National Science Foundation
WHERE DISCOVERIES BEGIN

MAJOR FACILITIES GUIDE

Prepared by the Large Facilities Office in the Budget, Finance, and Award Management Office (BFA-LFO)

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SUMMARY OF SIGNIFICANT CHANGES

This document has been cleared for publication under OMB approval number 1315-0239, which expires 9/30/2022. The purpose of this revision is to update the material and to improve the clarity and legibility of the guide for the targeted audience of users both inside and outside NSF. A summary of the changes for this revision is given below. Footers within each section of this document indicate the last revision date of the content in that section, while all page headers in the document include the date and NSF number of the current version of the Major Facilities Guide.

1. Replaced the title of this document from "Large Facilities Manual" to "Major Facilities Guide" and "Large Facility" to "Major Facility" throughout the document to align with the American Innovation and Competitiveness Act (AICA) terminology.
2. Revised Section 1.1, Purpose and Scope, to provide the basis for the use of cooperative agreements and contracts.
3. Revised Section 1.2, Precedence, to clarify the order of precedence for regulations and NSF documents.
4. Updated and moved the NSB Policies on Recompetition and No Cost Overrun from other sections of the guide to Section 1.4, Applicable Legislation and NSF Policy.
5. In Section 1.4, Applicable Legislation and NSF Policy, added the definition for mid-scale project.
6. Revised Section 2.1.3, The Major Facility Life Cycle, to clarify the five different stages of a facility's life cycle and the exit process from the Development Stage to Design Stage.
7. New material was introduced in Section 2.1.4, Summary of the Major Facility Implementation Process, on spiral development.
8. Figure 2.1.4-1, Summary Timeline for Major Facility Projects (Development and Design), was revised to clarify the two levels of oversight of major facilities within NSF.
9. In Section 2.1.6, Roles and Responsibilities for NSF Staff for Management and Oversight of Major Facilities, various edits and updated Figures were made throughout to add the Chief Officer for Research Facilities position, the Major Facilities Working Group, the Facilities Readiness Panel and the Facilities Governance Board and to delete the Large Facilities Working Group and the MREFC Panel.
10. Previous LFM version Section 2.4.2, Commissioning Plan, was moved to Section 3.4.2, Detailed Guidelines for Project Execution Plans.
11. New material was added to the reserved subsection 2.4.2.1, Project Close-out Process.

12. Moved material on annual reporting compared to planned from Section 4.2 to Section 2.5.1 under Annual Work Plan.

13. Moved the material on application of the guide to non-major facility projects from Section 2 to Section 5 Guidance for Mid-Scale Research Infrastructure Projects and revised content.

14. Material was removed from Section 3.2, NSF Facility Plan *[Reserved]*, and this section is reserved.

15. Revised Section 3.3, NSF Internal Management Plans for the Major Facility Life Cycle, to clarify NSF expectations for internal management plans.

16. Revised Section 3.4.1, Components of a Project Execution Plan, and added material to the reserved Section 3.4.2, Detailed Guidelines for Project Execution Plans, to clarify Commissioning and to add a requirement for a segregation of funds plan.

17. In Section 3.5.2, Procedures for Renewal or Recompetition of an Operating Major Facility, updated the issues for reconsideration for alignment with internal guidelines.

18. New material was added to reserved Section 3.6, Facility Divestment Plan, to describe potential elements of a transition plan from NSF stewardship to divestment. Sections 2.1.3 and 9.2 were revised to clarify the range of options for the Divestment Stage.

19. In Section 4.2, Cost Estimating and Analysis, major revisions were made to Sections 4.2.1 through 4.2.4 to clarify NSF guidance and requirements to ensure alignment with GAO guidelines and subsection 4.2.2.3 was added on the application of GAO's twelve steps of a high-quality cost estimating process.

20. Edited subsection 4.2.2.4, Supplementary Guidance for NSF Budget Categories from the PAPPG, to clarify the difference between subawards and contracts for alignment with the Uniform Guidance 2 CFR § 200.331, to emphasize Subrecipient monitoring requirements, and to update the NSF Budget Categories as related to Fee.

21. Subsections 4.2.5.1 and 4.2.5.2 were edited to move the "No Cost Overrun" policy language to Section 1.4 and clarify when the total project cost is established.

22. Revisions were made to Subsections 4.2.5.1 and 6.2.3.1 and the Lexicon, Section 9.2, to clarify the definitions of management reserve and contingency.

23. Subsection 4.2.5.8, Reporting Requirements, and Section 4.6.2, Recipient Performance Reports, was edited to clarify the required content of the monthly construction stage reports and to remove redundancies.

24. Section 4.2.6, Budget Contingency Planning during the Operations Stage, was revised to include strategies to handle risks on operations awards.

25. Section 4.3, Schedule Development, Estimating, and Analysis, was created and reserved for future content to provide NSF guidance and requirements for construction schedules and to ensure alignment with GAO guidelines.

26. Edited subsection 4.6.3.3, Business Systems Reviews (BSR), to delete the five-year cycle requirement for BSRs and add language regarding the annual major facility portfolio risk assessment.

27. Edited subsection 4.6.3.4, Incurred Cost Audits, to change the threshold for incurred cost audits to $70M and the name of the financial data collection tool and update Figure 4.6.3-1.

28. New material was added to the reserved Section 4.6.3.6, Earned Value Management Verification, Acceptance, and Surveillance, on the NSF requirements and process for verifying construction project EVM systems.

29. New material was added to the reserved Section 6.3, Guidelines for Cyber-Security of NSF's Major Facilities, on the implementation and monitoring of cyber-security good practices.

30. New material was added to the reserved Section 6.6, Guidelines for Property Management, on requirements for managing and disposing of property furnished by the Federal government or whose cost was charged to a project supported by a Federal award.

31. New material was added to the reserved Section 6.8, Guidelines for Earned Value Management Systems, on implementation and scalability for effective project management controls.

32. New acronyms (5) for new roles introduced in Section 2.1.6 were added to Section 8, List of Acronyms.

33. Section 9, Lexicon, contains a revised and updated Large Facility definition to Major Facility, additional terms, Independent Cost Estimate Review and Research Infrastructure, and updated definitions of terms (5) used in Section 4.2.

34. Revised numerous references to MREFC used to reference the construction stage of a major facility's life cycle to reflect the definition in Section 1.4.3, Major Multi-User Research Facility Project (Major Facility).

35. Corrections were made to various minor typographical errors and formatting errors. Document references were updated to latest versions where applicable.

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1 INTRODUCTION

1.1 PURPOSE AND SCOPE

A major responsibility of the National Science Foundation (NSF) is the support of scientific facilities as an essential part of science and engineering enterprise. Facilities are defined as shared-use infrastructure, instrumentation and equipment that are accessible to a broad community of researchers and/or educators. These facilities are generally intended to serve the science community that is critical to supporting innovation across the nation. Facilities supported by NSF may be centralized or may consist of distributed-but-integrated installations. They may incorporate large-scale networking or computational infrastructure, multi-user instruments or networks of such instruments, or other infrastructure, instrumentation, and equipment having a major impact on a broad segment of a scientific or engineering discipline. Historically, NSF has supported such diverse projects as particle accelerators, telescopes, remote research stations, research vessels, aircraft, and geographically distributed but networked observatory systems.

In general, NSF does not directly construct or operate the facilities it supports. The National Science Foundation Act of 1950 ("Organic Act," Public Law 81-507) establishes that the "principal purpose" of NSF's relationship with award Recipients is to fund and facilitate scientific and engineering research and education programs, and to appraise the impact of research upon industrial development and upon the general welfare. It states that NSF "shall not, itself, operate any laboratories or pilot plants". NSF makes awards to external Recipients that include nonprofit organizations, universities, and private sector (industry) to undertake construction, management, and operation of facilities. Such awards frequently take the form of cooperative agreements but may also be made in the form of contracts. The reasons underlying the selection of the cooperative agreement as the preferred award instrument are:

- Scientific justifications, design and specifications for facilities are prepared by science and engineering communities, and management and operations are conducted on their behalf;
- The facilities do not support NSF nor does NSF permanently station government personnel on-site;
- NSF involvement is to assure sufficiency of progress to justify continued sponsorship, and its award administration and oversight activities are not conducted for purposes of inspection or acceptance; and
- NSF does not maintain the unilateral right to change or redirect work under the agreement.

However, NSF's responsibility is for overseeing the Recipient's development and management of the facility as well as assuring the successful performance of the funded activities. **The Recipient is responsible for the day-to-day management of the facility.**

Cooperative agreement is the legal award instrument that reflects the above described relationship. Federal Grant and Cooperative Agreement Act ("Grant Act," Public Law 95-224) requires that executive agencies use cooperative agreements 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 "to carry out a public purpose of support or stimulation authorized by a law of the United States," and "substantial involvement is expected" between the agency and the non-federal entity in carrying out the activity contemplated by the agreement.

NSF uses cooperative agreements (CAs) to fund the construction and operation and maintenance (O&M) of large-scale research facilities. Cooperative agreements with universities, consortia of universities or non-profit organizations are governed by OMB Uniform Guidance.[1] Under the Uniform Guidance, cooperative agreements structure allows for additional oversight and accountability mechanism to be built into the agreements. Cooperative agreements also afford flexibility to tailor project-specific requirements and performance metrics. Unlike a contract, these can be readily adjusted as needed to ensure the appropriate rigor in oversight with relatively minimum administrative and time burdens.

Many major facility awards, including those for NSF-supported Federally Funded Research and Development Centers (FFRDCs), consist of a cooperative agreement as an umbrella award, establishing the overall basic provisions of the award, and separate cooperative support agreements. The cooperative support agreements contain specific terms and conditions for construction activities, management and operations, research activities that are co-sponsored by other agencies, and any other focused activities that NSF needs to monitor separately from the overall objectives of the cooperative agreement.

Procurement contracts could be used in circumstances where the agency "decides in a specific instance that use of a procurement contract is appropriate." Federal Acquisition Regulation (FAR) states that "contracts shall be used only when the principal purpose is the acquisition of supplies or services for the direct benefit or use of the Federal Government". The policies and procedures in this Guide apply to research infrastructure projects regardless of the award instrument employed. When using contracts, the FAR will take precedence in event of conflict.[2]

[1] 2 Code of Federal Regulation (CFR) § 200. The Office of Management and Budget's (OMB) Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards (commonly called "Uniform Guidance") was officially implemented in December 2014 by the Council on Financial Assistance Reform (COFAR). The Uniform Guidance – a "government-wide framework for grants management" – synthesizes and supersedes guidance from earlier OMB circulars

[2] See *Guide to the NSF Contracting Process* for information related to NSF contracts.

The *Major Facilities Guide* (MFG) contains NSF policy on the planning and management of major facilities through their full life cycle[1]. The purpose of the Guide is to:

- Provide guidance to NSF staff on conducting oversight of major facilities and to Recipients in carrying out effective project planning and management, and
- Clearly state the required policies and procedures as well as pertinent guidance and practices at each stage of a facility's life cycle.

NSF typically supports facility construction from two appropriations accounts: the Major Research Equipment and Facility Construction (MREFC) Account and the Research and Related Activities (R&RA) Account, but additional support may come from Education and Human Resources (EHR) Accounts. The MREFC Account was created in 1995 to fund the acquisition, construction, commissioning, and upgrading of major science and engineering infrastructure projects that could not be otherwise supported by Directorate level budgets without a severe negative impact on funded science. MREFC projects generally range in cost from seventy million to several hundred million dollars expended over a multi-year period. The R&RA account is used to support other activities involving a major facility that the MREFC Account cannot support, including planning and development, design, operations and maintenance, and scientific research. Construction and acquisition projects at a smaller scale, usually of a scale ranging from millions to tens of millions of dollars, are also normally supported from the R&RA Account. The provisions and principles in the *Major Facilities Guide* should also be applied to these smaller-scale facilities funded through the R&RA Account, but procedures should be modified appropriately to fit the needs of each facility (see Section 5).

The policies in the *Major Facilities Guide* apply to the full life cycle of all major facility projects funded by NSF, including:

- Facilities and infrastructure projects constructed or acquired with funds from the MREFC Account;
- Facilities and infrastructure projects constructed or acquired with funds from the R&RA (and/or leveraged with EHR Accounts) with a total project cost (TPC) greater than $100 million or that require National Science Board (NSB) authorization; whichever is less.

The policies in this Guide are also tailored for mid-scale research infrastructure projects as described in Section 5.

If, on a case-by-case basis, departures from the policies in this Guide are considered necessary or prudent, the Recipient must provide a written justification and discuss proposed deviations with the Program Officer, Large Facilities Officer (LFO) Liaison, and Grants and Agreements Officer or Contracting Officer as early as possible. Agreed upon deviations should be

[1] There are five stages in a facility's life cycle – development, design, construction, operations, and divestment. Section 2 of this Guide describes each of these stages in detail.

documented as part of the NSF Internal Management Plan (IMP) or the Recipient's Project Execution Plan (PEP), as appropriate.

1.2 PRECEDENCE

The *Major Facilities Guide* (MFG) comprises Chapter II.E.11 of the *Proposal and Award Policies and Procedures Guide* (PAPPG) and published as a public document under separate title. The MFG is managed by the Office of Budget, Finance and Award Management's (BFA) Large Facilities Office (LFO) and available on the LFO public website (https://www.nsf.gov/bfa/lfo/index.jsp) as well as through the internal LFO website. This version replaces the *Large Facilities Manual*, NSF 17-066, published in 2017, and incorporates changes in organization and content intended to clarify the policies and procedures by which Major Facility candidate projects are identified, developed, prioritized and selected.[1]

The MFG requirements flow from other NSF policies and statutory requirements. The hierarchy of documentation[2], in order of precedence, is as follows:

1. 2 CFR, part 200: Uniform Administrative Requirements, Cost Principles, and Audit Requirement for Federal Awards (*Uniform Guidance*).
2. The Solicitation and subsequent Award Terms and Conditions
3. NSF *Proposal & Award Policies and Procedures Guide* (PAPPG): The PAPPG is comprised of documents relating to the Foundation's proposal and award process for the assistance programs of NSF. The PAPPG, in conjunction with the applicable award terms and conditions, serves as the Foundation's implementation of the *Uniform Guidance*.
4. *Major Facilities Guide* (MFG): as referenced in the PAPPG
5. *Business Systems Review* (BSR) *Guide*

The MFG does not replace existing formal procedures required for all NSF awards, which are described in the publically available Proposal and Award Policies and Procedures Guide (PAPPG). Instead, it draws upon and supplements them for the purpose of providing detailed guidance regarding NSF management and oversight of facilities projects.

All facilities projects require merit review, programmatic/technical review, and a substantial approval process. This level of review and approval differs substantially from standard grants, as does the level of oversight needed to ensure appropriate and proper accountability for federal funds. The policies, requirements, recommended procedures, and good practices presented herein apply to any facility large enough to require interaction with the NSB or any facility so designated by the Director, the Deputy Director, or the Assistant Director/Office Head

[1] See the 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

[2] Assumes assistance awards, contract awards are governed by the Federal Acquisition Regulation (FAR) and requirements will be tailored as applicable to FAR.

of the Sponsoring Organization(s).[1] For all other facilities, NSF staff members should use their judgment in proportionately scaling the requirements and recommended procedures for specific projects.

This Guide will be updated periodically to reflect changes in requirements and/or policies. As part of the NSF Major Facilities Knowledge Management program, NSF will continue to identify and adopt good practices aimed at improving agency oversight and Recipient management of major facilities projects and at enabling the most efficient and cost-effective delivery of tools to the research and education communities.

[1] See Section 2.1.6 for definition of this and other key terms. It also describes the NSF organizations and officers that are involved throughout the initiation, development, approval and implementation of a major facility project. Readers not familiar with NSF and its processes should review this material before proceeding.

1.3 DOCUMENT STRUCTURE

This Guide is organized as follows:

- Section 1 introduces the purpose, scope, and historical perspective of this document.
- Section 2 describes the life cycle stages and the process and principles NSF uses to plan, construct and operate major facilities. The steps for approval and execution of major research facility projects and the roles and responsibilities of NSF staff are detailed.
- Section 3 describes the requirements for preparing and following the various detailed management plans required during the life cycle of a major facility, including Recipient's plans and guidance for NSF's Internal Management Plans (IMPs).
- Section 4 is an expanded compendium of several NSF key requirements and principles listed in Sections 2 and 3. It includes detailed descriptions of processes used to plan, acquire, and manage major facilities.
- Section 5 is guidance on scaling the Major Facilities Guide's principles to mid-scale projects.
- Section 6 contains extensive supplementary information on specific topics concerning NSF's role in the planning, oversight, and assurance of major facility projects. It consists of sections containing important explanatory and procedural information and pointers to separate documents (or modules) with similar information. The information in the documents is presented in a tutorial format that should be of particular benefit to individuals who are newly involved with major facility projects.
- Sections 7, 8, and 9 contain reference material: document references, list of acronyms, and a lexicon.
- Section 10 contains appendices contain other information relevant to construction projects and major facilities.

This Guide is intended for use by NSF staff and by external proponents of major facility projects for use in planning. However, there are occasional references to materials, such as the NSF *Proposal and Award Manual*[1] (PAM) and internal operating guidance documents, which are available only internally to NSF staff and refer to details of NSF administrative practices and procedures that are not relevant to external project proponents. Wherever these internal references are included, they are clearly noted as such. Any questions about the content of internal NSF documents by external proponents or Recipients should be addressed to the appropriate Program Officer.

Owing to the rigor of merit and programmatic review, constraints on funding, changing priorities and competing interests of NSF and the research community, only a limited number of projects will proceed successfully through all stages described herein. To improve the possibility of success, facility advocates should be thoroughly familiar with the entire contents

[1] The NSF *Proposal and Award Manual* is a compendium of internal policies and procedures.

of this Guide even if the proposed project is in the earliest stages of formulation. Anticipating downstream requirements will dramatically improve the efficiency of the process.

1.4 APPLICABLE LEGISLATION AND NSF POLICY

1.4.1 Research Infrastructure

NSF defines Research Infrastructure (RI) as any combination of facilities, equipment, instrumentation, computational hardware and software, and the necessary human capital in support of the same. Major facilities and mid-scale projects are subsets of research infrastructure. NSF's Research Infrastructure investments are described in the agency's annual budget request to Congress.

1.4.2 MREFC Threshold

NSF Director Memo NSB-2016-46 to the National Science Board dated October 20, 2016 informed the Board of the Director's decision to reduce the Total Project Cost (TPC) threshold for MREFC account eligibility to $70 million. This modification to the previous threshold of 10% of a Directorate's or Office's Current Plan was intended to enable innovative infrastructure projects.

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 is a science and engineering facility project that:

(A) exceeds the lesser of (i) 10 percent of a Directorate's annual budget; or (ii) $100,000,000 in total project costs; or

(B) is funded by the major research equipment and facilities construction account, or any successor account.

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

NSF interprets this to mean the Total Project Costs (TPC) as defined by the Construction Stage; NOT the full life-cycle cost. This aligns with the allowable use of MREFC account which is for construction, acquisition and commissioning. This interpretation applies to projects funded through MREFC or R&RA.

1.4.4 Mid-Scale Project

Per Section 109 of AICA, a mid-scale project means research instrumentation, equipment, and upgrades to major research facilities or other research infrastructure investments that exceeds the maximum funded by the Major Research Instrumentation program (MRI) and are below that of a major multi-user research facility project. The definition of major multi-user research facility projects is given in Section 1.4.3 of this Guide.

NSF interprets this to mean the Total Project Cost (TPC) as defined by the investment in construction or acquisition; not the operations or associated science program costs.

1.4.5 National Science Board Policy on Recompetition

NSB statement 2015-45 and resolution 2015-46 address competition, renewal, and divestment of major facilities. The NSB issued a statement that the question of whether to recompete or not should be assessed at the time of every potential renewal. Competitions would be launched when the NSF, in consultation with the NSB, judges that it is necessary to ensure the optimum scientific impact and the most effective use of taxpayer dollars.[1]

1.4.6 NSF "No Cost Overrun" Policy

NSF's "No Cost Overrun" policy was originally codified for major facility projects in the Fiscal Year (FY) 2009 Budget Request to Congress[2] 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 assure 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 Total Project Cost (TPC) at award and a strong NSF oversight position for major facility projects.

[1] See NSB Statement on Recompetition of Major Facilities - NSB-2015-45, https://www.nsf.gov/nsb/publications/2015/NSBStatementRecompetitionFacilities_2015-11-19.pdf, and NSB Resolution on Recompetition of Ongoing Facilities - NSB-2015-46, https://www.nsf.gov/nsb/publications/2015/NSBResolutionRecompetitionFacilities_2015-11-19.pdf

[2] See the MREFC Section of the NSF's 2009 Budget Request to Congress, page 3, available online.

2 MAJOR FACILITY LIFE CYCLE AND MAJOR FACILITY OVERSIGHT

2.1 PROCESS INTRODUCTION

National Science Foundation (NSF) investments through the Major Research Equipment and Facility Construction (MREFC) Account provide state-of-the-art infrastructure for research and education, such as laboratory and field instrumentation and equipment, multi-user research facilities, remote research stations, distributed instrumentation networks and arrays, and mobile research platforms. In addition, investment is increasing in highly sophisticated information technology (IT)-based infrastructure, including distributed sensor networks, extensive data-storage and transmission capabilities, advanced computing resources, and Internet-based distributed user facilities.[1]

This section describes the overall major facility life cycle as well as the roles and responsibilities of the various participants for oversight. It provides guidelines for planning and managing major research infrastructure facilities. Because each facility has unique aspects, each project necessarily requires adaptation of general principles. NSF promotes flexibility in the application of these guidelines but requires justification and substantiation for the specific approach taken in each case. That is accomplished through the processes of formal planning, documentation, and review.

[1] These resources, many of which are now in development, are collectively known as "cyber infrastructure."

2.1.1 Definition of the MREFC Account

The MREFC Account is an agency-wide capital account, created in 1995 with Congressional approval, which provides funding to establish major science and engineering infrastructure projects. Specifically, the MREFC Account is intended to:

- In accordance with legislation, provide a special account specifically for acquisition, construction and commissioning of major facilities and other infrastructure projects, including major upgrades;
- Prevent large periodic obligations from distorting the budgets of NSF Directorates and program offices; and
- Ensure availability of resources to complete large projects that are funded over several years.[1]

The MREFC Account funding is specifically for the construction stage. It cannot be used to support other activities related to the development, design, operations or divestment stages as defined in other sections of this Guide.

The MREFC threshold is set by internal NSF Policy (See Section 1.4.2).

[1] Reliable long-term funding commitments are essential to maintaining partnerships and for preventing cost overruns due to schedule delays.

2.1.2 Eligibility for MREFC Funding

To be eligible for consideration for MREFC funding, each candidate project should represent an outstanding opportunity to enable research and innovation, as well as education and broader societal impacts. Each project should offer the possibility of transformative knowledge and the potential to shift existing paradigms in scientific understanding, engineering processes and/or infrastructure technology. Moreover, each should serve an urgent contemporary research and education need that will persist for years beyond the often-lengthy process of planning and development.

In addition, a candidate project should:

- Be consistent with the goals, strategies and priorities of the NSF Strategic Plan;[1]
- Establish a long-term tools capability accessible to an appropriately broad community of users on the basis of merit;
- Require large investments for construction/ acquisition, over a limited period of time, such that the project cannot be supported within one or more NSF Directorate(s)/ Office(s) without severe financial disruption of their portfolios of activities;
- Have received strong endorsement of the appropriate science and engineering communities, based upon a thorough external review, including an assessment of (1) scientific and engineering research merit, (2) broader societal impacts, (3) importance and priority within the relevant Science and Engineering communities, (4) technical and engineering feasibility, and (5) management, cost, and schedule issues;
- Be of sufficient importance that the Sponsoring NSF Organization[2] is prepared to fully fund the costs of pre-construction planning, design and development, operation and maintenance, and associated programmatic activities (with full awareness that, for a long-lived facility, operations costs may ultimately amount to many times the construction costs); and
- Have been coordinated with other organizations, agencies and countries to ensure complementarity and integration of objectives and potential opportunities for collaboration and sharing of costs.

[1] *Empowering the Nation Through Discovery and Innovation: NSF Strategic Plan for Fiscal Years (FY) 2011-2016.*

[2] See Section 2.1.6 for definition of this and other key terms. It describes the NSF organizations and officers that are involved throughout the conception, development, approval and implementation of a major facility project.

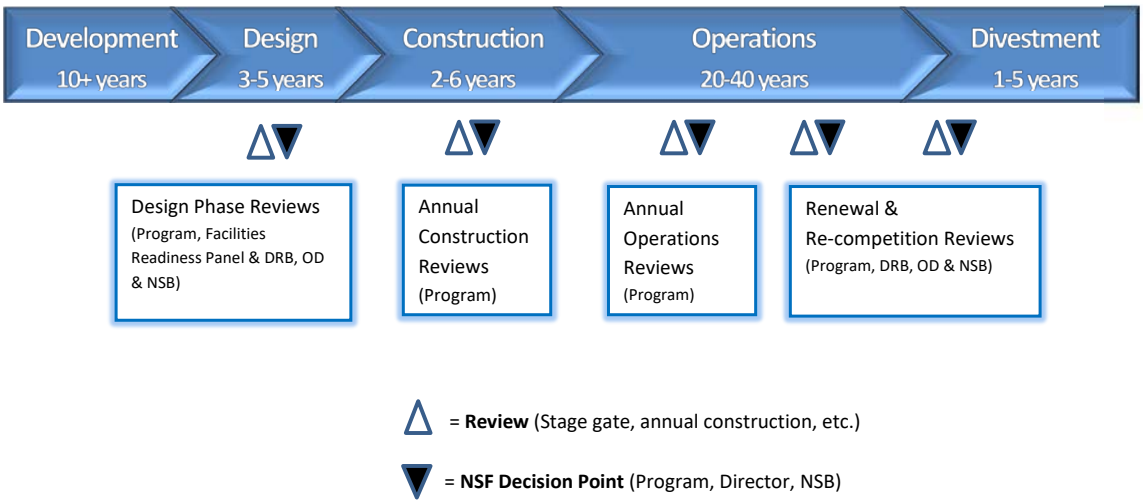
2.1.3 The Major Facility Life Cycle

A facility's life cycle is characterized by the following five stages:

1. Development[1]
2. Design
3. Construction
4. Operation
5. Divestment

Each life cycle stage involves different activities as well as certain actions by NSF and the Recipient that are necessary to advance the project to the next stage. These activities include reviews and approvals needed to obtain NSF funding, and the creation of budgets and NSF awards to support these activities. Entry and exit from each life cycle stage are defined in this Guide, including the required documents and deliverables. A high-level graphic of the progression through the stages is given below in Figure 2.1.3-1.

Figure 2.1.3-1 Progressive steps in the facility life cycle, showing the high-level review and decision points for exit and entry into each stage. The Design Stage is further broken down into phases.



Descriptions for each stage are given below. See Sections 2.2 to 2.6 for detailed discussions of the various procedures and deliverables for progression through each stage in the facility life cycle.

[1] A project in the Development Stage may be referred to as a "Horizon" or a Conceptual Development project in earlier NSF documents and references.

Development Stage

The development stage is where initial ideas emerge and a broad consensus built for the potential long-term needs, priorities, and general requirements for Research Infrastructure (RI) of interest to NSF. Investments in development by NSF, other government agencies, or private interests can be focused or sporadic, but these annual investments are generally smaller than in the Design Stage. The effort is focused on the high-level ideas, building community consensus on requirements, and setting priorities across a broad landscape of potential needs. This stage can last 10 years or more and consequently the cumulative investment over this period can be quite substantial. Next to the Divestment Stage, the Development Stage is often the most challenging to navigate depending upon how federal agencies and science communities are organized. The exit process from this stage occurs when the Sponsoring Organization sends a memorandum to the Chief Officer for Research Facilities (CORF) recommending that a project is ready to enter Design Stage, normally at the Conceptual Design Phase. At that point, the CORF conducts a senior leadership review focusing on strategic agency and science community issues followed by a recommendation to the NSF Director. If the NSF Director approves the transition to the Design Stage, it always carries the provision of no commitment to advance the project to the Construction Stage.

Design Stage

The design stage is where detailed, construction-ready budget estimates, schedules, technical specification and drawings, and management processes are developed by the Recipient. This is also the stage where the project is formally approved by NSF as a candidate for a future budget request and potential obligation of construction funding. Entrance into the Design stage occurs when NSF recognizes the proposed project as a national priority and the Sponsoring Organization obligates the necessary funding to advance refinement of the scope and the estimated cost and schedule. This stage generally lasts 3-5 years and can cost 10% or more of the estimated construction cost depending on the nature of the project. It is also the stage where estimated budgets are presented to Congress and where partnerships are generally formalized.

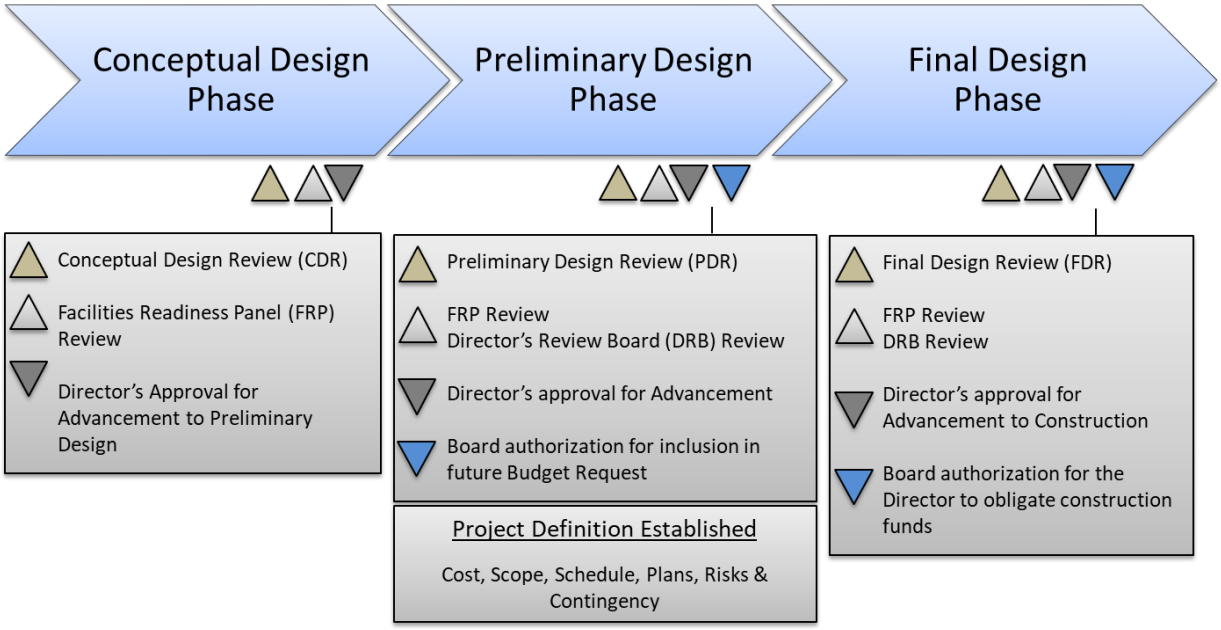
The Design Stage is divided into three phases – Conceptual Design, Preliminary Design, and Final Design; each with a formal and rigorous NSF review of the Project Execution Plan at the end of each phase to show readiness for advancement to the next design phase or construction stage, as shown in Figure 2.1.3-2 below. Advancement to the next phase is based on successful completion of the current phase by the Recipient and is not guaranteed. Review at the end of each phase is a potential off-ramp for the project.

> Conceptual Design Phase: This phase advances the approximate definition of the cost, scope and technical requirements from the Development Stage, determines feasibility (often through the development and testing of prototypes), and produces updated drafts of most elements of the Project Execution Plan, including parametric cost estimates, notional integrated master schedules, and a preliminary risk analysis.

Preliminary Design Phase: This phase further advances the project baseline 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 overall duration for a given Fiscal Year start and to establish the budget request to Congress. The Preliminary Design Phase ends with a thorough review of the design, the Preliminary Design Review (PDR), and NSF approval to continue on to development of a final design.

Final Design Phase: This phase further refines the project baseline definition and the Project Execution Plan and demonstrates that project planning and management meet requirements for readiness to receive funding and begin construction. The Final Design phase ends with a Final Design Review (FDR) and subsequently an NSF recommendation to approve the obligation of construction funds.

Figure 2.1.3-2 Progressive Phases within the Design Stage, showing review and decision points for advancement to the next phase and NSB authorization for budgeting and award.



For projects that have received previous development and design funding from NSF, other agencies, or private sources, a Sponsoring Organization can propose entrance to the Design Stage at the Conceptual Design Review (bypassing the Conceptual Design Phase) or the Preliminary Design Review (bypassing the Preliminary Design Phase) based on the technical readiness of the project. In either case, the strategic review by the CORF must be conducted in conjunction with a CDR or PDR-like review in accordance with Sections 2.3.1.3 and 2.3.2.3 of this Guide. The Preliminary Design Review is the latest point at which a project can be

considered a candidate for major facility funding since this phase is tied to the budget request. The Final Design Phase must always be conducted (see Section 2.3.3).

Construction Stage

The construction stage begins when funds are obligated for the acquisition and/or construction of the research infrastructure in accordance with the terms and conditions set forth in an award instrument between NSF and the Recipient(s). Depending on the technical nature and scale of the infrastructure or major facility, construction typically lasts 2-6 years and costs range from $70M to $800M, or possibly more. This stage has the most stringent requirements for overseeing Recipient performance in managing the scope, cost and schedule against plan, for reporting progress, and for formality of oversight and assurance by NSF. Progress is reported against the approved Performance Measurement Baseline (PMB) in the Recipient's Project Execution Plan (PEP). The project status is reviewed periodically to assess whether the project is capable of finishing within budget and schedule and what corrective actions (if any) might need to be taken. The Construction Stage normally includes activities to transition the facility to operations. Construction ends after final delivery and acceptance of the defined scope of work and an assessment facility performance per the terms of the award instrument.

Operations Stage

The operations stage includes the day-to-day activities needed to operate and maintain the infrastructure and to support scientific research. During this stage, the facility is actively collecting and distributing data for use by the science community. Operations may include activities necessary to complete the transition from construction to full operational capability (depending on the technical nature of the facility and how the construction scope is defined) and, during the lifetime of the facility, routine refurbishment activities, and major upgrade project development. The operations stage may also include activities that support transition to the Divestment Stage. The operations stage typically lasts 20-40 years, the total cost of which often greatly exceeds the cost of construction. It normally includes a series of periodic status reviews that assess performance. These reviews may be accompanied by decisions on continued investment, recompetition, or divestment. The Concept of Operations Plan refined during the Construction Stage (including robust operations and maintenance cost estimates and agreements between parties for funding, data sharing, etc.) should be finalized in preparation for entering this stage. The decision to divest is generally made when NSF, with input from the scientific community, determines that the facility is no longer considered an operational priority with regard to advancing science. This final decision is often the most challenging.

Divestment Stage

The decision to divest is generally made when NSF, with input from the scientific community, determines that the facility is no longer considered an operational priority for the Foundation. However, divestment does not necessarily lead to a reduction in project scope or in the performance or scientific output of a facility. As part of the divestment process, additional

support is often sought from other agencies or non-governmental entities, such as Universities, state-run programs, or charitable foundations. This decision to divest is often the most challenging step in the Operations Stage.

The decision to divest may be made at any time during the Operations Stage, though it is expected to occur after a project's primary science goals have been achieved (usually after many years of operations). Divestment 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), "moth-balling" the facility so that operations can be restarted at a later date, or decommissioning. This last option may include complete removal of the infrastructure and site restoration. The cost of decommissioning can be substantial and must be thoroughly researched. The decommissioning process may also be very complex, and must include careful assessment of the risks, benefits, and environmental impacts (in the form of an environmental impact statement). Entrance into the Divestment Stage occurs when an award is made to cover the costs of decommissioning or transitioning the facility to its new role. This generally takes the form of an award that ramps down NSF's investment over the award duration with the expectation by all parties that no further operations award from NSF will be forthcoming, other than potential scientific use through individual investigator awards.

It is important that NSF devise plans to address the specific issues that arise as part of the divestment of a facility. It is recommended that the Sponsoring Organization develop a plan that follows NSF policy on divestment decisions, engages the science community for the anticipated divestment of the facility, and includes the estimated costs and associated legal requirements. The first version of this plan should be developed as part of the construction Project Execution Plan. Periodic review of an evolving plan for the decommissioning of the facility, disposal of assets and other environmental obligations of the Government should be conducted during the Operations Stage. While not part of the annual budgeting process, this document informs the longer-term strategic planning for the agency.

2.1.4 Summary of the Major Facility Implementation Process

Major facility projects cover a wide range of disciplines and activities in science and engineering, so they can require different approaches to the development and implementation. The approach described in this Guide is derived largely from experience with large acquisition and construction projects and operations defined by the following characteristics:

- They serve a relatively broad and substantial community or collaboration, whose members have self-organized and agree on the basic parameters of the project
- They result from proposals to NSF, either solicited through a targeted NSF program or unsolicited, for the design and construction of research infrastructure
- Operation of research infrastructure may be carried out by the construction organization or, in some cases, by another organization

As the diagrams in Figures 2.1.4-1 and 2.1.4-2 indicate, the typical process for pre-construction development and design for a candidate major facility project progresses through a sequence of stage-gates with increasing investment, planning, assessment, oversight, and assurance. These stages help ensure that the technical evolution of a candidate project is coordinated with science community needs and NSF requirements; increasing the likelihood that it will be able to qualify for funding of continued planning and eventual construction.

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-profit, or the private sector (industry) depending upon the technical nature of the facility or infrastructure. 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 in an educational institution, the entire project may then be further designed and constructed by an award made directly to a competent managing organization, including industry.

Figure 2.1.4-1 Summary Timeline for Major Facility Projects (Development and Design)

	Development	Conceptual Design Phase	Preliminary Design Phase	Final Design Phase
Budget evolution	Preconstruction Planning Funded via R&RA and EHR funds			
		Develop construction budget based on conceptual design Develop budget requirements for advanced planning Estimate operations costs	Expend ~5-25% of construction cost on planning & design activities Construction estimate based on preliminary design Update operations cost estimate	Final design over approximately 2 years Construction-ready budget & contingency estimates Update operations cost estimate
Project evolution	Initial ideas emerge Broad science community consensus built for potential long-term needs, priorities, and general requirements High level concept developed	Formulate science goals: define requirements, prioritize, review Develop conceptual design identify critical technologies, high risk items Formulate initial risk assessment Develop top-down parametric cost and contingency estimates Initial proposal submission to NSF Initial Project Execution Plan (PEP)	Proponents development strategy defined in Project Development Plan Develop site-specific preliminary design, environmental assessments/ impacts (NEPA) Develop enabling technologies Bottom-up cost and contingency estimates, updated risk analysis Develop Project Management Control System Develop preliminary operations cost estimate Update PEP	Develop final construction-ready design & PEP Verify key technologies are ready for production or detailed production design Refine bottom-up cost and contingency estimates Finalize Risk Assessment & Mitigation, Management Plans Complete key staff recruitment
	NSF oversight defined in Internal Management Plan (IMP) updated at each development phase.			
Program oversight	Interface with the research community to nurture concepts for development Recommends to the NSF Director that a project advance to Conceptual Design	Integrated Project Team (IPT) organized Develop Internal Management Plan (IMP), estimate PD costs, timeline Establish interim review plan and competition milestones Forecast international and interagency participation, issues Initial analysis of NSF opportunities, risks Conceptual Design Review (CDR) – external panel review and internal review CDR Cost Analysis Merit review, apply 1st and 2nd ranking criteria	NSF Director approves PD phase Approve Project Development Plan (PDP) & budget Forecast external partner decision milestones Preliminary Design Review (PDR) – external panel review and internal review Establish target total project cost (TPC) PDR Cost Analysis Project Definition established – cost, scope, schedule, plans, risks, & contingency	NSF approves submission to NSB OMB/Congress negotiations on proposed project and budget profile Evaluate design costs, schedules; and operations cost estimate. Semi-annual assessment of baseline and projected operations budget for projects not in construction Finalization of interagency and international requirements, agreements Final Design Review (FDR) - external panel review and internal review FDR Cost Analysis - informed by an Independent Cost Estimate (ICE) if not done earlier EVMS Acceptance Establish project construction baseline
FRP, DRB, OD & NSB	Internal review regarding advancement to design stage. NSF Director approval to start Conceptual Design	Apply 3rd ranking criteria Facilities Readiness Panel Review NSF Director approval for advancement to Preliminary Design	Facilities Readiness Panel Review DRB Review NSF Director requests NSB approval for MREFC request & approves advancement to Final Design NSB authorization for inclusion in MREFC Budget Request and to proceed with final design	Facilities Readiness Panel Review DRB Review NSF Director approves advancement to construction stage NSB authorizes NSF Director to make a construction award

Figure 2.1.4-2 Summary Timeline for Major Facility Projects (Construction, Operations, and Divestment)

		Construction	Operations	Divestment
Budget evolution		MREFC or R&RA funds	R&RA, EHR funds	R&RA, EHR funds
		Expend budget & contingency per baseline, PEP, and Award document Refine operations budget Congress appropriates MREFC funds	Yearly budgets with out-year projects	Transition from operations budget to decommissioning and disposal costs
Project evolution		Construction per baseline and PEP	Annual Work Plans with goal setting Annual Reports that track progress relative to goals	Update Facility Divestment Plan developed as part of the construction PEP. Develop transition plan for transfer and/or decommissioning and disposal Execute the Divestment Plan
		NSF oversight defined in Internal Management Plan (IMP), updated at each lifecycle stage.		
Program Oversight	Congress appropriates funds	Review monthly project performance reports Review periodic financial reports Annual external panel reviews and internal assessment Site visit and assessment Approves usage of contingency above established thresholds Allocation of contingency funds Review commissioning plans EVMS Surveillance, generally annually Accounting System Review, as determined Business Systems Review, as determined Cost Incurred Audits, as determined	Annual Operations Review Preparation for facility re-competition, renewal or disposal/divestment Award Proposal Cost Analysis – informed by an independent cost assessment Accounting System Review, as determined Business Systems Review, as determined Cost Incurred Audits, as determined	Identify and devise plans for divestment of a facility at the end of its scientifically competitive life. Annual review of evolving plan for decommissioning and/or disposal of facility assets and environmental obligations External panel reviews as appropriate Cost analysis as appropriate Recommends to the NSF Director that a facility move into the Divestment stage.
FRP, DRB, OD & NSB	Congress appropriates funds	Review bi-monthly facilities report NSF Director "deep-dive" reviews, as appropriate NSB Facilities Portal with bi-monthly facilities report and EVM trend data NSB authorization for re-baselining that exceed thresholds	DRB review of Renewal and Re-competition packages NSF Director approval for award NSB authorization of renewals and re-competitions NSB authorization for awards that exceed thresholds	NSF Director authorizes transition into Divestment

Although all major facility projects progress though the five life cycle stages described in Section 2.1.3 above, there are appropriate alternate approaches to the Development and Design Stages, as well as alternate approaches to upgrade during the Operations Stage. Facilities at the leading-edge of the scientific endeavor never remain stagnant. It is not uncommon for major facilities and smaller research infrastructure to be in an almost continuous state of upgrade following transition to operations. Therefore, the more linear "waterfall" method described above is not always the most appropriate process to follow, particularly in fields where the technologies are unproven or changing rapidly.

When proposing to NSF, candidate projects should consider whether a "spiral development" model is more appropriate than the classic "waterfall" method as shown in Figure 2.1.4-3. Spiral development refers to the process of designing, building, testing and using a technology to increase understanding and reduce risk; and then repeating the process again. Although, almost all facilities use spiral development for various components and sub-systems during development, design and, at times, construction, the process described here is intentionally planned for and executed at the macro scale, with each spiral having a discrete total project cost (TPC). Figure 2.1.4-4 illustrates this concept of one project leading into follow-on projects.

The duration of the spirals can be relatively short (2 years) or quite long (a decade or more) depending on technical maturity and the rate of technological change. Risk is reduced following the completion of each spiral to improve confidence in the ability to meet the technical objectives of the next spiral within budget. A spiral development approach is generally imbedded within the Operations Stage and may combine aspects of the Design and Construction Stages. NSF oversight is based on the TPC and associated authorization thresholds.

Figure 2.1.4-3 Linear Design-Construct Process is Classic "Waterfall Model" Implementation

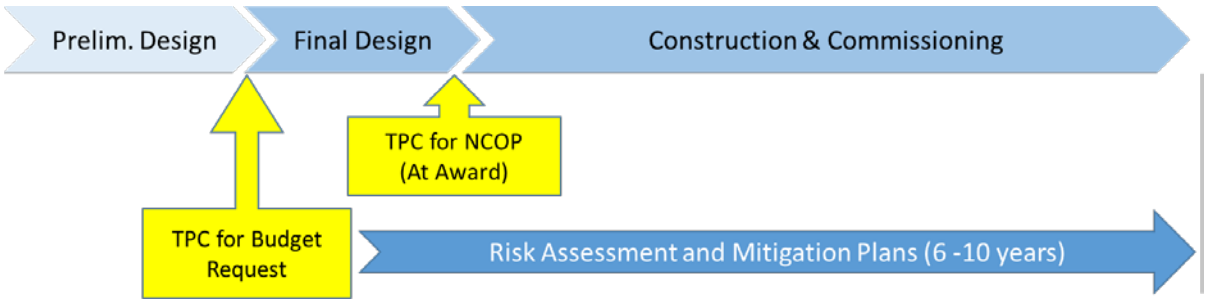
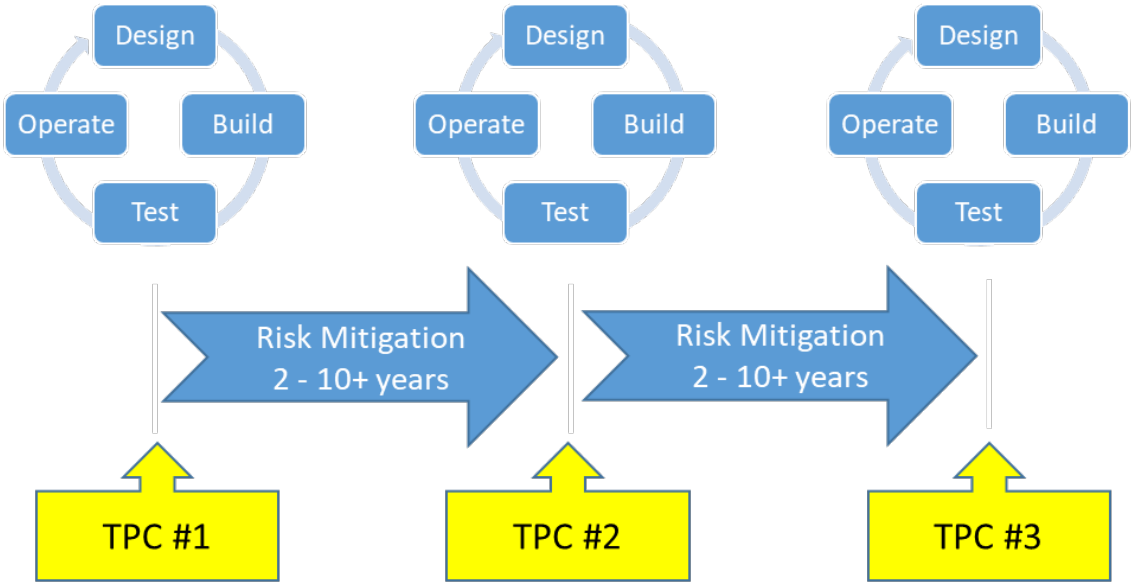


Figure 2.1.4-4 Spiral Development Process



In all cases, NSF is committed to the principle that flexibility does not preclude rigor. Every candidate major facility project – including those that call for novel treatment – is subject to the highest standards of merit review and technical evaluation. The approach used should be identified early in either the project Development or Design Stages and documented as part of the managing organization's proposal and eventually the Project Execution Plan (PEP), as well as NSF's Internal Management Plan (IMP). Proposing organizations should discuss the approach envisioned with the cognizant NSF Program Officer.

2.1.5 Timeline and Flowcharts for the Major Facilities Approval Process

This section, to be written, will illustrate when various preconstruction planning activities should be completed in order to commence construction in a particular future fiscal year. Although the majority of those activities proceed at a pace specific to the needs of an individual project, late-stage planning activities following completion of a project's Preliminary Design are paced by the process for developing NSF's annual Budget Request to Congress. This section will also explain key features of that process that are of particular interest to those involved with major facility projects.

2.1.6 Roles and Responsibilities for NSF Staff for Management and Oversight of Major Facilities

2.1.6.1 Overview

The Major Facilities Guide (MFG) describes the actions NSF takes to carry out its oversight and assurance responsibilities for major facility projects. One key element is the definition of the roles and responsibilities of the NSF participants who carry out those actions. The participants with primary oversight and management roles and responsibilities are listed below and highlighted in the NSF organizational chart in Figure 2.1.6-1:

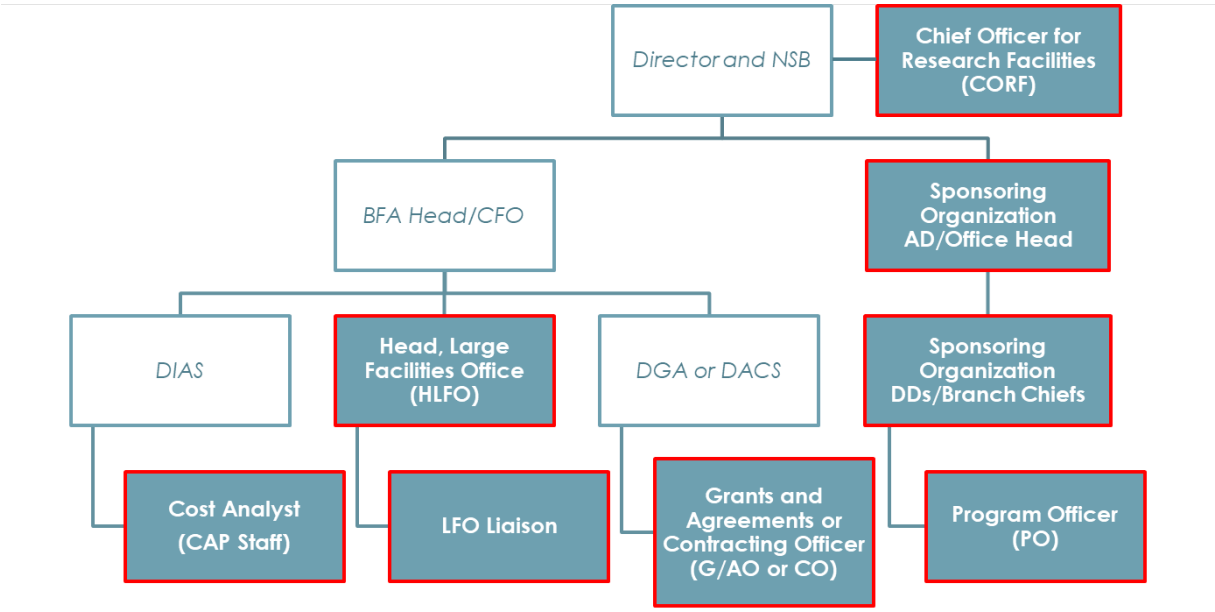
- **Program Officer (PO)** – A scientist or engineer having primary oversight responsibility within NSF for all aspects of the project.[1]
- **Sponsoring Organization** – The NSF Division, Directorate, or Office which proposes projects for funding through the MREFC Account or other funding source and is committed to pre-construction planning activities and eventual facility operation and use.
- **Senior Management of the Sponsoring Organization** – The leadership individuals who utilize community inputs, discipline-specific studies, advisory committee recommendations and internal NSF considerations to prioritize the opportunities represented by the candidate project relative to competing opportunities and demands for available resources.
- **Grants and Agreements Officer (G/AO)** – NSF Grants and Agreements Officer who has legal responsibility and authority for the business and financial management of grants and cooperative agreements.
- **Contracting Officer (CO)** – NSF Contracting Officer which has legal responsibility and authority for the business and financial management of award contracts.
- **Cost Analyst** – NSF staff from the Cost Analysis and Pre-Award Branch (CAP) Branch of the Division of Institution and Award Support (DIAS), which perform cost assurance reviews of proposals and monitor Recipient financial practices.
- **Chief Officer for Research Facilities (CORF)** – The individual who advises the NSF Director on all aspects of the agency's support for major and mid-scale research facilities throughout their life cycle and collaborates with NSF employees involved in oversight and assistance of the NSF multi-user research facilities portfolio.
- **Head, Large Facilities Office (HLFO)** – The individual who heads the Large Facilities Office (LFO). The LFO provides an NSF-wide resource for assistance with project oversight and assurance that agency policies and procedures are followed. The LFO is in

[1] The PO may have a title such as Program Manager or Program Director. The PO is administratively part of a Directorate or Office, comprised of Divisions, which serves a range of research disciplines. These are referred to as the "Sponsoring Organization" in this document.

the Office of Budget, Finance, and Award (BFA) and reports to the Chief Financial Officer.

- **Large Facilities Office Liaison** – The designated project management advisor from the LFO, who is assigned as project liaison by the HLFO. This individual is the PO's primary resource for assistance with all policy, process, and procedural issues related to the development, implementation, and oversight of major facility projects.

Figure 2.1.6-1 NSF organization chart highlighting staff who have primary oversight and management roles and responsibilities for major facilities and mid-scale research infrastructure.



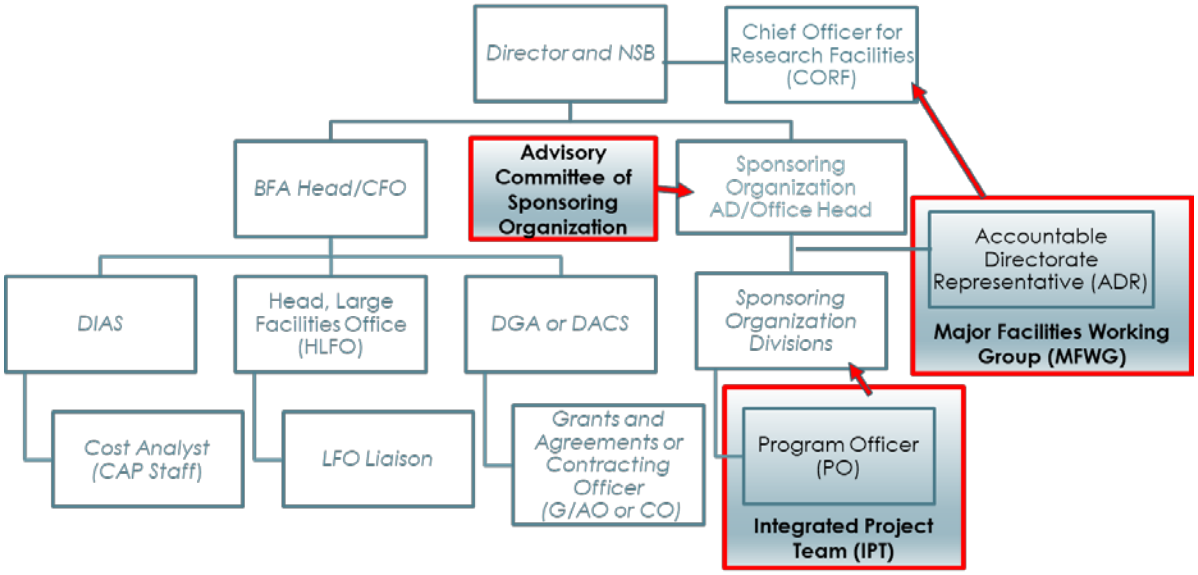
As shown in Figure 2.1.6-2, various bodies within NSF provide coordination, assistance, assurance, and advice to the main participants and to the agency as a whole:

- **Integrated Project Team (IPT)** – Three primary NSF groups comprise the IPT and represent the major oversight organizations within NSF: Science and Technical, Award Management, and Strategic. The Strategic group includes representatives from the Office of the Director (OD), Office of the General Counsel (OGC), the Office of Legislative and Public Affairs (OLPA), the Office of International Science and Engineering (OISE), and other offices under OD as deemed appropriate. The composition and size of each IPT depends on the risks, scope, and complexity of the project. The IPT is a coordinating body that provides internal agency assurance and guidance to the PO in the planning, review, and oversight of that project. The members of the IPT are selected by the management of the cognizant directorates and offices, in consultation with the PO, at the beginning of the Conceptual Design Phase. The IPT is chaired by the PO.
- **Major Facilities Working Group (MFWG)** – The purpose of the Major Facilities Working Group (MFWG) is to assure the uniform and effective programmatic oversight of major and mid-scale research infrastructure of the National Science Foundation throughout

their entire life cycles. Specifically, the MFWG provides input to the Facilities Governance Board regarding all strategy, governance, and implementation issues under consideration by that Board, establishes and maintains a list of NSF's major research infrastructure at all life cycle stages, supports the Head of the Large Facilities Office in reviewing the Major Facilities Guide, internal operating guidance, and procedures for NSF facility oversight, advises the Facilities Governance Board on the sufficiency and appropriateness of these documents, and shares good practices for the oversight of facilities across the Science directorates.

- **Advisory Committee of the Sponsoring Organization** – Comprised of researchers from the community (external to NSF), it advises the sponsoring Directorate or Office in a wide variety of programmatic areas, including major facilities.

Figure 2.1.6-2 NSF organization chart showing coordinating and advisory bodies for major facilities and mid-scale research infrastructure.



There are also planning and assurance bodies, shown in Figure 2.1.6-3, that review and make recommendations on the suitability and readiness as well as on the allocation of resources for the development, funding, and operation of major facility projects, according to the NSF strategic objectives:

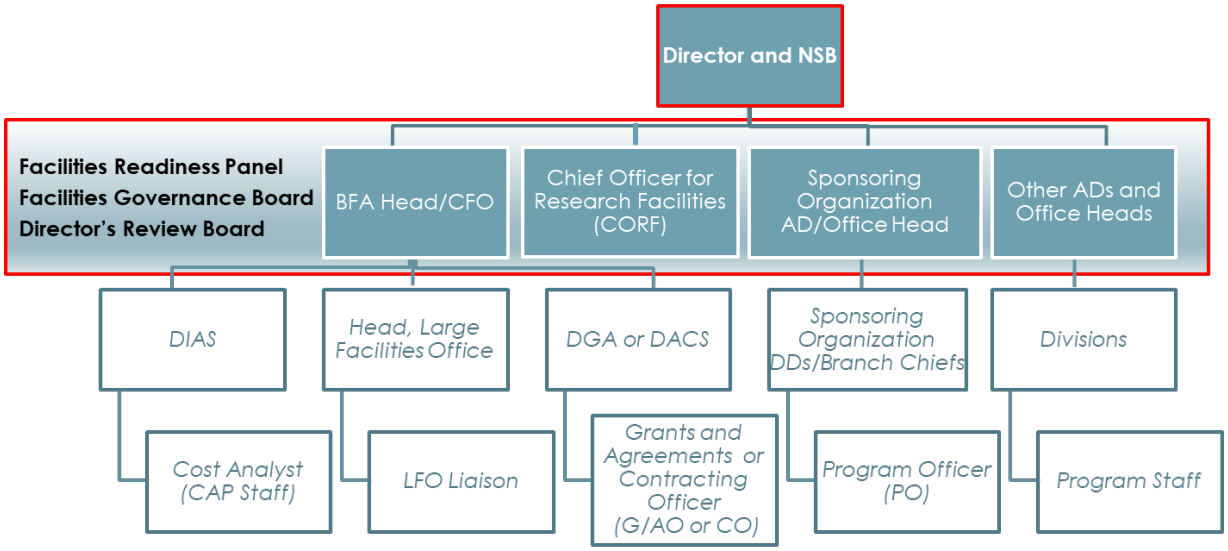
- **Facilities Readiness Panel (FRP)**- advise the Director on Recipient and Programmatic readiness to advance major and mid-scale facilities projects within the formal Design Stage as described in NSF's Major Facilities Guide (MFG); this includes the transition from Final Design to Construction. Readiness to enter the Design stage and whether or not to include in a future budget request are strategic decisions made separately.

- **Facilities Governance Board (FGB)** - Oversee and make recommendations on all aspects of governance of major multi-user research facilities and mid-scale research infrastructure of the National Science Foundation.
- **Director's Review Board** – Comprised of Senior Management Representatives from the Directorates and Offices of NSF, it reviews and approves the package of materials associated with all topics to be submitted to the National Science Board (NSB) for information or action, including major facility projects.

Finally, there are entities also shown in Figure 2.1.6-3 that set NSF policy and that approve the advancement, funding requests, and obligation of funds for the development, construction, and operation of major facility projects:

- **NSF Director** – Responsible for the implementation of NSF policies and practice for agency oversight of major facilities, and for proposing new major facility projects to the NSB, the Office of Management and Budget (OMB), and Congress.
- **NSB** – Establishes agency policy for major facilities, and reviews and authorizes the advancement of major facility projects including budget requests and Construction Stage awards. The Board also authorizes Operations Stage awards that are above certain thresholds. By statute, all projects funded from the MREFC account require Board authorization.

Figure 2.1.6-3 NSF organization chart showing policy and approval bodies for major facilities[1] and mid-scale research infrastructure.



[1] Refer to Figures 2.1.4-1 and 2.1.4-2 for a mapping of the Panels and Boards to the major facility life cycle stage and NSF oversight responsibilities.

The PO, G/AO or CO, and LFO staff members are the individuals that interact most frequently to carry out NSF's oversight and assurance role for major facility projects. Their roles and responsibilities are summarized, by life cycle stage, in Table 2.1.6-1. Fuller descriptions of their roles (and those of senior management in the sponsoring Directorate or Office, and the support, advisory, policy making, and approving entities) are provided in individual sections of this document following Table 2.1.6-1.

Table 2.1.6-1 Summary of Principal Roles and Responsibilities of the core members of the IPT (PO, G/AO or CO, and LFO) Liaison by Facility Life Cycle Stage

Program Officer (PO)	Grants and Agreements (G/AO) or Contracts Officer (CO)	LFO Liaison
Summary		
• Primary responsibility for all oversight aspects of a major facility project • Experienced or trained in management of projects. • Appointed by the Division Director (DD) or Section Head • Must not be a temporary employee of the NSF	• Primary representative of the NSF in all business dealings with the Recipient • Assigned to a project on a long-term basis • Experienced with Federal regulations and unique NSF requirements needed for adequate NSF oversight of major facility projects	• Program's primary resource for all policy or process issues related to the development, implementation, and oversight of major facility projects • Experienced and trained in project management of major facilities. • Advises POs on project management issues during project development and oversight
Conceptual Design Phase		
• Determines the importance and research priority to the affected research community of the science objectives motivating consideration of a future major facility • Works with the research community to develop an overall scope for a major facility project. • Develops the IMP • Organizes and chairs the IPT • Formulates a plan for eventual divestment of the facility • Devises and carries out strategies for renewal or closeout strategy that implements recompetition of the operating award wherever feasible	• Becomes acquainted with the anticipated scope of the proposed project • Participates in planning meetings to work out details of partnerships, international or multi-agency agreements, property issues, etc. • Participates in the development of the IMP • Serves on the IPT throughout the project to expedite financial and administrative actions and decisions concerning the project	• In collaboration with PO, plans CDR • Independently assesses the CDR outcome for the LFO • Serves on the IPT throughout the project to advise on management, business, and administrative issues • Participates in the development of the IMP

Program Officer (PO)	Grants and Agreements (G/AO) or Contracts Officer (CO)	LFO Liaison
Preliminary Design Phase		
• Creates solicitations for any enabling research, workshop, summer study, or other activity of the research community that supports proposal development • Works with the research community to develop a proposal that includes a preliminary Project Execution Plan (PEP) • Arranges external peer review of the proposal • Presents the proposed project to the Facilities Readiness Panel • Updates the IMP • Continues to meet with the IPT • Reports monthly to HLFO on project's technical and financial status	• Advises PO on creation of solicitations for any enabling research, workshop, summer study, or other activity of the research community that supports proposal development • Responsible for the business aspects of the proposal review and cost analysis and mentoring of the proposing institutions • Participates in preparation of materials for the FRP Review and Director's Review Board (DRB) • Serves on the IPT	• Advises PO • In collaboration with PO, plans Preliminary Design Review (PDR) • Independently assesses outcome of PDR for the LFO • Receives monthly reports on project development from PO, and provides independent assessment to the Head, LFO • Contributes to business aspects of the proposal review and cost analysis and in surveillance or mentoring of the proposing institutions • Serves on the IPT
Final Design Phase		
• Continues to monitor project in accordance with the IMP • Provides monthly project status updates to the HLFO • Organizes periodic cost update reviews • Organizes the Final Design Review (FDR)	• Instigates as required proposal review, cost analysis, and mentoring necessary to ensure that the Recipient follows NSF business and budgeting policies and requirements • Participates in periodic cost update reviews. • Participates in preparation of materials for the FRP Review and DRB • Serves on the IPT	• Continues to monitor project • Receives monthly project status updates from the PO, adds comments and evaluation • Aids the PO with the organization of the periodic cost update reviews in interval between PDR and FDR. • In collaboration with PO, plans FDR and independently assesses outcome • Contributes to business aspects of the proposal review and cost analysis and in surveillance or mentoring of the proposing institutions • Serves on the IPT

Program Officer (PO)	Grants and Agreements (G/AO) or Contracts Officer (CO)	LFO Liaison
Construction/Implementation Stage		
• Works with the G/AO to develop the award agreement (Cooperative Agreement (CA) or contract agreement) • Approves the establishment of a project baseline scope, cost, and schedule and other updates to the PEP • Approves significant changes to the project baseline • Receives monthly financial and technical status reports, quarterly and annual progress reports • Reports monthly to HLFO on project's technical and financial status • Conducts periodic reviews of project progress using an external ad hoc panel • Arranges internal review of Memorandums of Understanding (MOUs) • Regularly visits the project • Updates the IMP • Ensures compliance with Government Performance and Results Modernization Act (GPRAMA)	• Works with the PO to develop the award agreement (Cooperative Agreement (CA) or contract agreement) • Approves submittals from Recipient • Reviews the scope of activities associated with each award to ensure that the financial and administrative framework aligns with NSF's expectations for stewardship and reporting. • Receives and provides approval to the Recipient on award documents • Participates in baseline review and subsequent periodic reviews as necessary to assure the NSF that the Recipient follows agency financial policies • Serves on the IPT	• Advises PO • In collaboration with PO, plans construction reviews and independently assesses outcome • Receives monthly project status reports from the PO • Visits the project site periodically in coordination with PO • Participates in baseline review and subsequent periodic reviews as necessary to assure the NSF that the Recipient follows agency major facility management policies • Serves on the IPT
Divestment Stage		
Reserved for future content		

Program Officer (PO)	Grants and Agreements (G/AO) or Contracts Officer (CO)	LFO Liaison
Operations Stage		
• Prepares and participates in solicitation of award for Operations and Maintenance (O&M) CA or contract agreement • Ensures compliance with GPRAMA • Approves the Annual Work Plan (which includes high level performance goals) developed by the Recipient • Reviews and approves the Annual Report • Develops budgets that operate and maintain facilities • Obtains Condition Assessment reports • Monitors planning for IT and property security, and validates through periodic review • Organizes and participates in periodic reviews of the facility including annual operations reviews • Formulates a plan for eventual divestment of the facility • Devises and carries out a renewal or recompetition and closeout strategy of the operating award • Updates the IMP	• Advises the PO in development of solicitation for O&M award (shared responsibility with PO) • Creates special terms and conditions in the CA or contract agreement to capture requirements for annual performance goals (shared responsibility with the PO) • Defines business practices for renewal, recompetition, closeout, or termination of Award • Attends periodic reviews including operations and business systems reviews (BSRs) as appropriate • Assists in developing financial strategy, as appropriate, to budget for facility maintenance and replacement or refurbishment of long-lived capital-assets (shared responsibility with PO) • Prepares Decision Memo and performs independent cost analyses as required • Serves on the IPT	• Advises PO and G/AO or CO on effective operational oversight strategies, renewal and recompetition strategies, closeout, or termination • Periodically visits operating facilities in coordination with PO • In collaboration with PO and G/AO or CO, insures implementation of performance measures within the CA for operation • Assists with organizing and evaluating the results of operational reviews of major facilities • Advises PO and G/AO or CO on related project management issues in the event of recompetition of award for facility operation • Serves on the IPT

2.1.6.2 Main Participants

Program Officer (PO)

The PO is the research community's primary interface to the NSF. The PO's responsibilities are substantial, and crucial to NSF's success. Examples of these responsibilities are listed below:[1]

- They are typically the main contact a principal investigator (PI) has with NSF.
- They are the link between what is happening in the research community and the appropriately responsive program solicitation from NSF.
- They are the catalysts for the increasing amount of research that crosses traditional single-discipline boundaries.

[1] Paraphrased from *National Science Foundation: Governance and Management for the Future*, a report by a panel of the National Academy of Public Administration, April 2004. pp. 10-11.

- They are the coaches and encouragers for proposals from less experienced researchers – particularly ones with innovative ideas – as well as those from underrepresented segments of the research community.
- They are the recruiters and managers of a peer review process that involves numerous experts from the research community to assess the intellectual merit and broader impacts of proposals from the community for new research.
- They are the post-award managers and monitors for awarded research.

NSF's Authorization Act of 2002, 42 U.S.C.1862n-4I, signed into law on December 19, 2002, restricts the choice of POs (also referred to within the NSF as Program Directors or Program Managers) to be regular employees of the 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."*

Administratively, the PO is part of a Directorate or Office that provides supervisory oversight and the budgetary authority to fund PO actions. Depending on the administrative structure of the Sponsoring Organization, a Section Head, Division Director, Assistant Director (AD), or Office Head may assign a PO (or POs)[1] to oversee a particular facility-related initiative and will directly or indirectly oversee and guide the activities of the PO. Actions of the PO described here implicitly recognize the authority of the individuals within this supervisory structure to appropriately guide, direct, and approve the actions of the PO.

The PO exercises primary responsibility within NSF for all aspects of a major facility project, including:

- Project planning, both internally and in coordination with the relevant research community;
- Serving as the NSF interface with the research community to nurture concepts for development and utilization by the community of a facility;
- Formulating an IMP that defines NSF strategy for conducting project oversight, managing NSF risk, and providing project funding;
- Coordinating contact between the project proponents and other NSF staff members that may need to have direct contact with the project or that the project may wish to contact;
- Chairing the IPT;
- Conducting merit and programmatic/technical reviews of proposals for development, implementation, operation, and utilization of a facility (Conceptual Design Review (CDR),

[1] In some cases, more than one individual will be designated as a PO for a facility related initiative. Wherever the PO is referenced in this guide, it should be understood that the reference is to all the relevant assigned POs.

Preliminary Design Review (PDR), Final Design Review (FDR), construction and operational reviews);

- Preparing all required documentation for internal project review and approval within the NSF;
- Participating in developing the estimated costs of planning, construction, operations, maintenance and related programmatic activities, and, under management direction of the Sponsoring Organization, assigns budgets to these tasks; and
- Overseeing implementation, operation, and eventual divestment and closeout of NSF support for the project.

Senior Management of the Sponsoring Division, Directorate, or Office Assistant Director or Office Head

Assistant Directors (ADs) and Office Heads lead Directorates or Offices, and by extension their Divisions or Sections, which propose projects for funding through the MREFC Account or other funding source.

The AD (or Office Head) of the Sponsoring Organization utilizes community inputs, discipline-specific studies, advisory committee recommendations and internal NSF considerations to prioritize the opportunities represented by the candidate project relative to competing opportunities and demands for NSF resources. The AD determines that the scientific merit and relative importance of the proposed facility are sufficiently strong to justify advancement of the project to Readiness Stage (i.e., ready to begin Preliminary Design activities), and authorizes the PO to proceed with organizing the development and external review of a Project Execution Plan and with updating the IMP to explain how NSF will oversee and fund further development. The AD reviews and approves the IMP. The AD determines whether to propose a project to the Facilities Readiness Panel as a candidate for future construction funding, based on the project's relative scientific importance and on the Sponsoring Organization's commitment to pre-construction planning activities and eventual facility operation and use. The AD is regularly updated by the PO on the status of the project throughout the remainder of its life cycle phases and brings critical issues to the attention of the NSF Office of the Director (OD) and NSB as appropriate.

The AD has overall responsibility for advancing prospective projects for consideration of construction funding. In this capacity, the AD formulates strategic planning and budget development within the sponsoring Directorate or Office. This strategic planning includes prioritizing across the research objectives of the range of disciplines served by the Directorate or Office. The AD oversees and monitors development of NSF's project planning, with the assistance of supporting staff, advisory committees, and direct interactions with the broader community affected by the facility.

Unless delegated to a lower level, the AD oversees development of MOUs with other agencies, international partners, private foundations, and other entities and, with the approval of the NSF OD, enters into negotiations with those parties and either signs or delegates signature authority for these agreements on behalf of NSF when authority to do so is delegated by NSF OD.

Throughout a project's life, the AD has a primary responsibility to keep all major stakeholders in the project informed. Interested parties include policy stakeholders (the NSF, OD); funding stakeholders (OMB, Congress); and community stakeholders (scientific organizations and the relevant research community).

At each stage of project development, the AD has the responsibility for making key decisions within the Sponsoring Organization that advance a project or remove it from consideration for further development.

Specific responsibilities include, but are not limited to:

- Approving the IMP at the Directorate level;
- Ensuring that the qualifications of the relevant Division Directors reflect the requirements and expectations of the MFG and NSF policy, and the necessity to provide an environment of open communication and transparency in the management of research infrastructure;
- Assuring the evaluation and endorsement of a candidate project by the Directorate or Office advisory committee prior to submission of the project to the Facilities Readiness Panel for entry into the readiness stage;
- Overseeing the Division's organization of all design reviews including appointment of review panels, charges to the panels, and Directorate responses to review panel recommendations;
- Reviewing and approving all Director's Review Board packages and organizing representation of the project before NSF internal approval bodies, i.e., FRP, DRB, and the NSB;
- Representing the sponsoring Directorate or Office in decisions to recompete management of an operating facility, terminate support, admit new partners, and other major decisions affecting the facility;
- Selecting members of Directorate Office staff to serve as representatives on an IPT; and
- Establishing appropriate Delegation of Authority for awards following NSB action.

Division Director

The Division Director (DD), assisted by Divisional Staff, has primary responsibility for overseeing planning, review, oversight and funding of major facilities. This responsibility includes coordination of planning; serving as the interface with relevant scientific and engineering communities; preparing all required documentation for project consideration and approval;

conducting merit review of proposals; fully funding costs of operations, maintenance and relevant programmatic activities; and overseeing the project.

Administratively, a major facility in planning, construction, or operation, is under the purview of a Sponsoring[1] Organization, a Directorate, Division, or Office. The Sponsoring Organization provides supervisory oversight and budgetary authority. Depending on the administrative structure of the Sponsoring Organization, the cognizant PO is usually selected by the Divisional management (e.g., Section Head and DD collaborate in the selection) with concurrence of the AD. The PO's superiors directly or indirectly oversee and guide the activities of the PO.

The DD has overall responsibility for the conduct of programs in a related range of disciplines within NSF, and for the NSF interfaces between these programs and the scientific communities in these disciplines. For major facility projects, the DD:

- Evaluates and maintains, through appropriate mechanisms, the proper balance between the totality of life cycle costs for major facilities and the rest of the division's activity;
- Establishes and continually examines, through appropriate mechanisms and forums, the priorities among candidate projects within the discipline (those in development, under construction, and in operation);
- Appoints a cognizant PO for each project;
- Ensures that the program officer has the requisite experience and/or training to respond to the responsibilities of the position;
- Ensures that the cognizant PO follows appropriate good practices;
- Ensures that the PO is responding appropriately to the requirements of the Major Facilities Guide and other NSF policies and practices;
- Ensures that the PO is managing interfaces with other NSF units effectively and productively;
- Ensures that the performance plan of the program officer reflects the requirements and expectations of the MFG and other NSF policy statements; and
- Facilitates the flow of information at an appropriate level of detail and timescale to keep all NSF stakeholders appropriately informed of project progress, status, and problems.

Grants and Agreements Officer

The Grants and Agreements Officer (G/AO) has authority, subject to statutory limitations, to award and administer cooperative agreements (CA). The G/AO holds a cooperative agreements warrant and is the only individual authorized to obligate or de-obligate Federal funds. The G/AO, through their warrant, has the sole authority to award and administer the construction agreements(s) used in support of Major Facility projects. The G/AO is administratively part of DACS in BFA, except for mid-scale projects where they may be part of DGA (See Section 5 of this

[1] This is the "lead organization" in the case where more than one Division participates in sponsoring a project.

Guide). The timing of this assignment is at the discretion of the DGA or DACS DD, but should be early enough in the planning stage of a major facility project to allow the participation of the G/AO in the strategic planning and development of the IMP for a major facility project (i.e., during the Conceptual Design Stage when NSF begins to consider strategies for the business aspects of managing oversight of the proposed project).

The G/AO is an integral member of the IPT for a facility project when the award instrument is a cooperative agreement, in order to expedite NSF action on business and administrative issues related to the project. The G/AO participates in management reviews, risk assessments and issues affecting the management of the award. The G/AO plans and coordinates development of award instruments from early planning stages through award administration and closeout. The G/AO negotiates terms and conditions, interprets Federal and NSF policy, and reviews business proposals and budgets, subawards[1], MOUs, and partnership agreements. The G/AO also monitors awards for compliance with the most current NSF financial and administrative policies and procedures.

The G/AO is the primary point of contact at the NSF with the Recipient institution for all business and financial matters. The G/AO represents the NSF in conducting all of the financial and administrative business-related oversight of the Recipient, including:

- Providing approval or authorization for all financial transactions,
- Ensuring compliance with financial and administrative award terms and conditions,
- Accepting submittals or reports from the Recipient,
- Leading the cost analysis process of proposals and negotiating the budget, and
- Negotiating any specific terms and conditions which define the conduct and execution of a project, such as CAs and subsequent amendments, MOUs, property leases, etc.

The G/AO is responsible for oversight of the financial and administrative terms and conditions of the assistance award,[2] just as the PO is responsible for scientific and technical oversight. Unlike the PO, he/she holds the warrant to obligate Federal funds. The G/AO and the PO jointly share the principal technical and financial responsibilities for the oversight and assurance of a major facility project. In this capacity, the G/AO is jointly responsible with the PO for the success of a project.

The G/AO confers with the PO and other relevant offices to ensure that the NSF's technical and administrative oversight activities are well coordinated. The G/AO and the PO collaborate on

[1] Except for the purchase of materials and supplies, equipment or general support services allowable under the award, no portion of the proposed activity may be subawarded to another organization without written prior NSF authorization. All proposing organizations are required to make a case-by-case determination regarding the role of a Subrecipient versus contractor for each agreement it makes. See PAPPG II.C.2g (vi) e for further guidance.

[2] An assistance award is a grant or cooperative agreement (CA) to a non-Federal organization with fiduciary responsibility for the project or facility.

the preparation of solicitations and the proposal and award process. The G/AO has individual responsibility for developing and overseeing the implementation of financial and administrative aspects of the award process, and joint responsibility with the PO for recompetition planning and execution and for award termination or closeout.

The G/AO develops the CAs that establish a business relationship between the NSF and the Recipient. Consequently, the G/AO has an oversight responsibility that extends to the business practices of that Recipient, in addition to the specific business operations and oversight practices of the particular project that may be based with that Recipient.[1]

The G/AO, with the assistance of BFA resources, establishes that the financial stewardship and reporting practices of the Recipient institution, as they pertain to NSF instruments, are consistent with NSF requirements, 2 CFR § 200 (Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards), or Federal Acquisition Rules, as appropriate.[2]

Contracting Officer

The Contracting Officer (CO) has authority, subject to statutory limitations, to award and administer contracts for the construction and operations of facilities that are managed through contract rather than Cooperative Agreements (CAs). The CO is appointed by the agency Senior Procurement Executive and is administratively part of the Division of Acquisition and Cooperative Support within BFA. The CO is solely responsible for oversight of the terms and conditions of the contractual agreement.

The CO holds the warrant and is the only individual authorized to obligate or de-obligate Federal funds. The CO, through their warrant, has the sole authority to award and administer the prime construction contract(s) used in support of Major Facility projects.

The CO is an integral member of the IPT for a facility project when the award instrument is a contract, in order to expedite NSF action on business and administrative issues related to the project.

Cost Analyst

The G/AO or CO requests assistance from a NSF Cost Analyst from the Cost Analysis and Pre-Award (CAP) Branch of the Division of Institution and Award Support (DIAS), located within BFA, when cumulative or individual awards exceed certain thresholds or for Recipients with previously identified risks. The PO, G/AO or CO, and Cost Analyst all review proposed budgets to help determine if they are allowable, allocable, reasonable, and realistic for the scope of

[1] Refer to *the Business Systems Review (BSR) Guide* described in Section 4.6.3.3 for discussion on this point. When NSF is not the cognizant audit agency for the Recipient institution, its oversight of Recipient business practices is narrowly defined.

[2] Refer to the *Business Systems Review (BSR) Guides* for more details on the criteria and processes for this assessment.

work. However, the primary purpose of the NSF Cost Analyst's budgetary review is to support the G/AO or CO to ensure that the Recipient has properly estimated and calculated costs and that they are supported and documented with sufficient rigor. The Cost Analyst provides a written recommendation to the G/AO or CO stating whether costs are supported or unsupported. The recommendation may include advice on award terms and conditions or limitations or other concerns identified.

The Cost Analyst may also help determine if the Recipient has adequate business and accounting systems in place, assess a Recipient's financial capability and viability, validate indirect cost rates, or assist in other areas of concern as identified by the requesting G/AO or CO.

While the G/AO or CO is the primary point of contact with the Recipient for all award and cost analysis issues, this should not inhibit direct communications between the Cost Analyst and Recipient when necessary. Cost analysis communications with the Recipient should include the Cost Analyst, G/AO or CO, and PO to help ensure efficient resolution, close collaboration, and clear and consistent direction.

Chief Officer for Research Facilities (CORF)

The position of Chief Officer for Research Facilities (CORF) is within the Office of the Director and reports directly to the Director and has full life cycle oversight responsibility for NSF major research facilities. The CORF advises the NSF Director on all aspects of NSF major and mid-scale facilities throughout their life-cycle and collaborates with all at NSF who are involved in oversight and assistance for the NSF research facilities portfolio. The CORF chairs the Facilities Readiness Panel, the Major Facilities Working Group and the Facilities Governance Board.

This position also fills the previous statutory requirement for NSF to have a Deputy Director for Large Facility Projects.

Head, Large Facilities Office (HLFO) and BFA's Large Facilities Office

The NSF's Head, Large Facilities Office (HLFO), and the LFO supporting staff are the NSF's primary resource for all policies or processes related to the development, implementation, and oversight of research infrastructure. LFO is the Foundation's primary resource for all oversight practices related to major facility projects and is the NSF-wide resource on project management good practices. The LFO has the institutional authority and resources to effectively develop mandatory policies, practices and procedures, which are approved by senior management, for all stages of the facility life-cycle. The LFO works closely with the BFA and NSF Senior Management Officers, providing expert assistance on non-scientific and non-technical aspects of project planning, budgeting, and implementation for major facilities. It also provides assurance that all applicable requirements are followed in order to give credence to NSF's oversight capabilities. The LFO also facilitates the use of good practices by fostering

coordination and collaboration throughout NSF to share application of lessons learned from prior major facility projects.
The LFO develops and implements processes for insuring that all facility award instruments include, at a minimum, four performance evaluation and measurement components:

1. Clear and agreed-upon goals and objectives;
2. Performance measures and, where appropriate, performance targets;
3. Periodic reporting; and
4. Evaluation and feedback to assess progress.

Prior to NSF requesting NSB authorization to include a proposed project in a future budget request, the HLFO contributes to agency assurance that the project plans are construction ready, and that the construction and operations budgets are satisfactorily justified.[1] This assurance comes through assignment of the LFO Liaison to the IPT and membership (as assigned) on various governance bodies such as the Facilities Readiness Panel and the Director's Review Board.

The HLFO prepares a periodic status report for NSF Leadership on all ongoing major facility projects, candidate projects in planning, and other major facility projects designated by the Sponsoring Organization. Inputs to the monthly report are provided by each cognizant PO and their associated Directorate/Division. The Recipient submits a monthly report to the PO that summarizes the technical and financial status of the project, pending near-term milestones, and any other issues that should be brought to the attention of the LFO. The PO reviews the report and prepares a written response to the monthly report that is uploaded into eJacket. The HLFO combines all of these inputs into a single report, summarizes the key technical and financial status information, and provides an independent commentary on project management issues as necessary.

Under the direction of the NSF Senior Management, the HLFO prepares and presents a variety of information to the National Science Board (NSB) related to the status and plans for the portfolio of major multi-user facility projects that are either receiving or are candidates for receiving MREFC funds. This information supplements information contained in the NSF's annual Budget Request to Congress.

LFO Liaison

For each major facility project, the HLFO designates an LFO Liaison to work closely with the PO and the G/AO or CO, providing expert assistance on non-scientific and non-technical aspects of project planning, budgeting, implementation, and management to further strengthen the oversight capabilities of NSF. The LFO Liaison participates in each project IPT and also advises the cognizant PO of mitigating steps when project management challenges arise. The LFO

[1] See "Priority Setting for Large Facility Projects" (NSB-04-96), National Science Board White Paper, May 2004, Attachment 5 to NSB Meeting Report, https://www.nsf.gov/nsb/meetings/2004/may_srprt.doc.

Liaison works with the PO and the G/AO or CO, not directly with the Recipient or their project staff.

The LFO Liaison also collaborates with the PO and G/AO or CO to plan and carry out key project reviews including CDR, PDR, FDR, operations reviews, and other *ad hoc* project reviews in all life cycle stages as appropriate. While the PO is responsible for planning, carrying out, and assessing the full range of topics addressed in the review, LFO Liaison focuses on project management, business, and administrative issues, and assists the PO and G/AO or CO in these areas. The LFO Liaison independently assesses and reports to the HLFO on the outcome of these reviews with respect to project management issues.

The LFO Liaison participates in site visits in coordination with the PO and Sponsoring Organization, to strengthen project management and affirm aspects of NSF's oversight and assurance role. During these interactions, the PO is the single point of contact with the project for all programmatic issues, and the G/AO or CO is the point of contact with the Recipient institution for administrative issues. Any project-specific communications between the LFO Liaison and the project is coordinated through the respective PO, G/AO, or CO, and generally as part of the IPT process.

LFO also carries out BSRs of Recipient business systems for major facilities in design, construction or operation based on a regular review cycle and other potential risks, such as building institutional capacity in advance of a construction award. BSRs may also be conducted at smaller scale facilities at the request of NSF Leadership or the Sponsoring Organization. BSR objectives and processes are described in detail in NSF's *Business Systems Review (BSR) Guide*, described in Section 4.6.3.3.

2.1.6.3 Coordinating and Advisory Bodies

The Integrated Project Team

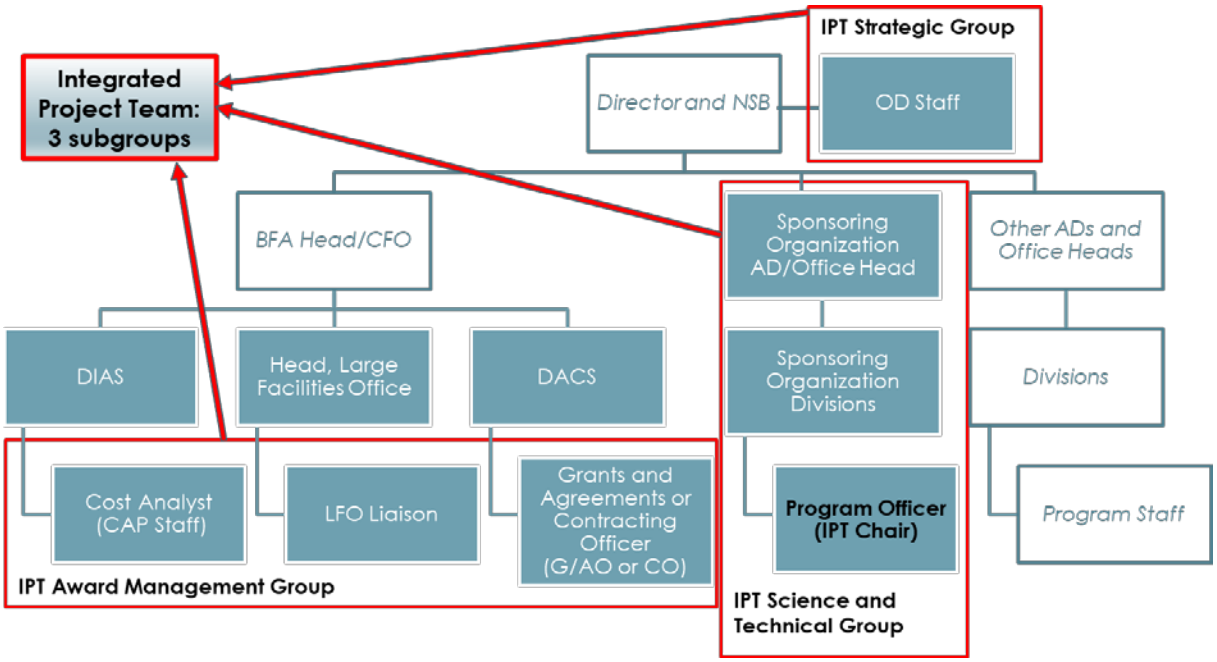
The Integrated Project Team (IPT) serves as a formal internal NSF coordinating body for major facilities oversight throughout the Design, Construction, and Operations Stages. The IPT consists of three primary sub-groups:

1. Science and Technical Group led by Program with primary responsibility for project oversight. This group may include other Staff from the Division and/or Directorate as deemed appropriate by Program (budget, science program, etc.).
2. Award Management Group comprised of various Offices and Divisions within the BFA. This group is primary responsible for assurance. The linkage with the Science and Technical Group is with the review and monitoring of cost, scope and schedule as well as the Project Execution Plan and Recipient performance. The linkage with the Strategic Group is related to internal NSF processes and procedures.

3. Strategic Group comprised of various offices within the OD. This group's role is primarily with assessing risk. The linkage with the Science and Technical Group is with communication with external stakeholders.

The IPT is chaired by the PO, see Figure 2.1.6-4. Members are selected by the DDs, ADs or Office Heads, in consultation with the PO. The PO will convene the IPT at least quarterly to address any project-related issues.

Figure 2.1.6-4 An Integrated Project Team (IPT), chaired by the Program Officer, is composed of three subgroups, with appointed Award Management Group members from BFA, Science and Technology Group members from the sponsoring program offices, and Strategic Group members from the Office of the Director.



Major Facilities Working Group

The Major Facilities Working Group (MFWG) assures the uniform and effective programmatic oversight of major and mid-scale research infrastructure of the National Science Foundation throughout their entire life cycles.

The MFWG is chaired by the Chief Officer for Research Facilities (CORF). The MFWG meets approximately monthly and at other times as required and carries out the following duties:

- Provide input to the Facilities Governance Board regarding all strategy, governance, and implementation issues under consideration by that Board.
- Establish and maintain a list of NSF's major research infrastructure at all life cycle stages, development through divestment, and the major upcoming decision points for those facilities.

- Support the Head of the Large Facilities Office in reviewing the Major Facilities Guide (MFG), Standard Operating Guidance (SOG), and Standard Operating Procedures for NSF facility oversight, and advise the Facilities Governance Board on the sufficiency and appropriateness of these documents.
- Provide concurrence on a bi-monthly report produced by the Large Facilities Office summarizing the status of all major research infrastructure facilities in their operation and divestment stages.
- Provide input, as appropriate, for the Large Facilities Office bi-monthly report summarizing the status of major facilities and related projects at stages ranging from development through the completion of construction.
- Maintain situational awareness of each relevant major research infrastructure in their home directorate and communicate important information via the CORF and the cognizant Assistant Directors in a timely way.
- Share good practices for the proper oversight of major research infrastructure, and work with the cognizant Assistant Directors to implement good practices across their directorates.

The MFWG membership consists of the following members:

- Chief Officer for Research Facilities (Chair);
- Head, Large Facilities Office (Vice-Chair);
- Accountable Directorate Representative (ADR), Directorate for Mathematical and Physical Sciences (MPS);
- Accountable Directorate Representative, Directorate for Geosciences (GEO);
- Accountable Directorate Representative, Directorate for Biological Science (BIO);
- Accountable Directorate Representative, Directorate for Computer and Information Science and Engineering (CISE);
- Accountable Directorate Representative, Directorate for Engineering (ENG), and
- Executive Secretary

<u>Advisory Committee of the Sponsoring Organization</u>

The Advisory Committee of the Sponsoring Organization provides input to the NSF AD, or Office Head of the Sponsoring Organization concerning priorities among and between projects and other activities sponsored by the Directorate. The NSF Director requires the endorsement of the Advisory Committee of the Sponsoring Organization prior to requesting NSB action authorizing a project's inclusion (at the Director's discretion) in a future NSF budget request to Congress.

2.1.6.4 Governing Bodies

Facilities Readiness Panel

The Facilities Readiness Panel (FRP) advises the Director on Recipient and Programmatic readiness to advance major and mid-scale facilities projects within the formal Design Stage as described in NSF's Major Facilities Guide (MFG); this includes the transition from Final Design to Construction. Readiness to enter the Design stage and whether or not to include in a budget request are strategic decisions made separately. Projects include the major multi-user research facilities as defined in the American Innovation and Competitiveness Act. Members of the FRP include:

- Chief Officer for Research Facilities (Chair);
- Head, Large Facilities Office, HLFO;
- Head, Office of General Counsel (or Designee);
- Division Director, Division of Acquisition & Cooperative Support (or Designee); and
- At least 4 senior Program Officers, Section Heads, Deputy Division Directors or Division Directors (at least 3 from MPS, GEO, BIO, CISE, or ENG)
- Executive Secretary

The primary duties include:

- Assess overall project readiness to advance based on the requirements and guidelines in the MFG and other internal NSF policies and procedures. This includes technical readiness of the project itself, business system and management readiness of the Recipient, and programmatic readiness with regard to adequate oversight.
- Assess whether or not agency risks, including significant project risks managed by the Recipient that may impact the agency, have been identified and properly considered by the Sponsoring Organization in developing the Internal Management Plan.

Facilities Governance Board

The Facilities Governance Board (FGB) oversees and makes recommendations on all aspects of governance of major multi-user research facilities and mid-scale research infrastructure of the National Science Foundation.

Members of the Board are:

- Chief Officer for Research Facilities (Chair);
- Assistant Directors for MPS, GEO, BIO, CISE, ENG;
- Chief Financial Officer; and
- Executive Secretary

The primary duties include:

- Advise the Director on all aspects of strategy, governance, and implementation of major multi-user research facilities and mid-scale research infrastructure.
- Approve the NSF Major Facilities Guide (MFG) and all agency-wide Standard Operating Guidance (SOG) and supporting Standard Operating Procedures for implementation of facilities oversight, with input from the Major Facilities Working Group.
- Maintain situational awareness for major multi-user research facilities and mid-scale research infrastructure at all life cycle stages, from development through divestment, and advise the Chief Officer for Research Facilities on oversight issues.
- Recommend to Director on renewal, recompetition, or divestment of major multi-user research facilities, based on the *Guidelines for Competition of Major Research Facilities* and subsequent Standard Operating Guidance.

Director's Review Board

The purpose of the Director's Review Board (DRB) is to assure the Director that all recommendations and proposed action items have undergone thorough review, assessment and discussion. The DRB reviews proposed actions for adequacy of review and documentation and for consonance with Foundation policies, procedures and strategies. The DRB also brings to the Director's attention any policy issues that have been identified.

The DRB is the Director's forum for reviewing timely recommendations to the NSB on a variety of critical NSF awards, actions, and information items, including those related to major facilities. The DRB reviews for responsiveness to questions that may be raised by the NSB.

Members of the DRB may include:

- Chairperson (NSF Deputy Director or other);
- Three ADs, serving on a rotating basis;
- Chief Financial Officer;
- Staff Advisor, OD;
- Executive Secretary, DRB; and
- Such other persons as the Director may designate (i.e., OGCs, Legislative and Public Affairs, etc.).

Joint meetings between the FRP and DRB may be scheduled as the particular situation warrants but keeping in mind their distinct roles and responsibilities as described above.

NSF Director

The NSF Director has ultimate responsibility for the approval of the obligation of funds from the MREFC Account and for proposing new MREFC projects to the NSB, OMB and Congress. The Director approves all materials submitted to the NSB, OMB or Congress.

National Science Board

The National Science Board (NSB) establishes policy, reviews and authorizes construction stage budgets, and reviews and authorizes specific large awards for funding, including major facility projects.[1] NSB is an independent body established by Congress in 1950 to set policies for NSF.

Along with the Director, the NSB oversees NSF and establishes NSF policies within the framework of applicable national priorities set forth by the President and the Congress. In this capacity, the NSB identifies issues that are critical to NSF's future, authorizes NSF's strategic directions, annual budget requests, new major programs and awards, and provides guidance on the balance between initiatives, infrastructure investments and core programs.[2]

NSB has established processes for reviewing and authorizes recommended actions and funding requests from NSF regarding major facility projects.3 The NSB performs certain reviews, including a periodic review of facilities, and prioritizes projects as necessary. NSB involvement at each life cycle stage includes:

- Setting Board-level policies and procedures for overseeing all life cycle stages of NSF's major facilities;
- Being kept apprised of the status of all major facilities funded by NSF through oral and written information items, particularly projects in the design and construction stages.
- Authorizes advancement through certain design phases;
- Authorizes inclusion of a candidate project in a future NSF Budget Request to Congress, after a PDR and NSF Director approval;
- If necessary, recommend priorities for construction start among projects;
- Authorizes the Director to obligate appropriated construction funding to the Recipient;
- Authorizes award of funds to operate major facilities if above the NSB threshold; and
- Authorizes recompetition strategies, divestment, or major reorganization for operations awards if above the NSB threshold.

[1] NSF policy requires the following items to be submitted to the NSB for authorization: (1) Large Awards. Proposed awards where the *average annual award amount* is 1% or more of the awarding Directorate or Office's prior year current plan (including any funds transferred from other Federal agencies to be awarded through NSF funding actions); (2) Major Construction Projects. NSB authorization is required when the resulting cost is expected to exceed the percentage threshold for NSB award authorization; (3) Awards Involving Policy Issues or Unusual Sensitivity. NSB interests may include the establishment of new centers, institutes, or facilities that have the potential for rapid growth in funding or special budgetary initiatives. (Note: In determining whether anticipated future commitments beyond an initial award amount for any award instrument meet or exceed the threshold for NSB authorization, every additional anticipated funding action should be added to the initial award amount. Awards should be submitted for NSB authorization under this criterion as soon as Program staff anticipate that the total ultimately to be committed is likely to exceed the threshold established for their Directorate or Office.)

[2] More about the NSB is available online at https://www.nsf.gov/nsb/

[3] See NSB's meeting minutes with "Annual Timeline for Integration of Board MREFC Process with NSF Budget Process" (NSB-10-66, approved August 2010).

2.2 DEVELOPMENT STAGE

2.2.1 Initiation of a Potential Major Facility Project

As in all NSF endeavors, inquiry begins with the research communities, whose members alert NSF program staff to the most promising and exciting questions and the most important equipment needed to explore them.

NSF POs, who work closely with those communities, should be attentive to the emergence of breakthrough concepts and actively encourage discussion and planning. 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 typically have a 5- to 20-year forward look and are brought to NSF in the form of a submitted proposal requesting funding for development. When there are competing concepts, it may be appropriate for NSF to issue a solicitation inviting proposals.

In most cases, program staff will take a proactive role in facilitating proposal submission, merit review, recommendations and decision. In so doing, however, a PO should maintain the position of a neutral, unbiased agent of NSF. Project advocacy should rightly come from the community, which also participates in the merit review process and whose input is a significant contributing factor in NSF's funding decisions.

During the early development stage, there should be sufficient investment by the Sponsoring Organization (Directorate and/or Division) so that the project is reasonably well defined and/or described in preparation for the formal design stage.

2.2.2 Exit from Development to Design Stage

Formal start of the Design Stage for a facility project occurs following a recommendation by the Chief Officer for Research Facilities (CORF) with input from the Facilities Governance Board (FGB) and other senior agency officials and written approval by the NSF Director is received. This process is initiated by a request from the Sponsoring Organization to the Director's Office once a project is determined to be ready. Generally, such a request is made when the Sponsoring Organization has determined that: (1) the project is a high priority for further development, (2) the project is eligible for MREFC funding (see criteria) and the MREFC funding route is preferred, and (3) the Sponsoring Organization is committed to begin explicit investment in more detailed design activities in the current or upcoming budget cycle using Directorate or Divisional funding (R&RA).

The CORF's recommendation (as Chair of the FGB) will focus on providing the Director with answers to the following questions:

Science

- Is there a compelling science case, and are the project's goals well-articulated?
- Does the project fit solidly within the NSF "mission," within the strategic plans of the NSF and that of the Sponsoring Organization, and within the broader NSF facility portfolio?

Planning

- Is the sponsor's plan for stewardship of the Conceptual Design Phase consistent with the guidelines set out in the Major Facilities Guide?
- Does the preliminary timeline for development and implementation include programmatic, NSB, budget and any necessary partnering milestones, including explicit project off ramps?
- Are potential opportunities for internal and or external partnering being considered, if not already underway?
- Are there any other major challenges regarding this project that the Director needs to be aware of?

Based on the CORF's recommendation and any further examination, the Director then approves (or disapproves) the project entering the Conceptual Design Phase as a "candidate" project. Note that no NSF commitment is implied beyond support for the development of a Conceptual Design. The CORF or Director might alternatively advise the Sponsoring Organization to look further into any issues and then return for further consideration.

2.3 DESIGN STAGE – CONCEPTUAL, PRELIMINARY, AND FINAL DESIGN PHASES

2.3.1 Conceptual Design Phase

2.3.1.1 Introduction – Conceptual Design Phase

The goal of this first phase of the major facility design stage is the creation of a comprehensive Conceptual Design that clearly articulates project elements that NSF will consider, including:

- Description of the research infrastructure and technical requirements needed to meet the science, including a definition and relative prioritization of the research objectives and science questions the proposed facility will address. Technical requirements must flow down from the science requirements. This description may be site-independent or site-specific depending on the nature of the project;
- System-level design, including definition of all functional requirements and major systems;
- Concept of operations including an estimate of annual operations and maintenance costs, staffing levels, and other activities
- Initial risk analysis and mitigation strategy for construction, identifying enabling technologies, high-risk or long-lead items, and research and development (R&D) needed to reduce project risk to acceptable levels;
- Potential environmental and safety impacts to be considered in site selection (see "Compliance with Environmental, Cultural and Historical Statues," at the end of this section);
- Description of the proposed construction performance baseline (scope of work, budget and schedule) needed to evaluate readiness and continue planning in preparation for the Preliminary Design Phase. This includes budget and contingency estimates appropriate to a Conceptual Design[1] level and based on the initial Risk Analysis and initial projections for the construction and commissioning schedule;
- Description of proposed Educational Outreach and Broader Societal Impact, included in the proposed scope of work, budget and schedule.

Many of these details are included as part of the PEP as described in greater detail in following sections and in Section 3.4. This Phase may take several years depending on development activities.

[1] The budget information should be provided using a Work Breakdown Structure (WBS) format, identifying the basis for estimates and including a WBS dictionary that defines the scope associated with each WBS element. Contingency estimates should include an explanation of the methodology used to calculate the estimate.

2.3.1.2 Conceptual Design Phase Activities

During the Conceptual Design phase there may be a number of coordinated and complimentary activities taking place with the various entities involved: (1) community activities, (2) NSF staff activities, and (3) funding considerations.

(1) *Community Activities*. Proponents of a project should provide NSF with an early concept proposal that makes a compelling case for the research that would necessitate development of a facility, and that describes, in general terms, its essential characteristics if the proposal is unsolicited. Generally speaking, major facilities projects are solicited. In that case, the proposal must respond to all NSF and programmatic requirements which generally include references to the Major Facilities Guide if it is already known as a major facility project. These initial proposals identify what is known at that point in project development, as well as what tasks remain to be accomplished in order for NSF to consider a project for eventual funding. In the near term, they also define what work should be done to develop the project to the Conceptual Design level of maturity.

An NSF PO[1] will be assigned to be the primary point of contact with the Principle Investigator (PI) and/or Project Manager. The NSF PO conducts a merit and technical/programmatic review of the proponents' proposal, and either recommends or declines the request for funding. If funded, the PO will work with their Directorate and/or Division to organize an Integrated Project Team to provide coordination on project oversight and assurance.

Proponents should acquaint themselves with NSF's expectations for the essential elements of a construction-ready PEP as described in Section 3. Proponents should also develop a skeletal plan that will result in the future definition of each of these elements, should NSF encourage further pre-construction planning. The plan should address, even if only in the most cursory way, each of the essential elements that should be realized in a formal construction-ready PEP.

For example, proponents may wish to develop a "straw man" PEP that contains sections labeled using each of the entries in Section 3.4, with as much supporting information provided based on the outputs from the Development Stage (if any) and/or the requirements in the solicitation. This serves to illustrate an understanding to all parties of the range and magnitude of the tasks ahead.

[1] Administratively, the Program Officer (PO) is part of a Directorate or Office that provides supervisory oversight and the budgetary authority to fund PO actions. Actions of the PO described here and in subsequent life cycle stages of facility development implicitly recognize the authority of the individuals within this supervisory structure to appropriately guide, direct, and approve the actions of the PO. In particular, when the phrase "PO concurrence" is used in the following text, this assumes concurrence at whatever management level the AD or Office Head has required. Refer to Section 2.1.6 for a brief description of the duties of the PO, AD, and others referred to in the Major Facilities Guide.

(2) *NSF Staff Activities*: In response to the development of an early version of a PEP, the PO, with the advice of the IPT, develops an Internal Management Plan (IMP).[1]

This internal document specifies how NSF will conduct its oversight and assurance of the project, and provides budgetary estimates for developing, constructing and operating the facility. It also identifies critical issues and risks facing the project (for example: project management issues, completion of essential R&D activities, partnership agreements, award closeout or divestment liabilities) and lays out a strategy for financing these activities.

The PO develops the IMP with advice and assistance from the IPT, following internal operating guidance. The IMP is approved by the cognizant NSF AD after review and approval within the Sponsoring Organization. The IMP describes the plan for NSF management and funding of the project to CDR, proposes transitional steps to be taken if the project is admitted to the Preliminary Design Phase, and lays out NSF's plan to oversee development of the project including internal and external review. Each major facility project undertaken by NSF has unique characteristics. Accordingly, the IMP should be adapted to meet the specific needs of a particular project. The IMP should state the justification for pursuing alternatives to the guidelines contained in the Major Facilities Guide.

3) *Funding Considerations*. During the Conceptual Design Phase, NSF and/or other institutions and agencies begin to invest research and development funds in design development, and in efforts that promote community building and planning. Investment in fundamental research activities, community building, and initial planning activities may occur over many years, and some are recognized as having contributed to the conceptual design effort only in retrospect.[2]

The cumulative pre-construction investment in research, planning and development that occurs during the Conceptual Design, Preliminary Design, and Final Design phases may range from five to 25 percent of total construction cost, depending on the complexity of the project, and typically amounts to about 10 percent of the construction cost. The technology needed to construct a facility may be uncertain, unproven or immature, requiring substantial development over a period of years.

NSF may decide to fund additional planning and development efforts for particular projects depending on the outcomes of the review and whether or not the Conceptual Design Phase was funded.[3] Such activities might include workshops in one or more disciplines, National

[1] Questions about Internal Management Plans should be addressed to the relevant PO."

[2] Some projects come to NSF very well developed, requiring little in the way of conceptual design phase support. They are subjected to the same rigorous scrutiny, however, as they are developed by the responsible NSF Directorates or Offices.

[3] Relevant program solicitations may be released to announce funding opportunities for these planning and development efforts.

Academies' studies, and research projects related to the development of new technologies.[1] These activities might be funded as part of the Conceptual Design Phase award, or through a separate proposal submission.

2.3.1.3 Conceptual Design Review (CDR)

The Conceptual Design Phase is complete when a package containing the Conceptual Design and funding request leading to a Preliminary Design is received, reviewed, negotiated and approved for funding. The funding request will generally be submitted as a supplemental request to the original award.

The package should include the refined PEP and any additional information required by Program to assess the project readiness and management to-date. Components of the PEP are given in Section 3.4.

NSF will subject the Conceptual Design package to external review, applying standard NSF criteria (Intellectual Merit and Broader Impacts) as well as other programmatic and technical criteria as given in the original solicitation and the panel charge. Projects that review well will be further evaluated by NSF to apply the second ranking criteria (agency strategic fit), in accordance with the principles stated in the joint *NSB/NSF Management Report: Setting Priorities for Large Research Projects Supported by the National Science Foundation (NSB-05-77)*. (See Appendix A for discussion of ranking criteria.)

The review panel will, as appropriate, involve external experts, consulting firms, and in-house expertise in the science, technology and business communities to scrutinize and validate the supporting planning documents. The scope of this review includes assessment of the scientific, technical and project-management aspects of the proposal.

The review is organized and conducted by the PO in consultation with the LFO Liaison and G/AO. The PO has overall responsibility for organizing the review, and throughout the review process acts as the interface between the NSF and the Recipient. The PO authors the review charge and organizes the review panel. The LFO Liaison and G/AO strengthens the review process by specifying language for incorporation within the charge and for aspects of the review agenda pertaining to project management issues and recommending panelists able to advise NSF in non-science related areas of the review. The PO, LFO Liaison, and G/AO concur on the implementation of these recommendations. Following the review, the PO and the LFO Liaison will each independently assess the review, confer on areas of concern, share their views, and report their observations through their respective supervisory chains – the PO via the administrative structure of the Sponsoring Organization and the LFO Liaison via the HLFO.

[1] NSF encourages disciplinary and interdisciplinary science planning by all of the research communities that NSF supports. In particular, NSF encourages formal planning in fields in which scientists and engineers have traditionally not been organized to identify major facility projects needed for breakthrough advances.

At this point, the conceptual design baseline is likely to have significant uncertainties. Cost estimates at CDR are generally parametric in nature. Contingency estimates, representing work scope not yet defined but nevertheless essential to the completion of the project, will be a significant fraction of the total project budget estimate. Significant unknowns and uncertainties often remain to be addressed in more advanced stages of planning and development. The conceptual design, system requirements, supporting budget estimates, risk analysis, and forecasts of interagency and international partnerships should be detailed enough for NSF program officials to decide whether the project concept warrants further funding for development.

In conjunction with the CDR, the initial high-level NSF Cost Analysis will be initiated and conducted jointly with key assurance members of the IPT; namely DACS, the Division of Institution and Award Support (DIAS), and the LFO. The Cost Analysis will be conducted following NSF internal operating guidance. Guidance on refinements to the Recipient's Cost Book will be provided as necessary in preparation for the Preliminary Design Phase.

2.3.1.4 Exit from the Conceptual Design Phase

Formal exit from the Conceptual Design Phase typically entails four NSF actions:

1. Successful completion of the CDR as described above,
2. Recommendation for advancement by the sponsoring Directorate,
3. Facilities Readiness Panel Review and Recommendation, and
4. Approval for advancement to the Preliminary Design Phase by the Director

Recommendation for Advancement by the Sponsoring Directorate

The AD relies on community inputs, discipline-specific studies, advisory committee recommendations and internal NSF considerations to prioritize the opportunities represented by the project relative to competing opportunities and demands for resources. If, in the judgment of the AD, the scientific merit and relative importance of the proposed facility are sufficiently strong to justify advancement of the project into the Preliminary Design Phase, the AD will submit a memorandum to the Facilities Readiness Panel recommending the project for support, that explains how it meets the requirements for construction funding and how it satisfies the following criteria:

- The project's science (research) program addresses one or more science objectives, clearly demonstrating a compelling need for the project;
- The project has been reviewed by the research community and by NSF, in consultation with Directorate Advisory Committees, and has been assigned a very high priority;[1] and

[1] Evaluation by NSF includes external merit review, using the NSF merit review criteria and the 1st ranking Criteria and evaluation by the Facilities Readiness Panel, using the 2nd ranking Criteria in Appendix A.

- The project's CDR indicates that: (1) the engineering design and construction plans are appropriately defined at the conceptual design level of project maturity and that the management plans and budget estimates for further planning and development, as well as constructing and operating the facility are reasonable; (2) the sponsoring Directorate endorses the IMP and Project Development Plan[1] (PDP) for further development to the Preliminary Design Phase; (3) the technology to create the facility exists or can exist shortly, and can be used without excessive risk; (4) other risks to development are satisfactorily defined and minimized or otherwise addressed in the IMP, and (5) there are no better alternatives to the facility (i.e., with a better mix of cost and quality) that would address the science objectives in a timely manner.

Supporting documentation, including the approved IMP, relevant review evaluations, and any other supporting information should accompany this memorandum. All materials are transmitted to the Facilities Readiness Panel (FRP) by the AD or Office Head of the Sponsoring Organization.

Approval by the Director

The Director evaluates the FRP recommendation and, if satisfied, approves advancement to the Preliminary Design Phase.

At its May meeting, the NSB reviews the portfolio of projects which are being considered for future funding and evaluates relative priorities that guide NSF's investment looking across the entire range of disciplines served by NSF within the constellation of other competing opportunities, existing facilities, and the balance of support for infrastructure, its utilization, and individual investigator-led research.

More information about the role of the NSB in selecting and prioritizing major facility projects is available in Section 2.1.6 on Roles and Responsibilities.

[1] The Project Development Plan is part of the PEP, providing the plan to develop the project design and definition to readiness for construction. See Section 3.4 for details.

2.3.2 Preliminary Design Phase

2.3.2.1 Introduction – Preliminary Design Phase

The Preliminary Design Phase further develops concepts to a level of maturity in which there are: a fully elaborated definition of the motivating research questions; a clearly defined site-specific scope; a PEP and an IMP that address major anticipated risks in the completion of design and development activities and in the undertaking of construction; and an accurate budget estimate that can be presented with high confidence to the NSF Director, NSB, the Office of Management and Budget (OMB), and Congress for consideration for inclusion in a future NSF budget request.

"Off-ramps"
Projects may be removed from the Preliminary Design Phase by the NSF Director due to:

- Insufficient priority over the long term;
- Failure to satisfy milestones or other criteria defined in the IMP/PEP;
- Eclipse by other projects;
- Collapse of major external agreements;
- Extensive estimated or actual cost increases;
- Significant changes in schedule for design readiness or eventual construction;
- Unexpected technical challenges;
- Changes in the research community that indicate eroding support for the project;
- Any other reason that the Director deems sufficiently well-founded.

To satisfy these requirements, the project is developed to a Preliminary Design[1] level of maturity. Results of this development are reflected in a revised and updated PEP.[2] Components of the updated PEP that deserve particular emphasis at this stage include:

- Update of the project development plan budget and timeline, with major anticipated risks in the completion of design and development activities;
- Refinement of the research objectives and priorities of the proposed facility;
- Update of the description of the required infrastructure, site-specific design, and definition of interconnections of all major subsystems;
- Environmental Assessments or Environmental Impact Statement (if applicable);
- Bottom-up budget and contingency estimates for construction, presented using a Work Breakdown Structure (WBS) structure and supported by a WBS dictionary defining the scope of individual elements;
- Scope management plans that include de-scoping options and scope opportunities that can be implemented depending upon available contingency levels.

[1] NSF utilizes the conventional definition of preliminary design as used by project managers – a site-specific design defining all major subsystems and their interconnections, a level of design completeness that allows final construction drawings to proceed, cost estimation based on construction bidding, and bottom-up estimates of cost and contingency. Preliminary design usually has a specific meaning within a particular industry or discipline, and NSF adopts the definition most appropriate to each particular project, as defined in the Project Development Plan part of the PEP.

[2] See Section 3.4 for a description of the PEP.

- Updated construction schedule with contingency estimate;
- Updated Educational Outreach and Broader Societal Impact plan that includes the scope of work, required budget and schedule to implement the plan, plus the budget and schedule needed to develop the plan from preliminary design to final design;
- Implementation of a Project Management Control System (PMCS) [1] and inclusion within the preliminary design of a resource-loaded schedule;
- Updated risk analysis, including regulatory issues affecting construction or operation, and time-dependent factors such as inflation indices, price volatility of commodities, etc. (The preliminary design budget estimate will be the basis for a future NSF budget request to Congress if the project successfully emerges from the Preliminary Design phase. Costs and risks should be projected forward to the anticipated award date for construction funds.)
- Demonstration that key technologies are feasible and can be industrialized if required;
- Plans for management of the project during construction, including preliminary partnership arrangements and international participation, oversight of major subawards and contracts, organizational structure and management of change control;[2] and
- Updated estimates for future operating costs, anticipated future upgrades, or possible decommissioning costs of the facility at the end of its operating life.

2.3.2.2 Preliminary Design Phase Activities

During the Preliminary Design Phase, the earlier conceptual design evolves into a more mature plan with respect to the baseline and contingency definitions. The WBS elements and resource estimates benefit from additional knowledge and planning. Consequently, budget uncertainty for projected construction is much reduced relative to the earlier conceptual design. At the end of the Preliminary Design Phase, the resulting total project cost is used to inform the budget request to Congress. Typically, a significant proportion (often one-third or more) of the total pre-construction planning budget is expended achieving the preliminary baseline estimate.

Interim reviews[3] during the Preliminary Design Phase will be conducted by NSF as described in the IMP. This stage culminates in a Preliminary Design Review (PDR), conducted by NSF, to ensure that all aspects of the project definition and planning are robust. The results of the PDR are reported by the Facilities Readiness Panel, followed by a recommendation from the CORF to

[1] The PMCS involves both 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 evaluate 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. See Figure 4.2.2-1 for examples of project controls systems inputs and outputs.

[2] These plans are a preliminary, but relatively mature version of the Project Execution Plan that defines how the project will conduct itself during the construction stage – see Section 3.4.

[3] Interim reviews are typically held semi-annually. Exceptions to this, dictated by the needs of a particular project, may be justified and will be listed in the award terms and conditions.

the Director for decision on forwarding to the NSB for possible inclusion in a future budget request.

2.3.2.3 Preliminary Design Review (PDR)

NSF conducts a PDR, organized and led by the PO, to assess the robustness of the technical design and completeness of the budget and construction planning. Like CDR, the review is organized and conducted by the PO in consultation with the LFO Liaison and G/AO. The PO has overall responsibility for organizing the review, and throughout the review process acts as the interface between the NSF and the Recipient. The PO authors the review charge and organizes the review panel. The LFO Liaison and G/AO strengthens the review process by specifying language for incorporation within the charge and for aspects of the review agenda pertaining to project management issues and recommending panelists able to advise NSF in non-science related areas of the review. Following the review, the PO and the LFO Liaison will each independently assess the review, confer on areas of concern, share their views, and report their observations through their respective supervisory chains – the PO via the administrative structure of the Sponsoring Organization and the LFO Liaison via the HLFO.

The review scrutinizes the effectiveness of project management through this phase of development, as well as plans for completion of final design and eventual construction and operation. The PDR may utilize, as appropriate, external experts, consultants and outside firms to evaluate proposed plans and budgets as described in the Project Execution Plan (PEP). The PDR also examines the management structure and credentials of key staff to assure NSF that an appropriately skilled management organization is ready to complete final design activities and execute the construction phase of the project.

Once the project has satisfied any recommendations made by NSF as a result of external review, and resolved any outstanding issues, the Directorate recommends to the Facilities Readiness Panel that the project is ready for advancement to the Final Design Phase of development and is a candidate for NSB authorization for inclusion in a future NSF budget request for construction funding. At any time, the Facilities Readiness Panel or the OD may request further external review.

Following the PDR, the PO updates the IMP to describe proposed plans for budgeting and oversight, and to finalize commitments from interagency and international partners during final design. The PO directs the Recipient to update the Project Development Plan (PEP-3.1) to lay out the work scope, budget and schedule necessary to bring the project to Final Design.

In conjunction with the PDR, the second, more detailed NSF Cost Analysis will be initiated and conducted jointly with key assurance members of the IPT; namely the Division of Acquisition and Cooperative Support (DACS), the DIAS, and the LFO. The Cost Analysis will be conducted following NSF internal operating guidance. Guidance to the Recipient on refinements to the Cost Book will be provided as necessary in preparation for the Final Design Phase.

The completion of project planning and development, culminating in a Final Design, should be aligned with the expected time-scale for requesting and appropriating construction funds. The NSF Budget Office is the coordinator for this critical planning activity, bringing projects forward for construction only if OMB and Congress are likely to approve the request and appropriation of funds within the time period in which the Preliminary Design plans and cost estimate remain valid.

2.3.2.4 Exit from Preliminary Design Phase

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

1. A successful PDR and subsequent support from the Directorate,
2. A review and recommendation by the Facilities Readiness Panel for advancement to the Final Design Phase,
3. A review and recommendation by the DRB for advancement to the Final Design Phase,
4. The NSF Director approves advancement and recommends to the NSB inclusion of the project in a future year budget request, and
5. The NSB authorizes inclusion in a future construction budget request.

2.3.2.5 NSF Director's Recommendation for Advancement to Final Design

The Facilities Readiness Panel and the Director should first be satisfied that the following conditions have been met before making a recommendation to the NSB for authorization:

- The AD of the sponsoring Directorate continues to assert the high scientific merit and importance of the project and has a sound financial plan for supporting the remaining pre-construction planning activities and the future operations and use of the facility.
- The Preliminary Design PEP has been successfully reviewed by an external panel of experts in order to obtain the best possible objective advice from authorities in the fields and disciplines utilized by the project.
- An appropriate Integrated Project Team (IPT) is in place and has provided assurance that the Preliminary Design total project cost has been satisfactorily analyzed at a high degree of confidence to support the budget request.
- Updated Internal Management Plan (IMP) has been reviewed by the IPT.
- The Facilities Readiness Panel concurs that the Preliminary Design PEP and IMP are reasonable and poses an acceptable level of technical/programmatic risk, and that anticipated costs for construction and operation are sufficiently well known.
- The NSF Director is satisfied that external participation in all phases of the project (other agencies, international and/or private sector entities, etc.) is well planned.

2.3.2.6 National Science Board Authorization

The final steps for exit from the Preliminary Design Phase are review and authorization by the NSB for advancement into the Final Design phase and inclusion in a request to the OMB for future year funding.

The Sponsoring Organization is responsible for preparing the documentation needed for the NSB to review and authorize a proposed major facility project for advancement to Final Design and inclusion in a future budget request.[1] Prior to NSB submission, the Director's Review Board (DRB)[2] reviews the completeness and appropriateness of the documentation supporting advancement of the project (such as prior phase reviews, committee evaluations, PEP evaluation and reviewed proposal ratings) to ensure adherence to NSF processes and policies.

As NSB considers projects for advancement to Final Design, NSF makes available to the NSB, upon request, the PEP and IMP, and the reviews from the community, the Major Facilities Working Group, the LFO, the Facilities Readiness Panel and other relevant parties. The NSB considers the following elements, applying primarily the third ranking criteria identified in Appendix A, as appropriate:

- The priority of the project in advancing NSF's strategic goals;
- The research and science enabled by the proposed facility;
- Construction readiness and risks to the agency;
- Budget justification for construction and operation of the facility; and
- The likelihood that funding will be available in the next few years.

As with all NSF proposals, the quality of the Intellectual Merit and Broader Impact activities, including educational outreach, plays an important role in funding decisions. If NSB authorizes a project for future-year funding, it specifies its priority among all projects in the approved stage.[3] If a project is not approved, or if an approved project's plans are no longer deemed to be clearly and fully construction-ready, NSB will remand that project to the Preliminary Design phase for further work or recommend that the project be terminated.

2.3.2.7 Inclusion in an NSF Budget Request

Each year, the NSF Director proposes, in priority order, the NSB-authorized construction-ready projects for the MREFC Account. If an MREFC "new start" is approved for inclusion in the President's Budget Request to Congress, then Congress may ask for additional information through formal hearings and/or informal briefings. Once Congress passes an appropriations act for NSF and the President signs it into law, NSF may then obligate funds.

[1] NSF Proposal and Award Manual (PAM) and internal operating guidance documents provide guidance on the DRB package.

[2] See Section 2 and Section 2.1.6 on Roles and Responsibilities.

[3] The Board assigns the very highest priority to projects that are under construction. There is no priority among active projects; they should all move forward at a suitable pace.

2.3.3 Final Design Phase

2.3.3.1 Introduction – Final Design Phase

The goal of the Final Design Phase is to meet the requirements necessary to advance the proposed project to the subsequent Construction Stage. Budgetary and administrative requirements for entry include NSF review and approval of the project's preliminary design as described in the PEP, and NSB authorization to include the project in a future NSF budget request.

Technical requirements include:

- Delivery of designs, specifications and work scope that can be placed for bid to industry;
- Refined bottom-up cost estimates and contingency estimates;
- Implementation of a PMCS for project technical and financial status reporting, including Earned Value Management Systems (EVMS);
- Completion of recruitment of key staff and control account managers needed to undertake construction of the project;
- Industrialization of key technologies needed for construction;
- Finalization of commitments with interagency and international partners; and
- Submission to NSF of a PEP[1] for construction.

Successful exit occurs after the following steps are completed:

1. Successful review of the final design baseline including any receipt of bids;
2. Joint review by the DRB/Facilities Readiness Panel;
3. NSB review and authorization for the NSF Director to obligate construction funds; and
4. Final negotiation of the terms and conditions of the award instrument for the activities in conformance with the final baseline.

2.3.3.2 Final Design Review (FDR)

Projects should continue to receive pre-construction development funds in order to produce a Final Design, which includes the following elements:

- A final construction-ready design;
- Tools and technologies needed to construct the project;
- A project management plan describing governance of the project, configuration control plans, EVMS, and plans for reporting technical and financial status, managing sub-Recipients and working with interagency and international partners;

[1] Refer to Section 3.4 for details of the PEP.

- A fully implemented PMCS, including a final version of the resource-loaded schedule and mechanisms for the project to generate reports – using an NSF verified Earned Value Management System (EVMS)[1] – on a monthly basis and use them as a management tool. Path dependencies, schedule float, and critical path are defined;
- The scope of work captured in detailed WBS format, accompanied by a WBS dictionary defining the scope of all entries, and a scope management plan including potential descope options and scope opportunities;
- Updated budget and schedule, with their respective contingencies, including detailed risk analysis and methodology, presented in the detailed WBS format;
- An updated Educational Outreach and Broader Societal Impact plan (including the scope of work, budget and schedule) that also includes the capital investment required to meet the needs of the proposed Educational Outreach and Broader Societal Impact plan;
- An appropriate proportion of the budget based on externally provided information such as vendor estimates or quotes, publicly available supplier prices, and the like;
- All necessary partnership agreements and MOUs;
- Fit-up and installation details of major components and commissioning strategy;
- Plans for Quality Assurance and Safety Management, integrated into the resource-loaded schedule;
- Updated operating cost estimates; and
- Certification that all of the pre-construction planning topics, including those listed in Section 3, are fully complete and determined to be adequate.

The PO is responsible for organizing and leading the FDR. The review is conducted according to the same standards and with the same respective roles for the PO and LFO Liaison as described previously for the CDR and PDR.

The scope of the FDR includes assessment of the technical and project-management components of the proposed project. A review panel may provide an objective view of the project and a critical evaluation of the plans and risks embodied in the proposed program as the schedule permits. In consultation with the IPT, the IMP should continue to be assessed annually by the Program Officer and updated as required to ensure that the underlying assumptions about the project remain valid. If construction funds fail to be appropriated as planned, the NSF Director may choose to mandate annual project status reviews to assure NSF of the continued viability of the project's plan and budget for construction.

[1] During construction, progress must be tracked and measured using an Earned Value Management System based on EIA-478 criteria (*OMB A-11 Capital* Programming *Guide (2016))*. This requirement applies to the award Recipient who acts as a prime contractor. Secondary contractors to the award Recipient are not required to follow formal EVMS, but must be able to provide the appropriate inputs to the prime for EV reporting.

Following the review, the PO and the LFO Liaison will each independently assess the review, confer on areas of concern, share their views, and report their observations through their respective supervisory chains.

In the event the project's construction plans are determined to be inconsistent with the pending budget request, NSF will undertake remedial action. Should remedial action be necessary following the review, the sponsoring Directorate recommends this to the OD after consultation with the IPT, internal deliberation, and if appropriate, consultation with the Facilities Readiness Panel. Remedial action may include, for example, revision of the project's budget, scope, and/or schedule, or withdrawal of NSF's request for construction funding (off ramp).

2.3.3.3 Exit from the Final Design Phase

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

1. A successful review of the Final Design PEP including any receipt of bids and subsequent support from the Directorate,
2. A review and recommendation by the Facilities Readiness Panel for advancement to the Construction Stage,
3. A review and recommendation by the DRB for advancement to the Construction Stage,
4. The NSF Director approves advancement and recommends NSB authorization for a Construction Stage award, and
5. The NSB authorizes a Construction Stage award.

2.3.3.4 NSF Director's Recommendation for Advancement to Construction Stage

The Facilities Readiness Panel and the Director should first be satisfied that the following conditions have been met before making a recommendation to the NSB for authorization:

- The AD of the sponsoring Directorate continues to assert the high scientific merit and importance of the project and has a sound financial plan for supporting the remaining pre-construction planning activities and the future operations and use of the facility.
- The Final Design PEP has been successfully reviewed by an external panel of experts in order to obtain the best possible objective advice from authorities in the fields and disciplines utilized by the project.
- Updated Internal Management Plan (IMP) has been approved by the Directorate.
- An appropriate Integrated Project Team (IPT) is in place and has provided assurance that the Final Design total project cost has been satisfactorily analyzed at a high degree of confidence to support the "No Cost Overrun" policy (NCOP).
- The Facilities Readiness Panel concurs that the Final Design PEP and IMP are reasonable and poses an acceptable level of technical/programmatic risk, that anticipated costs for

construction are sufficient to implement the NCOP, and the updated cost of operations are sufficiently estimated.

- The NSF Director is satisfied that external participation in construction and operations (other agencies, international and/or private sector entities, etc.) carries acceptable risk.

2.3.3.5 National Science Board Authorization for Construction

NSB reviews the recommendation and authorizes the NSF Director to obligate funds for construction award(s). Following the Director's approval, an award (either a cooperative agreement or contract) is negotiated between NSF and the Recipient, and construction activities begin in conformance with the negotiated Performance Measurement Baseline (PMB).

The NSB authorized Total Project Cost (TPC) following the Final Design Review (FDR) establishes the not-to-exceed cost under NSF's "No Cost Overrun" policy. Section 4.2.5.2 describes NSF practices to meet this policy.

The NSF Cost Analysis initiated in conjunction with the FDR and conducted jointly with key assurance members of the IPT; namely the Division of Acquisition and Cooperative Support (DACS), DIAS, and the LFO will determine the final negotiated award amount for Construction. The analysis will encompass such things as negotiated subawards and contracts associated with initiating construction and negotiation of final indirect cost and labor rates. The Cost Analysis will be conducted following NSF internal guidelines. Questions about the Cost Analysis should be directed to the PO and/or the relevant G/AO or CO.

2.4 CONSTRUCTION STAGE

2.4.1 Construction Award Management and Oversight

After Congress appropriates funds for the project, NSF proceeds to award the cooperative agreements (CAs) or contracts for construction, acquisition, and commissioning of the facility. The policies and procedures in the publicly available *NSF Proposal and Awards Policy and Procedures Guide*, apply to major facility projects awarded under a cooperative agreement. Questions about the internal guidance that covers details of the internal award process from proposal generation through merit review, DRB and NSB reviews, and final award should be directed to the PO. The Recipient(s) provides periodic financial and technical status reports to NSF according to the terms and conditions of the CA or contract. The project is subjected to periodic post-award reviews that may examine any or all of the following topics: technical performance, cost, schedule, and management performance. These reviews are typically held at the facility and are conducted at least annually. More frequent reviews may take be scheduled based on the project's expenditure rate or due to any other technical or management issues that arise.

NSF selects the annual review panel members who are typically external experts covering all aspects of the project, and assess technical progress, cost, schedule, and management performance. These panels report directly to NSF and provide advice on project direction and any needed changes. The reviews are organized and conducted by the PO in consultation with the LFO Liaison and G/AO. The PO has overall responsibility for organizing the review, and throughout the review process acts as the interface between the NSF and the Recipient. The PO authors the review charge and organizes the review panel. The LFO Liaison and G/AO strengthens the review process by specifying language for incorporation within the charge and for aspects of the review agenda pertaining to project management issues and recommending panelists able to advise NSF in non-science related areas of the review. (Note: Many projects invite panels of experts to review and advise on project plans and progress. Such panels report to the Project Director and are not a substitute for NSF-organized external oversight reviews.) Because panel recommendations are to NSF and not the Recipient, NSF will generally issue written guidance to the Recipients for subsequent response and action.

Progress against the project plan is provided through the use of formal Earned Value Management Systems (EVMS), which provide measurement of ongoing project status, including deviations or variances from the PMB. The results of the EVM reporting and analysis and any actions taken, are reported to NSF in the monthly progress report. The Recipient should consult with the PO and GA/O or CO as necessary on the requirements for the monthly progress reports. Further information is also provided in Sections 4.2.5.8 and 4.6.2 of this Guide. Generally, when cost and/or schedule performance begins to deviate from plans, change

control is exercised by the project through a Change Control Board (CCB)[1] action, resulting in modifications to the project's budget or schedule contingency. It is also normal practice for a project to update its budget and schedule Estimates to Complete (ETC), which also may result in PMB changes.

Whenever a project approves a change control action that results in allocating or returning contingency to the pool of contingency funds, 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.

Modifications to the PMB that are within the defined scope and do not change the total project duration or Total Project Cost 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 expended in an expected manner. If the allocations of budget and schedule contingency are below the budget or schedule thresholds identified in the award instrument (CA or contract agreement) between NSF and Recipient, the change requests are approved unilaterally by the project. NSF approval is required when the CCB recommends re-planning change actions that exceed the budget or schedule thresholds identified in the terms and conditions in the agreement or contract between NSF and Recipient. Each will have a different threshold for approval. Approval levels for scope changes are generally outlined in the award instrument.

Minor changes in scope may also fall under re-planning activities. The project maintains a scope management plan (PEP-4.4) which describes the project process for maintaining control of scope and outlines scope changes that can be implemented depending upon the project's forecast of its ability to complete the project within the approved TPC and duration. The project can elect to implement minor de-scoping options or to defer scope through the change control process if it needs to increase the amount of contingency as part of the strategy to prevent potential cost overruns. It can also elect to implement project enhancements that are within existing scope of work definitions, following the project change control process and approval process as set in the award or contract terms and conditions.

It is essential for the project management to respect the project PMB rigorously, maintaining each adjusted PMB in the project's database along with the attributed CCB actions. This allows the project and NSF to systematically track the evolution of the PMB from its initial release through all subsequent changes.

[1] A CCB comprises the senior project managers responsible for defining the project's resource requirements and allocating or expending those resources. It typically consists of the Project Director, Project Manager, Business Manager, control account managers of principal work breakdown structure elements, chief scientist and engineer, and systems engineer. It may include other project staff whose authority pertains to the range of activities considered by the Board.

"Re-baselining" occurs when the changes involve:

1. Increases in the NSB-authorized TPC,
2. An extension beyond the total project duration, and/or
3. Major changes in scope.

When the proposed changes reach the re-baselining level, the approval process involves NSF and may involve the NSB. Changes in project end date follow NSF's No-Cost Extension (NCE) policies. Major changes in scope should be part of the scope management plan and should follow the project change control process, including NSF approval; if science goals are significantly impacted, NSB authorization may also be required. An increase in TPC exceeding 20 percent of the NSB-authorized TPC or $10 million (whichever is less) must be reviewed and authorized by the NSB following a recommendation by the Director. Prior to requesting approval to re-baseline, a new external baseline review should be conducted to examine the nature of the problems encountered, and to determine whether de-scoping should be exercised per the approved scope management plan (PEP-4.4) or, if not, whether the problems can be solved by use of budget and/or schedule contingency or other means. Upon review and approval, scope, cost, and schedule are stabilized, and contingency is adjusted to appropriate levels.

Whenever significant scope, cost, or schedule increases are foreseen, it is most important that the LFO Liaison is consulted early, concurs with the PO on the details of the Sponsoring Organization's plan, and advises and concurs on details of the external re-baselining review. Similarly, when there are indications that project cost or schedule contingency will fall below reasonable standards,[1] the PO should discuss plans for dealing with the variance with the Project Director. This information should be clearly noted in the monthly status report that goes to the HLFO. The LFO is a resource for helping to deal with such problems and for helping to identify steps that can be taken to restore adequate contingency.

In addition to supplying regular status reports required in the terms and conditions of the award instrument, it is essential that project staff inform the PO and/or the G/AO (or CO) in a timely manner of major issues or significant changes in project status, such as a potential re-baselining, problems with partnerships, or surprising research and development results. NSF management, the Chief Officer of Research Facilities, and the NSB should in turn be informed of such developments by the PO. The primary mechanism for coordinating both the transfer of information and the coordination of any required actions by NSF is through the NSF Integrated Project Team (IPT).

On rare occasions, major facility projects under construction may encounter unforeseen budget, schedule, technical, or programmatic challenges that are of a substantial enough level

[1] See details in Section 4.6, Requirements for Performance Oversight, Reviews and Reporting.

to be considered grounds for termination or significant modification to the original project goals. NSF will provide the NSB with appropriate information and a recommendation by the Director. The NSB will decide whether termination or significant modification to the original project goals is warranted.[1]

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

2.4.2 Construction Award Close-out

2.4.2.1 Project Close-out Process

All NSF-funded research awards have final reporting and close-out procedures for the purpose of ensuring funds have been properly used and to provide the public with information on the research outcomes (PAM 2017, Chapter XIII). The close-out process for major multi-user research facility construction awards has the same basic purpose and is governed by the same NSF policy.

As part of the annual construction review process outlined above in section 2.4.1 Construction Award Management and Oversight, at an appropriate time approaching or following construction completion, NSF will 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.

The first step in the formal award-close-out process for major multi-user research facility construction assistance awards is for the Recipient to submit the Final Project Report and Project Outcomes Report for the General Public per the reporting requirements detailed in the Proposal and Award Policies & Procedures Guide (PAPPG). The Final Project Report should clearly map project accomplishments and deliverables to the Programmatic Terms and Conditions of the Cooperative Agreement and Cooperative Support Agreement and should be informed by the final construction review. There may be additional close-out reporting requirements detailed in the governing Cooperative Agreement (CA) or Cooperative Support Agreement (CSA). It is the Recipient's responsibility to understand and satisfy all close-out requirements.

The Program Officer (PO) reviews these reports and distributes, as appropriate, to other NSF offices involved in award close-outs such as Office of General Counsel, and the Office of Budget, Finance, and Award Management (BFA). Once the PO is satisfied with the Final Project Report as submitted, he/she formally approves the report by accepting it in eJacket. Following this certification all financial transactions with Recipient are closed and the award is closed-out.

2.4.2.2 Request for No-Cost Extension

The PO has the authority to recommend approval of the first NSF-Approved No-Cost Extension (NCE). However, the PO will generally work closely with members of the NSF Integrated Project Team (IPT) to ensure the request meets the requirements for major facility projects as described herein. Any subsequent NCE's must be approved by the Grants and Agreements Officer (G/AO) or Contracting Officer (CO), who is also a core member of the IPT. As the project nears completion, close-out activities will become a discussion item for the IPT.

Only tasks within the approved project scope may be included in the NCE. As stated in Section 4.2.5, Budget Contingency Planning for the Construction Stage, any unused funds (either contingency or positive cost variance) must be returned to the agency.

Many intended tasks will already be clearly contained within the approved project scope and can be directly associated with a particular WBS element. Tasks which cannot be found to fall within an approved WBS element will be allowed only after they have been reviewed and approved as new scope through the change and/or configuration control processes contained in the Project Execution Plan. Depending on the magnitude, this may require very high-level approvals within the agency. It is highly recommended that the discussion of scope, and the ability to assign to an approved WBS element, takes place prior to the NCE request.

Good practice suggests that all other project tasks, i.e. those not included in the NCE request, should be closed out by the original award end date. This means that all risks and liens for those tasks are also closed out, and that no funds are carried forward for remediation of problems that arise in the future. The close-out of completed tasks also allows for a more precise calculation of remaining cost variance and/or contingency which facilitates good decisions making on the part of the Project and NSF. If any tasks slated for close-out are not completed by the original award end date, then NSF must be notified that the tasks will be carried over into the extension period as part of the NCE request.

It is anticipated that the list of tasks to be performed during the extension may change with time as final negotiations and decisions are made and actual costs are realized. Some tasks may be held back and subsequently removed as scope contingency options when available resources or priorities change. Other tasks within the approved scope of the project may be added (for example, as a result of a reprioritization exercise following final acceptance reviews or because they are delayed past their close-out dates). Tasks may be added or removed from the list with adequate justification and with the written approval of NSF. All final close-out documentation will be saved to the official record by the PO.

Written requests for NCEs should be submitted to the PO and should include the information in the following list:

1. List of the tasks to be completed during the extension period and justification that they are within project scope.
    a. Link the tasks to the associated WBS element and give a short justification of how they fit within existing project scope. Risk mitigation effort should be associated with an identified and documented risk element.
    b. Provide the total burdened estimated cost for each task. Detailed cost estimates do not have to be provided but should be documented and available if requested.
    c. The justification for each task will typically fall into one or more of several categories: (1) open purchase orders and invoices associated with items whose

delivery is delayed beyond the current period of performance, for example due to subcontractor performance, (2) rework of existing tasks within the approved scope, for example due to workmanship or performance issues, (3) existing tasks within the approved scope that have not yet been completed, and (4) risk mitigation to address in-scope performance issues. An example of a task list with justifications is given in the sample Table 2.4.2-1 on the following page.

2. Indication of which tasks provide de-scoping options[1] if resources (time, staff, budget, etc.) become limited. Briefly indicate why each task is a candidate for de-scoping and give any deadlines for exercising the de-scope option. NSF must be notified when and if the scope contingency option is taken and tasks are removed from scope, including the impact on project deliverables or performance, if relevant.

3. Description of what funds will be used to cover the proposed tasks – remaining contingency, unexpended PMB budget, positive Cost Variance, partner funds, etc. Give the project PMB ETC with all tasks included and compare to remaining contingency and TPC. State a confidence level for completing all work within budget, including the use of any scope contingency options. Indicate if any tasks involve already obligated funds and give the amount of those funds.

4. Summary schedule or schedule highlights of the extended tasks, including significant milestones and the new project end date. Provide (BOE) for the new project end date, including schedule contingency, and give a confidence level for completing by that date.

[1] Scope contingency and management is defined in Section 6.2.3.

Table 2.4.2-1 Sample of a No-Cost Extension Tasks Table

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

2.5 OPERATIONS STAGE

2.5.1 Operations Management and Oversight

Although NSF does not directly manage the operations of the facilities it supports (with the exception of Arctic and Antarctic activities), the agency engages in oversight and assurance of facility awards during each stage of the facility's life cycle. In oversight, NSF employs a team-oriented approach in which scientific and engineering staff work closely with business operations staff. Additional detail on facility operations may be found in Section 3.5 of this Guide[1] and among the special topics found in Section 4, Key Management Principles and Requirements for Major Facilities.

The Recipient responsible for construction or acquisition of a new facility is normally the entity that submits a proposal for operation of the facility during the construction stage. However, the Operations Stage may be managed by a different entity, depending on circumstances stated in the IMP.

The operations proposal is merit-reviewed following NSF's guidelines. Operations activities are funded through NSF's R&RA and/or Education and Human Resources (EHR) account. Testing and acceptance, user training and engineering studies occur as the facility transitions to full operation. Operations include the day-to-day work required to: support and conduct research and education activities; ensure that the facility is operating efficiently and cost-effectively; and provide small- and intermediate-scale technical enhancements when needed to maintain state-of-the-art research capabilities.

The content of the operations proposal will be adapted to the specific nature of the facility, but at a minimum it should be compatible with the Concept of Operations Plan (PEP-15.3) established during construction and include:

- A detailed bottom-up cost estimate for operations per Section 4.2 of this Guide.
- A detailed description of how the operation of the facility will be managed, including the roles of key staff and use of advisory committees. This could be included as part of the proposal text or a separate Operations Plan.
- Description of plan for education and outreach.
- Description of research program supported through operations, if applicable.
- A listing of which Environmental, Safety and Health (ES&H) standards will be followed by the Recipient and a description of how adherence to those standards will be verified. A policy for reporting to the NSF accidents or environmental releases should also be given. This may be given as a reference to an existing ES&H plan (PEP-13.1) for the project.
- A listing of which cyber-security standards will be followed by the Recipient and a description of how adherence to those standards will be verified. A policy for reporting

[1] Further development of these sections is planned for MFG future version.

to NSF of any breaches of cyber-security should also be given. This may be given as a reference to an existing Cyber-Security Plan (PEP-12.1) for the project.

- A discussion of how major overhaul, repair or replacement of long-lived capital assets or components who useful life extends beyond the duration of the CA will be handled.
- A discussion and acknowledgement of the current plan for re-competition or divestment.
- A set of performance goals and metrics sufficient to establish that the facility is operating successfully. The Facility's performance against these metrics will be reported periodically as required by Program.
- Discussion on plans or progress toward major upgrades to the Facility to increase science capabilities.

Given the long operations stage of most major facilities, upgrades and refurbishment of equipment may be required over time in order to stay at the research frontier. In the case of an observatory, this may include new instruments and cameras. For a sensor network, it may include the deployment of additional sensors or renewal of cyber-infrastructure. At an accelerator facility, the upgrades may take the form of higher energy or luminosity or new detectors. In general, these upgrades and renewals will be funded from R&RA funds, either from a portion of the operating funds designed for such purposes or from separate equipment and instrumentation programs. Funding for more significant upgrades (if they exceed the major facility threshold) may come from the MREFC account. In that case, the approval process is the same as that for a new major facility project.

The PO should be closely involved in monitoring and assessing the facility's evolution and in supporting advanced R&D planning and budgeting. Evaluation of each NSF major facility, as part of its yearly operations review, should include a section on the plans for advanced R&D and should relate these plans to the anticipated evolving mission of the facility. This evaluation helps guide the PO in formulating a budget strategy for funding advanced R&D efforts.

A Program Officer (PO) may also request a periodic formal Condition Assessment report (an evaluation of capital assets requiring significant expenditures for periodic replacement or refurbishment and having a lifetime longer than the usual five-year award cycle), accompanied by an Asset Management Plan (a strategic plan for dealing with these issues), to inform NSF and the facility management of anticipated major and infrequent maintenance expenses that cause a significant departure from the routine funding profile. This allows NSF, as part of its budget allocation process, to proactively address these issues before they become immediate needs.

Generally speaking, there are three key aspects of NSF oversight and assurance of major facility operations, *which are codified in and required by the CA*: (1) Annual Work Plans, (2) Annual Reports, and (3) annual operations reviews. NSF or the cognizant agency may also conduct periodic audits or Business Systems Reviews.

Annual Work Plan

The Annual Work Plan (AWP) describes what the facility expects to accomplish in the coming fiscal year. For many facilities, the AWP, annual operations proposal, and Cost Estimating Plan (per Sections 4.2.2 and 4.2.4) can be combined as one document, so long as all elements are addressed. The AWP should include a series of high-level performance goals (clear and agreed upon goals and objectives, performance metrics and, where appropriate, performance targets) for the coming year. The goals should include both scientific and operations issues (i.e., installation of new equipment or commissioning of new buildings, maintenance, Education and Oversight Training and ES&H). The goals and metrics will naturally vary from facility to facility and should be agreed upon between the Recipient and the NSF Program Officer (PO). The PO will review the AWP goals to ensure they are aligned with the long-term scientific objectives of the facility.

It is the Recipient's responsibility to manage and maintain the NSF-funded facilities, equipment, and instrumentation used in the conduct research regardless of ownership. See Section 6.6 of this Guide. In accordance with federal guidance[1] on property that the government owns, leases, or otherwise manages, Recipients should annually provide a brief discussion, cost estimate, and actual expenditures at a high level for the following:

- Recurring routine maintenance and repair.
- Significant infrastructure changes, including modernization, overhaul, upgrade, replacement, and/or expansion for science facilities, equipment, utilities, and/or instrumentation.
- Utilities (including facility operation and purchase of energy)
- General support services (such as grounds and waste management).

Annual Report

The annual report describes in detail the activities of the facility in the previous year based on the award date and the award terms and conditions. This report is required by NSF policy (see PAPPG) and necessary to review progress on that year's performance goals as described in the AWP. Due to changing research priorities or external forces, not all performance goals may be met each year but an explanation of progress on each goal should be included. The Recipient should also report all expenditures relative to the planned budget in accordance with award terms and conditions. The PO reviews and approves the annual report.

Annual Operations Reviews

In most cases, NSF will annually conduct an operations review of its major facilities, utilizing an external panel of experts spanning the principal range of functions necessary to sustain facility operations, or carry out or participate in an alternate activity that accomplishes an equivalent

[1] 41 CFR 102-84 "Annual Real Property Inventory", GSA Guidance for Real Property Inventory Reporting

purpose. When NSF partners with other entities to fund operations, the MOU between the partners defines the process for monitoring: (1) identification and accomplishment of programmatic goals; (2) fiscal accountability; (3) stewardship of NSF assets; and (4) compliance with laws and regulations. Operations reviews should determine the extent to which the facility is meeting the goals of its Annual Plan, discuss any upcoming challenges for operations, and highlight good practices that could be applied to other NSF major facilities. Metrics and performance goals or targets should include objectives related to educational outreach and broader societal impacts, in addition to research goals of the operating facility. Whenever possible, the review should be conducted at the facility itself by an external panel comprised of experts in the operations of similar large scientific facilities and representatives of the user community served by the facility. The panel should produce a formal written report submitted to NSF. Results of the review are used by NSF to provide written guidance to the facility operator in the formulation of goals or targets for the coming year. (The operations review is not meant to compete with the Business Systems Review[1] (BSR) which looks at business processes.)

- The review is organized and conducted by the PO in consultation with the LFO Liaison and G/AO. The PO has overall responsibility for organizing the review (or representing NSF's interests in the case of a partnership), and for acting as the interface between the NSF and the project's proponents throughout the review process. The LFO Liaison and G/AO advises the PO during the planning and execution of the review to ensure that there is consistent practice across NSF in the formulation of performance goals, that goals and objectives are clearly stated and represent quantifiable performance measures or targets where practical, are periodically reported, and that an evaluation and feedback mechanism is implemented as an essential part of an ongoing program of continual performance enhancement.
- Following the review, the PO and the LFO Liaison will share their views and confer on areas of concern. As a result of internal NSF evaluation of the panel report and other supporting assessments, the NSF Program Officer should issue clear written guidance to the Recipient for subsequent response and action.
- In most cases, observers of the review must include the PO, the G/AO or CO, the LFO Liaison and other staff from the Large Facilities Office, and possibly other NSF staff from the Integrated Project Team. Budget considerations, logistical constraints, or alternate processes for review agreed to by NSF and its funding partners may result in exceptions to the number and range of NSF staff participating.

[1] See Section 4.6.3.3 for discussion of the BSR process as well as the NSF BSR Guide. To avoid duplication of effort, the scope of the BSR is adapted to utilize relevant information stemming from other reviews and audits.

2.5.2 Renewal/Recompetition

Most NSF facilities will be operated by a managing organization. Because facility lifetimes are long (some current facilities have operated in excess of 40 years), recompetition of management is appropriate at intervals. Whenever practical, NSF seeks to make competitive renewal awards for operation of major facilities after external merit review. See Section 3.5.2 for procedures for Renewal and Recompetition. The goal of competition is to stimulate new approaches toward more effective management that may offset any potential for increased costs, and ideally may achieve some cost savings. Important considerations beyond performance of current management include how recompetition might affect the scientific productivity of the facility and the burden it would place on the community. Even in cases where the existing management has been explicitly and rigorously reviewed and found to be effective, the benefits of competition may outweigh any short-term disadvantages of recompetition. The determination of whether to compete the effort is based on the expert advice of NSF staff and, where applicable, panel review and inputs from the user community of the facility, and the recommendation should be presented to the NSB for authorization as part the normal award process.

2.6 DIVESTMENT STAGE

To remain at the research frontier and support new facilities, NSF will consider retiring existing facilities when the science they enable is of a lower strategic priority than science that could be enabled by alternate use of the funds. Such decisions will be difficult to make, in part because of the number of stakeholders and interested parties, and will require extensive community consultation and input, which may come from "blue ribbon" panels, National Academies committees and professional societies. In some cases in which a facility can continue to be productive, it may be possible to transfer ownership or stewardship to another agency, a university or a consortium of universities. It is the responsibility of the Directorates and Divisions to periodically review their facilities portfolio and to consider which facilities may have reached an appropriate end of NSF support.

While not part of the annual budgeting process, proposals may be requested to address partial or full divestment of the facility following the award period, including property divestment, decommissioning, and disposition costs and other costs related to employee separations. Periodic reviews of these proposals should create and keep current a plan for the facility's divestment and closeout, along with its associated budget liability to inform the longer-term strategic planning at the NSF Division and Directorate levels.

Guidelines and requirements for creating divestment transition plans are included in Section 3.6, Facility Divestment Plan of this Guide. Since divestment strategies and liabilities may influence construction strategy, a divestment plan is a necessary element (PEP-1.5) for major facility projects and thus a draft plan should be created early in the Design Stage planning.

When the decision is made to close or transfer ownership or stewardship of a facility, a detailed transition plan will be developed, which includes all divestment costs and liabilities, including disposal or transfer of equipment, environmental and site remediation or restoration, pension and health care responsibilities, etc.

3 FACILITY LIFE CYCLE MANAGEMENT PLANS FOR MAJOR FACILITIES

3.1 INTRODUCTION

Section 3 contains descriptions and guidelines for creating the plans and documents that NSF and Recipients use in the management and oversight of major facilities. They include two plans produced by NSF and three plans that are the product of the facility designers, constructors, and operators.

The NSF Facility Plan, when requested by NSB, is as described in Section 3.2.

Section 3.3 describes an Internal Management Plan (IMP), the NSF document that captures how NSF will oversee awards for major facilities throughout the life cycle, from candidate facility projects in design, through construction and operation, and ultimately, through divestment. An IMP also provides financial strategies for funding given the budgetary estimates. The created IMPs are internal NSF documents.

The Project Execution Plan (PEP) is produced by the Recipient to detail how management and execution of design and construction of a major facility will be accomplished. The PEP advances in maturity from a rudimentary form required at the Conceptual Design Review to a fully mature document ready to support construction at the Final Design Review. Section 3.4 provides a list of the required components of a PEP and guidelines for creating those components.

Operations Plans are addressed in Section 3.5, including timelines for submission and review of operations proposals from prospective Recipients and guidelines for content of proposals and plans. Operation Plans cover all aspects of operations, maintenance, upgrades, and research and education programs. Guidelines are also given for the procedures for renewal or recompetition of an award for an operating facility.

Guidelines for plans to closeout operations under NSF awards are in Section 3.6, Facility Divestment Plan, and closeout of NSF funding and oversight of a facility may be accomplished through various options ranging from transfer to another agency or funding source to decommissioning and removal of the infrastructure and site restoration.

3.2 NSF FACILITY PLAN *[RESERVED]*

3.3 NSF INTERNAL MANAGEMENT PLANS FOR THE MAJOR FACILITY LIFE CYCLE

The Internal Management Plan (IMP) is the primary internal agency document that describes how NSF will oversee development, construction, operation and eventually divestment. The requirement to develop an IMP is described in Section 2.3.1 for major facilities. Three primary purposes are served by development of an IMP:

- It defines in specific detail how NSF will conduct oversight of a project;
- It describes plans for managing NSF-specific risks, and
- It provides budgetary estimates for developing, constructing and operating the facility, identifies divestment liabilities, and lays out a strategy for financing these activities as well as the concomitant NSF oversight requirements.

The IMP should be a living document that is updated at transition points between project life cycle stages, or as often as needed, to define review criteria, decision points, strategies for renewal or recompetition, plan for advanced R&D or technology refresh, upgrades, etc.

3.4 PROJECT EXECUTION PLAN

3.4.1 Components of a Project Execution Plan

Typical components of a construction-ready Project Execution Plan (PEP), common to most plans for construction of major facilities, are listed in Table 3.4.1-1 below, as an example of the extensive nature of the pre-construction planning that should be conducted prior to expending construction funds to execute the project. While many of the listed topics cannot be substantively addressed at the earliest stage of project planning, it is important that project advocates are aware, at the outset, of the full scope of pre-construction planning activities that should be undertaken, and the consequent pre-resources required. As the project matures through Conceptual Design, Preliminary and Final Design, these topics become correspondingly better defined. Some topics will continue to be refined during the Construction Stage, for example, Commissioning Plans and related sub-plans.

The PEP should ideally contain or reference all project related documents and be the standalone source explaining how and why the project meets all requirements and should proceed as planned. Various components of the PEP may often be detailed in separate documents, especially, living documents for future operations such as cybersecurity and data management plans. The PEP should reference these separate documents to summarize the complete scope of the pre-construction planning. In addition to referencing these separate plans, the PEP should provide a high-level summary, outline the associated goals, and/or identified responsibility for the specific plan.

It is important for PEP to document all assumptions and boundary conditions driving project design and implementation. Additions or alterations to the typical PEP components listed below are likely, due to the unique nature of each specific project. Any special construction elements should be identified and addressed in the PEP or a separate document such as the work breakdown structure dictionary or design requirements, drawings, and specification documents.

The PEP at the end of the Final Design Phase is incorporated as part of the construction award through reference to define the award scope, schedule, configuration and contingency control, and project governance.

Table 3.4.1-1 List of the Typical Components of a Project Execution Plan, with Sub-Topics and Descriptions

Component	Sub-Topics	Description of Sub-Section Requirements
1. Introduction	1.1 Scientific Objectives	Description of the research objectives motivating the facility proposal.
	1.2 Scientific Requirements	Comprehensive statement of the Requirements Matrix/ Key Science Requirements to be fulfilled by the proposed facility (to the extent possible identifying minimum essential as well as desirable quantitative requirements), which provide a basis for determining the scope of the associated infrastructure requirements.
	1.3 Facility / Infrastructure	Description of the infrastructure necessary to obtain the research and education objectives.
	1.4 Scientific & Broader Societal Impacts	Description of the Broader Societal Impacts associated with the purpose of the facility, including the scope of work, budget and schedule related to science community or society related actions or interactions.
	1.5 Facility Divestment Plan	Description of plans and estimate of divestment liabilities at the end of facility life for transfer, demolition, site remediation, decontamination, etc., where appropriate.
2. Organization	2.1 Internal Governance & Organization and Communication	Internal Project Governance and Organization Structure with clear lines of authority, responsibility, and communication between Internal and institutional governance and oversight and advisory committees.
	2.2 External Organization and Communication	External Project Organizational Structure and Governance, showing clear lines of authority, responsibility, and communication between NSF, any partners, and the Recipient.
	2.3 Partnerships	Role of interagency or international partners in future planning and development and/or construction. Plans, agreements, and commitments for interagency and international partnerships. Description of the project's stakeholders and their roles, responsibilities and meeting schedules.
	2.4 Roles and Responsibilities	Roles and Responsibilities of key project personnel and governance groups.
	2.5 Community Relations and Outreach	Community Relations and Outreach plans for building and maintaining effective relationships with the broader research community that will eventually utilize the facility to conduct research and with the public. Description of scientific and educational outreach programs.
3. Design and Development	3.1 Project Development Plan	Description of 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, forming partnerships, etc.

Component	Sub-Topics	Description of Sub-Section Requirements
	3.2 Development Budget and Funding Sources	Estimate of total budget required to perform Design and Development, including NSF funding and any contributions from partners and other outside sources.
	3.3 Development Schedule	Schedule of design and development activities and milestones, at a level of detail appropriate to the maturity and complexity of the work.
4. Construction Project Definition	4.1 Summary of Total Project Definition	Summary at Work Breakdown Structure (WBS) level II of total construction project scope, cost, and schedule required to complete the construction or implementation project, indicating the baseline (pre-award) or Performance Measurement Baseline (PMB) (post-award) and contingencies funded by NSF as well as any associated scope supported by other funding sources.
	4.2 Work Breakdown Structure (WBS)	WBS contains a product-oriented, hierarchical framework that organizes and defines the total scope of the project into individual project component that represent work to be accomplished, aggregating the smallest levels of detail into a unified project description. The WBS integrates and relates all project work (cost, schedule and scope) and is used throughout the project management to identify and monitor project progress.
	4.3 WBS Dictionary	WBS dictionary defining scope of each WBS element, through all levels.
	4.4 Scope Management Plan and Scope Contingency	The plan describes how the scope will be defined, developed, monitored, controlled, and validated, and how scoping opportunities and descoping options will be realized. Scope Contingency compiles savings from potential de-scoping options, with decision points for exercising options and time-phased cost and schedule.
	4.5 Cost Estimating Plan, Executive Summary, and Baseline Budget	A plan to establish and communicate how the preparation, development, review and approval of the estimate will be completed. An executive summary provides a summary of the costs at a high level and an overall basis of estimate.
	4.6 Budget Contingency	Contingency budget and description of method for calculating contingency, including confidence level for completing within budget.
	4.7 Cost Book, Cost Model Data Set, and Basis of Estimate	The Cost Book is the comprehensive and well-documented compilation of Cost Book Sheets for the total project cost. The cost model data set is used as input to software tools and/or project reports to organize, correlate, and calculate different project management information. The Basis of Estimate provides supporting documentation outlining the details used in establishing project estimates such as assumptions, constraints, and estimating methods, and referencing the technical information used.

Component	Sub-Topics	Description of Sub-Section Requirements
	4.8 Funding Profile	Show the proposed NSF Funding Profile by year with baseline commitment and anticipated contingency allocation profiles. Also provide a total funding profile from all sources if applicable.
	4.9 Baseline Schedule Estimating Plan and Integrated Schedule	Schedule (without contingency) for the overall project and each major subsystem, including system integration, commissioning, acceptance, testing and transition activities; as well as major milestones and milestones for reviews, critical decisions and deliverables. It uses formal scheduling programs, is based on the WBS hierarchy, and is resource-loaded before the construction/implementation stage. Baseline schedule does not include schedule contingency.
	4.10 Schedule Contingency	Schedule contingency amounts and project end date with contingency; state method of calculating contingency, including confidence level for meeting project end date.
5. Staffing	5.1 Staffing Plan	Staffing FTE plan, per NSF and other project-specific job categories, over time. Application of indirect cost rates must be articulated in Cost Estimating Plan (CEP) and Basis of Estimate (BOE) per Section 4.2 of this Guide.
	5.2 Hiring and Staff Transition Plan	Schedule and requirements for hiring and training staff, including timelines for increasing or decreasing staffing levels. Required qualifications for key staff.
6. Risk and Opportunity Mgt	6.1 Risk Management Plan	Risk Management Plan describes the methodology/process for identifying, ranking, analyzing, tracking, controlling, and mitigating risks. Describes both qualitative assessment and quantitative analysis methods.
	6.2 Risk Register	A tracking document or tool that provides a ranked list of identified risks, with risk impact analysis and prioritization, responsibilities, mitigation plans and opportunities of risk reduction, and risk status over time. Documents data and assumptions used in risk analysis.
	6.3 Contingency Management Plan	Contingency management plans and approval process using change control. Describe NSF approval requirements per cooperative agreements (CAs).
7. Systems Engineering	7.1 Systems Engineering Plan	Systems Engineering Management Plan; roles and responsibilities.
	7.2 Systems Engineering Requirements	System-level design and technical feasibility study, including definition of all functional requirements and major systems. Identifies all technical design requirements, drawings, and specifications.
	7.3 Interface Management Plan	Identification of interfaces between major components or WBS elements and plans for managing communication, interferences, and interactions. Interface Management Plan and Documentation.
	7. 4 QA/QC Plans	Quality assurance and quality control requirements and description of processes.

Component	Sub-Topics	Description of Sub-Section Requirements
8. Configuration Control	8.1 Configuration Control Plan	Configuration Control plans.
	8.2 Change Control Plan	Change Control Plan to manage accounting changes and changes in the baseline or PMB plan: changes in scope, modifications to budget or schedule, and movement of contingencies into or out of the PMB. Includes approval and documentation processes plus roles and responsibilities.
	8.3 Document Control Plan	Document Control Plan for managing version control, access, and archiving of project related documentation.
9. Acquisitions	9.1 Acquisition Plans	Describe acquisition plans, processes, subawards, and contracting strategy. Provide a time-based list of acquisitions and procurement actions.
	9.2 Acquisition Approval Process	Describe the approval process for acquisitions (NSF, internal), and create a year by year Acquisition Plan of actions that are estimated to require NSF approval.
10. Project Mgt. Controls	10.1 Project Management Control Plan	Description of the project management organization and processes.
	10.2 Earned Value Management System (EVMS) Plan	Description of the EVMS plans, processes, software, and tools.
	10.3 Financial and Business Controls	Description of Financial and Business processes and controls.
11. Site and Environment	11.1 Site Selection	Site selection criteria and description of selected site(s).
	11.2 Environmental Aspects	List need for any Environmental Impact Statements, permitting, site assessments, etc.
12. Cyber-Infrastructure	12.1 Cybersecurity Plan	Plan for protecting access, confidentiality, and integrity of key information assets of the facility.
	12.2 Code Development Plan	Plan to enable critical scientific/engineering capabilities and data flows within the facility as well as interoperability with key external collaborators or stakeholders.
	12.3 Data Management Plan	Plans for acquisition and integration of equipment or services from third parties.
13. Environmental, Safety and Health	13.1 Environmental, Safety and Health Plans	Environmental, Safety and Health plans (ES&H).
14. Review and Reporting	14.1 Reporting Requirements	Statement of reporting requirements, including notifications for specific events and periodic reports on progress and project technical and financial status per NSF contractual requirements or CAs.
	14.2 Audits and Reviews	Statement of the required and proposed reviews, audits, and assessments for progressing during project life cycle through project close-out.

Component	Sub-Topics	Description of Sub-Section Requirements
15. Commissioning	15.1 Integration and Testing Plan	Describes the acceptance criteria and technical activities that should be completed as part of construction to transition the facility to operations.
	15.2 Operational Readiness Plan	Plan for determining operational readiness; includes administrative (non-technical) acceptance procedures to transition the facility from construction to operations such as conducting the operational readiness review and the authorities for making the determination(s).
	15.3 Concept of Operations Plan	Plans for, and estimate of, annual operations and maintenance costs (staffing, services, material/supplies, etc.) and funding sources that will be needed when the facility has completed construction and is transitioned to operations. This plan should include activities to bring the facility to full science capability after acceptance.
	15.4 Segregation of Funding Plan	Financial accounting procedures for the Recipient to properly expense the activities between construction and operations funding per the Plans above.
16. Project Close-out	16.1 Project Close-out Plan	Procedures and criteria for closing out the project. Includes acceptance of verification of technical performance as well as documented completion of all scope contained in the WBS dictionary. Includes procedures documentation for closing out all acquisitions and financial accounting.

3.4.2 Detailed Guidelines for Project Execution Plans

This section elaborates on the various components outlined in the previous section, Components of a Project Execution Plan, and offers additional information that should be helpful to individuals newly involved in planning for construction and future operations. Each of the sub-sections below are aligned to the PEP Components identified in Section 3.4.1 and provides some cross-reference to other sections of this Guide.

3.4.2.1 Introduction *[Reserved]*

3.4.2.2 Organization *[Reserved]*

3.4.2.3 Design and Development *[Reserved]*

3.4.2.4 Construction Project Definition

Refer to Section 4.2.2.1 for guidance on the cost estimating plan (CEP). The cost estimate should include an executive summary of the estimate, including narrative, figures, and tables per Section 4.2.3.2.

3.4.2.5 Staffing *[Reserved]*

3.4.2.6 Risk and Opportunity Management

Refer to Section 6.2 for Risk Management Guidelines.

3.4.2.7 Systems Engineering *[Reserved]*

3.4.2.8 Configuration Control

Refer to Sections 2.4.1, 4.2.5.5, and 4.6.5 regarding changes to the performance measurement baselines (PMB) and the use of budget and schedule contingency.

3.4.2.9 Acquisitions *[Reserved]*

3.4.2.10 Project Management Controls

Refer to Sections 4.6.3.6 and 6.8 for more information and guidelines on earned value management systems (EVMS).

3.4.2.11 Site and Environment *[Reserved]*

3.4.2.12 Cyber-Infrastructure

Refer to Section 6.3 for guidelines on cybersecurity.

3.4.2.13 Environmental, Safety and Health *[Reserved]*

3.4.2.14 Review and Reporting

Refer to Sections 4.2.5.8 and 4.6.2 for more information on reporting to NSF.

3.4.2.15 Commissioning

Every major facility has 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. Therefore, the systems engineering documentation indicates the timing of and criteria for the facility's transition to operations. These principles should be applied to generate four plans prior to the start of construction.

Transition from construction to operations could be a single acceptance event or multiple depending on the nature of the project. Many facility projects require integration and testing, followed by commissioning activities to bring the facility up to the design level of operation. Depending upon the complexity and time needed to reach design specifications, commissioning may be split between the construction effort and operations. Commissioning milestones should be included in the resource-loaded schedule to identify key elements associated with this transition. The scope of construction activities is defined in the project's Integration and Testing Plan (PEP-15.1) and the Operational Readiness Plan (PEP-15.2) and is included in the initial construction budget request as part of the baseline. The PEP is included by reference in NSF's construction cooperative agreement (CA) or contract with the Recipient institution, documenting the mutual understanding of the work scope funded under construction.

The Integration and Testing Plan is a comprehensive set of prescribed inspections and tests within the project technical requirements and provides the means for a process of verification, throughout commissioning activities, that the facility is complete and ready for operations. Successful completion of all inspections and tests provides validation that the facility meets technical requirements and therefore passes all acceptance criteria. These tests should be included as part of the construction baseline and associated activities included in the resource loaded schedule.

The Operational Readiness Plan defines the process for acceptance at the end of construction and determining operational readiness. The Plan should include an overview of the acceptance inspections and tests that verify and validate technical requirements and interfaces to transition the facility from construction to operations. Verification is the process of checking that the construction meets specification as defined in the Integration and Testing Plan. Validation is the process of checking whether the construction meets the scientific objectives. Administrative acceptance procedures are to identify the authorities, such as project team members, review team or independent agents, for making the determination(s).

A Concept of Operations Plan (PEP-15.3), also required by the PEP, defines the resources and funding needs when the facility has completed construction and is transitioned to operations and is refined during the Construction Stage in preparation for entering the Operation Stage[1]. In some cases, particularly with distributed facility projects, early operations funding begins to increase as aspects of a facility come on line, although full construction funding may not have concluded. Although these Stages may overlap in time, the hand-off from construction project responsibility and funding to operations responsibility and funding must be defined and managed separately due to segregation of funds requirements (PEP-15.4).

These plans are to be reviewed during conceptual, preliminary, and final design reviews. The plans are updated as needed during the Construction Stage. At least one year prior to initial commissioning activities, the plans must be updated and provided to NSF for review. Commissioning verifies that the substantially complete facility operates over its full range of capabilities as specified in the final design documents. Once the commissioning planning is complete, an operations readiness review may be held (either separately or as part of a Construction Stage review) to examine and comment on the plan. This can be conducted separately or as a component of one of the required annual reviews. The review is organized and conducted by the Program Officer (PO) in consultation with the LFO Liaison and Grants and Agreements Officer (G/AO) similarly to other reviews.

Refer to Sections 3.5 and 4.4 for more information on operations planning and commissioning.

3.4.2.16 Project Close-out Plan

Refer to Section 2.4.2 for more information on project close-out.

[1] See Section 3.5 for operations planning guidance.

3.5 OPERATIONS PLANNING

3.5.1 Preparation of Proposals for Operations and Management

In order to avoid funding gaps, formal proposals to operate a facility should be prepared well in advance of the anticipated start date for operations: as much as two years prior to the end of construction and commissioning activities. Program Officers (PO) and Directorates/Offices are encouraged to take into account the time needed for internal NSF review, including NSB review, and offer guidance to the community. Estimates of the funds for operations and maintenance are provided even in the planning stages of a facility. The potential Recipient and/or the PO need to establish a dialogue with the user community to determine the resources needed to fully exploit the facility. In addition, the proposal should include:

- All costs to operate, maintain and periodically upgrade the facility, its instrumentation and the IT components, including cost and approximate time of investment (Note: A PO can expect that IT components will need to be upgraded at least every 3 to 5 years);
- The costs of an in-house research program (as a separate line item in the budget), if applicable, including an indication of how the overall research program will be managed and how research program resources will be allocated;
- Education and outreach plans and costs;
- A detailed management plan for operations of the facility, including the roles of key staff and plans for advisory committees.

Note that Section 4.2 provides requirements for cost estimating. The cost estimating plan may be incorporated in the annual operations plan.

The review of the proposal includes a realistic assessment of the costs to operate and maintain the facility in a safe and effective manner. The PO is also responsible for oversight of operational facilities through the various reviews and reports described in the Internal Management Plan (IMP) and the terms and conditions of the award instrument. In addition to following the procedures referenced as appropriate to Chapters V and VI of the *Proposal and Award Manual* (PAM), the PO considers (with the assistance of external reviewers with expertise in managing comparably scaled facilities) these questions:

- Is the facility ready for reliable operations and is the infrastructure (including personnel requirements) adequate to execute the proposed work plan?
- Do the operations and maintenance plans allow for optimal utilization of the facility by users (e.g., scheduled operating time versus down-time)?
- Is the data management plan in place and ready to support operations?
- Is there an appropriate balance between in-house research and research of external users?
- Are safety (including cyber-security and security of the physical plant), environmental and health issues, if any, addressed?

- Are plans for securing human subjects and/or vertebrate animal clearances included, if applicable (e.g., assessments of education-related activities)?
- Are the Educational Outreach and Broader Societal Impact plan and cost reasonable and include an appropriate strategy to evaluate the outcomes?
- Have all costs been considered and estimated and is the available funding sufficient, or is some adjustment needed?

Initial operations awards are generally either a five (5) or ten (10) year duration. Throughout the operational stage, the Recipient operates and maintains the facility in accordance with the terms and conditions outlined in the cooperative agreement (CA). The PO, together with the G/AO, drafts the CA that will govern the operational phase of the project in accordance with the procedures contained in Chapter VIII of the PAM. The CA will include plans for NSF oversight, reflect the needs of the facility users, and address how the user program will be managed and how user time will be allocated. The PO provides oversight for all aspects of operations, maintenance and the research and education program. The PO also maintains an awareness of emerging technical, managerial and financial issues through contact with the facility managers and users, and through oversight, reviews and reports.

Requests for annual funding increments may follow similar review and approval procedures as initial operations awards depending on the particulars of the Facility and the annual funding request. For some facilities, the annual report (submitted through FastLane) will constitute the funding request/proposal for the next year of funding.

3.5.2 Procedures for Renewal or Recompetition of an Operating Major Facility

At least two years prior to the expiration of an award for operations of a facility,[1] the Program Officer (PO) will plan a review of the results of research and education, the affected community's needs, and the facility's management, including the performance of its managing organization. The reviews will be used to determine whether to renew the award, upgrade the facility, recompete the award or terminate operation of the facility. If the reviews show that the facility is of low priority relative to other funding opportunities within the field(s) of research served by the facility, or is otherwise not meeting its goals and objectives, the PO, working with the Division Director (DD) and Assistant Director (AD)/Office Head, will prepare a plan for either upgrading the facility's capabilities or divesting/closing out support.

The evaluation of the need for a competition for either a continuing or transitioning facility should be deliberate and weigh the potential benefits of an effective management against the tangible and intangible costs of that competition. The review should analyze the costs and benefits of the facility, taking into consideration the following issues:

- Given the state of the relevant discipline, community recommendations, overall facility merit, and programmatic balance, should a major facility be continued, transitioned, or sunset?
- Is a change in awardee that could result from a competition feasible?
- Has NSF program management clearly defined its goals for a possible competition?
- Does the past performance of the incumbent facility operator, as evaluated by surveys, review visits, and site audits, warrant a competition?
- How long has it been since the last management competition?
- Has NSF identified and evaluated all encumbrances that may create significant obstacles to changes in the facility management?
- Is there the potential for a meaningful competition?
- In addition to the points raised above, are there other facility-specific issues and risks that could affect the decision and/or timing on undertaking a competition?

Federally Funded Research and Development Centers (FFRDCs) follow a slightly different process as outlined in the Federal Acquisition Regulations (FAR Part 35.017-4, Reviewing FFRDCs): An FFRDC review should include the following: (1) an examination of the sponsor's special technical needs and mission requirements that are performed by the FFRDC to determine if and at what level they continue to exist; (2) consideration of alternative sources to meet the sponsor's needs; (3) an assessment of the efficiency and effectiveness of the FFRDC in meeting the sponsor's needs, including the FFRDC's ability to maintain its objectivity,

[1] The PO should exercise judgment and consider the complexity of the facility in determining whether to begin the review process earlier.

independence, quick response capability, currency in its field(s) of expertise, and familiarity with the needs of its sponsor; (4) an assessment of the adequacy of the FFRDC management in ensuring a cost-effective operation; and (5) a determination that the criteria for establishing the FFRDC continue to be satisfied and that the sponsoring agreement is in compliance with FAR 35.017-1.

If the reviews show that the facility remains a high priority and has been successful in meeting its goals and objectives, the Sponsoring Organization considers whether renewal of the operating agreement with the Recipient institution, or recompetition, is in the best interests of NSF and the affected community. Awards may be renewed without recompetition or with only limited competition if there is sufficient justification (e.g., facilities or facility sites with special features that preclude relocation or recompetition, or partnership-related complexities that prevent recompetition).

After the appropriate review has been completed, the PO analyzes what can and what needs to be done in light of the available funding, and recommends one of the following actions:

- Recompete the award;
- Renew NSF support;
- Renew NSF support and plan upgrades to the facility;
- Renew NSF support to allow operations to transition to self-sufficiency (through, for example, institutional, industrial or other modes of support);
- Renew NSF support to allow operations to ramp-down, leading to divestment; or
- Closeout award, terminate NSF support and divest.

In the event that a decision is made to recompete or to closeout support for a facility, the PO will give the incumbent Recipient as much notice as possible, but not less than one year, so that all necessary arrangements to transfer (in the case of unsuccessful recompetition by the incumbent management entity) or terminate obligations to vendors and employees can be planned and implemented.

In most cases of recompetition, the managing organization of a facility is required to compete with other organizations for continuation of the management of the facility and renewal proposals are received from the Recipient institution and/or from other institutions. The proposal(s) is (are) merit reviewed in accordance with procedures in Chapters V and VI of the PAM. The normal thresholds for Director's Review Board (DRB) and NSB award authorization apply.[1]

[1] Refer to the footnotes in Section 2.1.6 for the National Science Board for award thresholds and properties requiring DRB recommendation and NSB authorization.

3.5.3 Detailed Guidelines for Oversight of Operations

Please contact the cognizant NSF program officer for additional details regarding NSF's oversight of the operational phase of major facilities. Internal operating guidance elaborates on the principles outlined in the Major Facilities Guide and offers additional information and examples that should be especially helpful to individuals newly involved in operational oversight.

3.6 FACILITY DIVESTMENT PLAN

After a decision for divestment is made for the closeout of the facility operation under a NSF award, the current operations management should start the preparation for the divestment. The current management should consult stake holders and the program office to appoint appropriate personnel or management team that will be responsible for managing the transition activities in the divestment process. The transition team needs to develop a transition plan and submit to NSF program office. To ensure the smooth and successful transition, the current operations management should be involved and be an integral part in the development of the transition plan. The transition plan should first specify the model of divestment and the final goal of the transition, such as a new operation model under different funding mechanism, or decommissioning. The following elements should be included in the plan:

- Target date for completing the transition;
- Organizations involved in managing the transition activities
- Estimated cost of transition, which includes labor and material cost, as well as the estimated contingency based on the uncertainties and risks
- Plan for environmental impact analysis;
- Plan for resolving contractual issues and closing of contracts
- Any additional costs and responsibilities (e.g., HR and personnel-related costs, environmental remediation, etc.) associated with divestment/decommissioning should be noted to the extent possible."

The plan should identify key steps during the transition period with each step detailed with a clearly defined goal and target timeline. The plan should identify the organizations that handle the transition matter at each stage with clearly defined authorities and responsibilities. If the divestment is accomplished through changing the funding source or a new model of operation, the transition plan should identify the new management organization and include the following elements:

- Description of the new model of operation and NSF's role under the new model;
- The costs to NSF under the new operation model, and
- A hand over procedure to the new management organization.

If the divestment is accomplished through decommissioning, the plan should identify the equipment or facilities that need to be disposed and include the following elements:

- Cost and procedures for proper disposal of equipment;
- Cost and plan for environmental and site remediation.

If there are pension and health care responsibilities after the divestment, the plan should describe how these responsibilities will be handled and the source of required funding.

The transition plan should also include the risk management during the divestment transition process. This includes list of risks, risk mitigation and management plan.

4 KEY MANAGEMENT PRINCIPLES AND REQUIREMENTS FOR MAJOR FACILITIES

4.1 INTRODUCTION

This section provides greater detail about key management, budgeting, and reporting activities that should be carried out throughout a project's life cycle stages, for both Major Research Equipment and Facilities Construction (MREFC) and non-MREFC projects, to ensure adherence to principles established by National Science Foundation (NSF).

Some of these activities will be funded via MREFC and others via R&RA, depending on life cycle stage.

4.2 COST ESTIMATING AND ANALYSIS

4.2.1 Overview of Guidance and Process for Both Construction and Operations Awards

As noted in Section 1.1, award instruments can take the form of cooperative agreements or contracts. Unless otherwise noted, the guidance in this section applies to major facility projects regardless of the award instrument employed. Proposed budgets must comply with the applicable federal regulations, as implemented by NSF in the MFG, the Proposal and Award Policies and Procedures Guide (PAPPG) or the Guide to the NSF Contracting Process. Recipients are required to follow the best practices within the GAO Cost Estimating and Assessment Guide[1] and GAO Schedule Assessment Guide[2], taking into consideration NSF policy and practice as provided in this Guide. These NSF and Government Accountability Office (GAO) Guides are intended for all Stages in a facility's life cycle. However, portions of these Guides may be tailored depending on what is relevant to the particular facility estimate. Accordingly, **Recipients must note any departures from these NSF and GAO Guides and explain their rationale in the Cost Estimating Plan (CEP)[3].** Additional guidance on how to apply the relevant practices from the GAO Cost Guide and examples of potential deviations are provided in Section 4.2.2.3.

The guidance herein clarifies NSF expectations for the format, content, supporting justification, and good practices for Recipient cost estimates. This guidance also explains the NSF cost analysis process and timeline. By following this guidance Recipients should expect a better estimate and a more efficient review by NSF, facilitating achievement of the science mission. For existing awards, the Recipient should consult with the PO.

NSF uses internal staff, outside experts, and panel reviews to analyze estimates for construction and operations awards. The Recipient estimates must meet two sets of criteria that also serve as the basis of the NSF cost analysis: (1) the cost principles of either 2 CFR § 200, Subpart E for non-profit entities or the Federal Acquisition Regulation, Part 31 for for-profit entities, and (2) the GAO Cost Guide. Cooperative support agreement estimates must be allowable[4], allocable, and reasonable per the 2 CFR §200, Subpart E, and realistic. To be deemed reasonable under the cost principles, the estimate must be developed in accordance with the best practices and twelve steps of the GAO Cost Guide to meet the four characteristics of a high-quality estimate

[1] GAO Cost Estimating and Assessment Guide[1]: Best Practices for Developing and Managing Capital Program Costs (GAO-09-3SP March 2009, or subsequent revision)

[2] GAO Schedule Assessment Guide[2]: Best Practices for Project Schedules (GAO-16-89G December 2015, or subsequent revision)

[3] 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.

[4] 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 Recipient's technical proposal (i.e., costs are not too low).

(well-documented, comprehensive, accurate, and credible), as outlined in Tables 2 and 25 of the 2009 GAO Cost Guide.

As described in Section 2 of this guide, Recipients must develop estimates for design, construction, operation and divestment of facilities. Estimates should be well documented, comprehensive, accurate, and credible and should facilitate appropriate analyses from a wide variety of reviewers at the various life cycle stages. It is understood that cost estimates will undergo further refinement at each stage-gate review and the materials required herein will evolve accordingly. NSF will review estimates at an appropriate level as the project advances through the various facility life cycle stages.

Figure 4.2.1-1 below depicts the general NSF cost analysis process performed for construction and operations awards. The NSF Program Officer (PO), Grants and Agreements Officer (G/AO) or Contracting Officer (CO), Large Facilities Office (LFO) Liaison, and Cost Analyst conduct a detailed analysis of the Recipient cost estimate. NSF may also utilize independent cost estimates and cost estimate reviews[1] done by external panels and independent contractors or agencies to inform the analysis. The G/AO or CO and Cost Analyst review includes the detailed sub-elements, cost categories, and supporting basis of estimate discussed in this section of the Guide. The PO review includes the technical scope, risks, level of effort, schedule, and assumptions. The LFO Liaison supports analysis of any risks and proposed contingency budget. The inputs from the various sources are integrated and addressed with the Recipient, which could potentially result 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 realism of the cost estimate, technical scope of the project, and the availability of funds. The G/AO or CO approves the Recipients' cost estimate and ultimately the award of the proposal and approved budget based on the results of the cost analysis.

For construction awards, the NSF cost analysis is done at the end of each Design Phase, in conjunction with CDR, PDR, and 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 recompetition 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 during construction or operations to support significant changes in scope, schedule, cost, risk or complexity. These latter types of analysis may only require 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 prior to proceeding to the next design phase or prior to 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. During the review time window, the Cost Analysis and Pre-Award (CAP) Cost Analyst may

[1] The definition for Independent Cost Estimate Review in Lexicon is adapted from Table 27 in GAO Cost Estimating and Assessment Guide.

perform a cost analysis (typically 60 calendar days duration) in parallel with other review activities to augment the G/AO review and target specific areas noted in Section 2.1.6.2 and Figure 4.2.1-1.

If there are issues with the provided information, the PO, G/AO or CO, LFO, and/or Cost Analysts may require additional documentation and justification and further interaction with the Recipient prior to completing the analysis. Communication among all parties as well as a sound initial basis of estimate are essential for timely and successful completion.

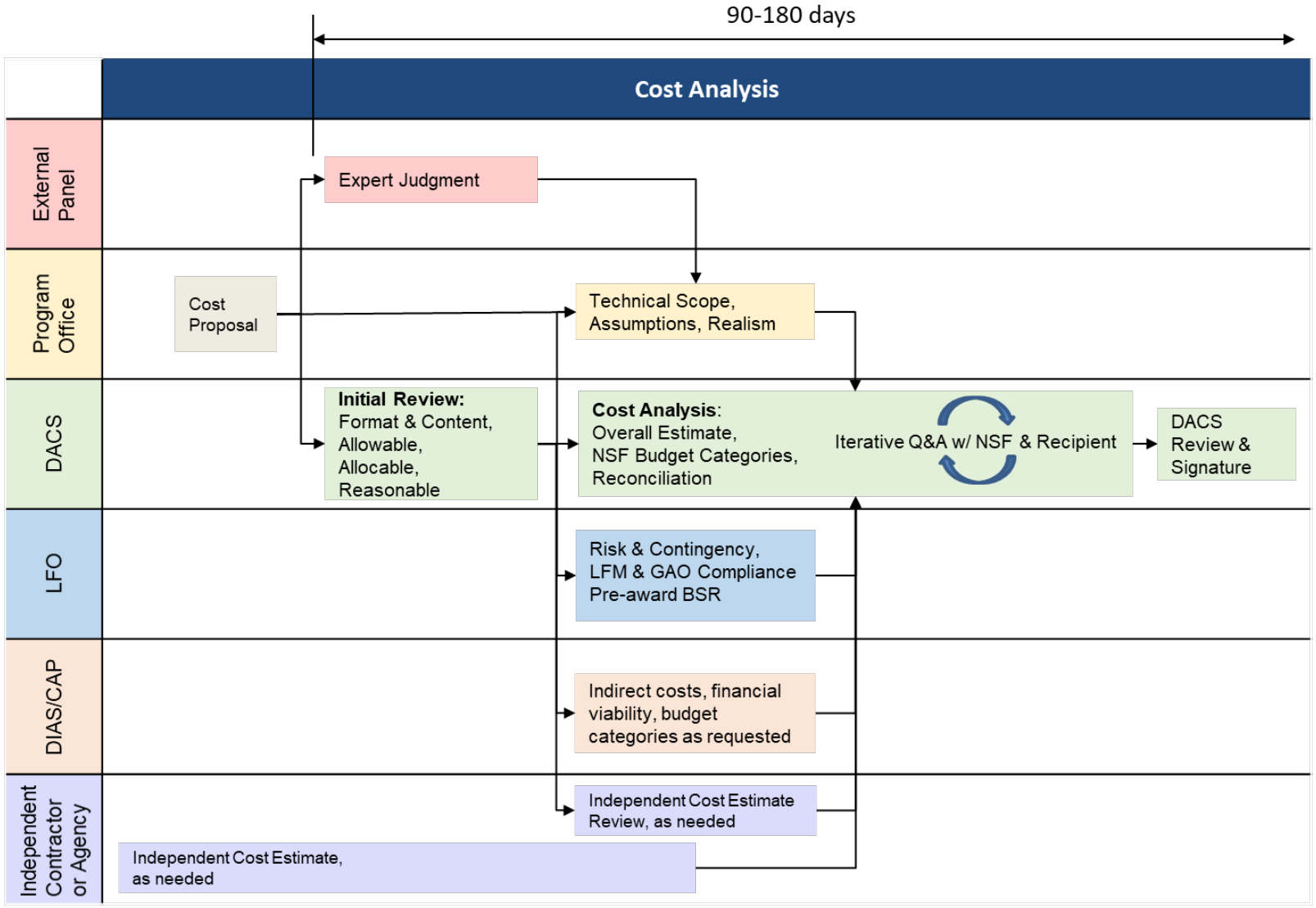
When submitting construction or operations estimates for cost analysis, Recipients must submit the following as a minimum:

- Cost Estimating Plan per Section 4.2.2.1.
- "Cost Model Data Set" per Section 4.2.2.1.
- Reports and Proposals per Sections 4.2.2.2 and either 4.2.3.2 or 4.2.4.2.
- The Work Breakdown Structure (WBS) per Section 4.2.2.7.
- Supporting information forming the Basis of Estimate (BOE) per Sections 4.2.2.3, 4.2.2.4, 4.2.2.5, 4.2.2.6, and either 4.2.3.4 or 4.2.4.4

For proposals that contain subawards[1], each subaward must include a separate budget justification.

[1] See the Section 9 Lexicon for the difference between a "subaward", which transfers significant effort from the Recipient to another entity, and a "contract, which involves the purchase of materials and supplies, equipment or general support services allowable under the award.

Figure 4.2.1-1 NSF Cost Analysis Process



4.2.2 Elements of Both Construction and Operations Estimates

4.2.2.1 Cost Estimating Plan

For new construction and operations awards, Recipients must develop and submit a Cost Estimating Plan (CEP) to establish and communicate how the preparation, development, review and approval of the estimate will be or was completed. For existing awards, the Recipient should consult with the PO regarding the CEP. Ideally the CEP will be developed and discussed with NSF far in advance of submission (e.g., one year for major facility awards) to ensure that that Recipient'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(s) that come later and, along with the basis of estimate, critically important for generating a high-quality estimate to facilitate management decisions and NSF cost analysis. Recipients should contact their NSF PO, G/AO or CO, LFO Liaison, and/or Cost Analyst for more information or guidance.

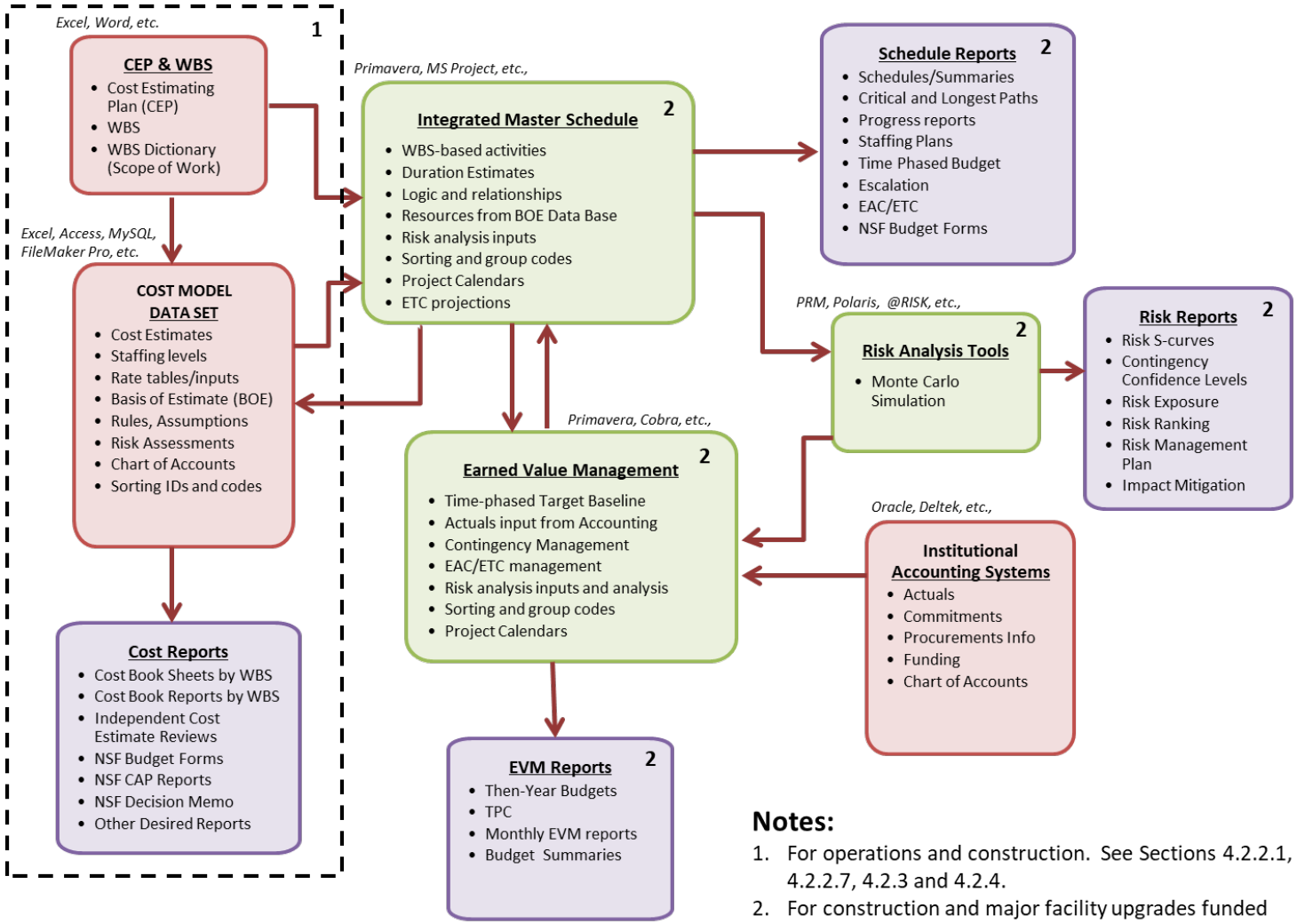
The CEP must state the purpose(s) of the estimate and describe how the guidance in Section 4.2 of this Guide, the PAPPG, "2 CFR Part 200, Subpart E – Cost Principles," and the GAO Cost Estimating and Assessment Guide will be or has been implemented. Recipients must note any departures from these NSF and GAO Guides and explain their rationale in the CEP**.** The CEP should also state the schedule of specific tasks, due dates, roles and responsibilities, practices, systems, and calculations used to develop the cost estimate. The CEP should describe the expected cost estimating methodology, maturity, and, if applicable, accuracy range[1] at each Stage or Phase (e.g., expert opinion, analogy, parametric, engineering build-up, historical data). The CEP 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. Recipients should also discuss the independent cost estimates and reviews, if any, they are planning to validate the project estimate.

The CEP should be tailored to the stage of the facility life cycle and address the most relevant costs, from Development and Design through Construction, Operation, and Divestment. The CEP should explain how the cost estimate may evolve over time. For example, the expected level of funding needed for the Operations Stage should be identified at the Conceptual Design Review. Operating cost estimates will be refined and updated throughout the design and construction process as further discussed in the Concept of Operations Plan, developed as part of the PEP described in Section 3.4 of this Guide. The CEP presented in an Operations Proposal, whether submitted by the Recipient of the construction award or by a separate entity, should be informed by the budget information and planning contained in the Concept of Operations developed in the PEP.

[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

The CEP should explain how the "Cost Model Data Set" will meet the various needs of the facility. The "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. Figure 4.2.2-1 provides an example of a how a "Cost Model Data Set," Work Breakdown Structure, and a Recipient's institutional accounting systems can be used as inputs in conjunction with scheduling, earned value, and risk analysis tools to generate a variety of output reports for project purposes. Sections 4.2.2.7, 4.2.3 and 4.2.4 of this Guide refer specifically to the work breakdown structure, "Cost Model Data Set," and "Cost Reports" blocks encircled with dashed lines in Figure 4.2.2-1. The CEP is included as part of the PEP as described in Section 3.4 of this Guide.

Figure 4.2.2-1 Sample Project Control Systems Relationship Diagram



Notes:

1. For operations and construction. See Sections 4.2.2.1, 4.2.2.7, 4.2.3 and 4.2.4.
2. For construction and major facility upgrades funded through operations based on the technical nature of the proposed activities. See Sections 4.2.6, 4.3, 6.3 and 6.8.

4.2.2.2 Estimate Formats

The Recipient must be capable of providing the cost estimate in multiple formats and reports, including but not limited to the following:

- Reports based on a deliverable-based work breakdown structure (WBS) for construction and a functional, activity, and/or deliverable based WBS for operations, as further described in Sections 4.2.2.7, 4.2.3.3, and 4.2.4.3 below. These reports support project management and execution and detailed cost analysis of sub-elements and are referred to as Cost Books.
- Reports based on the standard NSF budget category format[1], depicted in Figure 4.2.2-2 and Section 4.2.2.4 below, per NSF budget and budget justification guidance from the PAPPG. This format supports cost analysis of NSF budget categories. For contracts, NSF proposal requests may specify alternate formatting in lieu of the NSF budget categories.

The estimate is built-up from the individual WBS elements and sub-elements. See Section 4.2.2.7 for guidance on work breakdown structures. If the costs associated with each WBS element are binned into the appropriate NSF budget categories, then both of the above reporting formats can be readily produced. For example, costs can be coded with NSF budget format letters (A through I per Figure 4.2.2-2) to populate rolled-up NSF budget format summaries as well as the Cost Book organized by WBS. The estimate should 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).

The cognizant NSF PO and G/AO, or CO can be contacted with questions or for other specific programmatic requirements.

[1] Projects may choose to use broad, summarized budget categories for internal planning and reporting, but reports with the detailed breakout into NSF budget categories must be supplied when requested. (Examples: a single combined "E-Travel" category for internal use rather than "E-1 Domestic travel" and "E-2. Foreign travel" in Figure 4.2.2-2; a single category "Labor" combining all NSF labor categories A through B-6.

Figure 4.2.2-2 NSF Budget Categories Sample Format

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

4.2.2.3 Application of GAO Cost Guidance to Major Facilities

The MFG is intended to supplement not duplicate the GAO Cost Guide, PAPPG, and industry good practices and standards. The best practices (twelve steps) of the GAO Cost Estimating and Assessment Guide are highlighted below to help show how they can be applied or tailored to NSF major facilities, including potential deviations, and how they should be integrated with NSF processes. Concise summaries of GAO's twelve steps and four characteristics of a high-quality cost estimate can be found in Tables 2 and 25 of the 2009 GAO Cost Guide and additional checklists are provided at the end of each chapter. By following the GAO Cost Guide, Recipients should expect a better estimate and a more efficient review by NSF, facilitating achievement of the science mission. NSF and independent reviewers use these GAO criteria and other methods when analyzing Recipient cost estimates to determine whether to make an award. Application of the GAO Schedule Assessment Guide is discussed further in Section 4.3.

GAO Cost Guide's Twelve Steps / Best Practices:

1. Define estimate's purpose:
    - The purpose must be clearly defined. There are typically two general purposes: (1) to help managers evaluate affordability and performance against plans, as well as the selection of alternative systems and solutions, including value engineering and scope management, and (2) to support the budget and award processes by providing estimates of the funding required.
    - Defining the purpose helps clarify the intended use and package the estimate to facilitate review by a range of 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 it, recreate it quickly with the same result, and be able to determine if it meets the GAO's twelve 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.
    - For additional descriptions and guidance on the purpose and context of the estimate, including why it is developed and how NSF uses the estimate, see MFG Sections 1.1, 2.3.1, 2.3.2, 2.3.3, 3.4, 4.2.1, 4.2.2.1, 4.2.3.1, 4.2.4.1, 6.2.1, 6.2.8.1, and Figure 4.2.1-1 and Figure 4.2.2-1.

2. Develop an estimating plan: A CEP must be developed and address the details described in Section 4.2.2.1.

3. Define program characteristics: Characteristics of the program being estimated must be defined for construction projects per the Project Execution Plan in Section 3.4 and for operations awards per the Proposal and Work Plan in Sections 2.5 and 3.5.

4. Determine estimating structure:
    - The estimate must be organized by both the WBS and NSF budget categories as described further in Sections 4.2.2.2, 4.2.2.7, 4.2.3.3 and 4.2.4.3 and Figure 4.2.3-1 and Figure 4.2.4-1.
    - The estimate structure must have clear traceability between WBS, CEP, and BOEs, correctly roll-up to higher levels, and readily map between the WBS and NSF Budget Categories.

5. Identify ground rules and assumptions (GR&As):
    - The ground rules (a common set of agreed on estimating standards that provide guidance and minimize conflicts in definitions) and assumptions (a set of judgments about past, present, or future conditions) must be clearly defined and documented in the CEP, as described in Section 4.2.2.1.
    - The GR&As 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&As may be global, in which case they apply to the entire estimate and should be clearly and consistently used throughout the. GR&As may also be program-specific or WBS element-specific, driven by the particular technical requirements.
    - The potential impacts from changing GR&As should be considered when developing the sensitivity and risk analyses.
    - For NSF major facilities, GR&As often include inflation, escalation, indirect rates, travel, fringe benefits, schedule or budget constraints, acquisition strategy, participation of other agencies or governments, level of technology maturity and required research and development. GR&As also often define what is included and excluded from the estimate, such as use of existing or multi-purpose equipment and facilities.

6. Obtain data:
    - The estimating methods, level of detail, accuracy range, 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.
- Recipients should carefully consider data sources and the 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 cyber-infrastructure, and unique, complex, new and/or evolving technologies.
- The best 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: (1) Actual/historical data for the systems or operations being estimated; (2) Detailed engineering build-up; (3) Parametric data with adjustments to reflect differences (e.g., technical, size, weight, quantity, location, schedule); (4) Analogous data with adjustments to reflect differences; (5) Expert opinion, only if a secondary methodology is used to substantiate.
- Data sources, content, time, units, calculations and 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.

7. Develop point estimate and compare it to an independent cost estimate:
   - Recipients are encouraged to obtain independent cost estimates (ICEs) and cost estimate reviews to help validate and improve the quality of the estimate before submitting proposals to NSF. Recipients should address this as part of the CEP, as described in Section 4.2.2.1. Operations proposals do not typically warrant an ICE since analogous historical costs are readily available or the basis of estimate will typically not have the breadth and depth of technical and cost detail that is expected for a construction award.
   - As noted in Sections 4.2.1 and 4.2.2.1, NSF utilizes ICEs and independent cost estimate reviews done by external panels and independent contractors or agencies. An ICE is required prior to construction awards. An independent cost estimate review of some type is required of operations proposals prior to initial operations, renewal, and recompetition of awards. These ICEs and independent cost estimate reviews are used to validate the Recipient estimates, negotiate awards, check for compliance with GAO best practices and Uniform Guidance Cost Principles, and inform the NSF cost analysis. Far in advance of reviews, the NSF PO, G/AO or CO, LFO Liaison, and Cost Analyst determine the type, timing, scope, and team required. Recipients should be prepared to support these

efforts, address any findings, and participate in reconciliations of proposals with ICEs.

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, highlighted for Recipient 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 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 all at once. The results of the sensitivity analysis can therefore be used to help identify and quantify risks that are then used in a probabilistic risk assessment to develop the contingency budget and confidence level.
    - The results of the sensitivity analysis can also inform decisions when analyzing alternatives for design, acquisition, construction, operations, and maintenance. Analyses can also drive actions to avoid, mitigate, transfer, or accept a risk.
    - For operations estimates that may consist largely of level of effort work, a more qualitative sensitivity review could be performed and justification 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. May be a ground rule and assumption, especially those least understood or most at risk of changing. For NSF major facilities, sensitive elements may include electricity, fuel, major commodities, inflation specific to certain cost categories, requirements changes, location, domestic versus foreign sources/procurements, acquisition strategy.

9. Conduct risk and uncertainty analysis:
    - Described further in Sections 4.2.5 and 6.2 below. The risk register data, basis of estimate, assumptions, and detailed methodology used to calculate contingency budgets must be documented and provided if contingency is requested. As described in Section 3.4 for construction projects, this information is documented in the Project Execution Plan components 4.6, 4.10, and 6.

- For operations, also see Section 4.2.6. These analyses are not typically required for operations awards unless a separate contingency budget is requested for facility or instrumentation upgrades or replacement projects. However, a summary of key operational risks, 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 (Step 8).

10. Document the estimate: Described throughout Section 4.2.

11. Present the estimate to management for approval: Described in Sections 2.3, 2.5, 3.4, 3.5, and 4.2.1.

12. Update the estimate to reflect actual costs and changes: Described throughout Section 4.2 and for EVM in Sections 3.4.1 and 6.8. Typically, not required for operations awards though work plans and budgets may be adjusted annually to reflect actual work done and updates to planned work.

4.2.2.4 Supplementary Guidance for NSF Budget Categories from the PAPPG

This section discusses types of additional detailed information typically needed by Recipients to justify the estimates by the required NSF Budget Categories. This information is intended to supplement the standard guidance for the NSF Budget Categories described in Chapter II.C.2.g of the PAPPG and depicted in Figure 4.2.2-2. This guidance is not all inclusive nor is it required. It is intended to clarify NSF expectations, assist Recipients, facilitate NSF review with fewer iterative resubmissions, and prevent recurrent issues. For each NSF Budget Category, Recipients should provide specific justifications to demonstrate costs are allowable, allocable, and reasonable per the cost principles of 2 CFR §200, Subpart E, and realistic.

The PAPPG states that budget justifications must be no more than five pages per proposal. However, most cooperative agreements for major facility projects (both construction and operations) will require substantially more pages.

The following apply to the salary data listed below. All Personally Identifiable Information should be removed from the documentation. If not already covered in the CEP, Recipients should provide a salary escalation rate for multi-year proposals, which can include a component for annual raises similar to Cost of Living Adjustments (COLAs) and other pay increases for promotions within the position classification. Recipients should provide the rationale behind the salary escalation rate. In some cases, NSF may provide a base escalation rate in the solicitation for guidance, but Recipients should follow Section 4.2.2.6 of this Guide when proposing rates. Recipients may contact their NSF PO, G/AO or CO, LFO Liaison, and/or Cost Analyst for a “Master Labor Schedule” template spreadsheet that can be used to compile all labor data for ease of estimating and justifying labor costs.

A – Senior Personnel

- Recipients should provide verification of actual salaries paid for named senior personnel. Salary rates should be based on actual costs per current rate paid by payroll register, W-2s, or appointment letters. Recipients should note Academic Year (9-10 month) versus Calendar Year (12 month) appointments or time available to conduct independent research if such appointments so provide. The Recipient should also provide documentation to support reasonableness of the salary rate paid, such as salary rate surveys, salary comparators, Human Resource Department analysis, or other information.
- NSF has a policy which typically limits senior personnel to two months effort in any given year for standard NSF-funded grants. However, most cooperative agreements for major facility projects (both construction and operations) have senior personnel effort well in excess of two months. Compensation in excess of two months, if anticipated, should be disclosed in the proposal budget, and explained in the budget justification.

B.1 – Postdoctoral Scholars

- Recipients should provide the average salary rate or rate range for postdoctoral students at the organization in the field of science. Actual payroll data may not be available as these may be to-be-hired positions.

B.2 – Other Professionals, Technicians, Programmer, 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 will likely need to be obtained by individual or by position for salary calculations. Recipients should also provide a spreadsheet with the budget justification that includes: name or position number, location, WBS, title, salary rate and period, level of effort as a percentage or in person-months, and calculation of amount for each award year.
- Recipients should provide supporting documentation for the salary rates of the technicians, programmers, and other professionals proposed. For these types of positions, NSF recommends the use of Bureau of Labor Statistics (BLS) Standard Occupation Classification Codes (SOC) by position title and referencing their positions to BLS salary rates to establish reasonableness of proposed salary rates. The BLS data is also available by region or city. Other salary rate survey data may be used, and larger Recipient organizations may already have established salary ranges and qualification bases established internally by their Human Resources Departments.

B.3 – Graduate Students

- Recipients should provide the average salary rate or rate range for graduate students at the organization in the field of science. Actual payroll data may not be available as these may be to-be-hired positions.

B.4 – Undergraduate Students

- Recipients should provide the average salary rate or rate range for undergraduate students at the organization in the field of science. Actual payroll data may not be available as these may be to-be-hired positions.

B.5 – Secretarial – Clerical

- Recipients should provide the average salary rate or rate range for secretarial clerical personnel at the organization.

B.6 – Other Personnel

- Generally, the same as B.2 above but special classifications could justify different treatment.

C – Fringe Benefits

- Most Recipient organizations utilize a single tier fringe benefit rate or fringe benefit rate by class of employee. Occasionally these fringe benefit rates are approved in the Negotiated Indirect Cost Rate Agreement (NICRA). In such cases, the Recipient can verify the rate and provide a fringe benefit calculation (rates by class) for a sample project year. These cases should be noted in the CEP.
- Some organizations use an actual fringe benefit amount by class of employee. These amounts vary greatly by employee salary levels. While some fringe benefit costs are based on a percentage of salaries (such as statutory withholding or contributions to retirement and Paid Time Off (PTO)), other fringe benefits such as medical insurance may be a lump sum amount and are not directly tied to salary paid. The Recipient should provide an estimate of each fringe benefit provided as a percentage to salaries paid along with a description of the fringe benefit provided as a means to gauge the reasonableness of the fringe benefit package provided.
- In both cases, Recipients should explain differences in the treatment of PTO. Some organizations include this as a component of the fringe benefit rate and others include the full cost of salary (including PTO) in the salaries as budgeted.

D – Equipment

- There can be equipment expenses or materials and supplies that individually are less than the threshold but taken together exceed the equipment threshold, particularly when installed or fabricated by a Recipient.
- Recipients should list each item of equipment individually and include a description, estimated cost, and justification of need. Recipients should typically provide vendor or catalogue quotes for each item of equipment when available. These quotes should be indexed and numbered to the equipment items proposed. For unique scientific instrumentation or other equipment components where vendor quotes are not readily available, a clear basis of estimate should be provided.

E – Travel

- Generally, the cost estimate should be detailed by individual destinations, type of transportation (airfare or mileage), per diem (lodging and meals) and other associated expenses. The relation of the travel to the proposed activities should also be included. For renewal projects, historical costs can be considered as a means of assessing the reasonableness of travel costs. Where there are large numbers of trips and the actual locations may not be known in advance, then cost estimating relationships (e.g., average of $1,500 per traveler per trip) may be used.

F – Participant Support

- Justification should include the number of participants, stipend amount, travel cost estimate, and subsistence costs per participant. Recipients should also provide the number of days or weeks of the training activities to provide a basis for determining reasonableness of the proposed payments.
- Participant support costs may not be used for personnel at the Recipient institution.

Note: All contracts for procurements or services needed to carry out the project must be listed in G.1,2,3,4, to align with the type of budget activity or in G-6 Other. All contracts must follow 2 CFR § 200.317-326 including price and cost analysis, competition, competition, contacting with women's, small and minority businesses, and contract provisions. For procurements by micro-purchase, i.e., purchase of supplies or services using simplified acquisition procedures, the threshold amount for all awards is $10,000 based on the American Innovation and Competitiveness Act. Contracts must not be listed in G.5 Subawards.

To assist Recipients in determining the difference between a subaward and a contract, please refer to the "Subrecipient vs. Contractor Checklist," developed by the Association of Government Accountants.

G.1 – Materials and Supplies

- An itemized listing is not necessary unless an item represents a substantial amount of costs. Vendor or catalogue quotes, historical costs, or other cost estimating relationships may be used to establish reasonableness of the cost estimate.

G.2 – Publication, Documentation, Dissemination

- Recipients should provide an estimate of publication and dissemination costs.

G.3 – Consultant Services

- For each consultant identified, the Recipient should provide justification that the proposed rate of pay is reasonable.

G.4 – Computer Services

- Where it is established institutional policy to direct charge computer services, the Recipient may justify and include such costs in the budget. Generally, such recharges should be based on established internal institution usage rates. Recipients should provide a supporting institutional statement or policy document and rates by units of actual usage.

G.5 – Subawards[1]

- Recipients of cooperative agreements are expected to conduct a pre-award risk review of the subawards to include both cost and price analysis and to identify risk as outlined in the Uniform Guidance, 2 CFR § 200.331.
- Recipients should provide NSF with their pre-award analysis of each of the proposed subawards when submitting for approval of each subaward. Such Recipient pre-award analysis should include a determination of Subaward risk. This should include an assessment of financial capability and ensuring the Subrecipient is not on any Federal Government "do not pay" listing. The Recipient should also have performed a price or cost analysis of the Subrecipient's proposed work to ensure the reasonableness of costs.
- NSF reviews the Recipient's documentation on each Subrecipient to ensure sufficient rigor and detail was performed.
- The Recipient must keep copies of the risk assessment performed, which should detail any key risks identified and how those risks were mitigated and resolved, cost and price

[1] A subaward is for the purpose of carrying out a portion of a Federal award and creates a Federal assistance relationship with the subrecipient. See 2 CFR § 200.92 Subaward. Characteristics which support the classification of a subrecipient versus contractor can be found at 2 CFR § 200.330. See also PAPPG II C.2.g (vi)(e).

analysis, and results of searches of the System for Award Management (SAM.gov), and Federal Awardee Performance and Integrity Information System (FAPIIS).

G.6 – Other

- Itemized Other costs per PAPPG II C.2.g (vi)(f), including the applicable budget contingency, should be summed here and described separately in the Comments area of the form.
- Budget contingency, when applicable, should be presented as a part of the total amount of Other Direct Costs under section G.6 on the standard NSF budget form. Budget contingency budget estimates should be developed in accordance with Sections 4.2.5 and 6.2 of this Guide and should include all fully burdened contingency amounts. The proposal should include adequate documentation on the basis of estimate for the contingency amounts, indicating that they were developed in accordance with 4.2.5 and 6.2 and are supportable. Budget contingency and allocations of contingency will be called out in the Cooperative Support Agreement by the G/AO under the "Contingency" section, based on information provided in the negotiated budget justification.

H – Total Direct Costs

- The total amount of direct costs requested in the budget, to include Lines A through G, must be entered on Line H.

I – Indirect Costs

- When the Recipient 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 CEP.
- When a Recipient does not have a NICRA, the Recipient should provide a calculation and an indirect cost rate proposal. The Recipient should ensure that indirect costs are in accordance with NSF policies in NSF's Indirect Cost Rate Proposal Submission Procedures. Recipients should provide a clear description of rates and application bases. Recipients should also provide spreadsheet calculation of rate or rates by year clearly showing exclusions such as sub-contracts greater than $25,000, equipment or capital expenditures, and participant support. If a Recipient has different indirect cost rates across NSF budget categories in Figure 4.2.2-2, these rates should be clearly identified and justified. Any deviation to a Recipient's normal rate should also be justified.

K – Fee

- When the Recipient is proposing a Fee amount, it should be presented in line K. A Fee can only be proposed when the solicitation allows for it. Fee will be called out separately

in the award terms and conditions and based on information provided in the negotiated budget justification.

4.2.2.5 Fee

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 G/AO using a structured approach as prescribed by DACS. In part, the G/AO may use information such as the negotiation objective set forth in the Decision Memo and/or other cost negotiation memorandum as the basis for selecting the fee type and determining the fee amount. The amount of fee will not exceed the statutory limitations pertaining to cost contracts set forth at 41 U.S.C. 3905, notwithstanding that the fee is provided through a cooperative agreement. NSF will also provide guidelines for Recipients that receive fee to encourage the utmost discretion and appropriate consideration in the use of fee, to include examples of 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 a Recipient's actual use of fee. Accordingly, Recipients must separately track and account for uses of fee provided under NSF awards. The terms and conditions of each award will specify the fee arrangement. NSF will consider reductions in future fee if a Recipient's actual use of fee is in contravention with the guidelines on inappropriate uses.

4.2.2.6 Escalation

Recipients are not limited to using only broad and publicly available economic assumptions when doing cost estimates. NSF encourages organizations to use escalation information appropriate for the known situations or a particular industry as long as they can be justified. For example, specialized data may be available from the Department of Energy, Department of Defense, BLS, industry metrics, and/or historic experience with similar items. The justification for all escalation assumptions and inflation factors (including use of standard OMB inflation factors) should be included in the CEP and used consistently throughout the BOE.

Estimates should preferably be based on current information but may include appropriate escalation calculations and justifications to support the planned execution timeframe. 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). Recipients should consider cost sensitivity and establishing risks and associated contingency for future price variability and developing mitigating actions. (See Sections 4.2.2.3 and 4.2.6)

4.2.2.7 Work Breakdown Structure (WBS)

As described in the GAO Cost Estimating and Assessment Guide, a WBS is the essential cornerstone of every project because it defines in detail the work necessary to accomplish a project's objectives. For construction, the WBS is a deliverable-based and hierarchical framework structure that provides specific, manageable and schedulable tasks and may be composed of products, material, equipment, services, data, and support facilities that the project should yield. An operational WBS may be functional, activity, and/or deliverable based, depending upon the type of work. Level of Effort tasks should be confined to only those tasks that are not easily definable as deliverables. 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 for construction. WBSs are developed at varying levels of detail but should include at least three levels. 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 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.

Guidance and examples of common WBS elements can be adapted from GAO and other guidance and tailored for NSF projects, as depicted in Figures 4.2.3-1 and 4.2.4-1. The benefits of developing standardized or similar WBSs across the portfolio of facilities 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 schedule, scope, and cost
- Ease of judging completeness and reasonableness
- Better 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

4.2.3 Additional Guidance for Construction Estimates

4.2.3.1 Purpose and Process

As discussed in Sections 4.2.1 and 4.2.2 above, NSF utilizes internal staff, outside experts, and expert panels at the Conceptual Design, Preliminary Design and Final Design Reviews and during the Construction Stage to assure that proposed construction cost estimates and budgets meet expectations, incorporate relevant GAO Cost and Schedule Guide best practices, and are allowable, allocable, reasonable, and realistic. Cost Estimating Plans and Cost Books should be updated as necessary during each of the Phases in preparation for the Reviews. 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 must be sufficient to give NSF confidence in the estimated Total Project Cost (TPC) that advances for National Science Board authorization and potential inclusion in a future budget request. The FDR estimate and analysis must be sufficient to give NSF confidence in constructing and commissioning the facility within the TPC.

4.2.3.2 Construction Cost Book – Introduction and Executive Summary

Construction Cost Books are necessary at the CDR, PDR, and FDR, at minimum, to provide a comprehensive, consolidated estimate of construction costs.

The Project Execution Plan described in Section 3.4 of this Guide includes a Construction Cost Book (PEP-4.7) as one component of the overall Construction Project Definition. The Cost Estimating Plan and Construction Cost Book provide assumptions and detailed information forming the Basis of Estimate. The following additional high-level information should be provided as an overview and executive summary (PEP-4.5) to assist with the review process described in Section 2 of this Guide. Recipients should consult with the PO and G/AO or CO 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; reported both by WBS and in NSF budget format; providing Base Year and Then Year costs.
- A comparison of the current total project cost to past estimates and an explanation of any major changes, including impacts to 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).

4.2.3.3 Construction Cost Book – Format

Major facility construction projects must employ a deliverable-based and hierarchical WBS that provides specific, manageable and schedulable tasks and may be composed of products, material, equipment, services, data, and support facilities that the project should yield. Level of effort tasks should be minimized for optimizing tracking of spending against budget and accomplishments against plan in the project Earned Value Management reports.

Examples of potential components of a WBS, common to many NSF plans for construction of major facilities, are listed in Figure 4.2.3-1 and further described below. The intent is to provide a standard format to the extent feasible with 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 facility.

A basic description of each WBS is as follows:

1.0 Project Administration and Management Office – Include activities related to the management and administration of the project. This includes quality assurance and safety, reliability, document control, cost/schedule reporting and control systems, and configuration management.

2.0 Facility Infrastructure and Civil Construction – Includes the design, procurement, construction, and integration, of the supporting infrastructure. One example is a telescope and site construction, consisting of the facility enclosure, dome, and telescope mount.

3.0 Scientific Equipment and Instrumentation – Includes unique and specialized scientific equipment. For example, field sensors and gages.

4.0 Computers and Cyber-Infrastructure – Includes hardware and software needed to operate the system and collect and analyze data.

5.0 Systems Integration, Testing, and Commissioning – Includes the overall systems infrastructure and personnel needed to integrate other WBS elements to ensure they work correctly together for testing, commissioning, training, and operations.

Figure 4.2.3-1 Construction WBS and Cost Book Sample Format

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 Computers and Cyber-Infrastructure
- 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

4.2.3.4 Construction Cost Book – Detail

This section discusses additional detailed information needed for a high-quality Recipient cost estimate and NSF cost analysis. This information is intended to supplement the standard GAO best practices, grant guidance in the PAPPG, and industry standards and good practices[1]. The guidance should improve project execution, clarify NSF expectations, assist Recipients, facilitate NSF review with fewer iterative resubmissions, and prevent recurrent issues. It is understood that this information will become further refined as the Design Stages advance.

[1] Examples: AACE International Recommended Practice No. 18R-97, COST ESTIMATE CLASSIFICATION SYSTEM – AS APPLIED IN ENGINEERING, PROCUREMENT, AND CONSTRUCTIONS FOR THE PROCESS INDUSTRIES; and AACE International Recommended Practice No. 34R-05, BASIS OF ESTIMATE

Presentation and Linkages

- Individual WBS element costs must have a sound, fully justified and documented, and sufficiently detailed Basis of Estimate. Figure 4.2.3-2 below provides an example Construction Cost Book Sheet depicting the format and content typically needed to consolidate the "Cost Model Data Set" and to provide the appropriate level of 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
    - Resource Descriptions
    - Cost Basis Codes describing the estimate methodology (e.g., expert opinion, analogy, parametric, engineering build-up, historical data)
    - Direct Costs with Units and Hours
    - Associated Fringe and Indirect Costs
    - NSF Budget Category Code corresponding to the budget categories depicted in Figure 4.2.2-2 and Section 4.2.2.4 above, to allow mapping between WBS sub-elements in Construction Cost Book and NSF Budget Categories on NSF Budget Forms
    - Basis of Estimate source data, with breakout of sub-elements, typically including direct input from technical experts in that area with calculations using material and labor quantities and unit prices, with clear assumptions and sources referenced
    - Associated risk, uncertainty, sensitivity, or contingency information, if any.
- 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.
    - 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 Cost Estimating Plan, basis of estimate, supporting rate agreements, and Recipient accounting practices.
- WBS sub-element costs should be readily mapped to NSF Budget Categories depicted in Figure 4.2.2-2 and Section 4.2.2.4 above; for example:
    - If each cost element on the Figure 4.2.3-2 Cost Book Sheet is assigned an NSF Budget Category Code (e.g., "A for Senior Personnel," "E1 for Domestic Travel," "G4 for Computer Services," "I for Indirect Costs"), then the WBS elements can readily be compiled into standard NSF Budget Forms, which depict total cost

types across all WBS elements (e.g., all personnel, equipment, travel, indirect, or computer services costs across all WBS elements)

- If databases are sufficiently detailed, documented, and traceable, then automatic sorting and summarizing of costs will be facilitated for various purposes and for different reporting formats.

- Cost estimates may be directly linked to scheduling tools, to allow automatic cost updates with schedule changes.

<u>BOE Refinement Process</u>

- 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 construction of the Project, the plans will be fully detailed. As the project moves through the phases, detailed engineering build-up estimates using current quotes and prices should be collected, such that the proportion of estimated costs based on expert opinion, analogy, or parametric estimates is reduced. As the project finalizes plans for the start of construction the basis of estimate should include more vendor catalogue, quoted, or proposed contract prices.
- Direct labor rates, quantities, and skills mix should be justified, including information from subawards.
- If using consultants and contractors, Recipients should carefully justify substantial consulting costs, including the type of work performed, quantity of time proposed, and its cost, as compared to potentially less expensive current employee labor to accomplish the proposed work.
- Cost estimates should include adequate funding for project management, 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 clear demarcation between construction funded scope and operations scope as discussed in Section 3.4.1, Components of a Project Execution Plan; Commissioning (Component 15 of the PEP).
- Where partnerships are involved, monetary contributions to acquisition and eventual operations and usage should be timely, sufficient, and well documented in the PEP and IMP.
- Cyber-infrastructure technical requirements and costs (both initial cost 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 3 to 5 years.

- Cost of evolving technologies should be considered as part of budget development and through 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 4.2.3-2 Construction Cost Book Sheet Sample Format

4.2.4 Additional Guidance for Operations Estimates

4.2.4.1 Purpose and Process

In addition to the specialized scientific expertise required for operations, award solicitations can also include expectations for estimating budgets, business systems, and operational and financial reports. As discussed in the NSF PAPPG, individual solicitations, and Sections 2.5, 4.2.1, and 4.2.2, these systems and reports help ensure the science mission can be met in a cost effective way.

NSF utilizes internal staff, outside experts, and panel reviews to ensure cost estimates and budgets meet expectations, incorporate relevant GAO Cost and Schedule 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, as well as the costs to operate and maintain the facility long term. It is incumbent upon the Recipient 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 research and development (R&D) that will enable a facility to evolve its scientific program and best meet the needs of the research community. Funding for these kinds of up-grades may also come from separate equipment and/or instrumentation programs within the Directorate or Division.

4.2.4.2 Operations Awards Proposals – Overview

In addition to the guidance for Annual Work Plans described in Section 2.5.1 of this Guide and Proposals for Operations and Management described in Section 3.5, additional information may be requested by the PO or via the operations and management award solicitation. Recipients should consult with the PO and G/AO or CO as necessary to identify any other specific cost reports and content required to support the review.

- Periodic plans that 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, as necessary.
- Explanation of how program costs within functional areas are coded or otherwise related to the NSF Budget Categories depicted in Figure 4.2.2-2 and Section 4.2.2.4 above.
- 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).

4.2.4.3 Operations Awards Proposals – Format

As discussed in Section 4.2.2.7, there are numerous benefits of standardizing the framework for accomplishing operational goals with a Work Breakdown Structure (WBS). An operational WBS may be functional, activity, and/or deliverable based, depending upon the type of work, but the amount of scope assigned to Level of Effort tasks should be minimized for better tracking of spending against budget and tracking of accomplishments against plan. An example of a hierarchical WBS for an operations award is provided in Figure 4.2.4-1 below. The intent is to provide a standard format to the extent feasible with 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 facility. The level of detail contained in the cost reports may vary depending on Programmatic management requirements and cost analysis effort.

Figure 4.2.4-1 Operations WBS and Budget Sample Format

1.0 Project Director, Management, and 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

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 Preventive Maintenance
- 4.3 Utilities
  - 4.3.1 Energy (e.g., electricity, natural gas, central heating, central cooling)
  - 4.3.2 Information Technology, Communications, Cyber-Security
  - 4.3.3 Security
  - 4.3.4 Water
- 4.4 Other/General Support Services

5.0 Contingency (If justified, and supported by appropriate risk analysis and management)

4.2.4.4 Operations Awards Proposals – Detail

This section discusses additional detailed information, as follows, typically needed for a high-quality Recipient estimate and NSF cost analysis. This information is intended to supplement the standard GAO best practices and guidance in the PAPPG. The guidance should improve execution, clarify NSF expectations, assist Recipients, facilitate NSF review with fewer iterative resubmissions, and prevent recurrent issues. For existing awards, the Recipient should consult with the PO.

- When power costs are significant and volatile, a strategy for dealing with price fluctuation should be developed as part of the operations plan. 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.
- Multiyear budgets should take inflation into account, using factors discussed in Section 4.2.2.6 above.

Contingency, if requested, must be in compliance with Section 4.2.6 of this Guide.

4.2.5 Budget Contingency Planning for the Construction Stage

4.2.5.1 NSF Policy Positions

1. "Management reserve" is not allowable in the Recipient's portion of the risk-adjusted Total Project Cost (TPC) estimate; only "contingency." Management Reserve (if authorized) is held by NSF.
2. Directorates must be responsible for the first 10% of cost overruns which exceed the Board authorized TPC, or some portion of the NSF-held management reserve (if needed and included in the authorized TPC) as determined by the Director.
3. At the Preliminary Design Review (PDR), projects must have a time-phased, prioritized de-scoping options that equates to at least 10% of the baseline scope budget.
4. In support of NSF's "No Cost Overrun" policy, projects must use a confidence level for contingency estimates between 70 and 90 percent (under a probabilistic approach) based on the particulars of the project and the inherent ability to de-scope.
5. 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.
6. Although the initial TPC becomes public (i.e. through the budget request) after PDR, the TPC under the "No Cost Overrun" policy is set at award (post-FDR) to allow for refinement during the Final Design Phase.
7. Engagement with the National Science Board (NSB) on any cost overruns is based, in part, on their delegation order for award supplements.

4.2.5.2 Introduction

The intent of NSF's "No Cost Overrun" policy (see Section 1.4) is to instill diligence and rigor in establishing the TPC and giving NSF a strong oversight position. Mechanisms for offsetting potential cost increases are described herein and include, in order of precedence and assuming appropriate use in accordance with NSF policy and practice:

1. Re-planning
2. Use of contingency
3. Use of management reserve (if authorized)
4. De-scoping if science/cost trade study determines that science loss is acceptable
5. Request NSB authorization to increase TPC if science loss due to available de-scope options is not acceptable

"Contingency" is a critical component of the comprehensive planning and execution of the construction of major research facilities. This document describes the policies and procedures concerning the planning, use, and oversight of budget contingency in the construction of facilities fully funded by NSF and to the NSF-funded component of the scope when NSF partners with other entities. It also describes the NSF's process for assessing the sufficiency of

contingency, evaluating the effectiveness of management plans used for administration of contingency, and NSF's oversight role in the use of contingency funds.

For all assistance awards with academic institutions and non-profit organizations, contingency is held by the Recipient in accordance with the Uniform Guidance (§ 200.433).
Federal Acquisition Regulation (FAR) governs the planning, use and oversight of contingency for contracts with commercial organizations. Regardless of where contingency is held, the requirement for a well substantiated risk assessment and contingency estimate, as well as a robust oversight and administration is essential. Estimating contingency and managing risk is an integral part of the project planning and execution process. NSF positions on contingency, management reserve and de-scoping must be considered by the Program and the Recipient as part of that process. **Although strategies for other types of contingency are mentioned here, this document is only intended to address management of the budget contingency.**

The definition of contingency varies widely among project management practitioners and federal agencies. For NSF,[1] budget contingency covers the "known unknowns" and is used to mitigate identified cost or schedule risks as described in the Project Execution Plan[2] (PEP). The estimated risk-adjusted TPC, as defined in Section 9 of this Guide, is developed in accordance with the GAO Cost Estimating and Assessment Guide,[3] as explained elsewhere in this Guide. OMB's cost principles in the Uniform Guidance address budget contingency, and define it as:

> *… that part of a budget estimate of future costs (typically of large construction projects, IT systems, or other items as approved by the Federal awarding agency) which is associated with possible events or conditions arising from causes the precise outcome of which is indeterminable at the time of estimate, and that experience shows will likely result, in aggregate, in additional costs for the approved activity or project. Amounts for major project scope changes, unforeseen risks, or extraordinary events may not be included.*

In contrast, "Management Reserve"[4] is often used by industry and other organizations to cover the unforeseen risks, or the "unknown unknowns." **Except in rare circumstances, NSF does not**

[1] NSF terminology aligns with that of AACE International, the Association for the Advancement of Cost Engineering, and of the Project Management Institute's ***Project Management Body of Knowledge (PMBOK Guide).*** See Section 6.2.3.2 for NSF definitions of contingency and management reserve.

[2] See Section 3.4 for details regarding the PEP. Note that the PMBOK Guide refers to "Project Management Plan" rather than PEP, but the NSF definition of PEP is equivalent.

[3] Note that the NSF definitions and treatment of contingency and management reserves differ from those used in the GAO Cost Estimating and Assessment Guide.

[4] The GAO Cost Estimating and Assessment Guide (GAO-09-3SP, March 2009 uses the term "management reserve" for funds held for mitigation of "known unknowns" whereas NSF uses the term "contingency." For GAO, management reserves are included in the budget baseline and are managed at the contractor level. The value of the contract includes these known unknowns in the budget base, and the contractor decides how much money to set aside.

normally hold a management reserve for a specific project as part of the TPC. As a result, the Directorate is responsible for the first 10% of costs which exceed the authorized TPC. To mitigate this risk, the project's prioritized and time-phased de-scoping plan should equal **at least 10%** of the baseline budget when established at PDR. The ability to de-scope varies widely by project and the impacts on the eventual scientific capabilities of the facility will also vary. The scope contingency should be well considered and strive to minimize negative impacts. The Directorate may also choose to cover the cost overrun from programmatic funding (and increase the TPC) in lieu of de-scoping if it deems the science-support capabilities of the facility would be too severely impacted.[1] See Section 2.4.1 of this Guide for required approvals.

The PEP describes a construction project's scope, budget, schedule, and identified risks. It also articulates the project's plans for accomplishing the intended scope while satisfying the constraints of budget and schedule and managing those risks. An essential component of the PEP is the Risk Management Plan (RMP), which describes the project's procedures for risk identification, analysis, monitoring, and handling (including de-scoping if required) so that the project has a high likelihood of being accomplished within the total available budget. Budget contingency is only one tool used to control project risk. The RMP will also include methods and tools to manage scope contingency, schedule contingency, and provide robust risk handling and monitoring processes. Refer to Section 5.2, Risk Management Guidelines, for additional information.

The development of budget contingency entails estimating the future potential impacts of identified possible adverse events to the project (i.e. risks) if those events are ultimately realized. In accordance with the Uniform Guidance, NSF requires the use of widely accepted risk management practices (including parametric and probabilistic methods depending on project maturity) to estimate a range or distribution of contingency. An appropriate value is then selected from that range that will enable the project to successfully complete the required scope within the TPC that is sent forward for National Science Board (NSB) authorization. **In support of NSF's "No Cost Overrun" policy, confidence levels must be in the 70-90%[2] range following PDR depending on the nature of the project; including the ability to de-scope.** This applies even for higher risk projects. The resulting TPC estimate, including estimated contingency required, will ultimately factor into NSF's decision on whether or not to proceed with the project. **This policy position is in no way intended to discourage the construction of cutting-edge, high risk facilities needed to advance scientific understanding. It is intended to give a high degree of confidence that the project will come in on budget and clearly articulate the level of risk involved so that sound decisions can be made.** Following construction start, if

[1] Directorates are able to do this as a result of NSF's "transfer authority" which is dependent on continued inclusion in the appropriation act. The language may require that congressional appropriation committees be notified in advance of any reprogramming. Directorates should consult with the Budget Office during the decision-making process.

[2] GAO Cost Estimating and Assessment Guide (GAO-09-3SP, March 2009, pg. 158) states that the use of confidence levels of 70 to 80 percent is now common practice, particularly with projects having higher design complexity and technology uncertainty as with NSF-funded facilities.

subsequent analysis shows that confidence is declining and the Board-authorized TPC will be exceeded, NSF requires that a reduction in scope be considered as a strategy to bring the costs back in line with the budget.

Since development of contingency is statistically-based, there is a chance that not every risk will be realized at its maximum impact. Therefore, it is possible that contingency dollars will remain at the end of the project. Even if contingency is allocated, the Project may come in under budget for other reasons. Once project objectives are met and the project completed, **any residual funds must be de-obligated and returned to NSF** at which time NSF will request possible re-allocation of those dollars to other agency priorities. Awarded contingency shall be held by the Recipient until project completion, but no later. Budget, Finance and Award Management (BFA), the Large Facilities Office (LFO), and the Program Office will conduct a project close-out with the Recipient in accordance with NSF practice and as described in Section 2.4.2 of this Guide.

Major strategies used by NSF to ensure accountability in the management of contingency budgets include:

1. Contingency budgets are developed in accordance with widely accepted standards for risk assessment and planning. Contingency budget, scope, and schedule are similarly derived from probabilistic, bottom-up assessments of the entire project scope.
2. Contingency budgets are evaluated for reasonableness by NSF through use of expert review panels convened by the Program that examine the BOE and methodology, and compare the cumulative contingency amounts with historical experience on similar projects. This happens at each phase of the project (Conceptual, Preliminary, and Final Design) at increasing levels of refinement. Other divisions within NSF, and potentially contracted experts, will also evaluate the contingency estimate as part of the total project cost assessment as it moves through these phases.
3. NSF will obligate and allocate contingency based on need and performance of the Recipient. 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 on a periodic basis as specified in the award instrument. Balances will be measured against the total NSF-approved contingency budget and the allocated contingency to date. This is part of the standard project reporting and requires archiving in the permanent electronic record used by NSF (FastLane/eJacket).
4. Management and use of contingency is documented separately through the configuration and change control process and must reference the associated Work Breakdown Structure (WBS) elements and/or the previously identified Risk. The Earned Value Management (EVM) framework for financial status reporting will eventually reflect movement of contingency into the Performance Measurement Baseline (PMB) budget (increase or decrease in Budget at Completion; BAC). Although traceable as

allocations or returns to the contingency budget, contingency dollars become part of the PMB and are no longer separately identifiable as contingency once incorporated.

5. All project expenditures must be used only for scope as defined by the elements of the NSF approved baseline, and all are subject to financial audit.
6. Management of contingency is described in the Configuration and/or Contingency Management Plan (PEP-6.3). In this plan, thresholds are established (based on the nature of the project) on who has the authority to approve the use of contingency. These thresholds are also documented in the award instrument. Below the thresholds, the Recipient has authority to manage and allocate contingency budget to specific in-scope elements of the project WBS following the Configuration Change Control Process. Above these thresholds, approvals from NSF are required, with the level of approval corresponding to the magnitude of the proposed change.
7. Financial controls prevent the cumulative Recipient cash draws from exceeding the obligated spending authority in NSF's financial system.

4.2.5.3 Contingency Planning and Assessment during Conceptual Design

A budget estimate, like the measurement of a physical quantity, has a value and an uncertainty dependent on where the project is in the design process. The uncertainty in the budget estimate is a consequence of identification of foreseen project risks and other "known unknowns" that are under the control of the project; including scope that is not cost effective to define in detail during preconstruction planning or the earlier phases of design. The ability to estimate these risks and uncertainties naturally changes over time as the design is refined and the understanding of the project matures. Recipients are required to develop methods for qualitative and quantitative assessment of these risks, and to develop an optimized risk handling strategy that evolves with the project.[1] Regardless of the phase, the BOE for contingency development must be sound and well-documented but remain appropriate for that phase.

For the Conceptual Design Phase, both the baseline estimate and the uncertainty of that estimate should be based on expert judgment and parametric models developed by the project planners based on scaling and extrapolating historical data from projects with similar characteristics. When NSF conducts the Conceptual Design Review (CDR), it expects that Recipient will have developed a risk-based, budget contingency estimate at a similarly refined level of detail; one that is based on estimates for major elements or functional components of the proposed facility. NSF will conduct the CDR using a panel of experts able to apply prior experience to assess the reasonableness of the budget and contingency estimates. The budget

[1] See Section 6.2, Risk Management Guidelines, for more information about formulating and implementing Risk Management Planning, and standard references on project management, such as the PMBOK Guide, for a detailed explanation of the individual steps in Risk Management Planning: risk identifications, qualitative and quantitative risk analysis, risk handling, and risk monitoring.

contingency estimate will be evaluated by NSF as part of its first internal cost analysis for the project based on the CDR deliverables. This initial cost analysis will help inform the cost book and other deliverables developed during the Preliminary Design Phase.

4.2.5.4 Contingency Planning and Assessment during Preliminary Design

During the Preliminary Design Phase, NSF requires Recipients to develop budget estimates and associated risk estimates that are "bottom up" assessments[1] that consider every element of the entire project, using as inputs the definitions of the lowest appropriate WBS elements. For each lowest level element, the project should estimate its expected cost, **excluding** unusual risks or occurrences that are outside the control of the project. The project should also separately estimate, at the appropriate WBS element for the risk described, the technical, cost and schedule risks or uncertainties using a widely accepted method that is employed by all estimators. NSF expects to see the project utilize a probabilistic method of calculating a range of risk exposures appropriate to the project area in question and the maturity of the risk assessment. Expert judgment should always be applied to both the inputs (BOE) and outputs of this process, to the reasonableness of potential cost and schedule impacts, and to the applicability of the process to specific areas of the project. In some circumstances, such as where specialized knowledge of a particular technical area or market condition exists, it can be appropriate to override the outputs based on expert intervention. Supporting documentation should clearly articulate which risks elements were considered and how they were modified when making any adjustments to the model outputs.

It is not always realistic or even feasible to mitigate all anticipated risks. It is extremely unlikely that typical projects will encounter all of the risks and the full extent of possible consequences that have been identified. The contingency estimate should be appropriate to manage only the ensemble risk, which is much more likely to occur than the sum of the individual risks. This approach produces a more likely estimate for the TPC compared to an approach where Control Account Managers increase individual WBS elements to cover risk. **Use of rigorous probabilistic cost estimating methods that estimate confidence levels for the TPC (such as Monte Carlo methods based on probability distributions for risk) are preferred and NSF highly encourages application of these methods where practical.** As a result of these estimating activities, the project should develop the contingency estimate that provides a high degree of confidence that the project can be completed within budget per NSF's "No Cost Overrun" policy.

Budget, scope, and schedule risk are usually correlated to some extent. A change in scope, for instance, may mean more costs and additional schedule. Risk analysis and budget and schedule

[1] See Section 6.2, Risk Management Guidelines, for more information about formulating and implementing Risk Management Planning, and standard references on project management, such as the PMBOK Guide, for a detailed explanation of the individual steps in Risk Management Planning: risk identifications, qualitative and quantitative risk analysis, risk handling, and risk monitoring.

contingency estimation methods should consider the degree of correlation in estimating an appropriate level of budget contingency.

Budget contingency is developed based on risk assessment of individual WBS elements, but once defined; it loses its identification with any specific cost element and is fungible throughout the project to manage the overall project risk. Until then, contingency is held separately from the project baseline budget estimate[1] that is used for Earned Value Management reporting, but is included in the total project cost, regardless of the award instrument.

NSF requires the PEP to contain a baseline that defines the project's intended scope, budget, schedule, risk, and management plans. The PEP will include provision of schedule and scope contingency[2] for use by the Project Manager, developed according to the following additional considerations:

Schedule contingency: The construction schedule should be developed in the same manner as the budget contingency estimate, following the WBS structure at the lowest available level of detail. The project should make a technical estimate for each task's duration and its dependence on other tasks.

Scope contingency: NSF requires projects to assess possible use of scope contingency and develop a plan to make effective use of scope contingency, if necessary, during construction. This provides the project with an additional tool to manage the overall project.

NSF requires, at Preliminary Design Review (PDR), that the contingency budget, schedule, and scope are the outcome of detailed planning by the project for how best to handle the various risks that have been identified. Some risks are most effectively handled proactively by investing in additional developmental and design activities or resources intended to prevent the risk from occurring.

At the PDR, NSF requires a funding profile by fiscal year that includes the commitment and obligation of funds, plus anticipated contingency needs. The profile should be a consequence of the project's formulation of a resource-loaded schedule for EVM reporting. Since PDR informs the budget request to Congress, this allows NSF to determine the year-by-year construction funding profile. The annual Congressional appropriation must be sufficient to accomplish the work proposed and provide the financial resources needed to manage the risk activities foreseen during that period.

[1] That is, contingency is not included within the Budget at Completion (BAC). TPC = BAC + contingency.

[2] See Section 6.2.3 for definitions.

The budget contingency estimate will be further evaluated by NSF as part of its second internal cost analysis for the project based on the PDR deliverables. This second cost analysis will give assurance on the TPC brought forward to the NSB as well as help inform the cost book and other deliverables developed during the Final Design Phase in preparation for award.

4.2.5.5 Development of the Contingency Use Process

NSF examines the RMP at PDR to ensure that the PEP describes a formal process for Change Control[1] that includes the allocation of contingency within the project during construction. NSF approval of the RMP, including the change control process, must be documented and maintained in the agency's permanent record. Under the RMP, the Project Manager (or other designated individual) should have budget authority to transfer to or from[2] the contingency category to specific WBS elements, via a process that follows the project's Configuration Change Control Plan. A typical change control process, for example, may involve written application to the Project Manager by the affected Control Account Manager(s) and formal review and recommendation by a Change Control Board (CCB) consisting of all other system leads. The Program Officer must have the authority to then approve the requested funds, reject the request, or request a change in schedule, technical scope or other corrective action. All CCB change requests are to be logged, documented, and archived by the project, with the logs and documentation provided on a periodic, pre-determined basis to NSF for review. The defined CCB process must include a provision for seeking prior written approval from NSF (Program Officer or higher depending on the magnitude) for all actions that exceed the thresholds specified in the award instrument or NSF policy.

The CCB change request document, whether forwarded to NSF for approval or not, must have the minimum content requirements necessary to comply with relevant cost principles as well as to maintain an audit trail. See the sample change control request form at the end of this section. This process must be examined by NSF for compliance before approval of the Change Control Plan. CCB documentation must specify all control accounts that budget is being allocated to or recovered from, and tie to budgets itemized by cost element (i.e., labor, materials, supplies, etc.). Contingency allocations must be supported by analysis demonstrating that the proposed amounts to be allocated are considered reasonable and allowable and should be linked to the WBS and/or Risk Register ID. Allocations from contingency and returns to it change the PMB budget. Therefore, it is essential that historical information be logged and maintained in a manner that allows NSF to systematically track the evolution of the PMB from its initial release at award through all subsequent changes. In other words, PMB budgets must be traceable through historical records to the initial PMB release.

[1] Section 2.4, Construction Stage, contains additional information about NSF expectations for conducting change control.

[2] Some realized costs will be lower than initial estimates. Once a work package is complete, any savings should be removed from association with specific WBS elements and added to the contingency pool available to the Project Manager.

4.2.5.6 Contingency Planning and Assessment during Final Design

NSF requires the project to refine its cost estimates following PDR, adding additional definition and improved confidence with the tasks associated with accomplishing the project deliverables. At the Final Design Review (FDR) the budget estimate should be substantially based on externally obtained cost estimates (vendor quotes, bids, historical data, etc.). This added definition is expected to result in a change in the project's estimated Budget at Completion (BAC) and in the accompanying budget contingency, while keeping the sum of the two at or below the PDR TPC used to inform the budget request. Also, as part of the FDR, NSF assesses the methodology employed by the project to further refine its cost and contingency estimates including schedule and scope adjustments. All of this information would then factor in to the total project cost assessment being refined and evaluated by NSF to make the initial construction award.

4.2.5.7 Contingency Use and NSF Oversight during Construction

NSF will negotiate the award instrument with the Recipient to fund project construction activities (Construction Stage). This instrument will specify the contingency amounts and include thresholds above which prior written NSF approval is required before the Project Manager may allocate contingency (as described in the approved Change Control Process, PEP-8.2) to, or from, specific WBS elements.[1] The thresholds will vary depending upon the particulars of each project. Working with the Recipient, NSF will employ the following criteria when establishing the threshold or thresholds. These considerations must be documented in the award file as well as the PEP and the IMP.

- **Award and Subaward amounts** – A larger award amount may warrant establishment of higher thresholds to lower administrative burden.
- **Sufficiency of project plans and designs** – More detailed project plans, specifications and designs generally lead to higher confidence and better bids which may allow the thresholds to be higher.
- **Nature of identified project risks** – The more risk associated with the nature, timing and the severity of certain project work packages may increase the need for establishing a lower threshold.
- **Review Recommendations** – Expert panel findings and recommendations should be considered in setting thresholds.
- **Recipient or Subrecipient past performance history** – Available past performance information may help to indicate whether a Recipient's change control process is adequate or whether the Recipient has been successful in identifying contingencies, e.g., use and accuracy of contingency logs, and therefore support a corresponding appropriate threshold. Poor performance would support a lower threshold.

[1] Thresholds are necessary to allow the project to respond in a timely way to small, immediate needs for use of contingency, such as field changes during construction. This avoids potential cost escalation that could result from delay.

- **Known audit findings and their disposition** – Relevant audit findings/dispositions should be considered in establishing thresholds.
- **Sufficiency of Recipient administrative systems** – The adequacy of compliance with financial and administrative systems including accounting systems, historical cost data, and financial reports may impact the thresholds.
- **Degree of NSF substantial involvement in the project** – The complexity and risks associated with the project may warrant more NSF involvement and hence lower thresholds.

Once construction begins, the actual cost for some specific WBS elements may exceed the estimated cost and the Project Manager can choose to allocate contingency in accordance with the process defined in the PEP for Change Control. In other cases, the actual cost will be less than the estimates, and the Project Manager may decide to transfer budgeted funds from the affected WBS elements to contingency. In case, whether it's a risk realized or a risk retired, the Change Control documentation should tie this transfer back to an identified risk element in the Risk Management Plan to be allowable.

Contingency funds are to be used only to support scope that is part of the NSF-approved project baseline, as defined in the PEP and successive CCB actions. Depending on the thresholds, Project Manager, CCB, NSF, and NSB approvals are required to modify the project scope. **Unexpended contingency funds may not be used to support operations or other out-of-scope activities.**

4.2.5.8 Reporting Requirements

Each project in construction must report monthly to NSF on the status of the project, while projects in the Design stage are highly encouraged to submit a monthly report. Details on the required information for the monthly reports are outlined in section 4.6.2, Recipient Performance Reports.

Projects are expected to periodically compute and update the risk exposure, estimate to complete (ETC), and estimate at completion (EAC), and compare these quantities to the BAC and TPC. NSF will monitor the financial information provided and compare the available contingency to the estimated remaining risk exposure. NSF may request corrective action if the contingency budget appears inadequate to manage remaining risk. Recipients should consult with the PO and GA/O or CO as necessary on the format for the monthly reports. The information contained in the monthly report is not intended to supersede or replace other reporting requirements as specified in the Cooperative Agreement or Cooperative Support Agreement.

All CCB actions, irrespective of amount, or whether they increase or decrease the BAC, must be reported directly to Program Officer at least quarterly. All CCB actions exceeding defined

thresholds for allocation of budget, schedule, or scope contingency must be approved by NSF as codified in the PEP-8.2 and the CA. NSF-approved CCB actions must be made part of the award's permanent record. For all assistance awards, CCB documentation is maintained in NSF's electronic record system (eJacket) in accordance with the award terms and conditions.

NSF's financial system controls prevent the cumulative Recipient cash draws from exceeding the obligated spending authority. All funds are retained within NSF's obligated award amount to be drawn down by the Recipient 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.

4.2.5.9 Partnership Considerations

NSF may partner with other entities to plan and construct a major facility. The guidelines within this document are applicable when NSF funds a particular scope of work within a larger overall project. Risk assessment and contingency development processes are to be applied to those WBS elements funded by NSF. Similarly, the Recipient managing construction must report on the use of contingency during construction in accordance with the requirements regarding use of contingency funds.

More complex situations may arise when NSF funds a proportion of the total project cost, or where NSF contributes along with others to a common fund to build specific WBS elements within the context of a larger project. Because overall project risk is reduced as more WBS elements are aggregated into the risk analysis and managed through a centrally held contingency fund during construction, NSF encourages the development of unified management for project planning and execution of the entire project scope wherever practical. However, NSF recognizes other partners may have different processes for planning, funding, and conducting oversight, making it challenging to form a unified management structure. Consequently, the award instrument must define the specific procedures for handling contingency in those circumstances. Program Officers are advised to consult with the Division of Acquisition and Cooperative Support to determine an effective approach consistent with the principles of federal laws and regulations. The Large Facilities Office may be able to provide models of various approaches that have been used successfully in other projects.

Figure 4.2.5-1 Sample of a Change Control Request Form, with instructions for filling out the various sections

Sample Change Control Request

Change Request #: CR- All change requests, whether approved or not, should be assigned a number, entered into a change log, and archived. NSF must be notified of all pending and approved change requests. **Date:** _____

Change Request Title: _____

Impacted WBS: List the WBS IDs and titles for the elements impacted by this change, using the most appropriate summary levels as necessary. **Associated Risk ID #:** List the Risk Register IDs and titles of the risks or opportunities associated with this change.

Originator Name: _____ **Project Controls Rep:**

Originator Signature: Name and signature of the person making the request for this change. Identify any other personnel instrumental to this change, as desired. Examples are: management sponsor, preparer, the project controls implementers, etc.

Summary Change Description:

Give a summary description of the change request, including the nature of the change with respect to scope, cost, schedule, or performance; justification or motivation, including link to Risk Register opportunity or risk for contingency adjustments; and any net adjustments to contingency amounts.

Use check boxes or other means to indicate a need for any additional approvals per the Cooperative Agreement terms and conditions or the approved Project Execution Plan (PEP)

☐ NSF approval required
☐ Technical Review Board approval required

Scope or Technical Impact:

Give a description of requested scope or technical changes by Work Breakdown Structure (WBS), including any resulting impacts on other WBS elements.

Give details of justification and cite any pre-approvals, such as technical review board or advisory board recommendations.

Budget Impact:

Give a description of the budgetary impacts of the change, by WBS element. Identify net adjustment to project budget contingency. It is good practice to include a detailed basis of estimate as an attachment to the change request.

Provide a table with budget adjustments by WBS element. Cost control accounts may be included for traceability in the accounting system. Identify net adjustments to total project budget contingency. Including budget summary totals at WBS Level II and for the total project is helpful for monthly reporting of contingency usage.

Budget Impacts by WBS and Control Account

WBS Element	Control Account	Current Budget	Revised Budget	Change Amount	Change Description
WBS II Sub-Total		0.00	0.00	0.00	
WBS II Sub-Total		0.00	0.00	0.00	
WBS Sub-Total		0.00	0.00	0.00	
Total	Project Level Impact	0.00	0.00	0.00	Net Project Contingency Adjustment

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Sample Change Control Request

Schedule Impact:

Give a description of the impact on milestones and critical path for the project baseline schedule at a level low enough to reflect the effects of the change on all impacted tasks. Identify any adjustments to schedule contingency amounts.

It is good practice to provide a table or a schedule chart with schedule changes, showing WBS and activity IDs.

Changes to Project Milestones

WBS	Activity ID	Activity Name	Baseline Dates	Change Request Baseline Dates	Revision in Work Days

Project Acknowledgement and Concurrence Signatures:

Title/Name	Signature	Date

Titles and signatures of concurring staff – typically WBS Level II managers, the lead systems engineer, the configuration control manager, project controls manager, safety officer, quality control officer, and other key individuals appropriate to the unique needs of the project. Note that these individuals acknowledge and concur with the recommendation. Approval is retained by the chair of the Change Control Board.

Project Management Approval and Disposition:

☐ Change Approved
☐ Change Rejected

Signature: _____ Date _____
(CCB Chair)

Disposition:

Approval / disapproval and disposition is retained by the chair of the Change Control Board, usually the Principal Investigator or Project Director, as this is the individual held accountable by the NSF for the performance of the project.

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Sample Change Control Request

NSF Program Officer Approval (If required):

Program Officer Signature_____ Review Date_____

Comments:

Approval is given by the cognizant NSF Program Officer, if required by the terms of the Cooperative Agreement or PEP. This typically applies for major scope or performance changes and for changes above a specified threshold for contingency amounts.

Project Controls Implementation:

(Describe Actions Taken in Cost and Schedule Baseline)

Project controls staff documents actions taken to implement the change request.

Project Controls Staff _____ Implementation Date _____

Additional Documentation:

It is recommended that projects include or attach detailed supporting material, including basis of estimates for budget and schedule changes, calculations or other analysis, and any other relevant source documents providing justification or additional details of the change.

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4.2.6 Budget Contingency Planning during the Operations Stage

The processes and procedures to handle risk are very different between major facility construction and operations awards. As with construction, there are many inherent risks with operations. However, the risks are markedly different in nature. Estimates for operations are usually based on well-understood historical information and experience with routine risk exposure included in the Basis of Estimate (BOE) as part of the "most likely cost". The work itself is based on the day-to-day activities of science support staff and required consumables rather than the production, assembly and testing of discrete deliverables.

Operations award 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 is used by the Recipient per the award terms and conditions.
- Recipient reduces the level of science support effort (with NSF approval if significant).
- Recipient requests supplemental funding; assuming proper justification, availability of funds and recommendation by Program.

In contrast, risk handling on construction awards uses the strategy per Section 4.2.5 and NSF's "No Cost Overrun" policy.

As stated above, it is generally more appropriate for operating budgets to include only explicitly identified allowances[1] for repairs, replacement, maintenance and other factors such as "technology refresh" for cyber-infrastructure or other similar up-grades. However, any request for budget contingency must comply with paragraph § 200.433 of the Uniform Guidance. Unless a separate contingency budget is justified and fully supported through a formal risk assessment and a Risk Management Plan, projects 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 basis of estimate. A separate contingency budget may be preferable if the operational plan includes significant upgrade funded through R&RA that should be managed as a separate sub-project. Finally, since "contingency" has a specific meaning under the Uniform Guidance, and "management reserve" cannot be held by the Recipient, these terms should not be used in the basis of estimate.

[1] Definition in Lexicon is adapted from AACE International Recommended Practice No. 10S-90, Cost Engineering Terminology, Rev. March 1, 2016 and AACE International Skills and Knowledge of Cost Engineering, 6th Edition.

4.3 SCHEDULE DEVELOPMENT, ESTIMATING, AND ANALYSIS

[Reserved for future content]

4.4 SYSTEM INTEGRATION, COMMISSIONING, TESTING AND ACCEPTANCE

System integration, commissioning, testing and acceptance are Recipient functions, and are an essential part of complex construction/acquisition projects. Failure to perform them, or to adequately plan for them, can lead to serious cost and schedule overruns. The Recipient is required to describe its plans for system integration, commissioning, testing and acceptance in the PEP (Table 3.4.1-1, Component 15). The Program Officer (PO) approves these plans, but is also required to include periodic review of progress in these areas:

- **System Integration** – combining and coordinating the many physical and performance interfaces in a project;
- **Commissioning** – substantiating the capability of the facility to function as designed by bringing various system components on line first sequentially and then in simultaneous operations to study and affirm the interaction among subsystems;
- **Testing** – assessing the operation of the facility by applying the criteria established in the PEP to measure acceptable performance; and
- **Conditions for Acceptance** – specifying the expected condition of the facility, its performance attributes, the tests the Recipient 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. For example, for distributed-but-integrated facilities or for facilities with complex instrumentation and equipment, the PO will want the Recipient to demonstrate performance and perform acceptance procedures for part of the system prior to proceeding with construction and/or acquisition of other systems. The PO, in consultation with the Integrated Project Team (IPT), will determine whether the Recipient will conduct the tests and accept the facility or whether the PO will participate in the testing and accept the facility on behalf of the government.

Frequently, some aspects of construction and/or acquisition overlap with initial operation. A detailed Operational Readiness Plan (PEP-15.2) should be developed by the Recipient at least one year prior to the anticipated commencement of commissioning activities. Elements of commissioning and transition from Construction Stage to Operations Stage are first addressed during Conceptual Design and become progressively more detailed as planning evolves. During construction, the PO reviews the plan, utilizing internal staff, external experts, consultants, external review panels and the resources of the Large Facilities Office. The review of the plans for commissioning and acceptance should consider the following questions:

- Will the project have parallel periods of construction/acquisition and operations, with some components coming on line earlier than others?
- What is the project'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?

Even if limited operations are undertaken, the changeover from construction funding to operational funding does not have to occur until the facility has been accepted and the PO ensures that the budget is estimated accordingly. Where operational funding will be used prior to acceptance, the PO will 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 (PEP-15.4).

4.5 DOCUMENTATION REQUIREMENTS

The Recipient is responsible for ensuring that a document management system is in place that provides for retention and retrieval of essential and significant documentation related to the project. Recipient documentation may take many forms, from informal e-mail communications to formal letters, bids and contracts. NSF strongly prefers that this system be electronically accessible via Internet, rather than paper-based, but recognizes that some paper records are necessary. The documentation system should not only aid in identifying the types of documents to retain but should also 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. A sound document management system will help prevent miscommunications and misunderstandings and will ensure that the facility operators have the information required to maintain the facility.

Recipients should retain financial records, supporting documents, statistical records and other records pertinent to the award instrument (CAs, grants, subawards, and contracts) for a period of three years after submission of the Final Project Report. In addition, access to any pertinent 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.

The documentation required, and the responsibility for producing and maintaining it, varies within the facility life cycle. During the Design and Development Stage, the Program Officer (PO) is responsible for producing and maintaining documentation related to review and approval of awards. Managing the documentation pertaining to the review and processing of proposals and awards is the PO's responsibility throughout the life of the project. Chapter VI of the *Proposal and Award Manual* (PAM) requires that proposal decisions be clearly documented. Chapter XII of the PAM requires that NSF award records be retained and either retired or disposed of in accordance with Federal law and regulation. NSF documentation should include all partnership and other agreements, standard eJacket submission in the NSF-required format, the Internal Management Plan (IMP), the Baseline Project Definition (typically defined in the PEP), the record of oversight (including all reviews and reports), and all significant project correspondence.

During the Construction Stage, 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; and
- System integration, commissioning, testing and acceptance plans and results.

During the Operations & Maintenance Stage, the Recipient documents facility performance in terms of:

- The facility itself – e. g., historical record of all costs related to maintenance (preventive, deferred, repairs and/or emergency), operating time, and scheduled as well as unscheduled downtime, and
- Use of the facility for research and education (including a record of users that includes the name, affiliation, funding agency, award number and annual award amount for each user).

4.6 REQUIREMENTS FOR NSF PERFORMANCE OVERSIGHT, REVIEWS, AUDITS, AND REPORTING

4.6.1 Introduction to Oversight, Reviews, Audits and Reporting

Oversight, reviews, audits, and reporting requirements change as a facility moves through its life cycle and differ substantially between the Design, Construction, and Operations Stages. The Recipient is responsible for complying with the reporting requirements contained in the award instrument (e.g., technical and financial reporting), this Guide, and in the Proposal and Award Policy and Procedures Guide (PAPPG) – particularly with respect to property management and final reporting and requirements for closeout of the award. The Recipient is also responsible for managing the project and providing internal oversight of its own activities. This may require internal reporting and reviews by committees established by the Recipient institution. NSF is responsible for reporting its performance goals for construction projects based on Recipient EVM reports, per the Government Performance and Results Modernization Act (GPRAMA) of 2010.

Reviews and reporting are an important part of the oversight process that allows the PO to monitor performance against the project plan and goals. Due to the complex nature of major facilities, the level of oversight will be considerably greater than for a typical NSF research grant. The Program Officer (PO) has primary responsibility for oversight of the facility in accordance with the Internal Management Plan (IMP) and through various reviews and reports, such as consultation and coordination with the Large Facilities Office, coordination of assurance through the NSF Integrated Project Team (IPT), and periodic updates to the Facilities Governance Board (coordinated through the CORF) and the NSB.

Reviews and reporting incur certain costs. Depending on the size of the project and the distribution of the information, these costs may be significant enough to warrant explicit inclusion in the project budget. Review and reporting plans and costs should be identified in the PO's IMP and in the Recipient's PEP so that they can be adequately considered in the project budget and schedule. The PO should clearly define the reporting requirements that are the responsibility of the Recipient in the award instrument and these requirements should be noted as milestones on the project master schedule for construction. The Recipient's Project Director adheres to their internal practices regarding financial and business operations controls,[1] and internal reporting (e.g., to the Principal Investigator, Dean, etc., as applicable and required).

It is important that consideration be given to Conflict of Interest rules and Privacy Act restrictions when distributing and sharing reports containing proprietary or confidential information.

[1] See NSF "*Business Systems Review (BSR) Guide*."

4.6.2 Recipient Performance Reports

Reporting requirements vary by facility life-cycle stage (Design, Construction, Operation, and Divestment) and are specified, either explicitly or by reference, in the Terms and Conditions associated with the award between NSF and the Recipient. Performance reports are generally provided on a monthly and/or quarterly basis, with a comprehensive annual report provided by a predetermined date. Separate reporting activities are required for MREFC funds used for construction activity if the facility also receives Research and Related Activities (R&RA) funds. These are specified in the Terms and Conditions of the separate cooperative agreements for each type of funding.

NSF may occasionally request that Recipients provide additional information on a specific activity, often as a result of a unique request from within the government. Such requests may not be specifically included in the cooperative agreements due to their ad hoc and individual nature, nevertheless a Recipient must be prepared to respond. Examples include responses to audit requests from the Office of Inspector General and queries from the US Congress and Executive Branch agencies. Some projects, particularly those with construction activities or frequent changes in design, will need more frequent reporting intervals. For example, providing the written minutes from a weekly construction meeting is common practice.

During the Construction Stage, the Project Director, who is responsible for executing and controlling the project in accordance with the PEP and the award instrument, reports to the Program Officer (PO) on a periodic basis (monthly for MREFC-funded projects and no less than quarterly in other cases). Those reports should 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, 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 photographer acknowledgements;
- INTEGRATED PROJECT SCHEDULE. Chart or table of performance reporting milestones, indicating which are on the critical path, the current projected project completion date and other key milestones on which the EVM is based;
- FINANCIAL SUMMARY AND PROJECTIONS. A narrative describing the amount of construction funding to date and the amount of costs incurred thus far; a discussion of Earned Value metrics with attention to changes from prior month, an estimate of the amount of contingency funds needed to complete the project, and a funding summary and projections indicating actual funding and projected funding by fiscal year;
- EVM DATA TABLE. Earned Value metrics (BAC, PV, EV, AC, CV, CPI, SV, SPI, EAC, ETC), Planned, Actual, and Spent percentage complete, PMB completion date, Award completion date, and risk exposure, at least at the second level of detail in the WBS;

- STAGE TIMELINE OF TOTAL CONSTRUCTION SCHEDULE. "S" curve table comparison of the Actual Cost of Work Performed (ACWP) with the Budgeted Cost of Work Performed (BCWP) by quarter within each fiscal year up until the present quarter; and the Budgeted Cost of Work Scheduled (BCWS) for those quarters and extending to the end of the construction phase;
- ROLLING TWELVE-MONTH WINDOW. "S" curve table depicting the same data as the previous table in a twelve-month snapshot centered on the month of the report;
- SV AND CV TREND GRAPH. Cost and schedule variances and performance indexes (CV & CPI and SV & SPI) over a twelve-month period;
- DISCUSSION OF VARIANCE AND CORRECTIVE ACTIONS AT THE WBS LEVEL. 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 and remediation/recovery plans[1];
- BUDGET CONTINGENCY. Available balances of budget and schedule contingency, as a total amount (dollars or calendar days), and for budget contingency as a percentage of the estimated cost to complete (ETC) the project. A "liens" list of projected amounts of possible future calls on contingency and an updated change log indicating all contingency allocations ("puts and takes").

For major facility projects in the Construction Stage, the PO is responsible for providing to the LFO a written monthly summary of this information in a standard format provided by the Head, Large Facility Office (HLFO). Smaller-scale projects will provide status reports to the PO with a frequency and level of detail defined in their respective Internal Management Plans (IMPs). In every case, the PO is responsible for keeping the appropriate NSF staff (Grants and Agreements or Contracting Officer, Division Director (DD), Assistant Directors (ADs), Integrated Project Team (IPT) members, etc.) informed of the project status.

In executing and controlling the project, the Recipient manages the project to the Performance Measurement Baseline (PMB) definition for cost, schedule, and scope. As part of routine reporting process, the Recipient will notify the PO of project cost and schedule variances exceeding ±10%, including explanations of causes and any correction actions, at the WBS levels agreed upon between NSF and the Recipient. Per Section 4.6.4 NSF's Performance Metric for Construction, the Recipient will notify the PO of total project cost and schedule variances, at Level 1 of the WBS, exceeding ±10%, including a recovery plan, with an associated timeline.

[1] Variance reports provided by Recipients are used by NSF in its metrics for construction project performance goals, In accordance with the GPRA Modernization Act of 2010. See Section 4.6.4, NSF Performance metric for Construction.

4.6.3 Recipient Performance Reviews and Audits

4.6.3.1 Recipient Internal Reviews

The Recipient will demonstrate appropriate internal management by conducting its own reviews and internal audits in conformance with generally accepted accounting standards, project or operations management practices, and State and Federal regulations as appropriate. These reviews include, but are not limited to, technical, design readiness, procurement readiness, progress and planning, risk, safety and acceptance reviews as well as self-audits. The kind and frequency of all reviews and audits should be addressed in the Project Execution Plan (PEP-14.2). Although internal review team's members are typically project staff, consideration should be given to the inclusion of outside subject matter experts, who can provide a valuable independent perspective. Consideration should also be given to inviting NSF staff as observers.

4.6.3.2 NSF External Reviews

NSF requires periodic external reviews that provide advice on the status and anticipated future performance of the facility activities. The frequency and content of these reviews are specified in the terms and conditions of the award instrument. Typically, the periodic reports (monthly, quarterly, annual) are used to help evaluate and monitor progress and provide information to review panels. Additional ad hoc reviews may be conducted by the PO under certain circumstances, such as significant re-planning of construction projects, changes in management structure, and major changes in research technical design, direction, or scope. These reviews should determine the extent to which the facility is meeting the goals of their Annual Work Plan as well as the overall goals for the award, discuss any upcoming challenges and highlight good practices and lessons learned that could be applied to other NSF major facilities. Whenever possible, the review should be conducted at the facility itself by an external panel with expertise in the construction and operations of large scientific facilities.[1] The panel should produce a formal written report to NSF. In all cases, NSF should develop a review charge written to elicit advice matched to the specific needs and challenges of the facility at the time. Invitees to the review must include the PO, the Grants and Agreements or Contracting Officer, and staff from the Large Facilities Office. These reviews should be coordinated other reviews and audits listed in Section 4.6.3, such as the Business Systems Review (BSR).

Careful consideration should be given to the selection of independent reviewers, and in all cases the skill sets of the reviewers should be matched to the type and kind of review to be conducted. Broad programmatic review panels charged with reviewing all aspects of a project will generally have representation from the academic and broader national/international research community, as well as experts in administrative aspects of facilities/project

[1] Consult with the NSF Program Officer for guidance and good practices with respect to planning and executing External Reviews of NSF's major facilities.

management. A review panel focusing on specific administrative or technical aspects of a project would have a different set of skills.

The PO may use a standard review "template"[1] developed by the Division or Directorate. These provide a broad outline against which the project can be compared and may include checklists that can be used to assess the status of the project. These formats can be particularly helpful in the pre-award phase in ensuring that the project is ready to be implemented.

4.6.3.3 Business Systems Reviews (BSR)

The BSR is one of NSF's advanced monitoring activities that assist with oversight and provide assurance of the suite of business systems that support the administrative management of a major facility. These reviews are designed to provide reasonable assurance that the business systems (people, processes, and technologies) of NSF Recipients are effective in meeting administrative responsibilities and satisfying federal regulatory requirements including those requirements listed in *NSF's Proposal & Award Policies & Procedures Guide (PAPPG).* Specifically, a BSR verifies that administrative, including financial, policies and procedures are written; evaluates the extent to which these policies and procedures conform to OMB requirements, NSF expectations, and other applicable federal regulations; and validates they are being used to administratively manage the major facility in each of the core functional areas. BSRs are also intended to provide an opportunity for cross-fertilization of ideas through the identification of good practices and serve to refocus Recipients on the importance of administrative quality.

The LFO has the lead role in coordinating the assessment of these systems by using desk reviews and site visits to determine if the administrative business systems used in managing the facility meet NSF expectations and are in compliance with federal regulations.

BSRs are conducted on a regular review cycle which is informed by the internal NSF annual Major Facility Portfolio Risk Assessment. For major facility projects, the BSR can be used to strengthen the Institutional capacity in advance of a construction award. Risk factors reviewed during the annual Major Facility Portfolio Risk Assessment typically include:

- The timing and associated findings of other related reviews or audits of administrative business systems;
- Management structure providing administrative business systems support, and;
- Significant changes in funding levels or the Recipient's award administration.

Further information and various details of the BSR process are provided in the BSR Guide, [2] which defines and establishes the procedures for the planning, execution and follow-up

[1] Please contact the cognizant NSF PO for details and a description of good practices and/or preferred templates.

[2] See "Business Systems Review (BSR) Guide" at the NSF Large Facilities Office website.

activities associated with conducting BSRs. The Guide also defines the roles and responsibilities of NSF staff assigned to BSR activities and identifies core functional and targeted review areas.

4.6.3.4 Incurred Cost Audits

For cooperative agreements, NSF conducts an incurred cost audit for major facility awards above $70M at the end of the award and potentially during execution of the award based on an annual risk assessment conducted by the Large Facilities Office and the Cooperative Support Branch at NSF. These incurred cost audits are required for construction awards. Recipients should be prepared for such an audit at any time based on 2 CFR § 200.205-7 of the Uniform Administrative Requirements, Cost Principles and Audit Requirements for Federal Awards and as stated in the terms and conditions in the Cooperative Agreement. For contracts, incurred cost audits are performed in accordance with in the FAR, the cognizant Federal Agency procedures, and terms and conditions of the contract.

The purpose of the Incurred Cost Audit is to provide prudent oversight for those responsible for the effectiveness, efficiency, and economy of the Recipients' operations and the use of Federal funds. The Incurred Cost Audit is performed to assure the existence of adequate controls which will prevent or avoid waste, fraud, and abuse and inefficient practices.

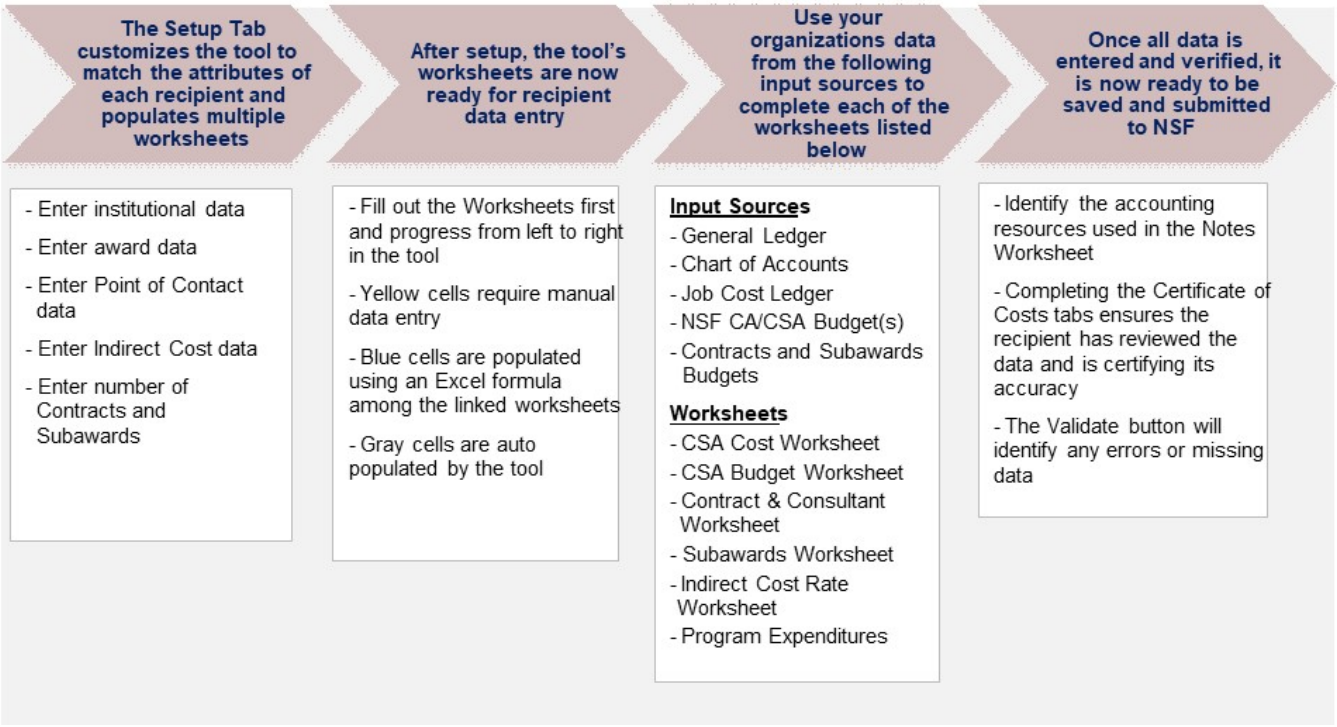
In preparation for an incurred cost audit, Recipients are required to submit financial expenditures (incurred cost) data to NSF on a frequency to be determined by the Grants and Agreements Officer and the Cooperative Agreement's Terms and Conditions. It will be no less frequently than annually. NSF Financial Data Collection Tool for Major Facilities, created by NSF to assist Recipients in preparing and recording financial expenditure information for its cooperative agreements for major facilities, is required for submission of the financial expenditures data. The NSF Financial Data Collection Tool for Major Facilities is a macro-enabled Excel workbook that provides Recipients a single, standardized method for submitting direct and indirect expenditure data with minimal effort and help to ensure data quality and accuracy. It will enable NSF and independent auditors to more easily and consistently collect the financial data required to maintain proper oversight and stewardship over funds and facilitate Recipient compliance in meeting its reporting requirements.

To complete the data collection, Recipients will need to collect expenditure information for all active Cooperative Agreements and Cooperative Support Agreements during the awards performance period. Suggested sources from which to collect this data include the Recipient's Chart of Accounts, General Ledger, Project Cost Ledger, NSF Award budget, and the award organization's Negotiated Indirect Cost Rate Agreement. To submit expenditure data, Recipients can download the NSF Financial Data Collection Tool for Major Facilities file from NSF at: http://www.nsf.gov/bfa/lfo/lfo_documents.jsp

Once downloaded, Recipients should save the file and then begin to enter data following the guidance provided in the tool. See Figure 4.6.3-1 for a flow diagram for data entry. Recipients

are instructed to submit this data collection annually to NSF as well at the end of your project or based on the Terms and Conditions of the award. When completed, this NSF Financial Data Collection Tool for Major Facilities will allow submission financial data electronically to the NSF Grants and Agreements Officer or an independent auditor. Questions regarding this collection should also be directed to the responsible NSF Grants and Agreements Officer.

Figure 4.6.3-1 NSF Financial Data Collection Tool for Major Facilities Process Flow Diagram, identifying the core data sources Recipients should utilize to complete the worksheets to accurately capture the data. Progressing through the tool's worksheets from left to right will streamline the data capture and submission process.



4.6.3.5 Accounting System Review or Audits

Recipients must maintain adequate internal controls, policies and procedures, and reliable accounting systems. NSF's efforts to implement additional procedures to enhance oversight capability include requiring accounting system analysis in certain circumstances. Specifically, in order to assess and determine if a Recipient's accounting system is adequate for use with cost reimbursement type agreements, NSF will analyze the Recipients' accounting systems / practices prior to entering into any new major facility construction cooperative agreements totaling $70 million or more, in those cases where such a review has not been performed within the past two years.

NSF may also procure accounting system reviews or analysis for Recipients when a Grants and Agreements Officer cannot conclude whether a Recipient's accounting systems are adequate or

determined needed during the annual risk assessment. NSF will review any recent accounting analysis or audit submitted by the Recipient, and to the extent such reviews meet NSF's needs, we will be used in lieu of a new review.

4.6.3.6 Earned Value Management Verification, Acceptance, and Surveillance

NSF requires major facility project Recipients use EIA-748 compliant Earned Value Management System (EVMS) as an integrated management tool for successful project planning and execution. To ensure that the Recipient's EVM data provide timely, accurate, and reliable performance information, NSF conducts project EVMS verification, acceptance, and surveillance based on the processes recommended in the National Defense Industrial Association (NDIA) Earned Value Management (EVM) Guides[1] as part of the project oversight and monitoring activities. Section 6.8 of this Guide discusses basic principles and guidelines for implementation of EVMS.

The project 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 EVMS verification and acceptance of a project is intended to ensure that the implementation of EVMS for the project is appropriately tailored to the project's management needs. For the project to utilize the full benefits of EVMS and aid the successful execution of the project plan, the EVMS should be properly scaled and the 32 guidelines applied in a way that reflects the size, complexity, risk, and nature of the work. NSF's acceptance of a project's EVMS is not intended to be a certification of a Recipient'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 Recipient. If a Recipient has a current EVMS certification from another Federal Agency, the NSF EVMS verification review may be modified, but NSF acceptance will still need to be documented and on-going surveillance performed.

The project's EVMS verification is performed through a Compliance Evaluation Review (CER) process. NSF strongly encourages projects to utilize EVM to the extent practicable during the Design Stage to prepare for full implementation during the Construction Stage. NSF will complete the CER well in advance of the award of construction funds. The NSF acceptance of the project's EVMS should occur before actual physical construction or major acquisitions commence and will be based on acceptable resolution of the findings from the CER.

The LFO has responsibility for NSF's EVMS verification, acceptance and surveillance process. Working closely with the Project Team, the LFO Liaison and the Program Officer will determine the best time for conducting the initial CER and any follow-up activities for acceptance. After acceptance, periodical surveillance reviews should be conducted during the construction stage to ensure that the accepted EVMS is being maintained and followed, and that the EVM data

[1] Refer to Section 7 Refences of this Guide for a list of these NDIA guides.

and information are being used to inform project management decision making. The frequency and focus of surveillance reviews are determined by the Program Officer in consultation with the Large Facilities Office via the LFO Liaison but are generally conducted as part of the annual construction review to minimize burden. The scope of the surveillance reviews can be inclusive of all EIA-748 guidelines or can concentrate on specific areas of interests. Targeted surveillance reviews may result from corrective actions, new procedures, and/or demonstration of practice.

4.6.4 NSF Performance Metric for Construction

In accordance with the Government Performance and Results Modernization Act (GPRAMA) of 2010 (Public Law 111-352); *Empowering the Nation Through Discovery and Innovation: NSF Strategic Plan for Fiscal Years (FY) 2011-2016;* and OMB requirements, NSF developed goals to measure construction/upgrade performance based on EVM systems used to monitor project cost and schedule. **For MREFC-funded projects[1] under construction and more than 10 percent complete, the NSF performance metric goal (using EVM) is keeping both the total project cost and schedule variances against the Performance Measurement Baseline at, or better than, negative 10 percent.** Projects that are less than 10 percent complete are not held to this goal because EVM data is less meaningful statistically in the very early stages of a project.

Total project variances exceeding 10 percent (positive or negative) should be reported to NSF by the Recipient and be accompanied by an explanation and a proposed plan and timeline for recovery or accommodation of the cost and schedule shortfalls (e.g., use of contingency, de-scope).[2]

[1] This includes facilities whose construction is partially supported by funds or in-kind contributions from outside agencies. In such cases, the variance for the total project and the variance for the NSF-funded portion should be reported separately. For example, if the total project variance is -7% and the NSF portion is -12%, then the -12% would be reported, accompanied by a recovery plan. Alternatively, if the total project variance is -15% and the NSF variance is -11%, then both variances would be reported with appropriate recovery plans with timelines.

[2] See section 4.6.2 for requirements on variance reporting at lower WBS levels for monthly progress reports.

4.6.5 Re-Baselining

If maintaining the original PMB via re-planning is no longer possible, and the scope, total project cost, or approved project end date are in jeopardy, the Recipient will consult with the PO to determine whether re-baselining the project is warranted. When deciding which course of action to pursue, the PO will need to balance the effect of failing to achieve the project's performance goals against the impact on the research and education proposed for the completed facility.

The PO should consult with the NSF Integrated Project Team and the Directorate/Division Leadership, prior to authorizing re-baselining a project. Variances may result from many factors – for example, inadequate project planning or management, or factors not within the Project Director's (or manager's) control. Examples include failure to identify the complexity in particular tasks (such as integration), failure to budget for adequate labor, materials or time versus unexpected increases in the cost of labor and/or materials, unavailability of labor and/or materials, unusually severe weather, etc.

For construction projects, uncertainties are normally managed through re-planning[1] and the use of contingency, per Section 4.2.5. Re-baselining for construction projects occurs for variances that result in:

1. Increases above the NSB-authorized Total Project Cost (TPC),
2. A change in the total project duration, and/or
3. Major changes in scope.

NSF approvals are required per Section 2.4.1 of this Guide. If only the schedule is extended without an increase in TPC, the terms and conditions of the award instrument apply (i.e. NSF policy on No-Cost Extension for CAs).

Re-baselined projects will generally go through external panel review depending on the timing and expediency required, all stage complete NSF cost analysis, and Board authorization. Once a re-baselined Project Definition has been authorized, the re-baselined requirements replace the Baseline Project Definition as the standard against which progress is measured. Consequently, costs exceeding budgeted amounts in the initial Baseline Project Definition are not referred as "overruns" once a new project PMB has been implemented by the project management and accepted by NSF.

[1] See Section 2.4.1 for the definitions of "re-baselining" and "re-planning".

4.7 PARTNERSHIPS

4.7.1 Partnerships Overview

For both major facility and smaller projects, partnerships are an essential consideration – beginning at project development and all the way through divestment. Partnerships may take many forms, but typically include coordinated funding from states or state institutions, other federal agencies,[1] non-governmental entities, and foreign funding agencies. International partnerships are generally the most complex.

Key issues in these partnerships, whether international or the result of interagency or state collaboration, present several important challenges that the Recipient and PO need to consider carefully.

The first is "culture shock." The science or engineering cultures in different countries will generally exhibit great variations in procedures when it comes to funding, managing and overseeing, constructing and operating a facility. Differences often include lack of mutual understanding or considerably different contexts for defining the role and function of project management. It is typically very challenging for each nation to manage its part of the project unless there is a means for integrated management and oversight by the central Project Manager.

The Project Director or Manager should be in place before funds are released and, to be most effective, should be given budget authority (or authority over in-kind resources) and should not simply act as a coordinator. In terms of oversight, reviews of project status by U.S. agencies are not universally accepted. U.S. agencies use reviews heavily, but not all countries do. In some countries, reviews that uncover problems may be received without a sense of urgency and may not be acted upon quickly. U.S. partner agencies may be able to insist upon resolution of issues when playing a majority role in funding; if not, other steps should be taken. Full project transparency is essential to success.

A second important issue is early negotiation with international partners. There is a need to start with a clear understanding by all partners as to how the construction project is to be managed, or, in the case of operations, how the facility is to be operated. It is also important to know how agencies (ministries) in different countries view the project in terms of shared goals, the science or engineering case for the project, and its priority. If participating partner countries all rate the priority of a project at the highest level, then commitments carry more weight.

Funding risks associated with international partnerships should be assessed and fallback plans developed regarding potential changes in commitment. Finally, early negotiation also provides

[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.

a means to establish and maintain regular agency-to-agency contacts, providing an early understanding of funding pressures and other emerging pressures in each country.

The cognizant NSF Program Officer should be informed of potential international partnerships early in the process and kept apprised of significant developments. The cognizant Program Officer will coordinate with the NSF Office of International Science and Engineering to ensure that potential international partnerships are in compliance with U.S. law, NSF policy, and current foreign policy and geo-political considerations.

4.7.2 Partnership Funding

Funding of projects involving partnerships is obviously a central consideration. International partner agencies need to understand the funding processes in the different countries involved. The complexity of the NSF process can lead to misunderstandings regarding the schedule of funding and project approvals. Because of the great variation among countries as to how labor costs are counted, it is good practice to adopt standard costing techniques for equipment, labor, commissioning and operations. MOUs need to be developed, detailing the foreign contributions. In some cases, these contributions may be in cash or in-kind level of effort; but deliverables should be clearly specified, and the contributions should be valued in U.S. equivalent terms (including all labor costs) for projects in which NSF is the lead agency. To aid project management and eventual close-out, it should also be made clear what scope NSF and the other partner are either paying for or contributing (by WBS element) and proper segregation of funding rules employed as appropriate.

As with all such projects, contingency funds (or their equivalent) need to be identified by all partners. There is great variation in practice among countries, again because labor costs may or may not be included in contributions to the project. This can have a great impact. For example, in a cost-overrun situation it may become expeditious to simply stretch the project out. This may work for one country, resulting in less focus on schedule issues; but it generally does not work for U.S. projects where "standing army" costs are directly allocated to the total cost for construction of a facility.

In addition, when partner funding is in cash, variations in exchange rate can have a large effect on the ability of a given country to meet its commitment on deliverables. Therefore, scope contingencies need to be explored. When international partners do not include adequate contingency, and the U.S. does, funding "caps" (agreed upon in advance) are an appropriate practice. Although caps may enforce discipline, they may have other effects. For example, when there are schedule slips and "standing army" costs rise, caps can limit the deliverables that may be provided. Strict adherence to caps may therefore compromise the overall performance goals.

Finally, a facility's project management and operations plans should be well understood by all partners. When different countries have responsibilities for separate subsystems, strong system integration and comprehensive interface documents become very important. The change-control process needs to be clearly understood. Change control is made very complex because performers in one country may be ill equipped to handle or adapt to required changes. It is also very important to establish a sound schedule baseline and adhere to it.

For partnerships with organizations or agencies in the United States, the following activities are advised:

- Evaluate NSF's role (NSF's authority and responsibility vary depending on its status as executive agent or as a majority, equal or minority partner). Assess risks and develop a

plan to address them, e.g., implementation of controls that limit NSF's exposure to overruns (see Section 5.2, Risk Management Guidelines).

- Ensure that all partners understand the review and approval processes of the other partners.
- Prior to entering into a partnership, develop and execute an MOU.

4.7.3 Memorandum of Understanding (MOU) with NSF

MOUs are broad, general agreements between NSF and other parties to pursue activities of mutual interest and benefit; cooperate in areas where science and engineering interests coincide; and provide a framework for cooperation. A typical MOU includes:

- The purpose of the Understanding; authority of the parties to enter into an Understanding;
- Scope of the Understanding, including a project description and the respective responsibilities of each party for funding, management and oversight (including procedures for resolving conflicts and dealing with defaults);
- Rights of each party with respect to access, ownership and intellectual property (Chapter VII of the PAM); means for resolving disputes; and
- A termination clause.

MOUs are developed by the PO and cleared according to procedures outlined in Chapter VIII of the *Proposal and Award Manual* (PAM).

5 GUIDANCE FOR MID-SCALE RESEARCH INFRASTRUCTURE PROJECTS

This section addresses guidance for the planning and oversight of mid-scale research infrastructure projects as defined in Section 1.4 of this Guide. These oversight processes draw on the well-established good practices within sponsoring directorates and divisions for such projects, which follow the requirements in the PAPPG.

Mid-scale project oversight requirements are to be tailored based on each project's unique characteristics such as the technical scope, the type and mix of work performed (e.g. standard procurement by the Recipient, software development, or civil construction), and an assessment of the associated technical and programmatic risks. However, NSF is committed to the principle that this flexibility does not preclude the requirement for appropriate rigor on the part of NSF or the Recipient. Appropriate use of NSF major facility oversight practices will be determined on a case-by-case basis as outlined below.

Similar to major facilities, mid-scale project proposals should include actual costs and budget estimates for all stages of the project life cycle: development and design, construction or acquisition, operations, and divestment, although these stages may be less rigorously defined depending on the project scope and history. For example, actual costs should be included for investments previously made during development and design when submitting a proposal for the construction or acquisition. Mid-scale project proposals should also include a Concept of Operations discussion and the strategy and timeline for eventual divestment so the proposal can include estimates for eventual operations and divestment. See the Project Execution Plan (PEP) discussion below. The detailed programmatic requirements for these estimates will be included in solicitations calling for mid-scale infrastructure.

Budgets should be supported by well-documented Basis of Estimates (BoE) developed in accordance with the best practices and twelve steps outlined in the GAO Cost Estimating and Assessment Guide to meet the four characteristics of a high-quality estimate: well-documented; comprehensive; accurate; and credible (see Section 4.2 of this Guide). If use of Earned Value Management (EVM) is proposed, schedules should be developed following the best practices outlined in the GAO Schedule Assessment Guide (See Section 4.3 of this Guide).

Selection Criteria: Mid-scale projects are selected based on the merit review criteria detailed in the program solicitation. However, some typical project characteristics that may be considered are listed below.

- Opportunity to enable frontier science and engineering (S&E) research and education;
- Compelling research needs;
- Priority within the relevant science communities;
- Accessibility to an appropriately broad user community;
- Level of maturity on collaboration of partnerships;

- Budget alignment with solicitation and life cycle cost impacts;
- Technical feasibility and consideration of risks; and
- A Project Execution Plan (PEP) appropriately scaled to the project.

Unless a risk for award is identified by Office of Budget, Finance, and Award Management (BFA) or Program during proposal review, there are generally no additional pre-award review requirements once the NSF review and selection process are complete and a subsequent award is made.

Review Process: Mid-scale projects are not subject to the formal stage-gate review process given in Section 2.3 of this Guide. However, the internal proposal review process used by NSF for construction/acquisition proposals should be sufficiently robust to assess readiness using a similar philosophy to the Final Design Review but scaled appropriately to the program. This review process will also include an assessment against the programmatic selection criteria given in the solicitation.

These reviews, as well as reporting to assess progress against plan during implementation, will be determined by the Program Officer in consultation with the Grants and Agreements Officer and LFO Liaison (if applicable, see below). Reporting and progress review requirement will be codified in the award.

Programmatic Deliverables: Mid-scale projects should be executed using well-established project management methodology. The specific project management approach used should be scaled to the needs of the project. For example, project management controls used to manage project resources and schedules, the use of EVM, financial and progress reporting requirements, and risk management techniques should be carefully considered such that burden does not outweigh the benefit.

A Project Execution Plan (PEP) is required for all mid-scale projects in order to document the foundation for how the project will be managed by the Recipient. Concurrence on an initial PEP must be reached between NSF and the proposing organization. It is reasonable to expect the PEP to evolve during the execution of the award.

The following list provides the minimum required components of the PEP for a mid-scale project as compared to Section 3.4.1 of this Guide. The contents of each PEP component should be tailored in both detail and scope to the specifics of the project. Refer to Section 3.4.1 of this Guide for descriptions of typical elements of each PEP component. Unless otherwise noted in the solicitation, the sub-topics within each PEP component should be included. Although, some of the material may also be included in the mid-scale proposal itself, inclusion in the PEP allows for completeness and reference in the award terms and conditions.

1. Introduction
2. Organization
4. Construction Project Definition
6. Risk and Opportunity Management
8. Configuration Control
9. Acquisitions
10. Project Management Controls. The scope, complexity, budget profile, and duration of a project should be assessed to determine the benefits for Earned Value reporting versus its reporting burden.
12. Cyber-Infrastructure
13. Commissioning, including Concept of Operations

The PEP should be included in the Supplementary Information section of the proposal.

If the project will be integrated into a larger facility or instrument, the proposal should include a section discussing planned system engineering activities. If the site selected has any known or potential requirements for permitting or environmental impact studies, a discussion of this should be included in the PEP. Section 6.5 of this Guide discusses environmental regulations associated with construction or modification of facilities. Inclusion of other PEP components detailed in Section 3.4.1 of this Guide is optional and should consider the unique attributes of the project.

The Performance Measurement Baseline (PMB) for the project is set by the proposed scope, budget, and schedule as defined at the time of the award. All reporting is done against this project baseline. The baseline budget, budget contingency and fee (if any) comprise the Total Project Cost (TPC). The estimation and use of budget contingency (if proposed) must follow Section 4.2.5.7 of this Guide.

Although substantial rigor is required in establishing the TPC, mid-scale research infrastructure projects are not subject to NSF's "No-Cost Overrun" policy used for major facilities projects as defined in Section 1.4.5.

PO Oversight: At the earliest practical point, each mid-scale project is assigned a cognizant NSF Program Officer (PO)[1] with primary responsibility for award management and project oversight. The PO (or POs) creates a Management Plan (MP) to document key project characteristics, the planned oversight approach, and any extraordinary exceptions or additions to the guidance presented in this section as part of the program solicitation development in accordance with NSF policy. Formal Internal Management Plans (IMP) used for major facilities are not required.

[1] Also referred to within NSF as Program Director or Program Manager.

Depending on the funding account, the PO assigned to manage mid-scale projects may be required to be permanent NSF employees, as required by statute. The technical background and experience of the cognizant NSF PO for a mid-scale project should be appropriate to late-stage design and construction activities as determined by the Sponsoring Organization.

Interaction with the Office of Budget, Finance and Award Management (BFA): Program Officers recommending mid-scale projects as defined in Section 1.4 of this Guide with a TPC over $20 million must consult with BFA prior to award. To support oversight of stand-alone mid-scale projects, the Large Facilities Office (LFO) will generally appoint one LFO liaison to assist Programs and the Grants and Agreements Officers in the appropriate BFA unit, either Division of Grants and Agreements (DGA) or Division of Acquisition and Cooperative Support (DACS), depending on the nature of the project and the funding program. For mid-scale projects that are upgrades to major facilities, the LFO Liaison assigned to that facility will provide support to Program and the Grants and Agreements (or Contracting) Officer.

Integrated Project Teams: Mid-scale projects consisting of upgrades to existing NSF major facilities should be coordinated through the NSF Integrated Project Team (IPT) for that facility. Formal IPT's are not required for stand-alone mid-scale projects.

Budget Inclusion and the National Science Board: Inclusion in the NSF budget is either done as part of a Directorate-level or agency-wide program as described in the solicitation. While major facilities require formal NSB authorization for future budget inclusion, the level of engagement for mid-scale projects by the National Science Board is based on the annual award amount, the current Board award authorization thresholds, and the account from which the project is funded.

6 SPECIAL TOPICS AND SUPPLEMENTARY MATERIALS

6.1 INTRODUCTION

This section contains extensive supplementary information on special topics having to do with the National Science Foundation (NSF) role in planning, oversight, and assurance of major facility projects. The materials are presented in a tutorial format to be of particular benefit to individuals newly involved with major facility projects. They are based primarily on current standards and good practices for project management.

6.2 RISK MANAGEMENT GUIDELINES FOR CONSTRUCTION STAGE

6.2.1 Introduction

Project risk management is a process which increases the probability of a successful project by identifying threats to the project, assessing the nature of those threats, and identifying actions that can be taken to either reduce the probability of those threats occurring or reduce the impact of the threats to the project. Even on a simple project, things seldom go as planned. With the highly-technical, scientifically ground breaking, and long duration projects undertaken by the NSF there will be many changes required to the baseline plan as a project matures. Successful projects anticipate problems, work to avoid those problems, and limit the impact those problems will have on a project.

Risk management serves two purposes; one is to forecast impacts of possible events on the project's cost and schedule, the other is to prioritize and inform project decisions on alternate strategies to mitigate the cost or schedule impact of a possible event or increase the technical performance margin of a system or subsystem. The former (quantitative risk analysis) creates a framework for quantifying the risks to the project goals in terms of cost in dollars, schedule in days, and performance for the purpose of forecasting the final cost, schedule, and performance of the complete project. The latter (qualitative risk analysis) helps the team sort through the hundreds and perhaps thousands of risks to identify and address the ones that are most likely to have the most significant impact on the project.

Qualitative risk analysis practices have remained relatively unchanged recently while quantitative risk analyses have been evolving rapidly as the software tools and their integration with scheduling software packages have evolved. While quantitative risk analysis has become easier and more sophisticated, it is unlikely to fully replace qualitative risk analysis because the quantitative analysis requires validated inputs that are more labor intensive to produce. Most projects utilize the qualitative risk analysis practices for their month-to-month risk management and implement quantitative risk analysis only when they need to re-forecast the estimate at complete cost and completion date of the project.

Risk management involves all project personnel. With an effective risk management project every project team member should be able to state the top project risks as well as the top risks to their subsystem. Risk management has an inherent Malmquist (completeness) bias – there will always be more risks to a project then are reflected in the risk register. To minimize this effect every project team member from every perspective in the program should be contributing threats, opportunities, and mitigation ideas to the risk board. The team also needs to be well aware of the risks associated with their subsystems, so they recognize how a mistake in their area would impact the overall project (an aspect of human error prevention and project safety).

Some projects refer to risk management as risk and opportunity management, to emphasis to the team that they should also be thinking about opportunities for changes in the baseline plan that could save cost, save schedule, or improve performance. This section follows the Hulett definition of risk that is in the Project Management Body of Knowledge (PMBOK) that includes opportunities in the definition of risk. Project teams should remind each other to keep thinking about new opportunities as well as threats to the project.

Risk and opportunity management feeds into the key decisions that make a project successful. It is a core activity for project managers, systems engineers, subsystem leads, program officers, and review panels.

NSF requires major facility Recipients to develop and follow formalized Risk Management during the design and construction stages of major facility projects.

Successful Risk Management entails early recognition, proactive planning, and aggressive execution of all risk management processes. Ideally Risk Management begins as early as the initiation stage of the project life cycle. This Guide provides detailed information on the Risk Management[1] methodologies and strategies commonly applied during project planning and execution.

There are three key products of Risk Management as applied to NSF construction projects:

- A Risk Management Plan that sets out how risks will be identified and managed by the project following standard risk management processes and practices,
- A Risk Register, or tracking tool, that documents identified risks, and
- A determination of Risk Exposure and the related amount of Contingency needed to control risks, based on quantitative risk analysis.

The Risk Management Plan (RMP) is a required element of the Project Execution Plan (PEP) described in Section 3.4 of this Guide (often as a separate document). A RMP should be included in the project planning and proposals no later than the start of the conceptual design phase. The 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. An example of an acceptable RMP outline is shown in Table 6.2.5-1.

The Risk Register – typically a spreadsheet or data base – is a tracking tool that includes a description of all risks that are deemed to be important to achieving project success, along with

[1] The NSF Program Officer, as part of oversight responsibilities, identifies project-related agency risks to NSF, formulates mitigation strategies, and documents them in an Internal Management Plan (IMP), accessible only to NSF staff.

an assessment of those risks that allows them to be prioritized for effective management. The Risk Register also includes the risk handling strategy, the person to whom each risk has been assigned for accountability purposes, the current status of the risk handling strategy, and comments. An example of a commonly used style for a Risk Register is given in Table 6.2.5-1. It should be noted that appropriate tracking tools will vary among projects because the types of information and indicators being monitored vary from project to project. The selection and definition of a tracking system to be used in a project should be commensurate with the size and complexity of the project and should be defined in the project's RMP.

Risk Management strategy involves the estimation of overall risk exposure and the determination of an adequate amount of contingency – a quantity of money, scheduled time, or reductions in scope intended to recover project objectives if uncertainties and risks occur with negative impacts. The values for cost and schedule contingencies are taken from distributions generated by Monte Carlo simulations with probability and impact ranges for uncertainty and risks for activities defined in the baseline. The confidence levels for meeting a chosen project end date and total cost should lie between 70% and 90%. Scope contingency involves identifying lower priority tasks that can be delayed or dropped from the project without a crippling impact to project objectives. De-scoping may be used if the project forecast indicates that cost or schedule overruns are likely. For NSF major facility projects, these contingencies are held separately from the project Performance Measurement Baseline (PMB)[1] budget, schedule, and scope. Strategies for using contingency are detailed in the project Risk Management Plan. Contingency is controlled and managed through the project Configuration/Change Control Process (CCP). The use of contingency is subject to approval by project leadership, and by NSF, if amounts are above certain thresholds, as defined in the cooperative agreement (CA).

While the text of this section tends to refer to projects in construction, good risk management practices can be useful throughout a project's life cycle, including during operations. "The best laid schemes of mice and men / Often go awry." Implementing preventative mitigations and pre-planning alternative strategies will reduce the likelihood and impact of these events. The following subsections provide guidelines for planning the Risk Management processes, developing the RMP, creating a Risk Register, and calculating a quantized measure of risk exposure that leads to the establishment of contingencies. Examples of accepted or good practices are included as guidelines.

[1] Performance Measurement Baseline (PMB) is the approved cost and schedule plan established at award for accomplishing the scope that can be changed only through formal change control process.

6.2.2 Definition of Project Risk and Risk Exposure

Risks are defined many ways. One of the most inclusive definitions, and the one used in these guidelines, is; "… an uncertain event or condition that, if it occurs, has a positive or negative effect on at least one project objective**."**[1]

Most international standards agree that risk is made up of both threats and opportunities. Capturing and capitalizing on opportunities to reduce costs, save time, and improve technical performance may improve the possibility of finishing on time, budget, scope and quality by offsetting the negative impact of threats to those objectives. The tools and methods employed in managing threats are also used to identify and take advantage of these opportunities for reducing project cost or schedule or improving technical performance. NSF requires Opportunity Management as a necessary component of risk management.

Project **Risk Exposure** is the quantized result on project objectives of various risks and uncertainties occurring. Project risk exposure is usually expressed as an amount of budget or time that is the output of a Quantitative Risk Analysis that combines probability of occurrence with consequence. Project risk exposure diminishes over time as risks are realized or avoided and should always be less than or equal to remaining contingency amounts.

[1] This definition is used in the *Guide to the Project Management Body of Knowledge*, (PMBOK® Guide), Project Management Institute, 5th Edition, 2013, Chapter 11.

6.2.3 Definition of Allowable Contingencies

Contingencies are a necessary component of risk management for NSF projects – they provide the wherewithal and flexibility to control risks and realize opportunities. Contingency allocations are for in-scope deliverables and are to be used to mitigate identified risks and uncertainties that may impact a projects ability to achieve approved project objectives.

6.2.3.1 Allowable Contingency

Most risk management guides define two general types of budget and schedule contingency:

> **Contingency:** *"a planned amount of money or time which is added to a baseline estimate to address specific, identified risks."*[1] *It is an estimated amount based on various risk management techniques and managed by the project.*
>
> **Management reserve:** *"a planned amount of money or time which is in addition to the baseline estimate and contingency to address unforeseeable events."*[2] *It is not managed by the project.*

NSF does not normally carry management reserves as defined above. For NSF projects, only the first type, **Contingency**, is allowed in the Recipient's portion of the NSB authorized Total Project Cost (TPC). This means that the estimation of contingency amounts should be tied to risks identified at the time the total budget and duration are set, and that such contingency can only be used to mitigate those pre-identified risks. See Section 6.2.7 for using proper quantitative estimating methodologies for determining risk-based contingencies.

In addition to budget and schedule contingency planning, NSF requires projects to assess possible use of scope contingency and to develop a plan to make effective use of scope contingency options, if necessary, during construction. This provides the project with an additional tool to manage the overall project. Use of all contingency is managed through formal change control processes, as described in Section 4.2.5.

6.2.3.2 Contingency Definitions

Contingency for NSF projects includes cost, schedule, and scope amounts, as defined below:

> **Budget Contingency:** *An amount added to a baseline budget estimate to allow for identified items, conditions, or events for which the state, occurrence, or effect is uncertain and that*

[1] Identified risks are often referred to as "known unknowns" in the literature. In other words, a risk that can be identified during planning is "known," but the probability of occurrence and the extent of its impact cannot be determined with accuracy and are therefore "unknown."

[2] Unforeseeable events are those that are not or cannot be identified during planning and are typically referred to as "unknown unknowns" in the literature. They may also include low probability, extreme events that are beyond project control, such as the effects of terrorism and war, natural disasters with impacts beyond expected historical ranges, or global economic crises.

experience shows will likely result, in aggregate, in additional costs. Typically estimated using statistical analysis or judgment based on past asset or project experience.

For major facility construction projects, the amount of budget contingency is determined by performing a probabilistic risk analysis on the baseline cost and schedule and selecting a total project cost with an acceptable confidence level (typically between 70%-90%). See Section 4.2.5 for details on total project cost requirements. Budget contingency is held separately from the Performance Measurement Baseline (PMB) and allocations of budget contingency to and from the PMB are managed through formal change control.

Schedule contingency: *An amount added to a baseline schedule estimate 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. Typically estimated using statistical analysis or judgment based on past asset or project experience.*

For major facility construction projects, the amount of schedule contingency is determined by performing a probabilistic risk analysis on the baseline schedule of activities and selecting a commitment finish date with a confidence level between 70%-90%. The project end date is determined by the sum of the baseline duration and the selected 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.

Scope contingency: *Scope included in the project baseline definition that can be removed without affecting the overall project's objectives, but that may still have undesirable effects on facility performance. Identified scope contingency should have a value equal to at least 10% of the baseline budget.*

Scope contingency can be retained or deleted, depending on project risk performance and available contingency, in order to stay within the total project cost. A scope management plan includes a time-phased estimate of available budget and or time from de-scoping options, based on key decision points. See Section 4.2.5 for details on requirements. Implementation of scope contingency options is managed through formal change control.

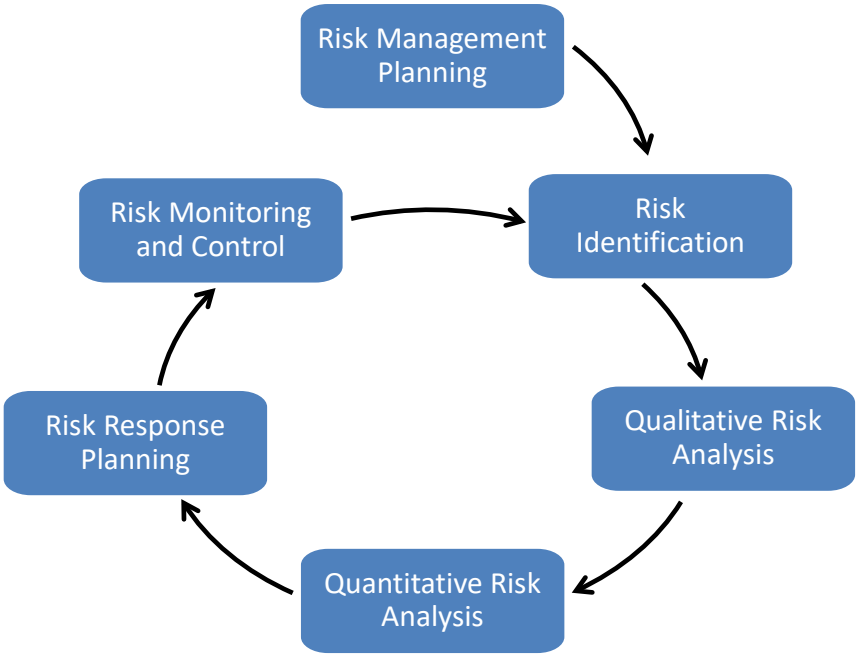
6.2.4 Risk Management Steps and Methodology

The steps involved in the Risk Management process have been defined variously by different practitioners. For the purposes of these guidelines, the Risk Management process is defined as comprising the following steps:[1]

- Risk Management Planning
- Risk Identification
- Qualitative Risk Analysis
- Quantitative Risk Analysis
- Risk Response Planning
- Risk Monitoring and Control

The relationship between these steps is shown in Figure 6.2.4-1.

Figure 6.2.4-1 Picture of Six Risk Management Processes (According to PMI)[2]



The Risk Management steps outlined above are iterative and continuous and any one step, or all of the steps, could be active at any given time. Risk analysis is performed continuously throughout the project life cycle. For example, a conceptual risk analysis may be conducted to

[1] The six steps are the same as the processes described in the PMBOK® Guide Chapter 11.

[2] Risk Handling and the Project Management Institute's Risk Response Planning process are somewhat equivalent. Risk Handling includes implementing the risk mitigation and other responses, whereas Risk Response Planning envisions that these actions will be included in the Project Execution Plan and implemented as part of the PEP.

facilitate selection between alternative options, to determine the level of project management required, to identify where the challenges lie, and to determine the level of technical information and development activity necessary to achieve project success. That risk analysis is then updated during each of the life cycle phases of the project. Performing risk analysis is particularly necessary in preparing for key project decisions. Periodic reviews of the risks at appropriate intervals should be performed to identify new risks, to evaluate progress in risk handling strategies, as well as to evaluate changes during the project development and implementation cycles. Risk Management Planning, and the RMP, may also need to be re-addressed at times of significant change, such as transitions from one project life cycle to another or during a re-baselining with significant modifications to the project baseline.

6.2.5 Risk Management Planning

Planning begins by developing and documenting a Risk Management strategy. Early efforts establish the purpose and objectives, assign responsibilities for specific areas, identify additional technical expertise needed, describe the assessment process and areas to consider, delineate considerations for mitigation planning, define a rating scheme, dictate the reporting and documentation needs, and establish report requirements. The strategy to manage root causes provides the program team with direction and a basis for planning. The output of risk management planning is a written document – the Risk Management Plan (RMP) – containing the details of how risk will be managed through application of tools and processes defined in the plan. See the next subsection for a description of requirements for the RMP.

One key strategic decision that should be made early in the Risk Management planning is the selection and assignment of personnel with appropriate capability in Risk Management to lead and/or guide the planning and analyses. As will be seen from the topics presented in the analysis portion of the section, the art and science of risk management can be extremely complicated for complex, high risk projects. While project managers, scientists and engineers may have expert knowledge and judgment for identifying, estimating impacts from, and defining mitigation for individual risks, they are usually not expert in estimating the overall or aggregate risk exposure to the project from the combined impact of many individual risks. Finding qualified resources to meet the risk management requirements of the project, particularly for establishing the amount of contingency, should be a high priority for early planning in order to ensure that methodologies and programming tools can be selected and implemented in a timely manner. Options include sending existing staff for specialized training in risk management and tool usage, directly hiring risk management experts, contracting with industry, or some combination of the above.

A second early key decision is the determination of what risk assessment methodologies and tools will be used, from first estimates through construction. The sophistication of the appropriate risk assessment tools typically increases with advancing planning detail and maturity, as well as with increasing project complexity. A project that includes a high number of procurements and in-house tasks typically requires software applications and methods that use a fully resource loaded schedule for risk assessment and contingency estimation, while a project entailing management of a single large contract may be adequately served by tools and methods that use cost spreadsheets and summary level schedules. Choosing the appropriate tools and methods at the outset can avoid the need and the burden of changing to different systems as the project planning matures.

Risk Management planning is iterative. Normally, the risk management methodology and procedures are defined as part of the risk management process planning early in the design stage, but they may be extended or modified during design and execution as long as the efforts remain within approved scope.

6.2.5.1 Risk Management Plan (RMP)

The Risk Management Plan (RMP) describes how risks are documented and risk management will be applied on the project. It is an integral part of the PEP, as outlined in Section 3.4 of this Guide. The level of detail in the plan and the scope, timing, and level of risk analysis should be commensurate with the complexity and maturity of the project as it advances through design and construction stages. The plan is a living document used throughout design and implementation and should therefore be under configuration management. The Risk Management Plan should include the following elements:

- Risk Management Strategy and Approach
- Roles and Responsibilities
- Processes used to apply the Risk Management process
- Baseline definition for Calculating Risk Exposure and Contingency needs
- Contingency Estimating and Management
- Resources assigned to and schedule, cost, and timing of risk management activities

The Recipient should periodically review the RMP and revise it, if necessary. Some events may drive the need to update an existing RMP, such as: (1) the baselining of a project, (2) preparation for a major decision point, (3) technical audits and reviews, (4) an update of other project plans, and (5) a change in major project assumptions. A sample format with the expected content for a Risk Management Plan (RMP) is outlined in Table 6.2.5-1.

Table 6.2.5-1 Sample Format for a Risk Management Plan

Section	Description
1. Introduction	This section should address the purpose and objective of the plan, and provide a brief summary of the project, to include the approach being used to manage the project, and the acquisition strategy.
2. Definitions	Definitions used by the Recipient should be consistent with NSF definitions for ease of understanding and consistency. However, the NSF definitions allow program officers flexibility in constructing their risk management programs. Therefore, each Recipient's RMP may include definitions that expand the NSF definitions to fit its particular needs. For example, each plan should include, among other things, definitions for the ratings used for technical, schedule, and cost risk in qualitative risk analysis.
3. Risk Management Strategy and Approach	Provide an overview of the risk management approach, to include the status of the risk management effort to date, and a description of the project risk management strategy.
4. Organization	Describe the risk management organization of the Recipient and list the roles and responsibilities of each of the risk management participants.
5. Resources Implications of the Plan	The resources to be used in managing risk on the project should include the time of management and project team members as well as risk specialists and contractors if appropriate, to manage effectively the risks on the project. These risk management costs should appear specifically in the project budget.

Section	Description
6. Schedule Implications of the Plan	The time periods in the project schedule when risk management activities are planned to occur. Activities providing sufficient time to perform the tasks and milestones to record their completion should be inserted in the project schedule and statused along with the schedule statusing plan.
7. Risk Management Process and Procedures	Describe the project risk management process to be employed, i.e., risk planning, qualitative and quantitative risk assessment, handling, monitoring and documentation, and a basic explanation of these components. Also provide application guidance for each of the risk management functions in the process. If possible, the guidance should be as general as possible to allow the project's risk management organization flexibility in managing the project risk, yet specific enough to ensure a common and coordinated approach to risk management. It should address how the information associated with each element of the risk management process will be documented and communicated to all participants in the process, and how risks will be tracked to include the identification of specific metrics if possible.
8. Risk Planning	This section describes the relationship between continuous risk planning and this RMP. Guidance on updates of the RMP and the approval process to be followed should be included.
9. Risk Identification	This section of the plan describes the identification process. It includes procedures to be used for examining the critical risk areas and processes to identify and document the associated risks.
10. Risk Register Analysis and Ranking	This section summarizes the analyses process for developing a qualitative or quantitative risk rating and populating the Risk Register. This rating is a reflection of the potential probability of each risk and the impact of each risk on the project schedule, cost, scope and quality. It also describes how the risk analysis data will be collected and maintained throughout the project's life cycle.
11. Probabilistic Risk Analysis and Contingency	This section describes the way the project will analyze the implications of identified and quantified risks on the total project schedule and cost objectives or major milestones. Typically, a Monte Carlo simulation is used based on the project resource-loaded schedule or on the cost estimate if a schedule is not available. This section also describes the use of the risk analysis results for setting contingency amounts and prioritizing risks for risk mitigation.
12. Risk Handling	This section describes the risk handling options, and identifies tools that can assist in implementing the risk handling process. It also provides guidance on the use of the various handling options for specific risks.
13. Risk Monitoring	This section describes the process and procedures that will be followed to monitor the status of the various risk events identified including the frequency and organizational level of risk review. It provides for identification and calibration of new risks should they arise. It should provide criteria for the selection of risks and risk mitigations to be reported on, and the frequency of reporting. Guidance on the selection of metrics should also be included.
14. Risk Management Information System, Documentation and Reports	This section describes the management information system structure, rules, and procedures that will be used to document the results of the risk management process. It also identifies the risk management documentation and reports that will be prepared; specifies the format and frequency of the reports; and assigns responsibility for their preparation and dissemination.

Section	Description
15. Risk Exposure and Contingency Management	This section describes the specific process and procedures used to determine construction project risk exposures and the concomitant contingencies for scope, cost, and schedule. It describes contingency management plans and processes and ensures that contingency use is linked to both an identified risk and an appropriate Work Breakdown Structure (WBS) element within project scope.

6.2.5.2 Roles and Responsibilities

Typically, the Project Manager or a designated Risk Manager (RM) is responsible for leading the identification and analysis of project risks. All stakeholders (e.g., users, designers, and sponsors) involved in the project are asked to provide input on what they deem to be the risks for the project, possible risk mitigations, and ways to capture potential opportunities. The RM consolidates the information collected and creates the list of risks with accompanying attributes, and manages the response to the risks. An example of a Roles and Responsibilities table for key stakeholders and project staff that meets requirements is shown below in Table 6.2.5-2.

Table 6.2.5-2 Example of a Risk Management Roles and Responsibilities Table

Roles	Responsibilities
Organization Management	• Support the risk management process. Encourage all levels of the project organization to participate fully and openly in the process. • Make project decisions based in part on the results of risk analysis. • Provide the culture that supports risk management and welcomes honest and realistic results.
Risk Manager	• Oversee the Identification and documentation of new risks (threats and opportunities) in the risk register • Oversee the analysis of risks by the project team and work with them to develop risk response plans (mitigate, avoid, accept, and transfer). • Oversee reporting and tracking of risk activities during project status meetings • Document and communicate risk activities frequently with stakeholders • Review risks as they are concluded, and identify lessons learned • Recommend and champion mitigation strategies to the Change Control Board (CCB) on behalf of the risk management team.
Project Team Members	• Assist the RM with the risk identification, qualitative and quantitative risk analysis and development of risk response plans (mitigate, avoid, accept, and transfer). Participate in risk workshops and interviews to provide risk data. • Submit new threats, opportunities, and mitigations into the risk system as they arise. • Assist the RM with the development and execution of risk response plans • Attend project risk status meetings, as needed, and assist RM with the reporting and tracking of risk activities • Assist the RM with documenting and communicating the risk (threats and opportunities) activities frequently with stakeholders • Review risks as they are concluded, and identify lessons learned

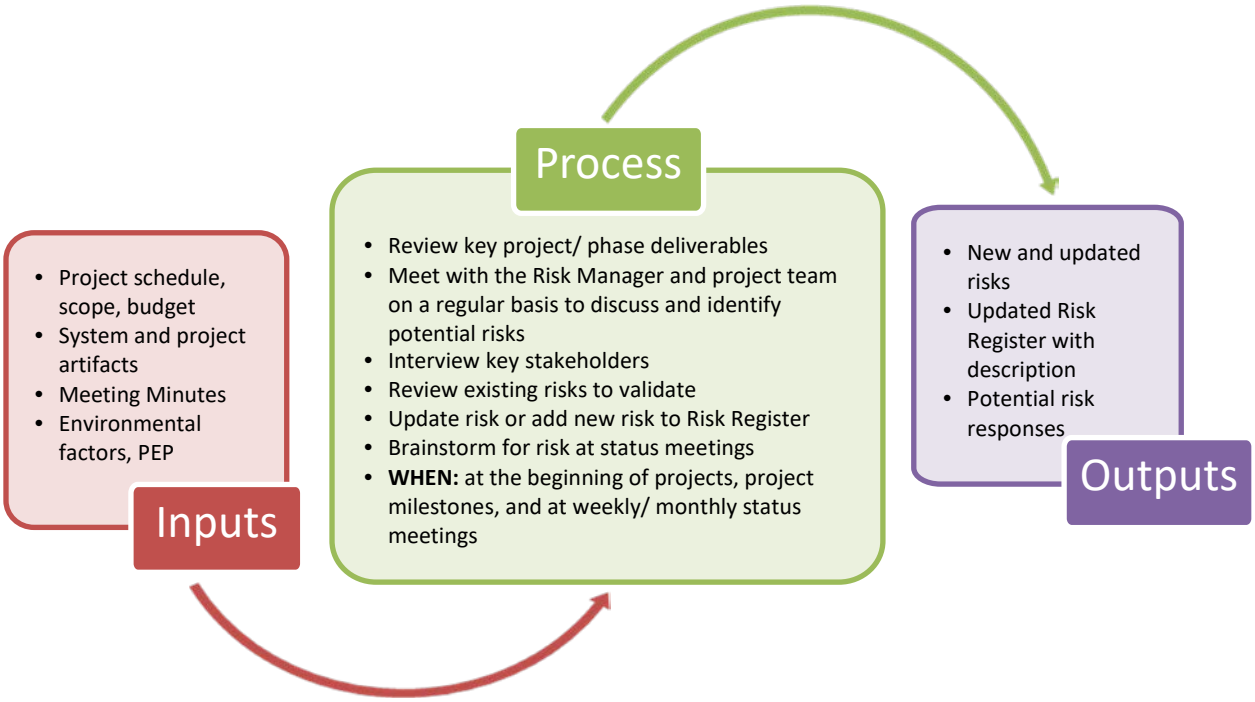
Roles	Responsibilities
Risk Owner	• Assist the risk originator (PM, RM, project team member, etc.) with development of the risk descriptions • Assist the RM and project team with the analysis development of risk response plans (mitigate, avoid, accept, and transfer) contingency plans • Update the risk register with modifications to risks • Monitor the risk triggers and update the risk register • Attend project status meetings, as needed, and assist the PM with reporting and tracking risk activities • Assist the RM and project team with documenting and communicating risk activities with stakeholders • Capture risk closure notes in the risk register and lessons learned

6.2.6 Risk Identification

6.2.6.1 Risk Identification Process

Risk identification is an organized approach for determining, listing, and describing events that might impact a project's objectives (for example, time, cost, scope, and performance). It is an iterative process that is conducted throughout the entire project life cycle. The risks are described with a basis as to why this event is considered a risk. Identification relies on the skill, experience, and insight of project personnel and subject matter experts (SMEs), as well as the Recipient's project manager, the NSF Program Officer, and the NSF Grants and Agreements Officer. The objective of risk identification is to describe all the relevant risks so that the group can focus on uncovering the probability and impact of the risks on project objectives (used in qualitative risk analysis) or activities / costs affected (used in quantitative risk analysis). The process for performing Risk Identification, along with inputs and outputs, is given in Figure 6.2.6-1.

Figure 6.2.6-1 Risk Identification Process



Techniques used in identifying risks include leveraging existing project artifacts and guidance documents, as well as proactively searching and gathering information to assist in that identification. The quality and completeness of risk identification is primarily dependent upon the knowledge and experience of the project team and its commitment to risk management processes. For example, the following basic methods can be used to assist in the identification of risks:

- Brainstorming

- Diagramming
- Interviewing
- Analysis of existing project artifacts
- Comparison to historical information

Formal risk identification is performed in the early part of the project life cycle and as part of a continuous effort during the project life cycle. Any person associated with the project should be encouraged to continually identify potential project risks. Risk Identification, whether in workshops or in interviews, should include at least the following participants:

- Project managers
- Project team leaders
- Project team members
- Business stakeholders
- SMEs Contractors
- SMEs outside the project team, for unbiased perspective
- Project partners (e.g., foreign agencies, organizations with diverse objectives)

One immediate outcome of risk identification is the populating of the Risk Register, or tracking tool, with the identified risks. The priorities based on impacts to project objectives and plans for handling and reducing impacts will be added after analysis and risk handling planning, as described in later sections. The Risk Register provides a means of tracking and reporting status as risks occur and mitigation strategies are implemented, and is an important tool for Risk Management implementation.

6.2.6.2 Risk Identification and the Risk Register

The Risk Register includes a description of all risks that are deemed to be important to achieving project success (from the Risk Identification process) along with an assessment of those risks (using Qualitative Risk Analysis) that allows risks to be prioritized for effective risk management. The results of identification, qualitative analysis, and risk handling – the major components in the Risk Register – can lead to further analysis (Quantitative Risk Analysis, for example).

Each risk should be assigned a unique identification number or code. Once a risk is entered in to the Register, it is never deleted. Its state may be changed to inactive (for example, retired, closed, or merged with another risk), but it should never be deleted from the register. Risk IDs are never reused.

The Register should be accessible (read-access) to all project members – the primary objective of the Register is to keep the project team thinking pro-actively about how to avoid or mitigate threats and take advantage of opportunities. It can be a spreadsheet, data base, or a specialized risk management software tool. Changes to the Register should be managed through the risk

process, which often may restrict ability to make changes (write-access) to a small team or to the Risk Manager. The mechanism for all project members to read, comment on, and submit new risks and mitigations should be established in the RMP.

The examples shown here and in Section 6.2.7, Qualitative Risk Analysis – Risk Register Ranking, lead to a Risk Register containing a ranked subset or summarized set of risks based on individual, qualitative impact analysis. Note that numeric impacts determined by the qualitative method for individual risks may not be summed or combined to give a value for overall project risk exposure.

Further discussion of Risk Register content is given in Section 6.2.7, Qualitative Risk Analysis – Risk Register Ranking, with a sample Risk Register shown in Figure 6.2.7-6.

6.2.6.3 Risk Description

The risk description serves as a key point in the Risk Register and will be generated and updated as needed. If there is a trigger event that causes the risk or foretells the risk's occurring, it should be described since it will specify what condition(s) would launch the risk and maybe activate a contingency plan.

Risks (both threats and opportunities) are typically identified and tracked using the following sentence structure for the Risk Description:

> *"Because of (some cause) a (risk) may occur, and (consequences) will happen."*

Example:

> *"Because foreign exchange rates may change, the cost of components in WBS 3.1 and 2.6 may increase or decrease, causing cost variances which affect contingency use."*

Using this format helps to distinguish the uncertainty or risk from its cause and its consequence, a distinction which is important for mitigation planning. For instance, a statement that "we have 5 schedule risks" is focused on an objective (schedule) that is impacted, not the root cause of the risk or uncertainty. Alternatively, a statement that "the risk is that the technology is really hard" does not lend itself to mitigation efforts. Difficulty of technology is a fact or a "cause" in this format, which cannot be changed. The risk may be that "we do not have the right skills on the project to handle the complexity" or "we may have to rely on third parties to gain control of this technology." That is a risk that can perhaps be mitigated. A possible risk description for this scenario may be:

> *Because the technology for the major components in WBS 2.7 is very advanced, we may have to rely on third parties for design, with the consequence that we have less control over cost and schedule and an added burden of increased communication efforts.*

Risks should be identified that are both internal, perhaps under project control, and external, likely to be beyond project control. Risks for which there are no plans for mitigation should also be included in the register.[1] However, note that NSF does not allow the use of contingency for risks that are commonly referred to as "unknown unknowns"[2] such as exceptional events or major changes in scope. These exceptional events may not be included in quantitative risk analyses used in determining contingency amounts.

6.2.6.4 Risk Identification Concerns

Efforts should be made to identify all risks to the project as early as possible, employing all stakeholders identified in and using the techniques listed in Section 6.2.6.1, Risk Identification Process. At the time of the risk analysis there are likely to be risks that are currently unknown but may be revealed at a later date. When they become apparent, they can be then analyzed and a "corrective action" can be specified and implemented. The objective of the Risk Management program is to minimize the number of unanticipated issues and to address them when possible and prudent.

Some people believe that project risk is often underestimated in both cost and schedule, leading to well-known, sometimes notorious, overruns.[3, 4] Historical experience suggests that mega-projects suffer from such problems systematically.[5] Strategic or overarching risks are often missed in the risk identification process since the participants do not think globally, only locally. Systemic or overarching risks are often not discussed or even considered during risk identification. There may be cultural bias that leads to optimistic thinking in which threats are systematically underestimated, outcomes are assumed to be achievable with less than realistic effort and the potential for set-backs and rework is ignored. Any tool or technique that will encourage people to "think outside of the box" when identifying project risk will help identify the possibility of large overruns – when caught early, these risks may be manageable.

One common issue in identifying and collecting project risks is that people's response and participation in the identification process may be "stove-piped." That means that people will ordinarily discuss threats and opportunities that have to do with their own area of concentration. In practice the project teams and other SMEs have experience and knowledge

[1] The fact that "we cannot do anything about it" or "we choose to accept the risk" does not disqualify it as a risk to the project. One can argue that these risks should be in the Risk Register and certainly in the Quantitative Risk Analysis.

[2] In many risk management guides, a portion of contingency is designated as management reserve for "unknown unknowns." NSF does not allow this.

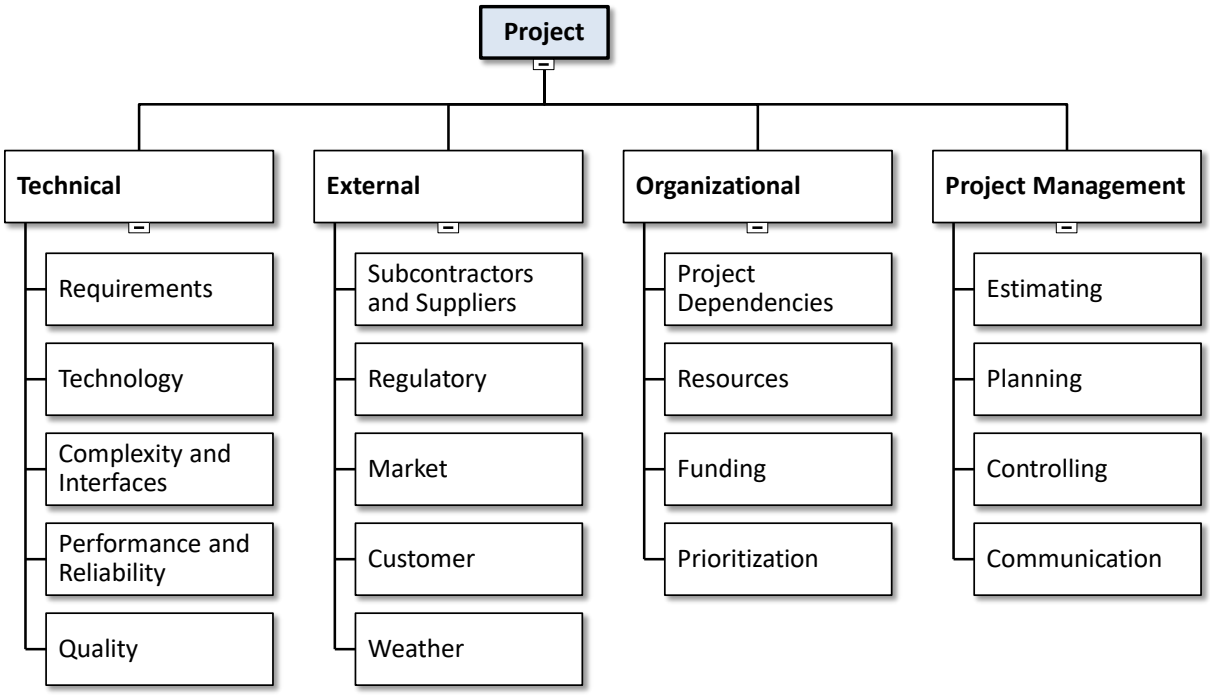
[3] See Bent Flyvbjerg, Nils Bruzelius, and Werner Rothengatter, Megaprojects and Risk: An Anatomy of Ambition, 2003 Cambridge University Press, and Glenn Butts and Kent Linton, "NASA the Joint Confidence Level Paradox – a History of Denial," NASA Cost Symposium, April 28, 2009.

[4] Challenges to Meeting cost, Schedule, and Performance Goals, NASA IG-12-21

[5] Edward W. Merrow, Industrial Megaprojects, 2011, Wiley.

outside these narrow areas, so the data collection method used should encourage them to think broadly and strategically when identifying risks. Reminding risk identification participants of external, organizational and project management source-areas of risks can help elucidate strategic risks that they know about but that are outside their narrow area of technical expertise or their work assignment. Often the use of a standard Risk Breakdown Structure shown in Figure 6.2.6-2 will encourage risk identification participants to think more broadly about risks to the project.

Figure 6.2.6-2 Typical Risk Breakdown Structure (RBS)[1]



Different approaches to Risk Management may subdivide risks into various categories for analysis. For illustrative purposes, this guide will use cost, schedule, and technical or performance risk as the categories used in examples. Other risk categories commonly in use are programmatic, business or economic, design requirements, software, and technology risks. Alternatively, the OMB Risk Categories shown in Figure 6.2.6-3 could be used as guidelines for identifying the various types of risk that apply to the project (refer to "OMB Risk Categories" document in Critical Infrastructure Protection (CIP) for detailed descriptions and examples of these categories). See the Government Accountability Office (GAO) Cost Estimating and Assessment Guide, GAO-09-3SP, Chapter 14, for more examples. Some projects may also decide to differentiate between internal and external risks. In many cases, it may be advisable to use different categories for various parts of a project. For instance, categories of risk may be

[1] This RBS was the initial model for the RBS in the PMBOK® Guide, Chapter 11 of the Project Management Institute

different for software development than for hardware procurement. Each project should decide which categories are most appropriate for its use while establishing the Risk Management Plan and processes.

Figure 6.2.6-3 OMB Risk Categories: to be used as a starting point for projects to select their own categories

1) Schedule	11) Overall Risk of Project Failure
2) Initial Costs	12) Organizational and Change Management
3) Life Cycle Costs	13) Business
4) Technical Obsolescence	14) Data/Info
5) Feasibility	15) Technology
6) Reliability of Systems	16) Strategic
7) Dependencies and Interoperability	17) Security
8) Surety (Asset Protection)	18) Privacy
9) Risk of Creating a Monopoly	19) Project Resources
10) Capability of Agency to Manage the Investment	

Another related social or cultural issue in identifying project risks is that people are often uneasy about (or even afraid to be) discussing risks that can be embarrassing or harmful to the project. This unease is often experienced during risk workshops or in other group settings. Social pressures to conform ("groupthink") – to suppress dissenting opinions clearly unpopular to the group, including management, to agree with others against personal opinion just to move the workshop along, and to defer to people perceived to have greater expertise even when in disagreement – often make it difficult for some people to speak out.[1] A possible solution to the impacts of social pressure is to conduct one-on-one, in-depth interviews with SMEs in which the interviewee is promised confidentiality. Such interviews often yield honest opinions about what might affect the project's success. Usually some or most of the risks revealed and discussed in these sessions are not on the organization's risk register and would not be analyzed in qualitative or quantitative risk analysis in the absence of the interviews. For these reasons it is important to provide a safe environment for project team members and others to identify and discuss project risks.

Risk identifiers may have concerns about including risks that are 100% likely to happen (sometimes these are called "uncertainties or issues") in the Risk Register. If the risks are 100% likely to happen and their impacts are known, they should be included in the PMB. Often, however, a risk that is certain to occur will have an impact that is not already included in the project execution plan and that needs to be handled somewhere else, such as in the risk analysis. Or the risk may have an uncertain impact on project objectives. These situations call for the risk to be identified, even if it is already happening or certainly will happen, so the risk

[1] These phenomena are discussed in Understanding and Managing Risk Attitude, David Hillson and Ruth Murray-Webster, Gower, 2005.

can be included in the Risk Register and the subsequent quantitative risk analysis. The objective of risk identification is to describe all the relevant risks so that the group can focus on uncovering the probability and impact of the risks on project objectives (used in qualitative risk analysis) or activities / costs affected (used in quantitative risk analysis). Once a risk that is certain to occur has been included in the PMB it can be removed from the Risk Register.

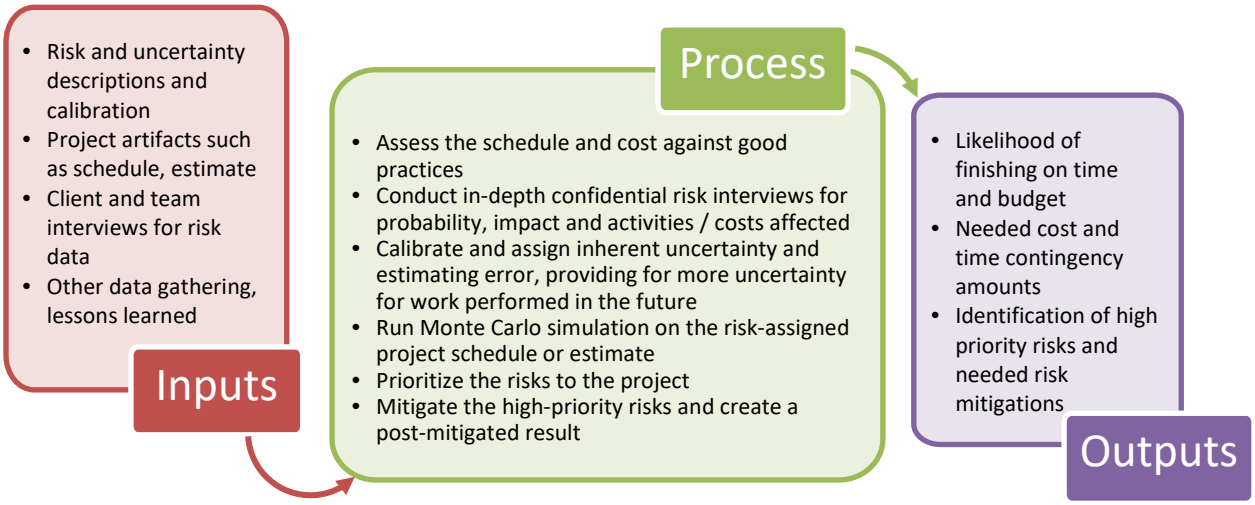
Care should be taken to provide the same thoroughness of identification for events far in the future as well as for the near term for projects that have an execution period of several years. Project team members usually find that it is easier to identify and discuss the risks that are current or on the near horizon than those that may occur much later in the project. Adding to the difficulty is the fact that future events may not be well defined at the time of risk analysis. The risk identification exercise should take special care to encourage the participants to look into the future, maybe with the help of lessons learned documents or their own experiences on prior projects, to see what risks are far down the project life cycle. Another useful technique is to "walk through" the activities planned for later execution. Examples of unidentified risks may include unexpected legal changes, technical performance issues, resource losses, etc. Other sources of future risks might include the reliance on unproven or even just conceptualized technology or on doing business with an organization or in a country unknown to the sponsors. The risk identification should include thinking about risks that have happened on other similar projects or might occur in later phases of this project. If the team spends some time discussing these down-stream risks, they can perhaps remember other projects or conceptualize the existence of risks that would otherwise go unreported.

6.2.7 Qualitative Risk Analysis – Risk Register Ranking

6.2.7.1 Purpose of Qualitative Risk Analysis

Qualitative risk analysis involves determining the probability of the occurrence of a risk, assessing the consequences of this risk on specific project objectives (time, cost, scope and quality) if it occurs, and using the two dimensions of a risk (probability and consequence) to identify a rank or "risk level." This risk level represents a judgment as to the relative risk to the project objectives and the project as a whole and is categorized as *Low*, *Moderate,* or *High*. Based on the risk level, risks can be prioritized for mitigation to responses. The results of Risk Identification, Qualitative Risk Analysis, and Risk Response Planning comprise the main elements of the Risk Register. The process for performing Qualitative Risk Analysis, along with inputs and outputs, is given in Figure 6.2.7-1 below.

Figure 6.2.7-1 Qualitative Risk Analysis Process



Achieving risk reduction is an integral part of setting priorities, sequencing project work, and responding to the most serious risks first. Thus, the identified risks should be prioritized. Note that Qualitative Risk Analysis is applied only to individual risks and is not used in estimating overall project risk exposure or in determining contingency amounts. The analysis of impact or consequence, however, may serve as input to Quantitative Analysis used to estimate overall risk exposure.

6.2.7.2 Considerations When Performing Qualitative Risk Analysis

A number of factors complicate qualitative risk analysis, including:

- Risk data, like data about the future contained in cost estimates or project schedules, have a significant content based on subjective, expert judgment. The evaluation of risks

to cost and schedule therefore generate approximate rather than precise results. "There are no facts about the future."[1]

- The term "risk" includes both "threats" and "opportunities" for NSF purposes. Project risk team members should look for uncertainties that could help improve the project's results or offset threats. Both threats and opportunities should be examined for total project impact, since opportunities for one project participant may be considered threats by another, and vice versa.
- 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 must be low" confuses the two parameters of probability and impact. SMEs should be asked to estimate the impacts as if the risk has occurred. Probability and impact will be considered together in the combined risk matrix approach.
- It is good practice to assess risks' impact on separate objectives such as time, cost, scope or quality/performance Impact ranges rather than creating a single, overall risk level for the risk. Thus, ranking levels are defined for each of these objectives. For instance, a risk can be judged to have a high impact on time but a moderate impact on cost and a low impact on scope.
- The definitions of impact on each project objective (very low, low, moderate, high and very high) are set by the Risk Manager and documented in the RMP.
- The definitions of combined risk level for probability and impact taken together (low, moderate or high; or green, yellow or red) in the Risk Matrix are set by the Risk Manager and documented in the RMP.
- 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 risk of many moderate risks may be high. The project may want to mitigate some low or moderate risk in order to reduce the combined threat from many risks.
- The risk register should include only root cause risks. Risks as defined in the plan may not be mutually exclusive, that is, they may have the same root cause risk. Put another way, if two or more risks are not mutually exclusive as written, their common root cause risk should be identified and used instead.

[1] Lincoln E. Moses, Administrator of the Energy Information Administration, Administrator's Message to the Annual Report To Congress, 1977, Volume Three.

6.2.7.3 Limitations of Qualitative Analysis

There are some limitations to the practice of qualitative risk analysis. Recognizing these will help the organization appreciate and use the results correctly:

- Qualitative Risk Analysis addresses the impact of individual risks on project objectives one at a time. As such it is dedicated to prioritizing individual risks based on subjective estimates of probability and subjective estimates of the impact to the project objectives. It is not equipped to forecast or estimate overall project results such as the finish date or total cost.
- Qualitative Risk Analysis is unlikely to yield valid quantitative results since it usually does not include all possible correlations and outcomes for impacted activities from a single risk. SMEs should consider the risk with its probability of occurring and all the activities in the schedule it would affect if it occurred, whether or not those activities are on the risk critical path (the risk equivalent to the critical path in CPM scheduling). They should also evaluate whether other risks might prevent mitigation of a particular risk from resulting in much improvement. All of this analysis is being done in the individual SME's head. Such complex calculations are best handled by the Quantitative Risk Analysis simulation method described in Section 6.2.7.
- The estimation of the impact of a risk on cost should consider the impact of that risk directly on cost plus the impact indirectly on the cost of time-dependent resources if the risk also affects time. This is another calculation that individuals are not well-equipped to make without a computer but is handled well by Quantitative Risk Analysis.
- Judging whether a risk has a high-priority for the project would involve reviewing the conclusions on each objective and asking the risk manager to prioritize the objectives. Some projects are time sensitive and some are budget driven, others have a fixed scope or could be de-scoped. These factors would need to be considered to determine whether the risk is low, moderate or high priority for the project as a whole. Some software packages that perform qualitative risk analysis assume that if a risk is "high" for any objective it should be judged to be "high" for the entire project. There is no real basis for doing so, since the risk may be judged to be high for an objective that is not the most important for the specific project under consideration.

6.2.7.4 Qualitative Risk Analysis – Probability and Impact Assessment

Risk level determination can be done using a variety of techniques. The method given here begins by assigning qualitative values for event probability and impact/consequence(s) to each objective separately. These will then be used to determine a qualitative risk level. A key feature of this method is that it requires independent assessment of the probability and consequence of a risk.

The probability of a risk occurring is usually given to a range of possible probabilities of occurring. Similarly, consequences are usually expressed in levels that represent ranges of impacts judged by the risk manager to be of very low, low, moderate, high or very high impact as the result of one risk among many. The ranking of a risk as it is applied to a particular objective (e.g., time) is determined by the combination of probability and impact ranges, where the project manager or some other stakeholder (e.g., the customer) determines which combinations would indicate that the risk is high, moderate of low priority for further study, quantitative risk analysis or handling.

The following steps provide the details of this Qualitative Analysis method:

1. Address each risk statement from the Risk Identification process individually.
2. Determine the qualitative probability of occurrence value (P) range that best describes the probability for each risk with appropriate basis and justification. Discuss the probability that the risk might occur on the project with some noticeable effect on the objective being discussed. Estimate the probability for the risk without regard to which objective(s) the risk affects if it occurs. The probability of occurrence is for the duration of all project phases. Table 6.2.7-1 provides an example of typical criteria for establishing probability values.
3. Determine the qualitative consequence or impact of occurrence value I range that best describes the impact for the objective such as time, cost, scope or performance for each risk with appropriate basis and justification. In the evaluation, assume that the risk has occurred and determine the recovery time, the cost of recovery, and the impact on scope or quality. The consequence of occurrence is for the duration of all project phases and for the objective being assessed. Table 6.2.7-2 provides typical criteria for establishing consequence values. This table illustrates the different definitions that are applied to the implications for time, cost, scope and quality. Of course these definitions should be tailored to the project by the project manager or some other stakeholder (e.g., the owner or customer).

Table 6.2.7-1 Sample Risk Probabilities Table

Each project should determine the appropriate number of levels and their definitions that match that project's circumstances.

Probability of Occurrence Descriptor	Probability of Occurrence Numerical Ranges equivalent levels[1]	Criteria in Words
Very Low	<0.1	Will not likely occur anytime in life cycle of the facilities; or the probability of occurrence is less than equal to 10%.
Low	>0.1 but <0.4	Will not very likely occur in the life cycle of the project or its facilities; or the probability of occurrence is greater than 10% but less than or equal to 40%.
Moderate	>0.4 but <0.6	Will likely with middling probability (e.g., a coin flip) to occur sometime during the life cycle of the project or its facilities; or the probability of occurrence is greater than 40% but less than 60%.
High	>.6 but <.8	Likely to occur with more than 60 percent chance during the project, or the probability of occurrence is between 60% and 80%
Very High	>0.8	Will likely occur sometime during the life cycle of the project; or the probability of occurrence is greater than or equal to 80%.

Table 6.2.7-2 Sample Risk Consequences[2] Table

The descriptors for the objectives of cost and time are explicitly given as numbers while those for scope and quality are expressed in narrative descriptions.

Defined Conditions for Impact Scales of a Risk on Major Project Objectives, e.g., Time Definition for Threats Only					
Project Objective	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
Cost	Insignificant Cost Increase	<5% Cost Increase	<5 - 10% Cost Increase	<0 - 20% Cost Increase	>20% Cost Increase
Time	Insignificant Time Increase	<5% Time Increase	<5 - 10 % Time Increase	<0 - 20 % Time Increase	>20% Time Increase
Scope	Scope Decreases are Barely Noticeable	Minor Areas of Scope Affected	Major Areas of Scope Affected	Scope Reduction Unacceptable to Sponsor	Project End Item is Effectively Useless
Quality	Quality Degradation Barely Noticeable	Only Very Demanding Applications are Affected	Quality Reduction Requires Sponsor Approval	Quality Reduction Unacceptable to Sponsor	Project End Item is Effectively Useless

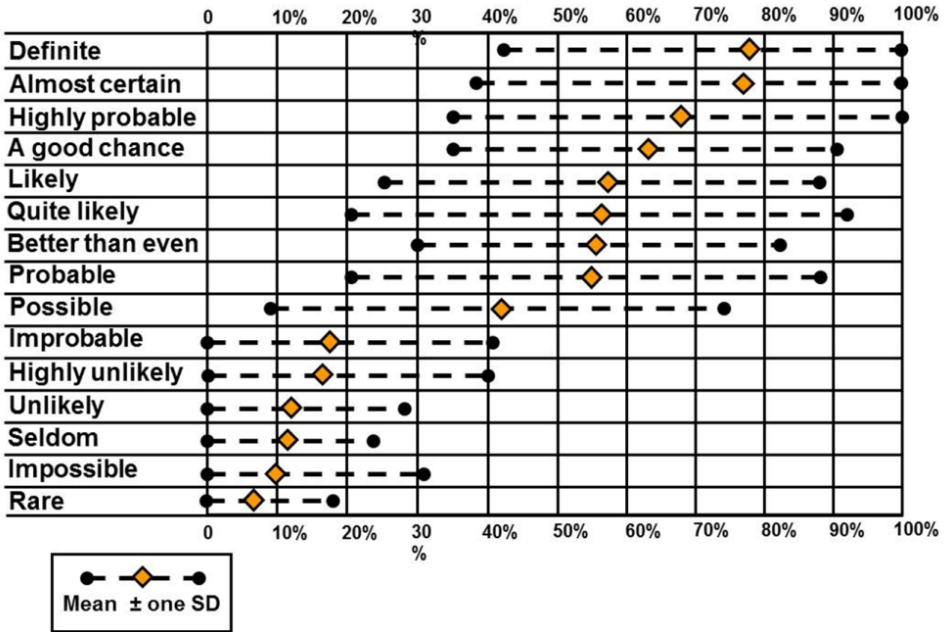
[1] The scales still should be calibrated per the discussion and reference in Section 6.2.9.

[2] An earlier version of this table was used in the PMBOK® Guide. The percentage ranges should be adjusted by the project manager for the project and translated into days and dollars for ease of use.

Notice that the definitions for time and cost can be quantitative but that those for scope and quality are generally descriptive. Sometimes a project's scopes can be quantified, though it may have several dimensions. Quality or performance might be measurable in terms of failure rates or number of "fixes" that would be needed. The more the impact levels can be quantified the more the responses by different people will be comparable. The project manager can calibrate the numerical ranges for the specific project. The consequence definitions of very low, low, moderate, high or very high (or *Negligibl*e, *Margina*l, *Significan*t, *Critica*l, and *Crisis*) may vary considerably from a small to a large project. These tables should be provided as part of the RMP.

It is preferable to refer to the numerical levels when gathering qualitative risk data since definitions in words are often misleading. For instance, two people may use the term "Likely" but mean different values. Or, one may say the risk is "likely" to occur and another may say "unlikely" but mean the same numerical value, or at least in the same "bucket" or range of values. Research has shown that the lack of overlap in assigning probability values with common word definitions is severe.[1] (See Figure 6.2.7-2.)

Figure 6.2.7-2 Overlap in Risk Probability of Occurring When Descriptors Are Used



Expert judgment is required in risk analysis, just as it is for project scheduling and project cost estimating. That is why several or many people need to be involved in providing their opinions and experiences when assessing project risks. With multiple people assessing the probability and impact of each risk against each objective, such as in the recommended in-depth

[1] Private research conducted by Dr. David Hillson in 2004 and presented at a PMI EMEA conference.

confidential interviews, there will be differences of opinion between them. The risk analyst has to consolidate the data from different sources into one set of parameters for each risk and objective from the dissimilar responses. This process uses expert judgment.

6.2.7.5 Alternative Approach to Qualitative Risk Impact Analysis – Maxwell

An alternative approach is that proposed by F. D. Maxwell for projects such as those supported by the Aerospace Corporation or the Space & Missile Systems Center of the US Air Force in Los Angeles. See Table 6.2.7-3. The "risk driver category" is not the same as the project objectives, but rather describes where the risks might be originating. This was not used by Maxwell in conjunction with the probability before 1990, but it does illustrate definitions of impact that were used on many aerospace and scientific projects. Maxwell stated that:

> *Special attention should be given to first-of-a-kind risks because they are often associated with project failure. First-of-a-kind risks should receive a critical or crisis consequence estimate unless there is a compelling argument for a lesser consequence value determination.*

Table 6.2.7-3 Maxwell Risk Driver Assessment Framework[1]

	Risk Driver Category	Very Low Risk Level	Low Risk Level	Medium Risk Level	High Risk Level	Very High Risk Level
1	Required Technical Advancement	Nothing New	Minor Modifications Only	Major Modifications	State of the Art	Beyond State of the Air
2	Technology Status	Currently in Use	Prototype Exists	Under Development	In Design	Concept State
3	Complexity	Simple	Somewhat Complex	Moderately Complex	Highly Complex	Highly Complex with Uncertainties
4	Interaction/ Dependencies	Independent of Other Risk Drivers	Dependent on One Additional Risk Driver	Dependent on Two Additional Risk Drivers	Dependent on Three Additional Risk Drivers	Dependent on more than Three Additional Risk Drivers
5	Producibility	Established	Demonstrated	Feasible	Known Difficulties	Infeasible
6	Process Controls	Statistical Process Controls (SPC)	Documented Controls (No SPC)	Limited Controls	Adequate Controls	No Known Controls
7	Manufacturing Precision	High	Adequate	Limited Margins	Known but Inadequate	Unknown

[1] Developed by F. D. Maxwell at the Aerospace Corporation. Included in "Estimating Cost Uncertainty when only Baseline Cost is Available," quoting R.L. Abramson and S. A. Book, "A Quantification Structure for Assessing Risk-Impact Drivers," Laserlight Networks, briefing presented to the 24th Annual DOD Cost Symposium (Leesburg, VA, September 5-7, 1990).

	Risk Driver Category	Very Low Risk Level	Low Risk Level	Medium Risk Level	High Risk Level	Very High Risk Level
8	Reliability	Historically High	Average	Known Limited Problems	Serious Problems of Unknown Scope	Infeasible
9	Criticality to Mission	Nonessential	Minimum Impact	Known Alternatives Available	Possible Alternatives Exist	"Show Stopper"
10	Cost	Established	Known History or Close Analogies	Predicted by Calibrated Model	Out of Range of Experience	Unknown or Unsupported Estimate
11	Schedule	Demonstrated	Historical Similarity	Validated Analysis	Inadequate Analysis	Unknown or Unsupported Estimate

6.2.7.6 Qualitative Risk Analysis – Risk Level Matrix

Once the probability and impact level of each identified risk is agreed to, the risk's position is determined on the probability and impact matrix shown in the following figures. The vertical matrix axis labels in the figures correspond to the definitions for probability levels given in Table 6.2.7-1, and the horizontal axis labels correspond to the values for impact defined in Table 6.2.7-2. Combinations of probability and impact for a risk are shaded as red, yellow and green for high, medium, and low risk level. The risk manager, project manager, or other stakeholder should set these regions for each risk level, based on an understanding of the definitions of the axes, which would cause the risk to rise to the appropriate level of attention.

Figure 6.2.7-3 shows a risk probability and impact matrix for one objective that is symmetrical. Figure 6.2.7-4 shows a risk probability and impact matrix for an objective that emphasizes the impact of the risk on its red-yellow-green status. This asymmetrical risk matrix indicates that any risk that has a very high impact will achieve "high risk" or "red risk" status without regard to the probability that the risk will occur on the project. Of course, the definitions of risk impact and probability buckets defined in the RMP will determine the relative score that the risk achieves.

Figure 6.2.7-3 Symmetrical Risk Level Matrix

Probability and Impact Matrix for a Specific Objective (Time, Cost, Scope or Quality)					
Probability	Symmetrical				
Very High	Mod	Mod	High	High	High
High	Low	Mod	High	High	High
Mod	Low	Mod	Mod	High	High
Low	Low	Low	Mod	Mod	Mod
Very Low	Low	Low	Low	Low	Mod
	Very Low	Low	Moderate	High	Very High
	Impact				

Figure 6.2.7-4 Asymmetrical Risk Level Matrix

Probability and Impact Matrix for an Objective (Time, Cost, Scope)					
Probability	Impact Averse				
Very High	Low	Mod	High	High	High
High	Low	Mod	Mod	High	High
Mod	Low	Low	Mod	High	High
Low	Low	Low	Mod	Mod	High
Very Low	Low	Low	Low	Mod	High
	Very Low	Low	Moderate	High	Very High
	Impact				

The Risk Level for each objective for a defined risk depends upon where it falls in the Risk Level Matrix according to the axes definitions. For example, a cost risk with an estimated probability of 70% of occurrence and an estimated impact of $280K, or cost increase of 9% for the item at risk, would fall into the High probability range and the Moderate cost impact range, according to Table 6.2.7-1 and Table 6.2.7-2. Thus, the Risk Level for cost for this particular risk occurring falls into the High, or “red” range in Figure 6.2.7-3.

It is important to scale probability and impact so that the risks can be distinguished. On the one hand, if the lower bound for an impact score of very high is easy to reach there will be many risks with the same “red” assessment and the method will not distinguish risks for priority Risk Handling. On the other hand, definitions of high or very high impacts that are very difficult to reach will lead to very few or no “red” risks. While that may be true for some projects it would be unusual for an NSF project with a high scientific impact.

The objective of the matrix is to communicate the choice of priorities for monitoring and response, which may best be done with the 2-D diagrams (5x5) shown herein. Depending upon the activity and the ability to differentiate the risk levels, other matrices may be chosen by the risk analysis team. For example, a 5x5x4 risk level (the fourth level represents the 4 objectives) matrix would then have five values for probability, five for consequence and four for objectives.

Recall that Risk Management entails the identification and ranking of opportunities as well as threats.[1] Opportunities that are assessed to be in the "High" category are viewed as "low-hanging fruit" that can be easily claimed for the project if sought. For instance, if people are coming off another similar project where they have had a good result, our project will benefit if we can encourage or otherwise get them to join our project team. However, if such an opportunity is not recognized in a timely manner, those productive people will go to other projects. Another example is a potential cost saving if older but acceptable technologies can be used in place of cutting-edge solutions without impacting performance or quality. This type of cost savings is common in data acquisition and storage systems, for instance.

The butterfly or mirror risk probability and impact matrix below shows scoring threats and opportunities in similar ways. The red-yellow-green ranges for threats have been discussed. The red risks for opportunities are those that have a high likelihood of occurring and if they occur they help the project achieve its objectives, if only by offsetting threats. Risk Response of opportunities needs to be proactive in order to secure these opportunities for the project.

Figure 6.2.7-5 Probability and Impact Matrix including Threats and Opportunities

Mirror or Butterfly Probability and Impact Matrix for Threats and Opportunities											
Project Objective (e.g., time, cost, scope, quality)											
Prob.	Threats					Opportunities					Prob.
VH	L	M	M	H	H	H	H	M	M	L	V
H	L	L	M	H	H	H	H	M	L	L	H
M	L	L	M	H	H	H	H	M	L	L	M
L	L	L	L	M	H	H	M	L	L	L	L
VL	L	L	L	L	M	M	L	L	L	L	VL
	VL	L	M	H	VH	VH	H	M	L	VL	
	Impact (threats)					Impact (opportunities)					

[1] An early discussion of the use of opportunities in project management can be found in: Effective Opportunity Management for Projects: Exploiting Positive Risk, David Hillson, Marcel Dekker, 2004.

6.2.7.7 Risk Level Input to the Risk Register

The Risk Levels per each objective for all identified risks are entered into the Risk Register. See the sample Risk Register in Figure 6.2.7-6. It is common practice to also include a column in the matrix for the probability descriptor for ease of reference. As mentioned before, it is good practice to list the Risk Level for each project objective separately and not combine them into a single risk level for the stated risk. Projects may choose, however, to designate a flag to identify some risks as "Major" or "Top" risks. These Top Risks are judged by the project management to call for more aggressive management and more frequent monitoring than other risks.

Communicating and tracking the status of the top project risks is a key element of project management. The Risk Management Plan should address the frequency with which these significant risks are tracked. Top risks should be reviewed and evaluated during standard sub-system team meetings and reviews as well as at project status meetings.

Projects should also include a status report for the top risks in the various required reports to NSF, including the monthly report, as well as for reviews. One simple method for communicating the summary status of top risks to various stakeholders is shown in the sample Top Risk Matrix shown in Figure 6.2.7-6, which shows risk level and trend data for selected risks.

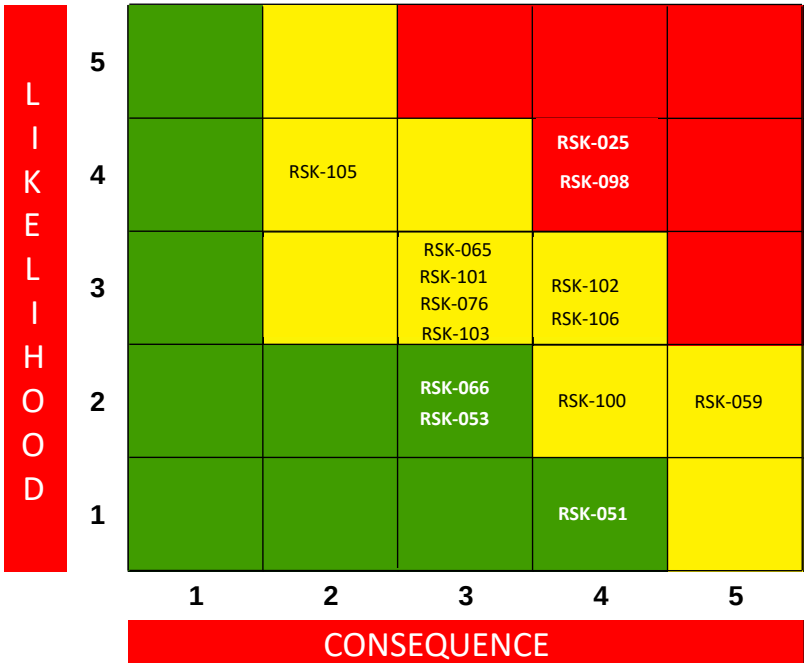
Figure 6.2.7-6 Sample Risk Register with Risk ID Number, Associated WBS Identification, Qualitative Probability and Impact for Initial and Post-mitigation States, and Mitigation Actions

			Pre-Mitigated Scores											Post-Mitigated Scores						
			Probability and Impacts				Resulting Risk Score			Risk Action				Probability and Impacts				Resulting Risk Score		
Risk ID	Risk Description	Associated WBS	Prob. Risk Occurs	On Sched.	On Cost	On Scope/ Quality/ Perform-ance	Risk on Sched.	Risk on Cost	Risk on Scope/ Quality/ Perform-ance	Risk Owner	Risk Mitigation Actions	Trigger or Watch date	Major Risk Flag	Prob. Risk Occurs	On Schedule	On Cost	On Scope/ Quality/ Perform-ance	Risk on Sched.	Risk on Cost	Risk on Scope/ Quality/ Perform-ance
PM1	If …., then …	2.2	H	VH	H	M	H	H	M					M	M	M	L	M	M	M
TECH1	If …., then …	3.2.5	H	VH	H	H	H	H	H					M	H	M	L	H	M	M
EXT8	If …., then …	3.1.3	M	VH	H	M	H	H	M					L	H	M	L	M	M	L
ORG4	If …., then …	1.2	M	H	M	M	H	M	M					L	M	M	M	M	M	M
PM4	If …., then …	2.4.1	M	H	H	M	H	H	M					L	L	L	L	L	L	L
TECH5	If …., then …	3.3.1	M	VH	H	M	H	M	M					VL	M	M	M	L	M	L
TECH6			L	H	M	M	M	M	M					VL	L	L	M	L	L	M
EXT6			L	H	H	L	M	M	L					VL	M	L	L	M	L	L
PM2			M	L	H	L	M	H	M					L	L	H	VL	L	M	L
TECH9			VL	VH	VH	L	M	H	L					VL	H	VH	L	M	H	L
TECH10			VL	VH	M	VL	M	L	L					VL	M	L	VL	L	L	L

Figure 6.2.7-7 Sample Top Risk Matrix and Status Report, showing list of project risks selected as most significant to monitor on a frequent basis, with ranking and trend data

Note that top risks include some with Low and Medium criticality (or ranking), as well as those evaluated as High criticality.

Project Top Risk Matrix



Trend	Rank	LxC	Risk ID	Approach	Title
▶	1	(4X4)	RSK-025	M	Inadequate Observatory Performance for initial operations
▲	1	(4x4)	RSK-098	M	Operations Staff Fatigue
▼	2	(3X4)	RSK-102	M	Lack of Adequate Planning for data analysis pipeline
▼	4	(3x3)	RSK-103	M	Lack of Data Extraction and Analysis Tools
▶	5	(4x2)	RSK-105	M	Scientist support staff resources
▶	6	(2x5)	RSK-059	M	Loss of single-point-failure component
▶	7	(3x3)	RSK-076	M	Maintaining Science Instruments
▶	8	(2X4)	RSK-100	M	Instrument support structural Integrity
▶	9	(3x3)	RSK-101	M	Undocumented Hardware Requirements
▷	3	(3X4)	RSK-106	M	Science Instrument Hardware Change Control
▶	10	(2x3)	RSK-066	W	Operations Staff Retention
▶	11	(2x3)	RSK-053	W	Changes in Safety and Reliability Requirements

Criticality	L x C Trend	Approach
High	▼ Decreasing (Improving)	M – Mitigate
Med	▲ Increasing (Worsening)	W – Watch
Low	▶ Unchanged	A – Accept
	▷ New since last period	R – Research

6.2.7.8 Other Qualitative Risk Analysis Methods

Expected monetary value, simulation, Bayesian probability theory, reliability, and the use of decision trees or its inverse, failure mode effects and criticality analysis (FMECA) are other risk analysis methods that are used in project management. They are not described in detail here but may be researched using the given references.

Expected monetary value is the product of the risk event probability multiplied by the value of the gain or loss that will be incurred. Schedule impacts and intangibles (i.e., a loss may put the organization out of business) should be considered when using this approach. This method for scaling contingency amounts does not take advantage of information about the range of possible impacts or probabilities. It can only provide a mean value of the contingency, not some other target level of confidence. It is not good for time risks or cost risks that have time risk components.[1]

Any schedule of a real project can easily be handled using Monte Carlo simulation techniques,[2] discussed in the next section on Quantitative Risk Analysis. Simulation uses a model of a system such as the project schedule to simulate a project using Monte Carlo analysis. Monte Carlo "performs" the project many times so as to provide a statistical distribution of calculated results under many different scenarios, since in each scenario different risks may occur with different combinations of impact. The use of Monte Carlo analysis to estimate the risk schedule or cost distribution by statistically combining risk costs is illustrated in the next section.

A decision tree is a diagram depicting key interactions between decisions and associated events and uncertainties as understood by the decision-maker.[3] A FMECA is a bottoms-up version of a decision tree, building up from the elements to the decisions. Either approach helps the analyst to divide a problem into a series of smaller, simpler, and more manageable events that more accurately represent reality to simplify decision-making.

Bayesian probability theory treats probability as a degree of belief or uncertainty in a given statement. More information may be found in Foundations of Risk Analysis. [4]

[1] Integrated cost-schedule risk analysis is presented in Section 6.2.8, Quantitative Risk Analysis.

[2] For schedule impact the organization should not use the Program Evaluation and Review Technique (PERT or the Method of Moments) to represent project risk in schedules. This method underestimates risk for the type of projects addressed herein. Refer to "Project Schedule Risk Analysis: Monte Carlo Simulation or PERT?" David T. Hulett, PM Network published by the Project Management Institute, February 2000, pp. 43 ff

[3] See Recommended Practice 85R-14, Use of Decision Trees in Decision Making, Association for the Advancement of Cost Engineering International (AACEI), 2014, David T. Hulett principal author. Also, "Use Decision Trees to Make Important Project Decisions," David T. Hulett, Cost Engineering (published by AACEI, July / August 2014.

[4] Pages 62 and 64 of Foundations of Risk Analysis by Aven.

6.2.8 Quantitative Risk Analysis – Estimating Contingency

6.2.8.1 The Purpose of Quantitative Risk Analysis

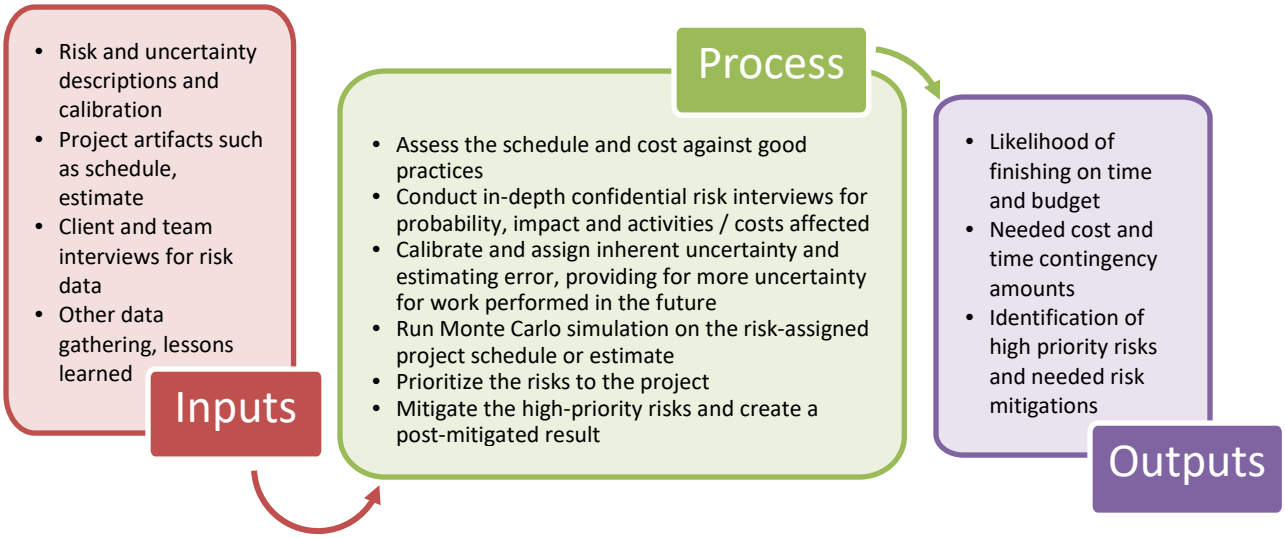
Quantitative risk analysis can analyze the impact of all of the risks and uncertainties on the project objectives of overall time and cost. Hence quantitative risk analysis can derive results that qualitative risk analysis cannot provide, i.e. the likely finish date and project cost when all risks are considered within a model of the entire project.

Quantitative risk analysis allows the risk analyst to estimate:

- How likely is the project to meet its schedule and cost goals?
- How much schedule and cost contingency is needed to achieve the project's desired level of certainty?
- Which risks are causing any potential overrun and are thus high priority for risk mitigation?

Quantitative risk analysis allows the analyst to estimate the finish date and cost of the project based on a probability distribution created by applying Monte Carlo simulation to a project plan such as the schedule, cost estimate or cost-loaded schedule. The inputs are uncertainty and discrete risk events, although there may also be probabilistic branches, weather / calendar effects and even conditional branches. The process for performing Quantitative Risk Analysis is shown in Figure 6.2.8-1 below. Outputs are the estimated total cost and finish date and associated contingency amounts above the baseline input cost and finish date.

Figure 6.2.8-1 Quantitative Risk Analysis Process



A quantitative risk analysis requires an accurate, up-to-date schedule as well as up-to-date risk data to be useful. The schedule used for analysis is often not the detailed Integrated Master Schedule (IMS), but is a summary schedule that can be resource loaded.

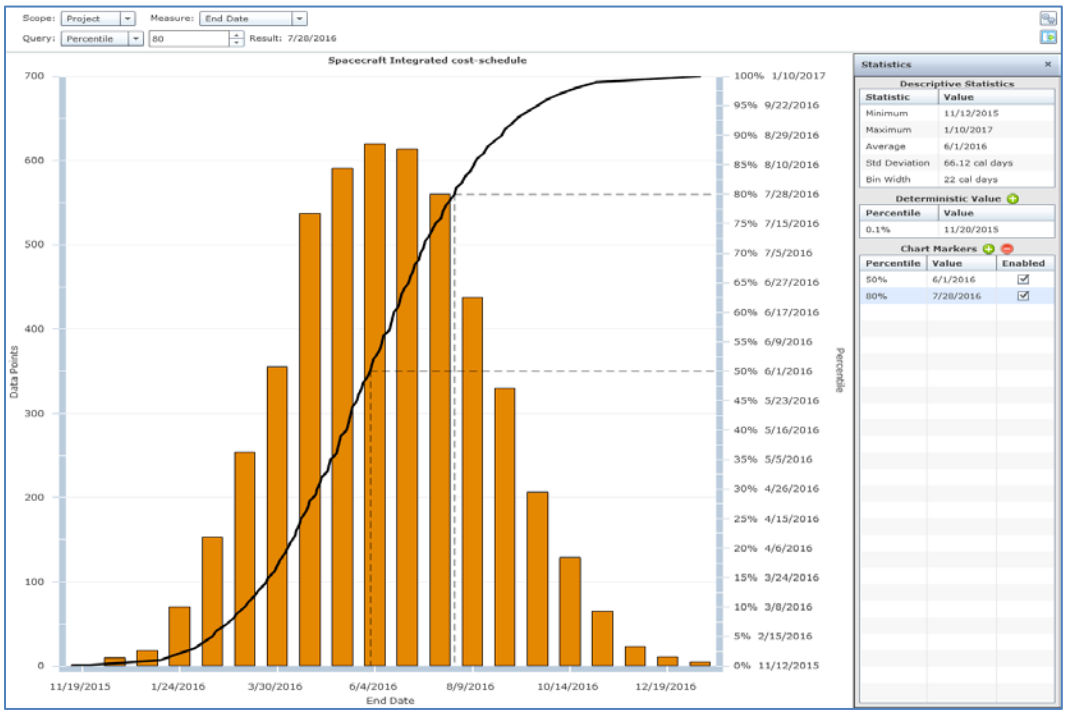
While software tools have made it relatively simple to run a Quantitative Analysis, the preparation work for a simulation run can take significant time and effort. Often, projects use Qualitative Analysis for month-to-month risk management and use Quantitative Analysis for establishing a new baseline or calculating an updated Estimate at Completion (EAC).

There are several commercial packages available that provide tools and programs for performing Quantitative Analysis using cost estimates and/or resource loaded schedules. While NSF strongly recommends probabilistic analysis methods for estimating total project risks and contingency amounts, it does not endorse or recommend any particular program or product.

A typical result of a quantitative schedule risk analysis using one such commercial tool, in this case a schedule risk analysis histogram of possible end dates, is shown in Figure 6.2.8-2. The estimated ranges of impact of risks and uncertainties on the duration of scheduled activities were fed into a Monte Carlo simulation program that generated a distribution of possible end dates based on a resource loaded schedule. For the histogram below, the horizontal axis shows the possible end dates. The right vertical axis shows the end dates for the confidence level curve.[1] The dotted lines on the plot represent the end dates for which the confidence level for completion by that date is 50% and 80% respectively. For this example, the PMB end date is 11/20/2015. If the project elects to use the 80% confidence level, then the chosen project finish date is 7/28/2016, indicating that the project needs to mitigate or provide contingency for an additional 8.3 months beyond the baseline date.

[1] NSF sets a required range for the confidence level unless an exception is requested and approved by NSF. See Section 4.2.5 for details.

Figure 6.2.8-2 Typical Result of a Quantitative Schedule Risk Analysis



Another typical output, from quantitative analysis of a resource-loaded schedule, is a time-cost scatter diagram. Figure 6.2.8-3 plots cost on the y-axis against end date on the x-axis. A line is drawn through the slope of the distribution. The plot illustrates the important fact that time and cost are related. In this case, longer schedule activities with labor-type resources generate higher cost.

Figure 6.2.8-3 Time-Cost Scatter Diagram: Each data point represents one realization of the simulation

6.2.8.2 Key Elements in Quantitative Risk Analysis

The platform for quantitative risk analysis is the project cost estimate or project schedule. Since most cost estimates are developed in a spreadsheet, a risk analysis of the project's cost estimate alone is often conducted using a software package that simulates a spreadsheet model.[1] Schedule risk analyses simulate a project schedule, so software that is able to simulate schedules developed in the organization's preferred scheduling package should be used.[2] Integrated cost-schedule risk analyses involve a good-quality PMB schedule (i.e., without cost or schedule contingency) with loaded resources representing the cost estimate attached to the activities they support.

[1] Two commonly-used packages are @RISK from Palisade Corporation and Crystal Ball from Oracle. (NSF does not endorse or recommend any particular package.)

[2] There are several schedule simulation packages available. Two of the schedule simulation packages with the most capabilities are Polaris from Booz Allen Hamilton and Primavera Risk Analysis from Oracle. Others include Acumen RISK from Deltek, Risky Project from Intaver Institute, @RISK for Project from Palisades, JACS from Tecolote and Full Monte from Barbecana. (NSF does not endorse or recommend any particular package.)

The elements of risk that may affect the cost, duration, or both cost and duration of a project include uncertainty, identified discrete risk events, and possible discontinuous events.

- Uncertainty represents inherent variability in predicting the outcome of future events. The uncertainty may be from people and organizations' inability to do the same thing the same way reliably or from the fact that future events cannot be predicted with complete accuracy. Uncertainty has a probability of 100% (since it is always present) and an estimated range for duration or cost. The range often has a positive tail (opportunity) and a negative tail (threat) such as -5% and +10%. These ranges represent the confidence in the estimates of activity duration or cost element actually occurring as estimated. The uncertainty ranges are often specified as a 3-point estimate with low, most likely and high values for a specified distribution shape, often a triangular distribution. For every iteration in a simulation, the software pulls a random impact multiplier for each duration and/or each cost item from within the chosen distributions. That value, say 1.07, is then multiplied by the activity duration or element cost in the model to get the value to be used for that iteration.
    - There may be asymmetry in the range of uncertainty since it is often easier to overrun than underrun an estimated value. Hence the optimistic tail of the distribution may not have as much probability as the pessimistic tail has. Also, the most likely value may not be the assigned value in the schedule or estimate. Hence a fairly typical uncertainty range could be .95, 1.05, and 1.15 – the middle value implies that the duration or cost is most likely 5% higher than in the baseline model.
    - The range of uncertainty can also be used to cover potential, but as yet unidentified, discrete risks that may surface later in the project than at the time of analysis. The inability to identify discrete risks is common for events that occur significantly later in the project or for activities that cannot yet be well defined. Most often these uncertain risks can be addressed by allocating a wider range of uncertainty to these durations or costs than to those assigned to better understood activities occurring in the early years of the project. In this way the generally higher level of uncertainty for durations and costs in the later years of the project can be included in the risk analysis leading to the size of the contingency reserve.
    - Some types of activities have more inherent uncertainty than others. It may be more difficult to make estimates of duration and cost for testing than for design, whereas fabrication may be somewhere in between. Therefore, some categories of activities may have wider uncertainty ranges than others. These activity-type specific uncertainty bands are sometimes termed reference ranges.
- Discrete Risk Events include those already identified and quantified in the Risk Register as well as any that may be discovered when interviewing for risk data to use in the quantitative risk analysis. Discrete risks are specified by their probability and range of impact if they happen to activity durations or cost elements.

  - The probability determines the fraction of the Monte Carlo iterations that they appear in.
  - The impact range is related to the duration of the individual activities or size of cost line items that they are assigned to. Hence the concept of impact range for quantitative analysis is not the same as that used for qualitative risk analysis, which is impact on the final date or total cost for the entire project.
  - A risk can affect many activities or cost elements. Activities or cost elements can be affected by more than one, sometimes many, discrete risks.
  - Discrete risks can be represented by adding a risk to a cost element or schedule activity or by specifying a multiplicative factor to apply to the estimated cost (risk register method) or activity duration (risk driver method).
- Discontinuous Risk Events are discrete events that can have consequences beyond adding duration to existing activities or cost to an existing budget element. Technically challenging projects such as NSF facilities typically have numerous discontinuous risks. Capturing a complete list of these risks is critical to effective RM and project success. For example, failing a qualifying test (or other discontinuous event) may require adding new activities and cost to the schedule in order to recover from the event. These activities and cost elements are almost certain not to be in the baseline schedule or cost estimate since those artifacts are usually based upon success of the baseline plan.

6.2.8.3 Platforms for a Project Quantitative Risk Analysis

A project schedule risk analysis starts with a good-quality Critical Path Method (CPM) schedule:

- The schedule can be a summary or roll-up of the detailed schedule of the project and should not have any padding or contingency for risk. Estimated project end date and schedule contingency duration are outputs of the risk analysis. The detailed project schedule is not always a good candidate for risk analysis input since it usually has several thousand activities and may be difficult to debug. That is, the detailed project schedule, perhaps a contractor's schedule, may not conform to scheduling best practices.[1] Hence, and in recognition that a schedule risk analysis is a strategic analysis of the project, summary or "analytical" schedules may be used instead of the detailed schedule. This analytical schedule needs to represent all the work of the project (including contractor and other participants such as the customer) and be validated against CPM good practices. It is recommended that the summary or analytical schedule format adheres to the project WBS to facilitate reporting of contingency usage.

Characteristics of a schedule used for Quantitative Risk Analysis are:

1) It represents all the work of the project,
2) All logic links are established,

[1] One source of complete scheduling best practices is the Government Accountability Office (GAO) Schedule Assessment Guide, 2015.

3) All constraints are appropriate, and
4) It is resource loaded.

Since the schedule validation process can require significant effort by project leaders, some references[1] recommend creating a 300-1000 line summary schedule from the project IMS and resource loading it with a minimal number of summary resources. (Some multi-billion-dollar projects have been known to use as few as eight summary resources.) That methodology is followed in the exercise demonstrated in the following case study.

A cost risk analysis starts with a complete, PMB cost estimate:

- The PMB cost estimate is complete for all in-scope work but does not include any built-in "padding" or contingency for risk. The estimated cost contingency amount is an output of the risk analysis. The cost estimate is usually specified in spreadsheet format and may be simple or detailed. It is recommended that the summary or analytical schedule format adheres to the project WBS to facilitate reporting of contingency usage.

An integrated cost-schedule risk analysis starts with a resource loaded schedule for a PMB with cost and schedule estimates:

- A schedule, either analysis or detailed level, that is loaded with resources. For the purpose of a risk analysis the resources do not have to be detailed at the same level as the Cost Book, but they do have to distinguish between time-dependent (e.g., labor, rented equipment) resources that will cost more if their activities are longer and time-independent (e.g., materials, purchased equipment) resources that may have variable cost but not because of uncertainty in duration. Again, it is recommended that the summary or analytical schedule format adheres to the project WBS to facilitate reporting of contingency usage.

All quantitative risk analyses require:

- Good quality risk data collected in the Risk Register but usually enhanced using good interview techniques. Note that SMEs are often more willing to talk freely about extreme good and bad possible risk results in confidential interviews.
- A professional schedule risk simulation package[2] that can perform a Monte Carlo risk analysis simulation on a risk-loaded schedule.

[1] David T. Hulett, principal author, Recommended Practice 57R-09, Integrated Cost and Schedule Risk Analysis Using Monte Carlo Simulation of a CPM Model, AACEI, 2011.

[2] There are several different software packages that can do this analysis. The package used for these charts and tables is Polaris® from Booz Allen Hamilton.

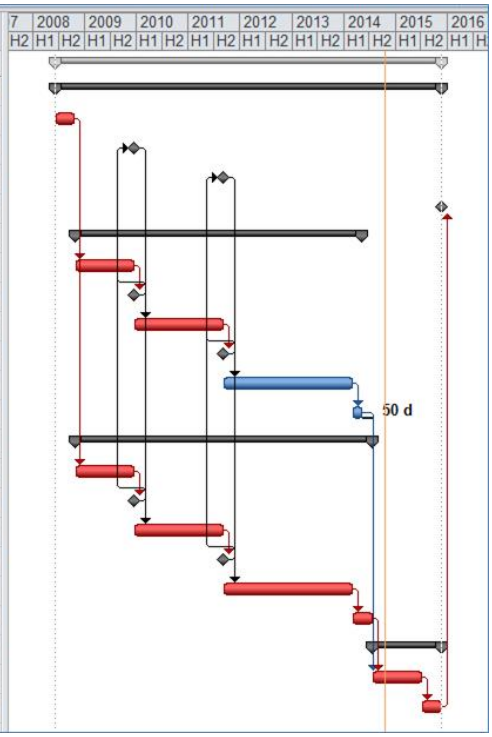
- An organizational culture that is committed to conducting an unbiased and realistic risk analysis and to use its output, such as total risk to objectives or prioritized risk events to be mitigated in order to improve the prospects of the project.

6.2.8.4 Case Study: Quantitative Risk Analysis[1] Exercise

These steps will be illustrated with a simple case study of an integrated cost-schedule risk analysis of design and fabrication of a space vehicle, as shown in the resource-loaded Gantt chart schedule shown in Figure 6.2.8-4.

Figure 6.2.8-4 Resource Loaded Schedule Used for a Simple Case Study of an Integrated Cost-Schedule Risk Analysis for Design, Fabrication, Testing, and Delivery of a Space Vehicle

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



This is a project starting June 1, 2008, with a ship to launch site end date of November 20, 2015. The project cost is estimated at $651.6 million.[2] Resources are shown on the bar chart and include mostly labor, with some equipment in the First Stage and Upper Stage Fabrication activities.

In this case study the resources, as shown in Table 6.2.8-1, are few and summary.

1 David T. Hulett, principal author, Recommended Practice 57R-09, Integrated Cost and Schedule Risk Analysis Using Monte Carlo Simulation of a CPM Model, AACEI, 2011.

[2] This schedule has been developed in Microsoft Project. Another popular scheduling package is Primavera P6 from Oracle. Most schedule simulation packages can import projects from these two scheduling packages.

Table 6.2.8-1 Resources for Quantitative Risk Analysis Example

Resource Name	Type
Preliminary Designers	Work
Detail Engineers	Work
Fabrication	Material
Integrators	Work
Integration Testers	Work
Specification Writers	Work
Unit Testers	Work
Fabricators	Work

6.2.8.5 Schedule Risk Analysis – Uncertainty

The schedule risk analysis starts with uncertainty reference ranges, estimated by the project SMEs. Recall that the probability for uncertainty occurring is 100%, and thus occurs for all simulation iterations for all assigned durations. The ranges shown in Table 6.2.8-2 are the SMEs' estimates of uncertainty in the task durations. Note that three of these imply that the SME interviewees assess the "Most Likely" value to be greater than the durations in the schedule. This may be because they view the schedule as being built with optimistic durations or that more has been learned about activity durations, leading to a higher estimate of the "most likely" durations. Although not shown here, their evaluation could also have resulted in lower, mostly durations. The use of Risk Drivers allows these distributions to have both threat and opportunity tails.

Table 6.2.8-2 Schedule Duration Risk Reference Ranges

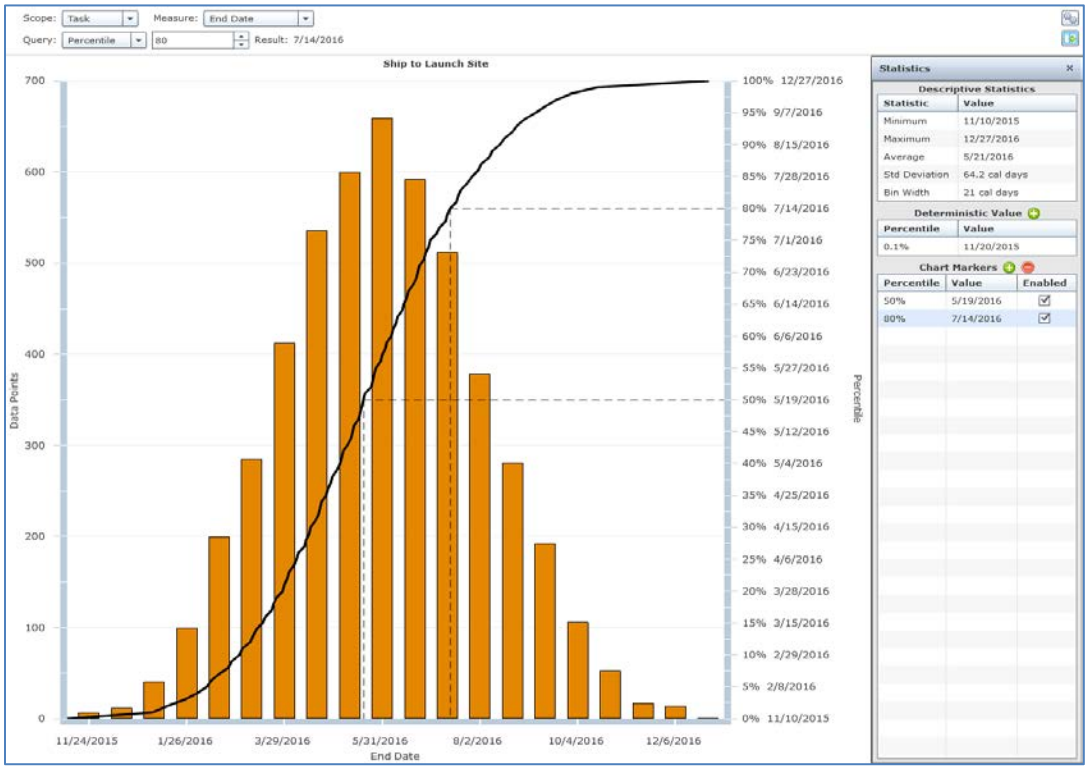
Activity Category	Low	Most Likely	High
Designers	0.90	1.00	1.20
Fabricators	0.95	1.05	1.20
Integrators	0.95	1.05	1.20
Requirement Writers	0.90	1.00	1.15
Testers	0.85	1.10	1.25

Notice that these are fairly narrow ranges that represent inherent variability, for instance, but do not represent the impact of discrete risks on the activity durations. These ranges are applied to the activities in the named categories by a triangular distribution, in this case, from which the computer pulls at random a multiplicative factor that is applied to the schedule duration. The example exercise demonstrated here uses 5,000 iterations because the software is fast, but 3,000 iterations would generally be enough.

Uncertainty ranges should be wider the further out into the future the work is being planned and estimated. This is because it is harder to estimate durations or costs several years into the future, since the work has not been contracted yet and may not actually be detailed with any specificity. Also, there will be risks in the future that cannot be identified today as discrete risks but should be provided for with wider uncertainty ranges.

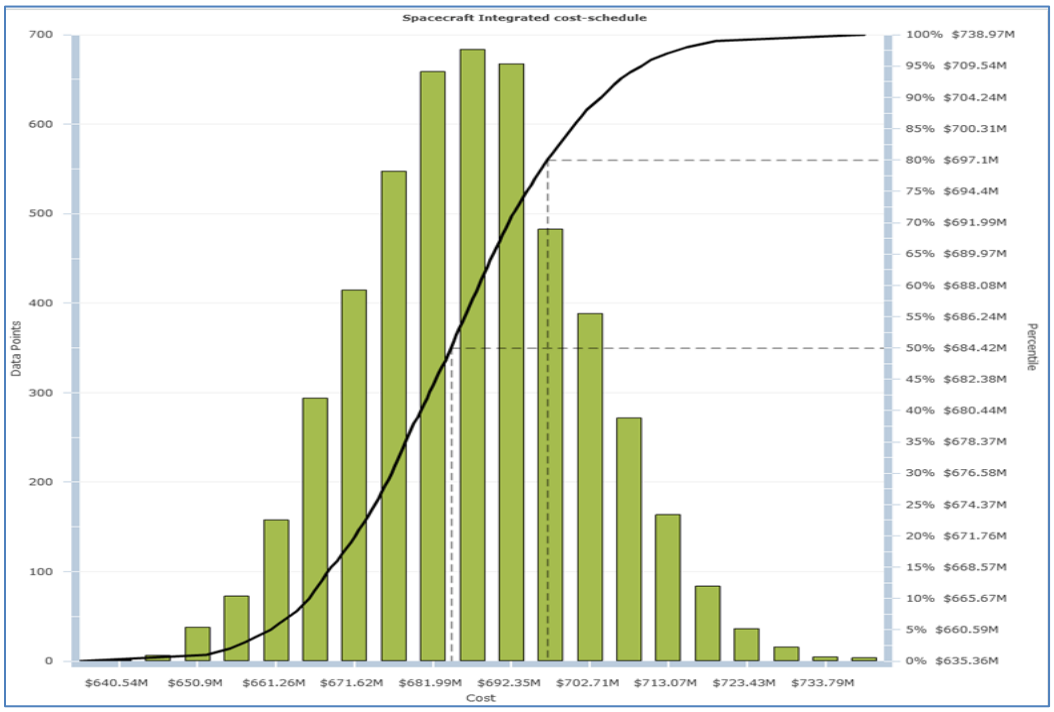
The analysis is performed using the reference ranges. If the analysis stopped at this point with just uncertainties, the schedule results would look like the histogram shown in Figure 6.2.8-5 below. The 80th percentile has been chosen as the target level of confidence for this example. The target confidence level for actual projects is chosen by the project or the customer.[1] The related cost risk histogram shown in Figure 6.2.8-6 represents the effect of duration uncertainty alone on the costs for time-dependent resource.

Figure 6.2.8-5 End Date Results for Schedule Duration Uncertainties



[1] To show these results one software package, Polaris, was chosen. However, these results can be achieved using Primavera Risk Analysis, JACS, Risky Project and others.

Figure 6.2.8-6 Cost Result for Schedule Duration Uncertainties



The results can also be shown in tabular form, with the 5% and 95% values included to determine if the total range is believable. For uncertainties alone, the results in Table 6.2.8-3 are believable.

Table 6.2.8-3 Results with Schedule Uncertainties Assigned

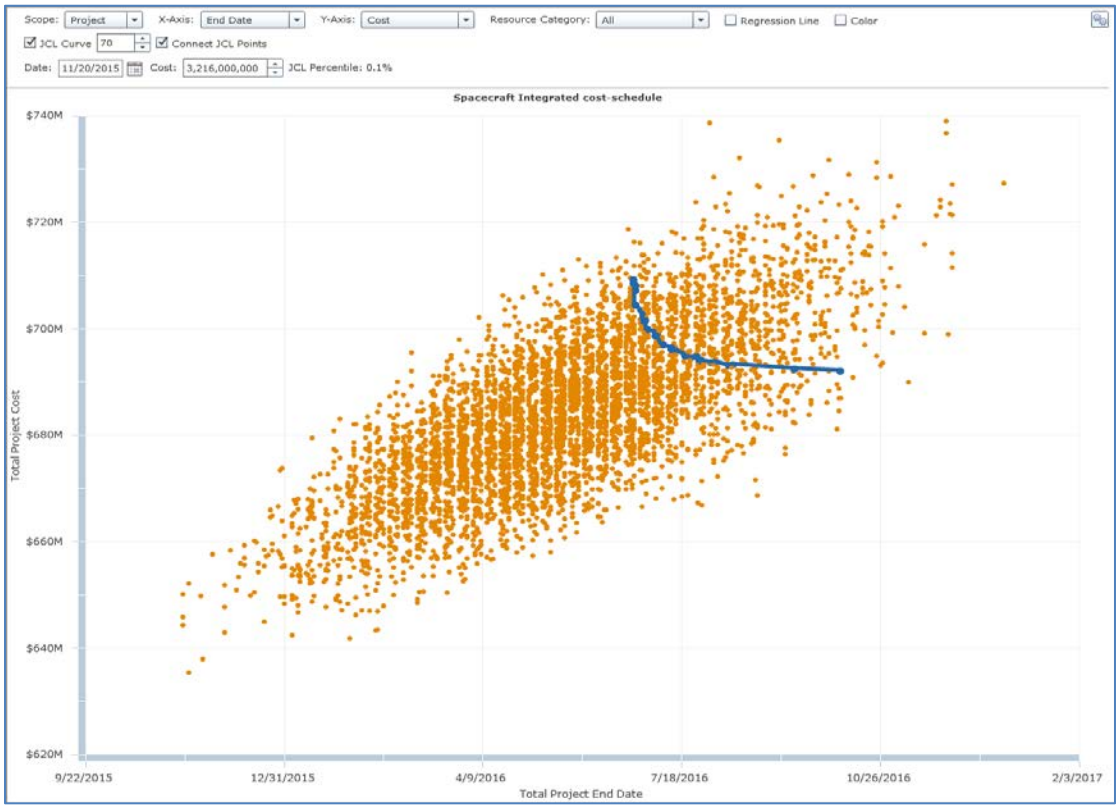
Schedule	Baseline	5%	50%	80%	95%
Dates	20-Nov-15	8-Feb-16	19-May-16	14-Jul-16	7-Sep-16
Months from Base		2.6	6.0	7.8	9.6

Cost	Baseline	5%	50%	80%	95%
Dollars (millions)	651.6	660.6	684.4	697.1	709.5
% above Base		1%	5%	7%	9%

Because this is an integrated cost-schedule risk analysis there is interest in the relationship between time and cost. This is shown in a finish date – total cost scatter diagram shown in Figure 6.2.8-7. The scatter plot has a dot for each of all 5,000 iterations. The scatter slope indicates the positive relationship between time on the horizontal axis and cost on the vertical axis. The curved line toward the top right of the scatter represents those combinations of cost and schedule results that exhibit a 70% probability of meeting both objectives, given the uncertainties applied to the cost-loaded schedule. The target of 70% confidence level for

budgeting and scheduling was chosen in this case since it is often used by several government funded agencies, such as NASA.[1]

Figure 6.2.8-7 Total Cost and End Date Scatterplot for Schedule Uncertainties



Note that the schedule uncertainty data in this example are assumed to be not correlated. If they were correlated (i.e. if one is high in its range then the others would also be high in their ranges), the extremes in cost and time would be greater and the correlation between time and cost would be tighter than shown above. The analyst should explore whether the uncertainty distributions should exhibit correlation or not. If so, then the analyst will want to exploit the capabilities of the chosen analysis package to handle correlations.

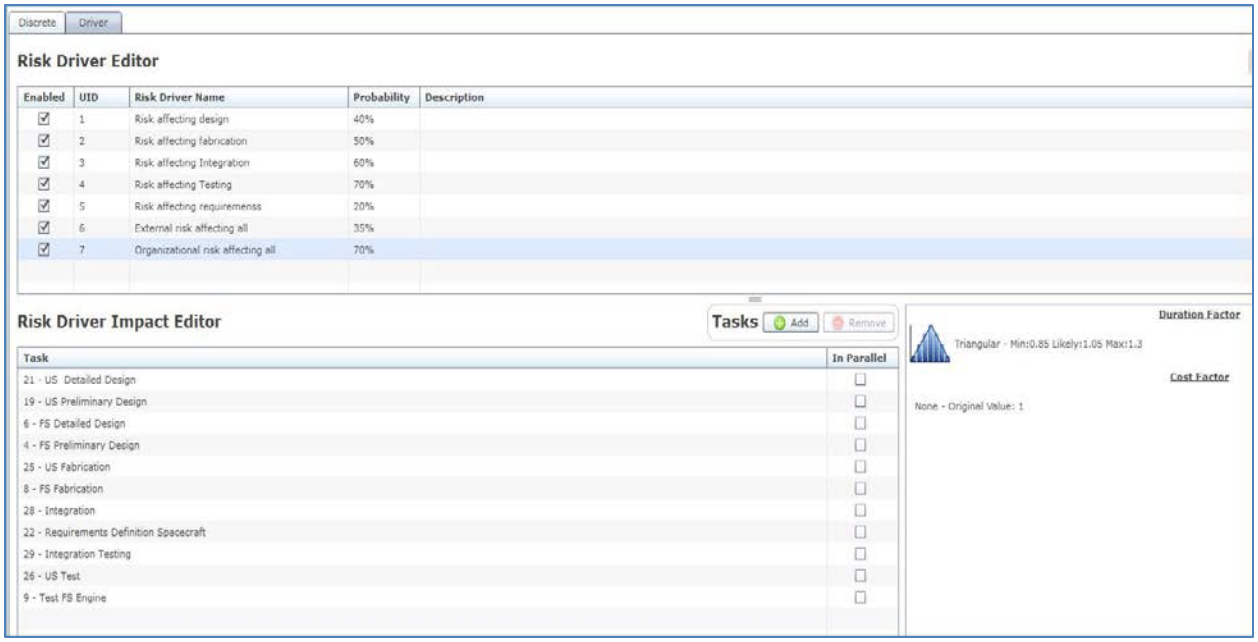
6.2.8.6 Schedule Risk Analysis – Discrete Risks Added as Drivers

The second step is to identify, calibrate and assign discrete risks to the project schedule. The risks used in this example are applied to the categories of activities, including design, fabrication, integration, testing and requirements. For this exercise the risks are given generic names, but in an actual analysis the risks would be taken from the Risk Register and augmented by risks discussed in the confidential risk interviews. The generic risks for this exercise, with their probabilities are shown in the top section in Figure 6.2.8-8. One risk, "Organizational risk

[1] See: "Understanding the Joint Confidence Level (JCL) at NASA," NASA Office of Evaluation at 9/4/14.

affecting all," has been selected to show its assigned impact range next to the triangle symbol on the right: Min 0.85, mode 1.05, Max 1.3. The Organizational risk has a probability of 70% and is assigned to all tasks since its impact is felt on everything. Although the description has not been filled in for this exercise, the organizational risk could stem from "lack of ready access to key decision makers that can increase durations" or to "organizational red tape that could slow decision making," for example.

Figure 6.2.8-8 Schedule Risk Drivers – Organizational Risk



When these risk drivers are assigned to multiple tasks or activities, those activities' durations become correlated since (1) if the risk occurs it occurs for all activities to which it is assigned, and (2) the multiplicative factor chosen for that iteration is applied to all of those activities. If only one risk is involved the activities become 100% correlated. If other risks are also assigned the correlation between activity durations is reduced. In this way the risk driver method models how correlation occurs so SMEs do not have to guess at the correlation matrix. With the addition of discrete risks to the analysis, the schedule impacts are more pronounced, and the results show a later start (by 15.4 months) and higher cost (by $100 million) than with just the uncertainties for the 80% confidence level. See Table 6.2.8-4 below. Note that the cost increase is due to schedule duration risk drivers alone, and not to any cost uncertainty or risk.

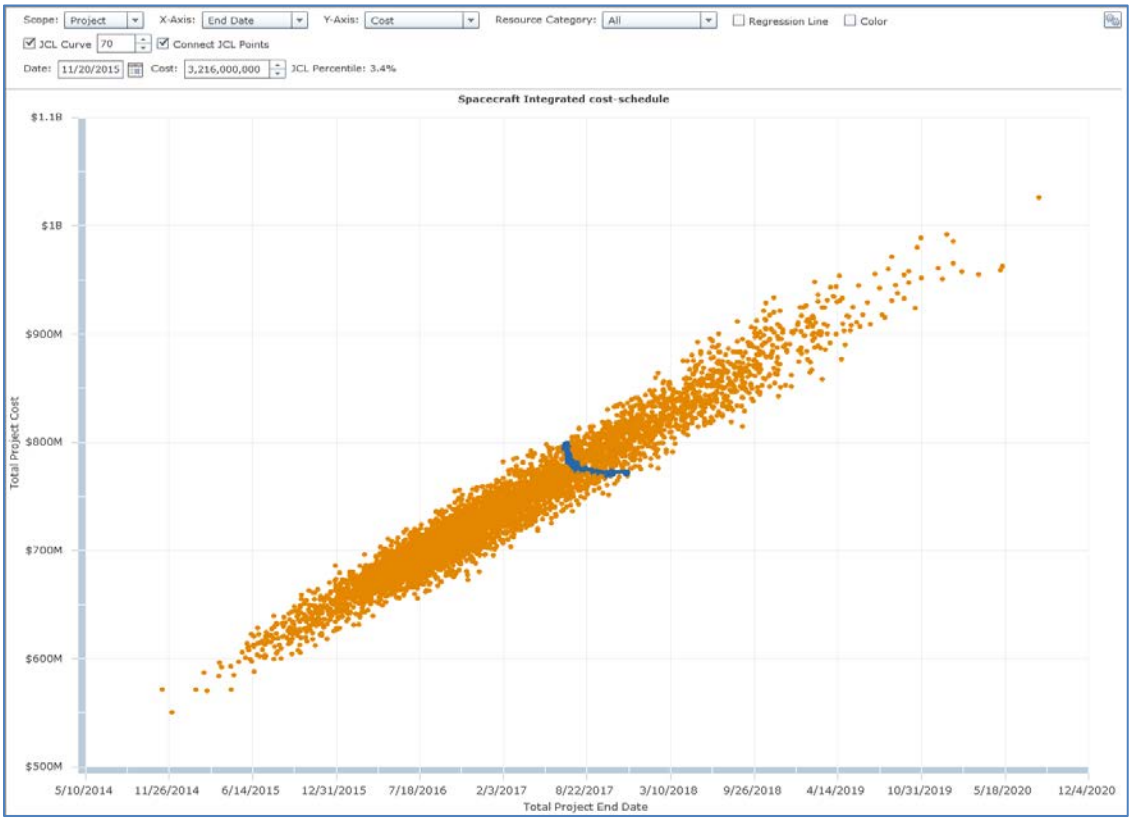
The scatterplot in Figure 6.2.8-9 shows greater correlation of time and cost risk than the previous plot showing uncertainties only, since the Organizational risk driver was assigned to all activities.

Table 6.2.8-4 Results with Schedule Uncertainties and Discrete Risks Assigned

Schedule	Baseline	5%	50%	80%	95%
Dates	20-Nov-15	5-Jan-16	28-Dec-16	26-Oct-17	16-Aug-18
Months from Base		1.5	13.3	23.2	32.9

Cost	Baseline	5%	50%	80%	95%
Dollars (millions)	651.6	650.7	730.6	797.6	865
% above Base		0%	12%	22%	33%

Figure 6.2.8-9 Total Cost and End Date Scatterplot Showing Greater Correlation of Time and Cost Risk



6.2.8.7 Cost Risk Analysis – Uncertainty and Discrete Risk Drivers

The last consideration in this simple example is whether there are uncertainties and discrete risks for cost which would cause cost variations that are independent of schedule.

Examples of uncertainty could be errors in the time independent cost of fabrication, variances in the time-dependent activities' daily "burn rate" due to uncertainty in the number of hours/workers needed per day, and/or uncertainty in the estimated salaries. These risks, if they

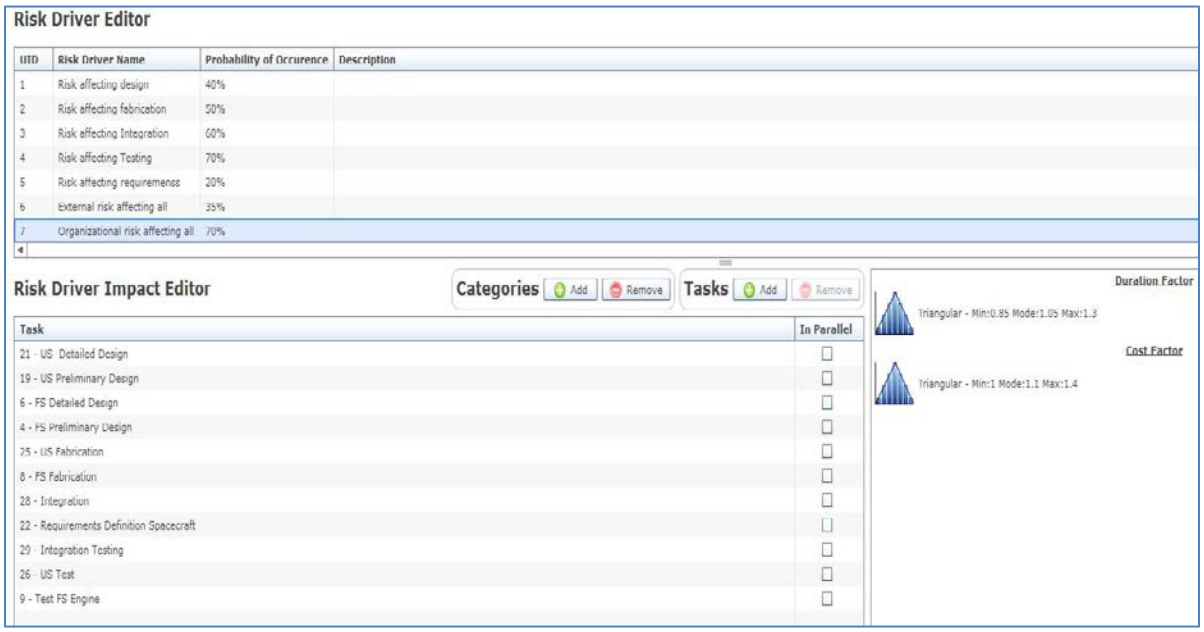
occur, are in addition to the cost impact from schedule duration risks already discussed in the previous material. The cost estimating error on the burn rate of labor or total cost of equipment can be entered by resource as uncertainties, with probability of 100% and a range of impact. Example uncertainty reference ranges for cost uncertainty as applied to different resources for this exercise are shown in Figure 6.2.8-10.

Figure 6.2.8-10 Uncertainty in the Burn Rate and Total Cost

Resources and Their Utilization Uncertainty				
UID	**Resource**	**Type**	**Planned Units per Unit or Day**	**Rate Per Unit or Day Min - Most Likely - Max**
1	Preliminary Engineers	Time Dependent	640	600 - 650 - 700
2	Detail Engineers	Time Dependent	960	900 - 960 - 1,020
3	Fabrication	Time Independent	1	0.9 - 1.05 - 1.15
4	Integrators	Time Dependent	1,200	1,100 - 1,250 - 1,500
5	Integration Testers	Time Dependent	1,200	1,150 - 1,250 - 1,550
6	Specification Writers	Time Dependent	800	750 - 800 - 850
7	Unit Testers	Time Dependent	800	700 - 825 - 950
8	Fabricators	Time Dependent	720	680 - 720 - 760

Discrete Risk drivers affecting cost can also be included to the analysis, in addition to the uncertainty factors. These cost factors can be entered as the implication of identified risk drivers, just as in the previous exercise for schedule drivers. If both cost and schedule risks occur, the burn rate, cost estimate, and duration will vary, and each driver will cost to vary. While new risks may be entered that just affect the burn rate or total cost of equipment, the existing risks with schedule drivers already included can have those impacts as well. For example, a cost factor has been added to the Risk Driver Editor for the previously identified Organizational risk affecting all tasks, as shown in the Figure 6.2.8-11.

Figure 6.2.8-11 Screenshot of Risk Driver Editor



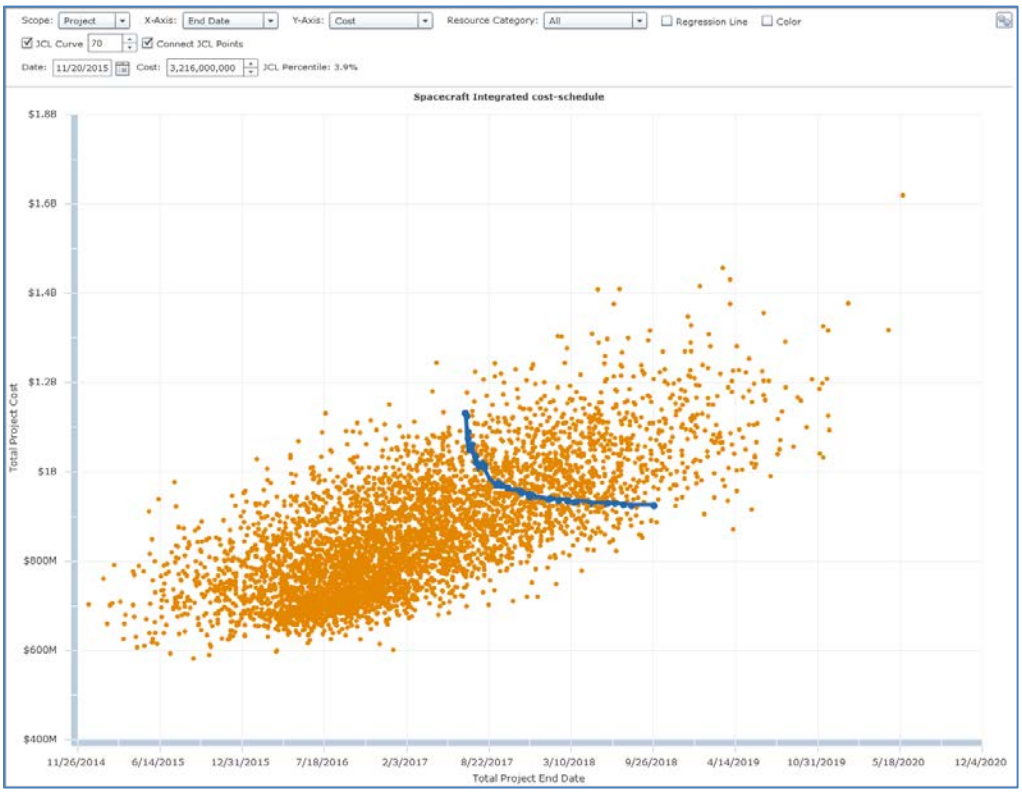
After running the program with the addition of cost uncertainties to resources and allowing risk drivers to affect costs directly rather than only through schedule risk, there is a direct impact on cost, as can be seen in Table 6.2.8-5 below. The schedule table is not shown, since the cost drivers included in the exercise do not by themselves impact duration. Note that some risks will have just schedule duration uncertainties and risk drivers, some will have just cost uncertainties and drivers, and some will have both. Cost will be affected in all cases, but schedule is affected only for those risks with duration uncertainties and drivers.

Table 6.2.8-5 Results with Uncertainties and Cost Risks Assigned

Cost	Baseline	5%	50%	80%	95%
Dollars (millions)	651.6	679	838.6	975	1100
% above Base		4%	29%	50%	69%

Adding the uncertainty and risks affecting the costs independently of time to the simulations results in a time-cost scatterplot shows less connection between time and cost, as shown in Figure 6.2.8-12.

Figure 6.2.8-12 Scatterplot Showing Less Connection between Time and Cost

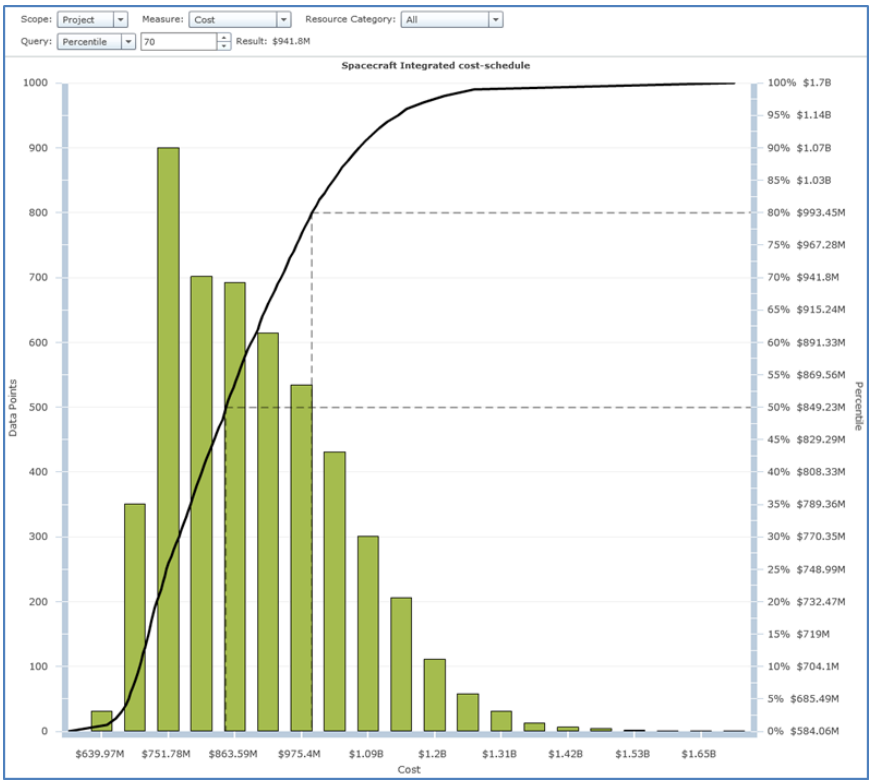


6.2.8.8 Handling Inflation

Inflation is a part of the NSF budgeting and project planning. The program should select an acceptable source for the future inflation rate and use it in the baseline and the risk analysis of that baseline. For the case study in this exercise, the baseline cost is projected at $651.6 million in base year dollars, that is, without inflation. With risks but no inflation the risk analysis simulation shows a cost in base year dollars of $975 million at the 80th percentile of certainty.

The analysis program can be used to factor in inflation if the cost estimating has been performed in base year dollars. Adding the factor of cost inflation and setting it at the rate of 3% causes the risked cost at the P-80 level to increase to $993 million in then-year dollars as shown below in Figure 6.2.8-13:

Figure 6.2.8-13 Scatterplot with Addition of Cost Inflation Factor



The value of 3% inflation may be a most likely number, but the software used in this exercise does not support an uncertain inflation level in simulation. A suggestion is to perform two scenarios where the inflation rate is either lower or higher than 3%.

- At 2% inflation the cost is estimated at $987 million
- At 4% inflation the cost is estimated at $1 billion.

These scenarios can help understand the total "then dollar" cost of the project that is risk adjusted, and the impact of the inflation assumption on that number.

6.2.8.9 Prioritizing the Discrete Risks – Risk Mitigation Workshop

The organization is encouraged to use these results to help improve the prospects of the project by mitigating the important risks. To do this the risks are prioritized. See Table 2.1.6-1 for sample prioritization from this exercise. This prioritization method uses the Monte Carlo simulation, a 60-year old method, and the schedule which the project team is using to manage or at least summarize the project. It is thought that this prioritization of risks is more realistic than that using qualitative methods resulting in the risk register, in part because it recognizes the structure of the schedule and handles correlations.

Table 6.2.8-6 Savings and Days Saved

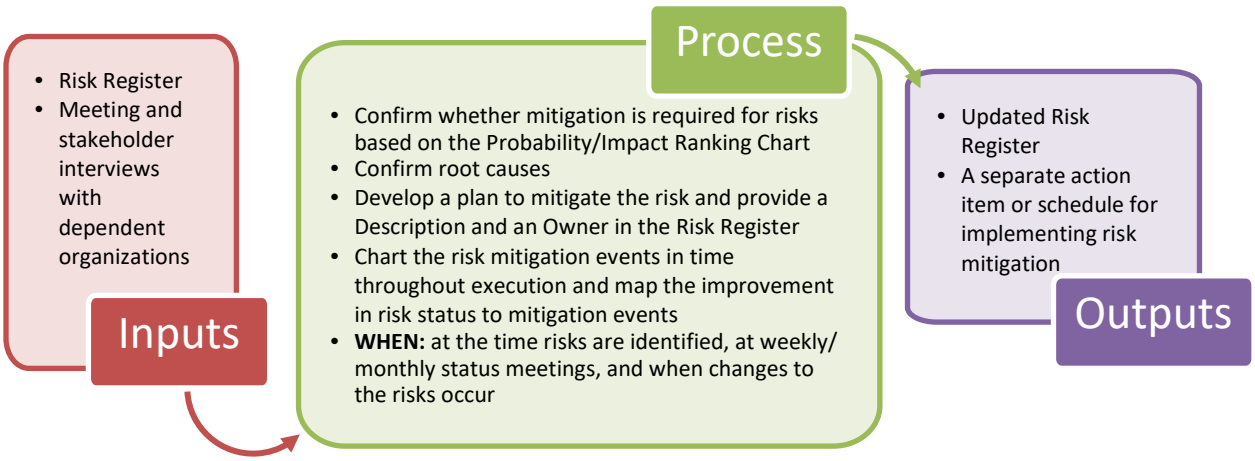
ID	Name	Cost Savings	Days Saved
7	Organizational risk affecting all	$196.15M	207
7	Uncertainty	$48.03M	152
6	External risk affecting all	$34.97M	41
2	Risk affecting fabrication	$23.8M	31
4	Risk affecting testing	$4.28M	34
3	Risk affecting Integration	$10.86M	32
1	Risk affecting design	$5.35M	10
5	Risk affecting requirements	$0	0

The risk mitigation exercise should be done in a workshop setting since many people have to contribute and commit to the mitigations.

- This workshop includes the PM, DPM, team leads and others involved in mitigation of risk.
- Given the prioritized list of risks for a project that may overrun cost and schedule targets, the project team can develop risk mitigation actions. The mitigation workshop estimates the improvement in the probability and impact parameters is expected to result from the various mitigations planned for each identified risk (uncertainty cannot be mitigated in concept).
- For the mitigation actions to "count" against the project risk management should commit to them as evidenced by their post-mitigation budget, schedule and assignment of people to monitor the risks and their mitigations. These risks should be added to the risk register as well so they are reviewed frequently.
- Each risk mitigation action accepted is modeled and the post-mitigation amount of risk to time and cost is recorded, along with the cost of the risk mitigation. A post-mitigation simulation will determine how much benefit is expected from the mitigations.
- The final report includes post-risk mitigation results and the overall project cost and schedule risk if those risk mitigation actions are taken and mitigate the risks. Note that the original cost and schedule target will generally not be met since that would require complete mitigation of the risks that caused the estimate of overrun in the risk analysis itself.

6.2.9 Risk Response Planning

Figure 6.2.9-1 Risk Response Planning Process



A known risk (often referred to as a "known unknown") is a risk that has been identified and can be calibrated (probability and impact) and analyzed. Examples of known risks may include strategic or overriding aspects of the project environment such as poor project management practices, lack of resources, multiple projects, external dependencies, relationships between project participants, technical complexity etc. Identified risks need to be proactively managed throughout the project life cycle by identifying who owns the management of that risk and by outlining risk symptoms, triggers, and contingency plans that would prevent the risk from occurring or that would lessen the project impact should it occur.

The Risk Response Planning step includes considerations related to risk mitigation and response planning. This includes the assignment of one or more persons to take responsibility for each identified risk and the development of measures and action plans to respond to the risk should it become an issue. PMI PMBOK® Guide defines Risk Response Planning as the process of developing options and actions to enhance opportunities and to reduce threats to project objectives.

Risk response actions for threats are generally categorized as:[1]

- **Avoid** – This strategy involves changing the project to eliminate the threat from identified risk
- **Mitigate** – This strategy involves taking early action to reduce the likelihood and/or impact of risk
- **Transfer** – This strategy involves shifting the responsibility and ownership of the risk to another party. Although this strategy is seldom used for NSF projects, it typically

[1] This listing and these descriptions are described in the PBMOK® Guide, 5th Edition, 2013 PMI

involves purchasing insurance against the type of risk or requiring vendors to assume more risk.

- **Accept** – This strategy involves acknowledging the threat as part of the project and accepting the consequences of its occurrence. An example of this is political or legislative risk that is out of the control of the project team. The consequence of acceptance may mean that contingency resources may need to be applied if the risk is realized.

Risk response actions for opportunities are generally categorized as:

- **Exploit** – This strategy seeks to eliminate the uncertainty associated with this opportunity to ensure it happens. This is similar to Avoid threats.
- **Enhance** – This strategy seeks to increase the probability and / or the positive impacts of the opportunity. This is similar to Mitigate threats.
- **Share** – This strategy seeks to share the benefits of the opportunity with another organization that is in the best position to secure the opportunity for the project. This is similar to Transfer for threats.
- **Accept** – This strategy accepts an opportunity if it arises but does not envision pursuing it, similar to Accept for threats.

For the most part, project risk response planning will consist of defining risk thresholds for action, confirming risk triggers, and then planning a mitigation strategy and/or developing backup plans if risks occur. A risk trigger is an event or events that activate the execution of a backup plan, should the risk become an issue. Triggers should be specified in the Risk Definition in the Risk Register, as well as the date that risk resolution is required for each risk. Mitigation strategies identify actions that may minimize or eliminate project risks before the risk occurs or document decisions to accept the consequences of risks without action. A risk may have several mitigation activities that attempt to balance the reduction in the probability and/or the severity of the risk occurrence with the cost-effectiveness of the mitigation strategy. Mitigation planning requires that the root cause(s) of the risk be identified and that the mitigation strategy and plans be aligned accordingly. Backup plans define actions to be taken in response to identified risk triggers in hopes of reducing potential project impact as a result of a realized risk (often defined in the literature as an “issue”).

A tabulated example of the impact of Risk Response evaluation is given below in Table 6.2.9-1.

Table 6.2.9-1 Impact of Risk Handling on Project Cost

	Before Handling				After Handling			
						Residual Risk Cost Estimates ($K)		
Risk Item or Basis	**Risk Level**	**Worst Case Cost ($K)**	**Handling Strategy**	**Cost Implement Handling**	**Risk Level**	**Best Case**	**Most Likely**	**Worst Case**
Redesign to solve problems identified during reviews	Moderate	3,360	Mitigate	75	Low	0	150	500
Do analyses or design per external comments	Moderate	390	Avoid	0	--	N/A	N/A	N/A
Rework design documents during concept evolution	Moderate	5,720	Mitigate	0	Moderate	0	750	2,500
Redesign for add'l equipment for ops or pretreat interface	Moderate	160	Mitigate	0	Low	0	40	100
Design for sintering equipment	High	500	Mitigate	308	Moderate	0	0	200
Redo design for SNF re-sizing	Moderate	200	Accept	0	Moderate	0	50	200
Redesign; contamination control in process room	Moderate	5,000	Mitigate	361	Moderate	0	300	3,000
Change design basis, due to scale-up impact	Low	50	Accept	0	Low	0	15	50
Redesign, for SC furnace	Low	800	Mitigate	0	Low	0	0	50
Redesign to add gas-trapping system	Low	1,550	Accept	0	Low	0	0	1,550
Rework to add waste streams to design	High	3,000	Mitigate	0	Moderate	0	250	2,300
Rework robotic features design	High	7,440	Mitigate	53	Moderate	0	500	2,000
Redesign for characterization	High	5,000	Mitigate	176	Moderate	0	600	3,000
Redesign to meet canister requirements	Moderate	3,000	Accept	0	Moderate	0	100	3,000
Design for new cables	Moderate	400	Mitigate	0	Low	0	0	50
Redesign for additional MC&A equipment	Moderate	400	Mitigate	0	Low	0	0	50
Redesign, to apply new structural criteria to 105L	Moderate	1,500	Mitigate	300	Low	0	0	700
Redesign, per SGS inputs	Low	500	Accept	0	Low	0	0	500
Redesign for changes, per NRC interface	Moderate	200	Mitigate	0	Low	0	0	150
Additional utility design features	Moderate	500	Accept	0	Moderate	0	300	500
Delays initiating design, awaiting R&D completion	High	5,360	Mitigate	0	Moderate	0	240	720
Delays redesigning for classified process control system	Low	60	Avoid	0	--	N/A	N/A	N/A
Add features to meet IAEA	Moderate	500	Mitigate	0	Low	0	0	50
Uncertainty in obtaining contingency funds	Moderate	2,000	Avoid	0	--	N/A	N/A	N/A
Disposal of bundling tubes	Moderate	100	Avoid	75	--	N/A	N/A	N/A
Decontamination of final-product canister	Moderate	500	Avoid	341	--	N/A	N/A	N/A
Storage location for depleted uranium	Moderate	100	Avoid	75	--	N/A	N/A	N/A
Availability of emergency generator and fuel tank	Moderate	40	Avoid	0	--	N/A	N/A	N/A
Redesign for necessary structural supports	Moderate	300	Avoid	225	--	N/A	N/A	N/A
Arithmetic Sums:		48,630		1,989		0	3,295	21,170

The risks with mitigation plans and risk triggers are all listed in the Risk Register with their Qualitative Risk Assessment status. After Risk Response Planning has been performed the entire entry for the risk includes:

- Its statement or definition
- Analysis and ranking of initial risk
- Assignment to a risk owner
- Risk mitigation actions and backup plans
  - Costs
  - Timing and risk triggers
  - Expected results
- Status of mitigation efforts
- Analysis and ranking of residual risk after mitigation

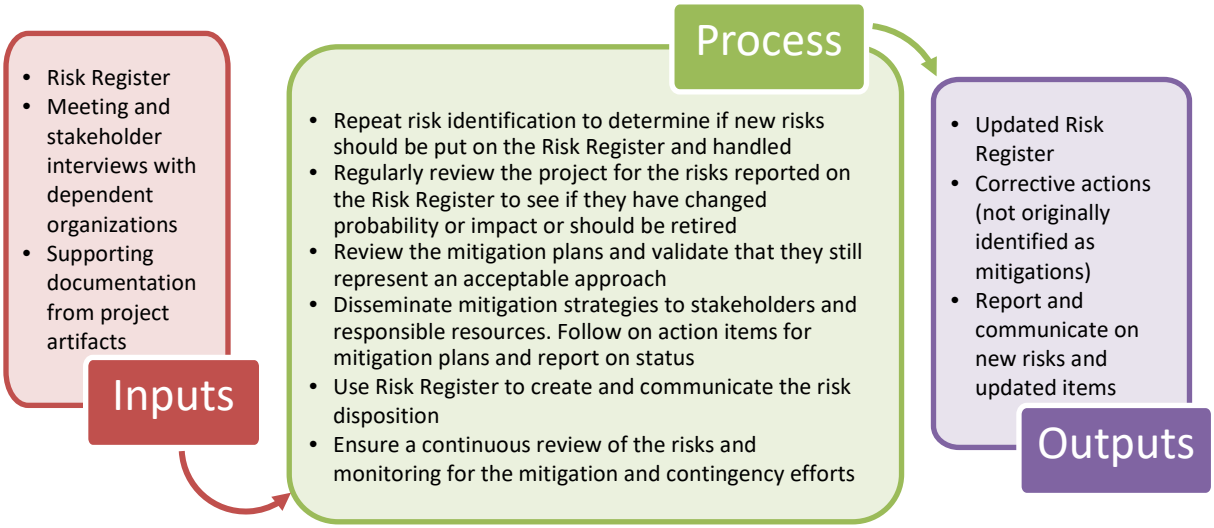
The last item listed above is the expected residual risk and ranking after mitigation has been applied. This is accomplished by repeating the analysis of probability and ranked impact on project objectives with successful mitigation assumed. Thus, the Risk Register shows "before" and "after" views of the analysis, with risks migrating down from red to yellow to green with the mitigation steps that cause the improvement in risk status and timing of those steps. The sample risk register shown in Figure 6.2.7-6 shows columns with headings for "Pre-Mitigated" and Post-Mitigated" analysis results.

6.2.10 Risk Monitoring and Control

Risk Management requires continuous monitoring of project risk and iterative application of the risk identification, analysis, and response processes. Existing risks need to be monitored, controlled, and ultimately retired, while new risks should be identified and added to the Risk Management process. Risk Monitoring and Control is the process of identifying, analyzing, and planning for new risk, keeping track of and re-analyzing identified risks, monitoring risk symptoms and triggers, reviewing the execution of risk responses strategies while evaluating their effectiveness, and reporting status to stakeholders. The Risk Register, as the tool that supports Risk Management and provides a means of communication, should be kept up to date with status and changes. The frequency and process for reviewing project risk is set out in the project Risk Management Plan.

Risk Control includes the process of regularly updating the Risk Register and communicating to stakeholders the latest risk status, with resulting impacts on the project and mitigation plans. Reporting of project and program level risks should be included as part of regularly scheduled status meetings with, and in formal status reports to, internal project members as well as eternal stakeholders and the NSF. The NSF has emphasized the need to communicate the risks at regularly scheduled status meetings to ensure that continued focus and awareness is placed on risk management.

Figure 6.2.10-1 Risk Monitoring and Control Process



When risks are resolved, they should be retired from the list of active risks. When the project ends, the risk register may be closed. If some risks pose other future threats to the program or future projects, consideration should be given to re-opening a risk with the appropriate operations management, or at the program level as an “ongoing risk.”

6.2.11 Contingency Management for Risk Mitigation

6.2.11.1 Contingency Budget Timeline

NSF expects the project to refine its WBS budget estimates following the Preliminary Design Review (PDR), adding additional definition to the tasks associated with accomplishing the project's deliverable activities. At Final Design Review (FDR) the PEP budget estimate should be substantially based on externally obtained cost estimates (vendor quotes, bids, historical data, etc.). This added definition is expected to result in an increase to the project's estimated Budget at Completion (BAC) and project schedule, and a concomitant reduction in its budget and schedule contingencies, while TPC and the risk-adjusted, committed schedule finish date remain constant. The quantitative risk analysis should have a component to anticipate this increase in cost and time so that the original contingency amounts are sufficient to provide for this increase.

As a project progresses, the baseline cost estimate and schedule will typically be exceeded and contingency amounts of dollars and time will be used. Periodically the project cost estimate must be revised to reflect all new information, including actual costs and use of contingency funds, adjustments to the risk profile, learning curves for manufactured items, etc. This new estimate of the cost of the remaining work is called the Estimate to Complete (ETC), and the Actual Cost of Work Performed + ETC is equal to the latest revision of the Estimate at Completion (EAC). The EAC should be compared to the sum of BAC plus remaining contingency to ensure that it is less than the TPC. If the sum of BAC plus remaining contingency is greater than the TPC, de-scoping may be necessary. See Section 4.2.5 for details on requirements for budget contingency use.

The project should create and maintain an expected contingency allocation profile. Contingency allocation profiles usually do not track the commitment or spending profiles. For many projects, the highest use of both schedule and budget contingency occurs during procurement and during final commissioning/integration phases. A contingency allocation curve for such a project would be bi-modal, 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 burn down over time, there may be significant reworking of hardware, for example, needed as a result of knowledge gained during integration and commissioning activities.

6.2.11.2 Change Control for Contingency Adjustments

Adjustments to cost, schedule, and scope are documented and approved under the project Change/Configuration Control Process (CCP, PEP-8.2). The Risk Management Plan describes how the project uses the Change/Configuration Control Process (CCP) to assign contingency to specific WBS elements when risks materialize, and how budget contingency is de-allocated from WBS elements and returned to the contingency category when budget underruns occur. The Change Control Process should be initiated when the Total Project Cost target is established at

the Preliminary Design Review and followed for the duration of the project. All change control actions that affect the use of contingency – cost, schedule, or technical performance and scope – should include a link to an identified and documented risk and indicate the affected WBS elements at the first meaningful level of technical differentiation within the project. The CCP must make provision for seeking prior approval from the NSF Program Officer for all actions exceeding thresholds as defined in the CA. All change requests are to be archived by the project and made available for review by NSF. The Project must keep a log of all change actions such that contingency actions, including puts and takes, can be reported and summarized. See Section 4.2.5 for further details and a sample Change Request form.

Note that use of contingency does not automatically require a change to the baseline. For instance, a change control action can authorize contingency to cover a cost overrun which is tracked as a variance on the baseline Budget at Completion (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. See Section 4.2.5 for further details on approval levels for use of contingency.

Adjustments to contingency should include taking advantage of opportunities to assign savings and underruns to contingency. Savings should not be left in associated WBS elements if they are above thresholds set out in the Risk Management Plan, nor should they be shifted to other tasks without going through the Change Control Process for return to contingency and subsequent allocation to a different WBS element. Budget and cost underruns should be moved to contingency as risks are retired and WBS elements are closed out and reconciled. Savings realized through the implementation of planned de-scoping options should also be placed into contingency. Returning the savings allows the best use of contingency for overall project priorities.

6.2.11.3 Liens List: Forecasting and Opportunity Management

The Project should 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 or 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, and anticipated opportunities for returns to contingency. It can also be used to record the need for contingency to cover variances that will not/cannot be mitigated. It does not serve the same purpose as a watch list or major threats list from the Risk Register. It 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 CCB action.

The affected WBS elements should be identified, at the second level (or the first meaningfully specific level of scope description), where known.

Projected amounts of possible future adjustments to contingency in the Liens List are to be periodically reported to NSF. NSF recommends including this information within the monthly status report as well.

6.2.11.4 Updates of the Estimate at Complete and Risk Exposure

The project should maintain an estimate of total costs and risk exposure by periodically updating the schedule, the Estimate at Completion (EAC), and the analysis of overall project risk. Estimated contingency amounts should be appropriate for the risk exposure throughout the project life cycle. During concept and early development stages, a qualitative risk analysis and risk register may provide an adequate estimate of risk exposure for both the design and construction planning estimates. As project planning reaches the preliminary design phase, the drawbacks of qualitative analysis – limited subset of risks, ignored correlations, and arithmetic sums of averages – do not allow that method to adequately portray total project risk.[1] Project planners should transition to quantitative risk analysis in order to establish a substantiated total project cost at the time of the PDR.

For the construction stage, initial contingency is a part of project total budget as defined by the award instrument; or in other words the Budgeted Cost of Work Scheduled (BCWS) under EVM. 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; either from a risk being retired or work packages coming in below the estimated budget. The total remaining available budget contingency should be compared to the remaining risk exposure to determine whether the project has adequate funds to cover anticipated risks. Remaining available contingency should always equate to the difference between the project total budget (Budget at Completion, BAC) minus the Estimate at Completion (EAC) and any liens.

The sum of the (EAC + liens) should include variances (backward looking actuals) and updated estimates (forward looking forecasting) in the current plan, not the target baseline BAC. The EAC should equal the BAC only at project start and after major changes to the baseline from re-planning or re-baselining.

It is good practice to re-estimate EAC and Risk Exposure yearly, unless stated otherwise in the CA. Specific dates may also be appropriate times for re-evaluation, such as at major milestones dates. The Project Manager periodically re-assesses the current risk assessment to identify and address any new risks that arise as the project progresses. This assessment should result in a determination of whether cost and schedule contingency remain sufficient for project risks.

[1] Projects usually adopt a more conservative certainty target such as the 80th percentile.

6.2.11.5 Contingency Use and NSF Oversight during Construction

The NSF Program Officer must concur on all CCB actions exceeding CA- or contract-defined thresholds for allocation of budget, schedule, or scope contingency. NSF will negotiate a CA with the Recipient institution to fund project construction activity which will specify thresholds above which prior NSF approval[1] is required before allocation of contingency (following formal CCB review) to specific WBS elements. Contingency may only be used to support in-scope work for the approved project baseline. See Section 4.2.5.7 for additional details.

6.2.11.6 Documentation and Reporting of Contingency Use

Risk management actions involving Change Control actions fall under the following documentation and reporting requirements, as stated in more detail in Section 4.2.5:

- All Change Control Requests, irrespective of amount or whether they increase or decrease the BAC, are to be reported directly to NSF Program Officer
- The Recipient will keep an archive of all Change Control Requests
- The Recipient will keep a summary log of all Change Control Requests
- Projected amounts of possible future adjustments to contingency ("liens") are to be periodically reported to NSF.

NSF recommends including this information within the monthly status report. Note that National Science Board (NSB) approvals[2] are required when Change Control actions exceed the even higher thresholds defined by NSB policy.

The required summary log of all Change Control actions should include the following:

- Change control action title,
- Change control document reference number,
- Change control approval date,
- Amounts of change in budget, scope, and/or schedule, for each affected and identified WBS element,
- Any adjustments to contingency amounts,
- WBS elements affected by the changes (at WBS Level II or at the first meaningful level of technical differentiation within the project)
- Risk Register ID number and description for the risk being addressed, and
- NSF approval date if required.

[1] Thresholds are necessary to allow the project to respond in a timely way to small, immediate needs for use of contingency, such as field changes during construction. This avoids potential cost escalation that could result from delay.

[2] See Section 2.4, Construction Stage, for details on NSF policy on how and when NSB authorization is required.

Monthly reports must also include the status of contingency as part of the Earned Value Management (EVM) reports. See Sections 4.2.5.8 and 4.6.2 for details on reporting.

6.2.12 Partnership Considerations for Contingency Management

NSF may partner with other entities to plan and construct a major facility. The guidelines within Section 4.2.5.9 of this document are applicable when NSF funds a particular scope of work within a larger overall project. Risk assessment, contingency development processes and contingency status reporting are to be applied to those WBS elements to be funded by NSF.

NSF encourages the development of unified management for project planning and execution of the entire project scope wherever practical.

6.3 GUIDELINES FOR CYBER-SECURITY OF NSF'S MAJOR FACILITIES

6.3.1 Introduction

Data creation, sharing, and analysis are central to the progress of science. As information has becoming increasing digital and increasingly accessible from anywhere, the confidentiality, availability, and integrity of information and information systems has raised the importance of cybersecurity considerations. Cybersecurity protects the availability of instruments and systems; promotes trust in, and availability of, data; and provides confidence in the integrity of the research resulting from use of facility information and information resources. At the same time, inappropriate, inefficient, and ineffective cybersecurity compliance regimes can be costly in time, human capital, and funding. Cybersecurity programs for a facility must appropriately balance risk with cost and research innovation. Thus, a cybersecurity program is based on a structured approach to planning, developing, and maintaining levels of information security and risk appropriate to a facility's mission and phase. A cybersecurity program should be scoped to the key assets, resources, and the full lifespan of the facility. It is necessarily a living program that adapts, adjusts, and advances. As such, cybersecurity programs require reporting, evaluation, and updating as appropriate.

6.3.2 Major Facility Cybersecurity Program

Uniform Guidance §200.303 states that the Recipient'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 (COSO)[1]. Further, the Cooperative Agreement Supplemental Financial & Administrative Terms and Conditions (CA-FATC) for Recipients of major facilities or Federally Funded Research and Development Centers (FFRDC)[2] requires an information security program[3] and identifies a modest set of required components for the program. Additionally, an information security plan is a required element of the construction stage Project Execution Plan (PEP) per Section 3.4 of this Guide.

The foundation for developing and maintaining a project's cybersecurity program lies in the research mission and goals of the facility itself. Related foundational considerations are project phase, size, complexity, project budget, and the project's required data management plan which identifies key information assets. In addition, geographic and institutional distribution can be an important overall factor. The three pillars of a cybersecurity program which rest on this foundation are governance; resources; and controls. Like other facility project components, the cybersecurity program should be appropriately represented in standard project documents and NSF oversight activities such as the project execution plan, project risk management plan, project budget, project reports, and project reviews.

The following sections define and describe a suggested framework for the facility cybersecurity plan. This framework is based on the previously mentioned three pillars of information security programs: Governance, Resources, and Controls.[4] Major facilities may use these pillars as a framework for founding, operating, evaluating, and improving their information security programs, and meeting the award terms and conditions. Since there are interdependencies among the pillars, an integrative approach is required. The exact content and emphasis of the information security program should be tailored to the mission, phase, size and scope of an individual facility.

The three pillars of a cybersecurity program rely on a project-specific inventory of "information assets" to be protected. Risk-based approaches to protection of information assets are further determined by a project-tailored "information classification"[5] which recognizes varying degrees

[1] Standards for Internal Control in the Federal Government and Internal Control – Integrated Framework,

[2] These documents are updated every 6 to 12 months. Check at https://www.nsf.gov for the most recent version that applies to major facilities or FFRDCs.

[3]For the purposes of this section, there is no distinction among the terms "information security," "cybersecurity," and "IT security" as referenced in the award terms and conditions. However, this section specifically addresses digital information.

[4] See, NSF Cybersecurity Center of Excellence program guidance, e.g., https://trustedci.org/guide

[5] https://www.scribd.com/document/203236714/CISO-Perspectives-Data-Classification

of value, priority, and/or sensitivity of the information assets. The information asset inventory and information classification are described in the Controls section.

6.3.3 Governance

Recommended governance elements for cybersecurity programs include: roles and responsibilities; policies and practices, risk acceptance and management.

6.3.3.1 Roles and Responsibilities

Successful cybersecurity programs require an active role for facility leadership in policy development and implementation, assigning information asset ownership, and accepting residual risk.

A second essential role is that of information asset owner. This is a person, position, or entity given formal responsibility for an information asset (or set of assets) within an organization. There are typically multiple information asset owners. The asset owner understands the risks to the asset and ensure adequate controls are in place over the life of the project.

In addition, cybersecurity programs should have an identified senior security role, such as a Chief Information Security Officers (CISO) or Information Security Officer (ISO) as owner of the cybersecurity program and lead decisionmaker for operational aspects of the cybersecurity program. This individual also facilitates the formation of informed cybersecurity policies, practices and risk management decisions by facility leadership and information asset owners.

6.3.3.2 Policies

Every facility project with information assets will require the development, approval and implementation of some information security policies within its cybersecurity program. Policies are driven not only by the facility's information assets and classifications, but also by relevant regulations. Regulations may be international, national or local. Regulations may be specific to an information asset (e.g. HIPAA, FERPA, etc.) or to specific needs of a facility collaborator or user (e.g. ITAR, FISMA). Examples of common policies include: Acceptable Use Policy; Access Control Policy; Incident Response Policy. Sample templates may be found at the Trusted CI website[1]. Trusted CI's guidance recommends developing a "Master Information Security Policy & Procedures" (MISPP) document as an initial policy-making step. A master policy provides an overview of the project's information security program including a summary of roles and responsibilities, as well as an organized list of specific information security policy documents. Additional sources of policy templates and forms include the Higher Education Information Security Council (HEISC) Resources Center,[2] and SANS Institute's Information Security Templates page.[3] Using example and template policies can streamline the policy production process, even if substantial customization is warranted. The policies themselves only reduce

[1] See, NSF Cybersecurity Center of Excellence program guidance, e.g., https://trustedci.org/guide

[2] https://www.educause.edu/focus-areas-and-initiatives/policy-and-security/cybersecurity-initiative/resources

[3] https://www.sans.org/security-resources/policies

risk if attached to other elements of the cybersecurity program (e.g. roles and responsibilities, controls) and integrated into overall project governance and management.

6.3.3.3 Risk Management and Acceptance

Cybersecurity programs employ a risk-based approach to information security and as such, there is inherent acknowledgement by NSF that any valuable activity requires acceptance of residual risk. Residual risk is that risk that remains in the presence of controls. An important output of a risk-based information security program is a documented set of well-informed risk management and project leadership acceptance decisions. Due to the rapidly changing technology landscape, a flexible, informal risk assessment process is often more valuable than a formal, detailed risk assessment that is out of date long before it is completed. In addition to the Trusted CI guide which is tailored to the scientific community, the Open Science Risk Profile Working Group (OSCRP), has developed and released a "best practices" document[1] to assist NSF, NIH and DOE projects in assessing cybersecurity risks related to Open Science projects. Finally, the Armed Forces Communications and Electronics Association International (AFCEA)'s I Cyber Committee has produced a useful and relevant publication: The Economics of Cybersecurity, A Practical Framework for Cybersecurity Investment[2].

6.3.3.4 Evaluation

Given the dynamic technology and cybersecurity landscape, organizations should plan for periodic evaluations of the cybersecurity program, including policies, practices, and controls. While project management and NSF oversight will involve regular reporting and review of program milestones, outcome metrics, and incidents, the project is encouraged to consider periodic self-assessments, external or stakeholder reviews, and evaluation of incident response. Tools are available from variety of sources to aid in assessment.[3] [4]

[1] http://trustedci.github.io/OSCRP/

[2] https://www.afcea.org/committees/cyber/documents/cybereconfinal.pdf

[3] https://library.educause.edu/resources/2015/11/information-security-program-assessment-tool

[4] https://cset.inl.gov/SitePages/Home.aspx

6.3.4 Resources

6.3.4.1 Budget

Overall, worldwide cybersecurity spending is on the rise[1][2] driven in part by response to increased cyber crime and new data protection regulations. There is wide variability in the cost of cybersecurity as a percent of overall IT budgets (3-12%) depending on the mission of the institution (e.g. Defense and Aerospace industries have more stringent requirements and proportionally higher costs.)) and size of the institution (Small institutions may not achieve economies of scale.). A secondary contribution to variability is the considerable discrepancy in what is within the cybersecurity budget as well as what is in the IT budget. A 2016 NSF Cybersecurity Summit examination of public data on DOE open science laboratory cybersecurity spending[3] indicated that approximately 0.5% of the overall lab budget and 8-12% of the IT budget (excluding scientific IT) were spend on cybersecurity.

6.3.4.2 Personnel

In addition to the CISO/ISO, ongoing access to skilled cybersecurity professionals is key to a successful cybersecurity program. The CISO may manage a team of dedicated information security professionals or oversee staff/activities in various departments within the facility.

Considering the demand for experienced cybersecurity professionals,[4] [5] organizations may need to consider outsourcing security services. In any scenario, information security resources outside the facility such as a parent institution/campus, peer organizations, commercial security consultants, intrusion detection and log monitoring services, and incident response services can be an important source of security expertise, training, evaluation, and recommendations.

While technical skills are important, teaching skills, communication skills and negotiating skills are endemic to cybersecurity programs and are, therefore, necessary personnel considerations.

[1] https://www.gartner.com/newsroom/id/3836563

[2] https://securityintelligence.com/news/cybersecurity-spending-poised-to-rise-in-2018-gartner-reports/

[3] https://static1.squarespace.com/static/5047a5a6e4b0dcecada15549/t/57b4b32dd2b857a1b6827a7f/1471460142220/Cybersecurity+Budgets+NSF+Summit+2016.pdf

[4] https://www.monster.com/career-advice/article/future-of-cybersecurity-jobs

[5] https://www.csoonline.com/article/3201974/it-careers/cybersecurity-job-market-statistics.html

6.3.5 Controls

Controls are tailored to the facility's portfolio of information assets and aligned to protect confidentiality, integrity, and availability based on the corresponding information classification for those information assets.

6.3.5.1 Information Asset Inventory

Organizational identification and location of information assets is a prerequisite to competently securing those assets. See, CIS Critical Security Controls 1 and 2,[1] and NIST 800-53 control CM-8.[2] The inventory might include many details, but at a minimum it should identify the asset and indicate the value or sensitivity of the system and/or classification of the information. The facility data management plan which is a required document for proposal submission is a key source for both asset identification and classification.

The asset inventory can be built by manually using publicly or commercially available templates or worksheets or by constructing a custom database. The Open Science Cyber Risk Profile (OSCRP) provides guidance on assets to consider for science projects.[3] Trusted CI [4] has developed substantial guidance[5] for information security programs in NSF projects, including a template for recording data about information assets. To reduce the manual effort, security products or scanners[6] can aid with asset discovery and inventory.

Information is any communication or representation of knowledge such as facts, data, or opinions in any medium or form, including textual, numerical, graphic, cartographic, narrative, or audiovisual.[7] Organizational information may be stored and used within the organization's information systems, as well as flow out to third party systems.

An ***information system*** is a discrete set of information and related resources (such as people, equipment, and information technology) organized for the collection, processing, maintenance, use, sharing, dissemination, and/or disposition of information.[8]

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[1] https://www.cisecurity.org/controls/

[2] http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-53r4.pdf

[3] https://trustedci.github.io/OSCRP/OSCRP.html

[4] Trusted CI, the NSF Cybersecurity Center of Excellence, is an NSF-funded center dedicated to assisting the NSF community, including Major Facilities, with information security needs. More information is available at https://trustedci.org

[5] https://trustedci.org/guide

[6] https://www.cisecurity.org/white-papers/cis-controls-sme-guide/

[7] See, National Information Assurance (IA) Glossary, CNSS Instruction No. 4009, Apr. 2010.

[8] See, 44 U.S.C. 3502

6.3.5.2 Information Classification

Information has varying degrees of organizational value, sensitivity, and protection requirements.[1] These qualities are key factors to consider in analyzing the anticipated impact of security incidents. In addition, some information assets may be subject to additional external control (e.g. federal or state privacy laws, international regulations, contractual obligations). In most cases, information can be classified into two to four categories (e.g., public, internal, and controlled).

6.3.5.3 Control Set

Controls or *mitigations* are the administrative, technical, and physical safeguards and countermeasures implemented to support the facility's mission and ensure the appropriate protection of information assets. Control selection, implementation and evaluation are ongoing processes in any information security program.

While efficiency and effectiveness will require customization of controls, there are several authoritative sources to assist in selecting baseline controls. [2,3,4] Scientific facilities may merit special security considerations (e.g. diverse research data flows; identity management for distributed science communities[5]; non-facility device connectivity to facility networks and data; unique Industry Control (ICS) and/or Supervisory Control and Data Acquisition (SCADA) systems[6]; application software development[7, 8, 9]).

[1] https://www.scribd.com/document/203236714/CISO-Perspectives-Data-Classification

[2] https://www.cisecurity.org/controls/ ; for more detail including history, see https://www.sans.org/critical-security-controls

[3] https://www.asd.gov.au/publications/protect/essential-eight-explained.htm

[4] https://www.nist.gov/cybersecurity-framework

[5] https://refeds.org/sirtfi

[6] https://ics-cert.us-cert.gov/ See, also, NIST SP 800-82r2. Available at http://csrc.nist.gov/publications/PubsSPs.html

[7] https://social.technet.microsoft.com/wiki/contents/articles/7100.the-security-development-lifecycle.aspx

[8] https://www.owasp.org/index.php/Category:OWASP_Top_Ten_Project

[9] https://software-security.sans.org/resources/swat

6.4 GUIDELINES FOR PLANNING AND EXECUTING EXTERNAL REVIEWS OF NSF'S MAJOR FACILITIES

This document, which is in preparation, will describe the process for evaluation and review of all NSF major facility projects proposed for construction, under construction or currently in operation. It will provide assistance to the Program Officer (PO) in preparing and planning a review of the *non-research related aspect* of the project's management, budgets, schedule and related activities. The information contained will offer guidance for three situations: reviews of facilities in planning; reviews of construction activity; and operational reviews of ongoing facilities. A description of the overall process of planning and carrying out an external review of a major facility project will be provided as an aid to the PO or associated staff who may be unfamiliar with these processes or need a reference source on good practices.

The evaluation and reviews covered in the document include assessment of management, schedules and budgets, as well as other matters relevant to a major facility project, such as changes to technical aspects or scope. It does not address the intellectual merit or the broader impact criteria used to select the project for support, but rather focuses on evaluation of the Recipient's planning and implementation activities.

The reports and recommendations from these external reviews are made directly to NSF. NSF evaluates the review panel input, determines the appropriate response, and issues written guidance to award Recipients for any subsequent response and action.

6.5 ENVIRONMENTAL CONSIDERATIONS IN MAJOR FACILITY PLANNING

NSF's funding for the construction or modification of facilities constitutes a Federal Action that triggers compliance with several statutes designed to protect the Nation's environmental, cultural and historic resources. Awareness of, and strict adherence to, all relevant environmental regulations are extremely important considerations in the planning, construction and operation of facilities.

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 its implementing regulations focus on activities that take place within the United States, proposed activities that take place outside of United States may also be subject to NEPA. Furthermore, there are international agreements and treaties that deal with environmental impacts. For further information, see the *Proposal and Award Policies Procedures Guide* Chapter II.C.2.j and consult with the PO.

NSF regulations governing compliance with the National Environmental Policy Act (NEPA) are found at 45 CFR §640. NSF regulations supplement the Council on Environmental Quality's (CEQ) regulations, published at 40 CFR §§1500-1508. Program Officers, as required by NSF regulations, are responsible for evaluating the environmental impacts that may result from the implementation of a Foundation award and determining into which category incoming proposals fall (i.e., CATEX, EA, or EIS). Compliance with NEPA also includes providing opportunities for public input on issues such as potential environmental impacts and ways to avoid, minimize, and/or mitigate adverse impacts. Determining the required level of compliance activities – including what documentation, consultation and/or permits may be required – is a complex task. The Program Officer (PO) should not attempt to determine the extent of compliance requirements without consulting the Environmental Compliance Team within NSF's Office of the General Counsel. NEPA compliance may require the preparation of an Environmental Assessment (EA) in cases where no significant environmental impacts are expected or the more extensive documentation of an Environmental Impact Statement (EIS) where adverse effects are anticipated. Failure to take necessary steps can cause undue delays in a project's schedule, significant cost escalation and potential federal litigation.

Additionally, in conjunction with or independent of its NEPA compliance, NSF may be required to initiate consultations with Native Americans and other interested parties pursuant to the NHPA and/or initiate informal or formal consultation with the U.S. Fish and Wildlife Service under the Endangered Species Act. These compliance requirements can introduce significant schedule and cost risk into the project which should be considered and addressed. Furthermore, 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.

Given the above considerations, the following guidance is offered:

1. It is imperative that the PO contact the Environmental Compliance Team within NSF's Office of the General Counsel early in the conceptual design stage to seek guidance on specific requirements for compliance. The time required to complete environmental compliance can take a year or more depending upon the level of impacts associated with a proposed project.
2. It is extremely important that the PO and the project get cost estimates for the compliance process and factor these into the project's scope, schedule and budget early in the design process.

The cost drivers associated with these activities (their impact on the project construction cost) need to be well understood by PDR since the PDR budget and risk assessment provide the basis for the construction funding request.

6.6 GUIDELINES FOR PROPERTY MANAGEMENT

NSF retains ownership to major research equipment and facilities it funds only if specified in the terms and conditions of the award, otherwise title resides with the Recipient. At the end of the award, NSF may choose to invoke its contingent interest in NSF-funded property and equipment to take title or transfer to another organization. This stewardship responsibility is necessary to protect the U.S. Government's and the public's investment in these unique research facilities.

The requirements for management of property procured using NSF funds are detailed in key NSF documents: Cooperative Agreement and Cooperative Support Agreement specific to the award; Chapter IX Grantee Standards, Section D; Property Management Standards of the NSF Proposal and Award Policies and Procedures Guide (PAPPG); the NSF Cooperative Agreement FATC, Article 6, Equipment; Article 61, 62, 63, 64, 65 of the Cooperative Agreement Modifications and Supplemental Financial & Administrative Terms and Conditions for Major Multi-User Research Facility Projects and Federally Funded Research and Development Centers; or other supplements. In addition, 2 CFR § 200.310-316 prescribes standards for managing and disposing of property furnished by the Federal government or whose cost was charged to a project supported by a Federal award. It is incumbent on the Recipient to understand these policies and maintain a property management system.

Each NSF major research facility is unique in its mission and its circumstances and thus the approach to property management will likely be unique but must comply with federal regulations and NSF policy. The policies and procedures governing the management of Federally funded property and equipment should cover the following general topic areas:

- The process for acquisition and procurement;
- The process for retention of financial records (physical and electronic) necessary for property audits or closeout;
- The process for inventory management including custody, location, use, and disposition (note that awardees should seek instruction from NSF in most disposition cases);
- The process for marking or identification of equipment, as appropriate;
- The process to establish and perform routine and preventative maintenance, and
- The process to secure property while in operation, storage, or transit.

6.7 GUIDELINES FOR FINANCIAL MANAGEMENT

[Reserved for future content]

6.8 GUIDELINES FOR EARNED VALUE MANAGEMENT SYSTEMS

Earned Value Management (EVM) is a recognized project management methodology that provides insight into a project's technical, cost, and schedule progress. NSF recognizes that a properly implemented Earned Value Management System (EVMS) can provide accurate and reliable performance measurement metrics, forecast cost and schedule information, and uncover potential problems to support sound and timely management decisions. A properly implemented EVMS is also essential to inform NSF's oversight of the project.

6.8.1 EVMS Requirements

NSF requires major facility project Recipients to use EVMS as the management tool for project planning and execution. The project should adhere to the seven basic principles outlined in the EIA-748 Standard for EVMS:

- Plan all the project's work scope to completion using discrete work packages and planning packages.
- Break down the project work scope into finite pieces that are assigned to a responsible person or organization for control of technical, schedule and cost objectives.
- Integrate project work scope, schedule, and cost objectives into a performance measurement baseline plan against which accomplishments are measured. Control changes to the baseline.
- Use actual costs incurred and recorded in accomplishing the work performed.
- Objectively assess accomplishments at the work performance level.
- Analyze significant variances from the plan, forecast impacts, develop corrective actions, and prepare an estimate at completion based on performance to date and the remaining work to be performed.
- Use the EVMS information in the project's management processes.

The 32 guidelines of EIA-748 Standard should be used in establishing the project's EVMS process. These guidelines are high-level and goal-oriented. They state the qualities and operational considerations of an integrated management system using EVM methods without mandating detailed system characteristics. They give a project sufficient flexibility within the 32 guidelines to develop an integrated management process that is tailored to the project's specific needs. Therefore, the project's management team should implement an EVMS in a manner that employs the most effective and efficient performance management methods and techniques. The project's EVMS process should be documented in the Project Execution Plan (PEP-10.2). The document address how the 32 guidelines of the EIA-748 are implemented and describe how the processes are integrated into an effective approach for project management.

6.8.2 Scaled Application of EVMS Guidelines

To realize the full benefit of EVM for effective project management, the 32 EVMS guidelines should be applied in a way that suits the size, complexity, risk, and type of work. For large science projects, the unique challenges of being on the fore-front of enabling scientific research and the need of scientific collaborations should be taken into account. EVM data should not be viewed simply as static metrics or as a compliance report. Instead, the project's EVMS should be implemented in a manner that can provide the Recipient management team with a reliable basis for objectively assessing performance against plan, identifying potential issues, forecasting future trends, and initiating corrective actions.

When implementing the EVMS guidelines, the Recipient management team should evaluate the project's inherent complexity, external dependencies, unique challenges and constraints, and scale the EVMS accordingly. The Earned Value Management System Guideline Scalability Guide published by NDIA Integrated Program Management Division (IPMD) provides a reference in scaled application of EVMS. A properly implemented EVMS should be no more complex than is necessary to inform sound project management decisions while reflecting the business practices and other related documents (such as the WBS) as outlined in the PEP.

6.8.3 Guidelines for Establishing an EVMS

Earned Value Management (EVM) is an integrated management methodology and an Earned Value Management System (EVMS) is an integrated set of processes, people and tools for managing projects using earned value management. The primary purpose for establishing an EVMS is to support successful management of the project by the Recipient. As stated above, each project should consider the nature of the project's work, unique challenges and constraints in establishing the process to ensure the process supports the project's management needs. There is no single correct process for establishing an EVMS. Below is an outline of what is typically involved:

- Obtaining institutional support for the project's implementation of EVMS
- Selecting and implementing the project management tools for EVMS
- Assessing the project's needs and existing processes to establish the project's EVMS process following EIA-748 EVMS guidelines
- Documenting the EVMS processes and procedures in the PEP
- Training the project management team to facilitate implementation of the project's EVMS and instill a culture that accepts the use of EVM as a credible management tool
- Developing structured surveillance and training programs
- Conducting an NSF EVMS verification review
- Receiving NSF's acceptance that the EVMS meets the intent of 32 guidelines (see Section 4.6.3.6)
- Conducting NSF surveillance reviews throughout the Construction Stage

7 REFERENCES

NSF Reference Documents

NSF Business Systems Review (BSR) Guide
https://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf13100

NSF Proposal and Award Policies and Procedures Guide (PAPPG)
https://www.nsf.gov/pubs/policydocs/pappg18_1/index.jsp

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8 LIST OF ACRONYMS

AC	Actual Cost
AD	Assistant Director
ADR	Accountable Directorate Representative
AICA	American Innovation and Competitiveness Act
AMBAP	Award Monitoring and Business Assistance Program
AWP	Annual Work Plan
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
CAP	Cost Analysis and Pre-Award
CATEX	Categorical Exclusion (NEPA)
CCB	Change Control Board
CCP	Change/Configuration Control Process
CDR	Conceptual Design Review
CEP	Cost Estimating Plan
CER	Compliance Evaluation Review
CFR	Code of Federal Regulations
CISO	Chief Information Security Officer
CO	Contracting Officer
CORF	Chief Officer for Research Facilities
CPI	Cost Performance Index
CPM	Critical Path Method
CSB	Cooperative Support Branch
CV	Cost Variance
DACS	Division of Acquisition and Cooperative Support
DD	Division Director
DGA	Division of Grants and Agreements
DIAS	Division of Institution and Award Support
DRB	Director's Review Board
EA	Environmental Assessment
EAC	Estimate at Completion
EHR	Education and Human Resources
EIS	Environmental Impact Statement
ES&H	Environmental Safety and Health
ETC	Estimate to Complete (for Cost)
EV	Earned Value
EVM	Earned Value Management
EVMS	Earned Value Management System

FAR	Federal Acquisition Regulations
FDR	Final Design Review
FFRDC	Federally Funded Research and Development Center
FGB	Facilities Governance Board
FRP	Facilities Readiness Panel
FY	Fiscal Year
GAO	Government Accountability Office
G/AO	Grants and Agreements Officer
GPRA	Government Performance and Results Act
GR&As	Ground Rules and Assumptions
HLFO	Head, Large Facilities Office
ICE	Independent Cost Estimate
IMP	Internal Management Plan
IMS	Integrated Master Schedule
IPT	Integrated Project Team
ISO	Information Security Officer
IT	Information Technology
LFO	Large Facilities Office
MFG	Major Facilities Guide
MFWG	Major Facilities Working Group
MOU	Memorandum of Understanding
MP	Management Plan (for mid-scale projects)
MREFC	Major Research Equipment and Facilities Construction
NCE	No-Cost Extension
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NICRA	Negotiated Indirect Cost Rate Agreement
NRC	National Research Council
NSB	National Science Board
NSF	National Science Foundation
O&M	Operations and Maintenance
OD	Office of the Director
OGC	Office of the General Counsel
OMB	Office of Management and Budget
PAM	Proposal and Award Manual
PAPPG	Proposal and Award Policies and Procedures Guide
PDR	Preliminary Design Review
PEP	Project Execution Plan
PI	Principal Investigator
PMB	Performance Measurement Baseline
PMBOK	Project Management Body of Knowledge
PMCS	Project Management Control System
PMI	Project Management Institute

PO	Program Officer
PTO	Paid Time Off
PV	Planned Value
R&D	Research and Development
R&RA	Research and Related Activities
RBS	Risk Breakdown Structure
RI	Research Infrastructure
RM	Risk Manager
RMP	Risk Management Plan
S&E	Science and Engineering
SOG	Standard Operating Guidance
SME	Subject Matter Expert
SPC	Statistical Process Control
SPI	Schedule Performance Index
SV	Schedule Variance
TPC	Total Project Cost
WBS	Work Breakdown Structure

9 LEXICON

9.1 LEXICON PREFACE

This Lexicon contains definitions of project and program management terms used in this Guide, as applied to NSF major facilities. It is a combination of specialized terms defined by NSF and used in the management of its major facilities, and terms and definitions commonly used in professional project and program management. A subset of common project management terms compatible with NSF usage were selected from a standard source, the *PMI Lexicon,*[1] for inclusion in this lexicon.

The Lexicon provides a common set of standard terms and definitions that should facilitate communication and understanding between stakeholders when used in documents and correspondence related to major facility management.

The terms and definitions included in this lexicon are in development and are subject to modifications in future versions.

[1] Entries in italics in this lexicon have been reproduced with permission from Project Management Institute, Inc., *[PMI Lexicon], (2012)* Copyright and all rights reserved.

9.2 TERMS AND DEFINITIONS

Acceptance Criteria. *A set of conditions that is required to be met before deliverables are accepted.*

Activity. *A distinct, scheduled portion of work performed during the course of a project.*

Actual Cost. *The realized cost incurred for the work performed on an activity during a specific time period.*

Allowance. Resources included in the basis of estimate for baseline cost estimates to cover the cost of known but as-of-yet undefined details or requirements for an individual WBS element. May be used when the level of project definition may not enable certain costs to be estimated definitively or times when it is simply not cost effective to quantify and cost every small item included with the WBS element, but reliable correlations are available.

Analogous Estimating. *A technique for estimating the duration or cost of an activity or a project, using historical data from a similar activity or project.*

Apportioned Effort. *An activity where effort is allotted proportionately across certain discrete efforts and not divisible into discrete efforts. (Note: Apportioned effort is one of three earned value management [EVM] types of activities used to measure work performance.)*

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 to.

Award Instrument. An agreement between NSF and a Recipient with the terms and conditions set forth in (cooperative agreements, contracts, etc.).

Backward Pass. *A critical path method technique for calculating the late start and late finish dates by working backward through the schedule model from the project end date.*

Baseline. The 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 Earned Value Measurement comparison, it is referred to as the Performance Measurement Baseline.

Baseline Definition. The description of the approved scope of work and resources for a construction project, including a hierarchical, product-oriented Work Breakdown Structure (WBS) and associated WBS dictionary; the cost and schedule Performance Measurement Baselines (PMB). Any contingency amounts, cost and time, are added to the baseline to establish the Recipient managed TPC.

Basis of Estimate. *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.*** *The sum of all budgets established for the work to be performed.* (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.)

Change Control. *A process whereby modifications to documents, deliverables, or baselines associated with the project are identified, documented, approved, or rejected.*

Change Control Board. *A formally chartered group responsible for reviewing, evaluating, approving, delaying, or rejecting changes to the project, and for recording and communicating such decisions.*

Change Control System. *A set of procedures that describes how modifications to the project deliverables and documentation are managed and controlled.*

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.

Code of Accounts. *A numbering system used to uniquely identify each component of the work breakdown structure.*

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, including parametric cost and schedule range estimates and a preliminary risk analysis.

Contingency. A planned amount of budget and time added to the baseline estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs. These events are often referred to as "known-unknowns" and are considered manageable by the Recipient. Budget and schedule contingency are typically estimated using statistical analysis and professional judgment based on experience. Budget contingency is called out separately as part of the Total Project Cost estimate and obligated to the project for the Recipient to manage based on need per NSF policy.

Contingency Report Table. A table containing a list of change control actions and allocations, with ties to associated WBS elements and identified risk events, for all Performance Measurement Baseline (PMB) changes that impact the use of contingency.

Constraint. *A limiting factor that affects the execution of a project, program, portfolio, or process.*

Construction Stage. The period of time 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 Recipient(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 management plan.

Cost Book. A compilation of Cost Book Sheets, typically used to present baseline or total project cost, 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 Estimating Plan. A plan to establish and communicate how the preparation, development, review and approval of the estimate will be completed.

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.*

Crashing. *A technique used to shorten the schedule duration for the least incremental cost by adding resources.*

Critical Chain Method. *A schedule method that allows the project team to place buffers on any project schedule path to account for limited resources and project uncertainties.*

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.

Data Date. *A point in time when the status of the project is recorded.*

Decision Tree Analysis. *A diagramming and calculation technique for evaluating the implications of a chain of multiple options in the presence of uncertainty.*

Decomposition. *A technique used for dividing and subdividing the project scope and project deliverables into smaller, more manageable parts.*

Defect Repair. *An intentional activity to modify a nonconforming product or product component.*

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 (Plan). See Scope Management Plan.

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 with regard to 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.

Discrete Effort. *An activity that can be planned and measured and that yields a specific output. (Note. Discrete effort is one of three earned value management [EVM] types of activities used to measure work performance.)*

Divestment Stage. The stage in the facility life cycle encompasses divestment of the facility starting after of the NSF Operations Stage ends and funding for divestment begins. Divestment 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), "moth-balling" 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.

Early Finish Date. *In the critical path method, the earliest possible point in time when the uncompleted portions of a schedule activity can finish based on the schedule network logic, the data date, and any schedule constraints.*

Early Start Date. *In the critical path method, the earliest possible point in time when the uncompleted portions of a schedule activity can start based on the schedule network logic, the data date, and any schedule constraints.*

Earned Value. *The measure of work performed expressed in terms of the budget authorized for that work.*

Earned Value Management. *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.*

eJacket. An electronic Web portal for NSF staff to perform essential business functions related to proposal and award processing and to access associated documents.

Enterprise Environmental Factors. *Conditions, not under the immediate control of the team, that influence, constrain, or direct the project, program, or portfolio.*

****Estimate at Completion.*** *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.*** *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.)

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.

Facility Life Cycle. The sequence of steps or stages that characterize the lifetime of a facility from beginning to end. For NSF**,** the stages are Development, Design, Construction, Operations, and Divestment.

FastLane. NSF online website through which we conduct our relationship to researchers and potential researchers, reviewers, and research administrators and their organizations. Other web portals used by Recipients to submit proposal and reporting actions include Grants.gov and Research.gov.

Fast Tracking. *A schedule compression technique in which activities or phases normally done in sequence are performed in parallel for at least a portion of their duration.*

Final Design Phase. The third and last phase of the Design Stage, after a successful Preliminary Design Phase, that further refines the project Baseline Definition and the Project Execution Plan 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.*

Forward Pass. *A critical path method technique for calculating the early start and early finish dates by working forward through the schedule model from the project start date or a given point in time.*

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.*

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.*

Independent Cost Estimate Review. As defined by Government Accountability Office (GAO), there are eight different types of reviews that may be used by NSF to help validate the Recipient's estimate. An Independent Cost Estimate (ICE) is one of the eight types.

Internal Management Plan. The internal document that defines NSF strategy for conducting project oversight and assurance, managing NSF risk, and providing project funding.

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. *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, and coverage of variances.

Logical Relationship. *A dependency between two activities or between an activity and a milestone.*

Major Facility. A facility for which the construction cost is more than a specified percentage of the sponsoring NSF organization's budget plan, or paid for out of MREFC funds. Construction costs for major facilities typically range between $70M and $800M.

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 estimate to address unforeseen events or uncertainties that are beyond the control of the Recipient 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 Recipient estimates per the Uniform Guidance.

Milestone. *A significant point or event in a project, program, or portfolio.*

Most Likely Duration. *An estimate of the most probable activity duration that takes into account all of the known variables that could affect performance.*

"No Cost Overrun" Policy. NSF policy requiring that a Total Project Cost estimate established at the Preliminary Design Stage have adequate contingency to cover all foreseeable risks. However, NSF conducts its oversight of projects against the Total Project Cost authorized by the NSB following Final Design Review (FDR).

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 Divestment Stage.

Opportunity. *A risk that would have a positive effect on one or more project objectives.*

Optimistic Duration. *An estimate of the shortest activity duration that takes into account all of the known variables that could affect performance.*

Organizational Breakdown Structure. *A hierarchical representation of the project organization, which illustrates the relationship between project activities and the organizational units that will perform those activities.*

Organizational Project Management Maturity. *The level of an organization's ability to deliver the desired strategic outcomes in a predictable, controllable, and reliable manner.*

Oversight. Watchful and responsible care of something or some activity; regulatory supervision.

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 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.)

Pessimistic Duration. *An estimate of the longest activity duration, which takes into account all of the known variables that could affect performance.*

Phase Gate. *A review at the end of a phase in which a decision is made to continue to the next phase, to continue with modification, or to end a project or program.*

Planned Value. *The authorized budget assigned to scheduled work.*

Portfolio. *Projects, programs, subportfolios, and operations managed as a group to achieve strategic objectives.*

Portfolio Management. *The centralized management of one or more portfolios to achieve strategic objectives.*

Precedence Diagramming Method. *A technique used for constructing a schedule model in which activities are represented by nodes and are graphically linked by one or more logical relationships to show the sequence in which the activities are to be performed.*

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, that 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.

Preventive Action. *An intentional activity that ensures the future performance of the project work is aligned with the project management plan.*

Probabilistic Risk Assessment. 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, in order 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.

Probability and Impact Matrix. *A grid for mapping the probability of each risk occurrence and its impact on project objectives if that risk occurs.*

Procurement Management Plan. *A component of the project or program management plan that describes how a team will acquire goods and services from outside of the performing organization.*

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.*

Progressive Elaboration. *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 Calendar. *A calendar that identifies working days and shifts that are available for scheduled activities.*

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* Execution *Plan.*** *The document that describes how the project will be executed, monitored, and controlled.*

Project Life Cycle. *The series of phases 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 Office. *A management structure that standardizes the project-related governance processes and facilitates the sharing of resources, methodologies, tools, and techniques.*

Project Manager. *The person assigned by the performing organization to lead the team that is responsible for achieving the project objectives.*

Project Phase. *A collection of logically related project activities that culminates in the completion of one or more deliverables.*

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 Scope Statement. *The description of the project scope, major deliverables, assumptions, and constraints.*

Quality Management Plan. *A component of the project or program management plan that describes how an organization's quality policies will be implemented.*

Re-Baselining. Project re-planning 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; or 3) project scope, except for approved options in the scope management plan. 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, total project duration, or overall scope objectives; or the implementation of approved de-scoping options. Formal change control processes are followed for all baseline changes. Retroactive changes to past performance should not be included in re-planning.

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 Infrastructure. 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 Calendar. *A calendar that identifies the working days and shifts upon which each specific resource is available.*

Resource Leveling. *A technique in which start and finish dates are adjusted based on resource constraints with the goal of balancing demand for resources with the available supply.*

Responsibility Assignment Matrix. *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 taken action 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 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 Management Plan. *A component of the project, program, or portfolio management plan that describes how risk management activities will be structured and performed.*

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.*

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.*

Schedule Compression. *A technique used to shorten the schedule duration without reducing the project scope.*

Schedule Management Plan. *A component of the project or program management plan that establishes the criteria and the activities for developing, monitoring, and controlling the schedule.*

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.*

Scope Baseline. *The approved version of a scope statement, work breakdown structure (WBS) and its associated WBS dictionary, which can be changed only through formal change control procedures and is used as a basis for comparison.*

Scope Contingency. Scope included in the project baseline definition that can be removed without affecting the overall project's objectives, but that may still have undesirable effects on facility performance. Identified scope contingency should have a value equal to at least 10% of the baseline budget.

Scope Management Plan. A component document of the Project Execution Plan that describes how scope contingency is determined, monitored, and controlled over the project lifetime.

Scope Creep. *The uncontrolled expansion to product or project scope without adjustments to time, cost, and resources.*

Scope Management Plan. *A component of the project or program management plan that describes how the scope will be defined, developed, monitored, controlled, and validated.*

S-Curve Analysis. *An earned value management technique used to indicate performance trends by using a graph that displays cumulative costs over a specific time 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.*

Staffing Management Plan. *A component of the human resource plan that describes when and how team members will be acquired and how long they will be needed.*

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 Recipient of an NSF for the purpose of carrying out a portion of a Federal award and creates a Federal assistance relationship with the Subrecipient. 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 Recipient considers a contract. All subawards require written prior NSF authorization.

Successor Activity. *A dependent activity that logically comes after another activity in a schedule.*

Summary Activity. *A group of related schedule activities aggregated and displayed as a single activity.*

Termination. The ending of a Federal award, in whole or in part at any time prior to the planned end of period of performance.

Threat. *A risk that would have a negative effect on one or more project objectives.*

Three-Point Estimate. *A technique used to estimate cost or duration by applying an average or weighted average of optimistic, pessimistic, and most likely estimates when there is uncertainty with the individual activity estimates.*

To-Complete Performance Index. *A measure of the cost performance that is required to be achieved with the remaining resources in order to meet a specified management goal, expressed as the ratio of the cost to finish the outstanding work to the remaining budget.*

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. 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.

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 Duration. The sum of the amount of time (in months) for the Performance Measurement Baseline schedule duration and the schedule contingency. The NSB authorized duration is the estimated project duration plus approximately 6 months.

Trigger Condition. *An event or situation that indicates that a risk is about to occur.*

Variance Analysis. *A technique for determining the cause and degree of difference between the Performance Measurement Baseline and actual performance.*

Variance at Completion. *A projection of the amount of budget deficit or surplus, expressed as the difference between the budget at completion and the estimate at completion.*

WBS Dictionary. *A document that provides detailed deliverable, activity, and scheduling information about each component in the work breakdown structure.*

What-If Scenario Analysis. *The process of evaluating scenarios in order to predict their effect on project objectives.*

Work Breakdown Structure. *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 Package. *The work defined at the lowest level of the work breakdown structure for which cost and duration can be estimated and managed.*

Workaround. *A response to a threat that has occurred, for which a prior response had not been planned or was not effective.*

10 APPENDICES

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* (http://www.nap.edu/books/0309090849/html/R1.html)[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?

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?

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 US 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 interagency commitments that should be met?

[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

- 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?