to at least 10% of the baseline budget at the Preliminary Design Review.

Scope creep. *The uncontrolled expansion to product or project scope without adjustments to time, cost, and resources.*

Scope options. The various approaches, decisions, and strategies that can be considered and employed to define, manage, and control the scope of a project.

S-curve. *An earned value management technique used to indicate performance trends by using a graph that displays cumulative costs over a specific period.*

Secondary risk. *A risk that arises as a direct result of implementing a risk response.*

Sponsor. *A person or group that provides resources and support for the project, program, or portfolio, and is accountable for enabling success.*

Stakeholder. *An individual, group, or organization that may affect, be affected by, or perceive itself to be affected by a decision, activity, or outcome of a project, program, or portfolio.*

Start-to-Finish. *A logical relationship in which a successor activity cannot finish until a predecessor activity has started.*

Start-to-Start. *A logical relationship in which a successor activity cannot start until a predecessor activity has started.*

Subaward: Award made by the prime Awardee of an NSF for the purpose of carrying out a portion of a federal award and creates a federal assistance relationship with the Subawardee. It does not include payments to a contractor or payments to an individual that is a beneficiary of a Federal program. A subaward may be provided through any form of legal agreement, including an agreement that the prime Awardee considers a contract. All subawards require written prior NSF authorization.

Successor activity. *A dependent activity that logically comes after another activity in a schedule.*

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Task. A specific piece of work or activity that needs to be accomplished to achieve a project's objectives. Tasks are typically identified during project planning and are listed in a project schedule or work breakdown structure (WBS).

Termination. The ending of a federal award, in whole or in part at any time prior to the planned end of period of performance.

Time-Phased Budget. A financial plan that allocates the overall project budget across specific time periods over the duration of the project and details how much money will be spent and when, aligning financial resources with the project schedule and milestones.

Title [Titled]. A right to something (for example, property), but the actual rights conferred may be limited; for example, Awardee-titled property routinely carries limitations on use, management, and disposition under the "property trust relationship" between the government and the Awardee.

Then-year. The budget that accounts for the actual costs expected in the year they will occur, including the impact of inflation and other economic factors over the duration of the project. It is also known as a current-year budget or nominal budget.

Threat. *A risk that would have a negative effect on one or more project objectives.*

Total float. *The amount of time that a schedule activity can be delayed or extended from its early start date without delaying the project finish date or violating a schedule constraint.*

Total Project Cost (TPC). The sum of the baseline budget (including indirect costs), the budget contingency, fee/profit (as applicable), and management reserve (if authorized) for the Construction Stage. For other life-cycle stages, it is referred to as the "authorized award amount."

The TPC authorized by the NSB following FDR is a "not-to-exceed" figure against which NSF manages the No Cost Overrun Policy. The initial award may be at or below this figure.

Throughout the Design and Construction Stages, the TPC is an estimate and only at the end of the project will the final TPC be known.

Total Project Definition. A project's planned scope, quality, cost, and schedule, including the performance measurement baseline documents (WBS including any unfunded contributions, WBS Dictionary, Quality Acceptance Requirements, Integrated Project Schedule, and Time-phased budget), all associated contingencies and approved fees planned for the project. See also Project Definition.

Total Project Duration (TPD). The sum of the amount of time (in months) for the Performance Measurement Baseline schedule duration and the schedule contingency. The

NSB authorized award duration is typically the project duration plus approximately 6 months.

Transition. The change from a Major Facility to another class of RI or scale of activity where NSF retains ownership or conditional interest and oversight responsibility of the assets. Mothballing (i.e., putting assets into caretaker status) and long-term lease of real property are considered forms of transition. Transition may involve the assignment of an award or a competitive process for selecting the Awardee. Following transition, the asset(s) is no longer considered an NSF-funded Major Facility, or part of an NSF-funded Major Facility, from an oversight perspective. However, other terms and conditions would apply under the new award(s), as appropriate.

Trigger. *An event or situation that indicates that a risk is about to occur.*

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Uncertainty.[1] Inherent variability in predicting the outcome of future events. Indefiniteness, lack of certainty. Fundamental inability to perfectly measure or predict something due to unknown and imperfect information. Uncertainty has a probability of 100% since it is always present and can include an estimated range for a cost or duration. It is an inherent aspect of project management and can affect planning, execution, and control.

Unknown-unknows. Significant threats to the project that are either unknowable during the project planning process or are unreasonably too large to carry as a managed risk in the project's Risk Register.

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Validation. The process of confirming that a product, service, or system meets the requirements and expectations outlined in the project scope. It involves assessing whether the deliverables align with the predetermined criteria and specifications, ensuring that they fulfill their intended purpose and provide value to stakeholders. It typically occurs towards the end of a project or phase, after the completion of the work, but before final acceptance or approval. It answers the question, *"Are we building the right product?"* and is typically performed after the product is completed.

Variance analysis. *A technique for determining the cause and degree of difference between the Performance Measurement Baseline and actual performance.*

Variance at Completion (VAC). *A projection of the amount of budget deficit or surplus, expressed as the difference between the budget at completion and the estimate at completion.*

Verification. The process of confirming that project deliverables, products, or components

[1] Definition adapted from: AACE International (AACEI) Recommended Practice (RP) 10S-90: Cost Engineering Terminology, September 30, 2021; DOE Cost Estimating Guide, DOE G 413.3-21A, June 6, 2018; NASA Cost Estimating Handbook, Version 4.0, February 2015.

meet the specified requirements, standards, and criteria established in the project scope. It ensures that the work results align with the intended objectives and that they adhere to the defined quality standards and specifications. It answers the question, *"Are we building the product right?"* and involves reviews, inspections, and testing during the design and development stages.

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Work Breakdown Structure (WBS). *A hierarchical decomposition of the total scope of work to be carried out by the project team to accomplish the project objectives and create the required deliverables.*

Work Breakdown Structure (WBS) Dictionary. *A document that provides detailed deliverable, activity, and scheduling information about each component in the work breakdown structure.*

Work Package. *The work defined at the lowest level of the WBS for which cost, and duration can be estimated and managed.*

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9.0 APPENDICES

9.1 APPENDIX A – RANKING CRITERIA FOR PRIORITIZING MAJOR FACILITY PROJECTS

Excerpted from the National Academies' Report: *Setting Priorities for Large Facility Projects Supported by the National Science Foundation*.[1]

9.1.1 First Ranking – Scientific and Technical Criteria Assessed by Researchers in a Field or Interdisciplinary Area

- Which projects have the most scientific merit, potential and opportunities within a field or interdisciplinary area?
- Which projects are the most technologically ready?
- Are the scientific credentials of the proposers of the highest rank?
- Are the project-management capabilities of the proposal team of the highest quality?

9.1.2 Second Ranking – Agency Strategic Criteria Assessed across Related Fields

- Which projects will have the greatest impact on scientific advances in this set of related fields taking into account the importance of balance among fields for NSF's portfolio management in the nation's interest?
- Which projects include opportunities to serve the needs of researchers from multiple disciplines or the ability to facilitate interdisciplinary research?
- Which projects have major commitments from other agencies or countries that should be considered?
- Which projects have the greatest potential for education and workforce development?
- Which projects have the most readiness for further development and construction?

9.1.3 Third Ranking – National Criteria Assessed across All Fields

- Which projects are in new and emerging fields that have the most potential to be transformative? Which projects have the most potential to change how research is conducted or to expand fundamental science and engineering frontiers?
- Which projects have the greatest potential for maintaining U.S leadership in key science and engineering fields?
- Which projects produce the greatest benefits in numbers of researchers, educators and students enabled?
- Which projects most need to be undertaken in the near term? Which ones have the most current windows of opportunity, pressing needs and international or

[1] As referenced in Joint National Science Board —National Science Foundation Management Report: Setting Priorities for Large Facility Projects Supported by the National Science Foundation (NSB-05-77); September 2005. http://www.nap.edu/books/0309090849/html/R1.html

interagency commitments that should be met?

- Which projects have the greatest degree of community support?
- Which projects will have the greatest impact on scientific advances across fields taking into account the importance of balance among fields for NSF's portfolio management in the nation's interest?

9.2 APPENDIX B – OUTLINE OF PLANS BY LIFE CYCLE STAGE

9.2.1 Design Stage

Design Execution Plan (DEP). First submitted during the Conceptual Design Phase and revised for the Conceptual Design Review (CDR) and Preliminary Design Review (PDR), it utilizes the 10-section format of the Project Execution Plan (PEP). The sections include Design Execution Overview, Organization, Design Baseline, Scope Acquisition and Delivery, Safety, Health and Environmental Protection, Controls, Information Management, Risk Management, Award Close-out, and Post-Award Plans and Exceptions.

9.2.2 Construction Stage and Implementation Planning

Project Execution Plan (PEP). Structured into ten sections, the PEP outlines the planning, management, execution, and closure of a project. It specifies deliverables, performance metrics, management structure, resources, timeline, milestones, and risks. All Major Facilities and Mid-scale RI projects require a PEP tailored and scaled to the type of project and its complexity.

PEP Component 3 – Performance Measurement Baseline Plans

- **Scope Management Plan.** Outlines the strategy for managing project scope, including identification, documentation, and control, along with roles and responsibilities. It specifies processes for handling scope changes, de-scope, and up-scope options and their impact on cost, schedule, and decision-making timelines.
- **Schedule Basis and Estimating Plan.** Details the methodology, tools, and processes for developing the project schedule, including estimating techniques, guidelines, and assumptions. It covers schedule logic, external dependencies, critical path drivers, key dates, and assumptions regarding procurement, operations, funding, travel, staffing, and resource limitations.
- **Cost Estimating Plan.** This plan outlines the methodology, tools, and processes for developing, documenting, reviewing, approving, and managing the project budget. It includes critical assumptions, constraints, cost-estimating techniques, validation methods, and significant factors, guiding project estimators and informing the NSF.

PEP Component 4 – Risk and Contingency Management Plans

- **Risk Management Plan**. Describes the tools and techniques for identifying, analyzing, responding to, and tracking project risks and includes ongoing processes for managing, mitigating, and controlling risks.
- **Contingency Management Plan.** Details the estimation and management of budget, schedule, and scope contingency to manage risks and uncertainties.

PEP Component 5 – Acquisition Plans

- **Scope Acquisition Plan**. Outlines plans for acquiring all project scope, including approaches for remaining development, high-risk acquisitions, and site considerations. It lists significant procurements with details and timelines, ensuring each Work Breakdown Structure deliverable has a straightforward acquisition approach, with child element plans noted at the parent level.

- **Systems Engineering Plan**. Details the systems and subsystems with their technical requirements and interfaces. It includes planning and design documentation defining inspection and test regimes for facility commissioning and acceptance.
- **Quality Management Plan**. Outlines a robust strategy for system integration, testing, and commissioning activities for projects, as well as conditions for acceptance.
- **Resource Management Plan**. Outlines how human and non-labor resources required for the project will be identified, acquired, allocated, managed, and monitored.

PEP Component 6 – Environmental, Safety, and Health Management Plans

- **Environmental Protection Management Plan**. Outlines the strategy to protect the environment, emphasizing compliance with relevant laws, statues, and regulations, during and after the project, including impact identification, mitigation plans, and reporting.
- **Safety Management Plan**. Details the worker safety and equipment protection strategy, including regulations, hazard identification and mitigation, safety facilities, documentation, reporting, and training.
- **Occupational Health Management Plan.** Outlines steps to protect workers' physical and mental well-being, including stress management, work-life balance initiatives, and access to mental health resources. Covers health regulations, assessment, mitigation, monitoring, documentation, and reporting.

PEP Component 7 – Project Controls Plans

- **Project Management Control Plan**. summarizes the main categories of project control plans: Performance Measurement and Management, Change Control, Project Documentation and Reporting, and Business and Financial Control. It details how these plans will be utilized to manage the project and outlines the tools (such as spreadsheets, databases, and commercial software products) that will be employed for various Project Control functions.
- **Performance Measurement and Management Plan**. Covers scope and quality assessment, schedule progress, budget assessment, variance assessment, forecasting, and performance management.
- **Change Control Plan**. Outlines how the project manages, controls, and reports changes to the Total Project Definition.
- **Segregation of Funding Plan**. Establishes guidelines for allocating expenses to the appropriate award when design, construction, or operations overlap. It outlines procedures to ensure costs are appropriately expensed and clearly defines the separation between funding sources.

PEP Component 8 – Cyberinfrastructure and Information Management Plans

- **Cyberinfrastructure Plan (CI Plan)**. Outlines the structured approach for planning, implementing, and managing CI aspects of RI, covering the scientific mission, CI elements and requirements, internal and external CI, facilities and resources, and implementation and operational approaches.
- **Information Assurance Management Plan (IAMP)**. Details plans for managing project information during construction, including policies, roles and responsibilities, data security, response plans, and training.
- **Data Management Plan**. Outlines the management of digital assets, including code, software deployment, hardware, network architecture, and 3D designs.
- **Documentation Management Plan**. Outlines the document management system for retaining and retrieving essential project documentation, preventing miscommunications, and ensuring future facility operators have any necessary information.
- **Communications Management Plan**. Details the approach to managing project communications, including meetings, websites, newsletters, and blogs, focusing on stakeholder interactions.

PEP Component 9 – Project Closeout Plans

- **Technical Closeout Plan**. Describes how the project will complete all scope, verify compliance, finalize transitions, and document deliverables to meet quality criteria, and includes plans for scope completion and verification, transition to operations, lessons learned, and archiving documentation.
- **Transition to Operations Plan (T2O Plan)**. Outlines the process for determining operational readiness and transitioning deliverables from construction to operations. It includes readiness reviews, demonstrations, verification of deliverables, operations and maintenance manuals, staff training, and transfer of title/ownership.
- **Administrative Closeout Plan**. Details how the Awardee will complete administrative activities, including contract closeouts, financial reconciliation, resource transfers, and legal obligations, ensuring proper handling of funds and release or transfer of resources.
- **Programmatic/Award Closeout Plan**. Outlines processes for obtaining NSF validation of project completion to close the award.

PEP Component 10 – Post Project Plans

- **Concept of Operations Plan (ConOps)**. Details high-level expectations for the post-project Operations Stage and will be finalized by the award time. It's only revised if new issues or insights on operations and maintenance arise.
- **Concept of Disposition Plan**. Outlines post-NSF funding divestment expectations, maturing by the Construction Stage award. It is less detailed than the Disposition Plan and only revised if new issues arise during project execution.

9.2.3 Operations Stage

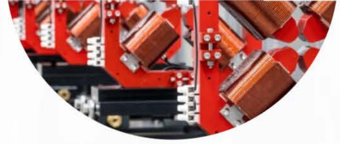
Strategic Plan. Establishes the Science Support Program's long-term goals, objectives, and activities. The plan should be revisited at least every five years and include a framework for resource allocation and program evolution.

Asset Management Plan (AMP). Outlines a strategy to address Facility Condition Assessment Report issues, specifying the timeline and resources needed. Steps include prioritizing items based on urgency, aligning with the scientific mission, and developing a management strategy. The plan identifies funding needs over the facility’s expected life and lists deferred maintenance items.

Annual Work Plan (AWP). Explains the Science Support Program’s goals for the upcoming performance period, detailing operations, maintenance, education, outreach, management tasks, and deliverables. Includes objectives, milestones, targets, assumptions, and risks, serving as a baseline for assessing planned versus completed activities. Submitted annually for NSF review and approval, it informs the funding release and focuses on plans and compliance with award terms.

9.2.4 Disposition Stage

Disposition Plan. A comprehensive plan to ensure transparency, accountability, and successful RI disposition submitted to the NSF Program Office for review and approval. Key topics include an overview, scope, roles and responsibilities, risk management, contracts management, environmental impact analysis, and pension and healthcare responsibilities.



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