MPS AC Subcommittee on MPS Facilities and Major Research Infrastructure

Second Report, December 2023

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on
MPS Facilities and Major Research Infrastructure
December 2023

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I. Introduction

The National Science Board (NSB), in its Vision 2030 report, calls for the U.S. to remain a global leader in innovation by ensuring that America's researchers have access to "scientific facilities that will astonish the world - tools that let them see further, faster, and deeper." These facilities are central to the National Science Foundation (NSF) mission to *promote the progress of science*.

To this end, it is imperative that the NSF continue to play its remarkable key role in providing preeminent and foundational scientific facilities, thereby ensuring U.S. global leadership in scientific discovery and innovation, as well as the health of the research ecosystem and that of the U.S. economy.

Major research facilities serve a wide variety of essential scientific purposes. They enable the discoveries that are only possible using large-scale instruments, provide education and training of workforces, and support innovation for both the public and private sectors. They support collaboration and cooperation both within the U.S. and around the world, across stakeholders that range from universities and national laboratories, to philanthropic organizations and government agencies, as well as industries both new and established.

Facilities epitomize the important values that underlie science, such as wonder and discovery, impact, openness, broad access, teamwork, peer review, and partnership, all for mutual benefit. In short, facilities are essential to many scientific fields and provide unique capabilities that enable progress and breakthroughs in a broad range of research areas.

The challenge addressed in this report of the NSF Mathematics and Physical Sciences Advisory Committee (MPSAC) Subcommittee on MPS Facilities & Major Research Infrastructure is that of providing recommendations for NSF’s Directorate for Mathematical and Physical Sciences (MPS) to use in navigating and prioritizing the expanding landscape of facilities that will open new pathways for discovery across multiple disciplines. Decisions to construct and operate large research facilities should be based on fair and open evaluation processes and inclusion of the broadest community of stakeholders possible, and above all, enable discovery and understanding.

II. Summary of Findings and Recommendations

The NSF currently faces an unprecedented challenge in setting priorities and managing design, construction, and operations costs, given the magnitude and number of requests from the scientific community.

The complexity of MPS prioritization extends beyond the high demand for limited funds, and includes:

- ensuring the broad engagement and participation of all communities;
- balancing open access with the need to maintain national security and economic competitiveness;
- the processing of massive amounts of data, and incorporating new and evolving tools like machine learning and artificial intelligence.

Our Subcommittee reviewed previous reports, and engaged with numerous stakeholders including NSF leadership, the European Strategy Forum on Research Infrastructures, the White House Office of Science and Technology Policy, and leaders of existing major research infrastructure projects. These studies and discussions affirmed the importance of previous prioritization considerations, such as those in a National Academy of Sciences report in 2004 and a National Science Board report in 2005, but the Subcommittee also understood the call for new considerations to be added, to respond to societal changes and evolution of the research environment.

This Report offers a set of considerations to be used in prioritizing proposed and competing Major Research Equipment and Facilities Construction (MREFC) projects and should also allow ongoing evaluation of project proposals in the context of evolving conditions.

The recommendations for prioritization of major facilities in this Report fall into three categories:

- **Scientific and Technical Need and Impact**
- **Readiness to Proceed**
- **Alignment with Broader Missions**

While all three categories are essential, they are listed in a tiered ordering: after *Scientific and Technical Need and Impact* is established, the *Readiness to Proceed* is considered, followed by *Alignment with Broader Missions (*national and agency priorities, with consideration of broader impacts). Additionally, the relative weights of the items within each category may vary depending on changing conditions. For example, it will be important to consider the plans of other agencies and nations while assessing and prioritizing project ideas.

The Subcommittee has additional observations and suggestions that it believes are key to successful implementation of these prioritization recommendations. These include:

- Communicating NSF priorities in an open and public manner, ensuring community participation and endorsement of the prioritization process.
- Maintaining a portfolio of projects that are reviewed as a group, ensuring that project prioritization includes consideration and comparison among facilities competing for funding, and enabling a decision process that balances risk. This entails a reimagining of the existing prioritization processes and a *new vision for infrastructure*.
- Utilizing the process of prioritization within and across Divisions as well as at the Directorate.

Finally, project prioritization should take into account that MREFC is the unique budget source for large facilities funded by the NSF, such as those featured in the first interim report of the Subcommittee.

III. Charge to the Subcommittee

In May 2021, the NSF Mathematics and Physical Sciences Advisory Committee (MPSAC) established a Subcommittee on MPS Facilities & Major Research Infrastructure to create a report “to support the MPSAC responsibilities with respect to potential new facilities and provide strategic advice on issues, opportunities, and challenges posed by the MPS large and mid-scale research infrastructure portfolio.”

A First Interim Report was accepted by the MPSAC in March 2022 in which the Subcommittee articulated the importance of major and mid-scale facilities to NSF’s scientific leadership and MPS’s role.

This Second Interim Report is in response to a Charge that is detailed and put in context here. Specifically, the Subcommittee was asked to: “Provide to MPS a set of considerations for prioritization of major facility projects across the competing needs of the communities served by the Directorate that incorporate the financial and societal realities of the scientific enterprise in the 2020s and the current and future needs of

MPS communities, in order to ensure a vibrant infrastructure portfolio that delivers the scientific mission of MPS, specifically, and NSF, overall."

IV. Current Challenges

The NSF Directorate for Mathematical and Physical Sciences (MPS) is experiencing an increased community demand for support for new, large research facilities across multiple disciplines. This increase in proposals is accompanied by an increase in the costs for design, construction, operation, maintenance, and upgrading facilities. As a result, it is necessary to reconsider the methods MPS uses to prioritize responses to the scientific community's need for major research equipment and facilities.

Because there are many critically important scientific fields competing for limited total funding, MPS must find a way to balance resources across the many fields that require large-scale facilities. Several additional factors contribute to the complexity of MPS prioritization beyond the high demand for limited funds, including:

- ensuring the broad engagement and participation of all communities;
- balancing open access with the need to maintain national security and economic competitiveness;
- the processing of massive amounts of data and incorporating new and evolving tools like machine learning and artificial intelligence.

For major facilities in particular, MPS must also factor in rapidly escalating costs of design, construction, operation, decommissioning, as well as concerns about environmental impacts.

V. Current Guidance on Prioritization

To create a new framework for prioritization, our Subcommittee was guided by a wealth of previous work, including:

- The 2004 National Academy of Sciences (NAS) Report[1] (also referred to as the *Brinkman Report*) which set forth the criteria used by NSF in prioritizing large research projects.

[1] https://nap.nationalacademies.org/catalog/10895/setting-priorities-for-large-research-facility-projects-supported-by-the-national-science-foundation

- The 2005 National Science Board (NSB) Report[2] that interpreted and expanded upon the Brinkman report.

- The NSB Vision 2030 Report[3], released in 2020, provided guidance by identifying infrastructure as a key element of NSF's science and engineering (S&E) leadership role in the context of NSF's mission.

- NSF's Major Facilities Guide[4] laid out additional criteria and is currently in place at the agency level to determine eligibility for major facility construction funding.

Our Subcommittee reviewed and built on the criteria in these reports by identifying additional concepts that stakeholder communities have developed since those reports were published. The First Interim report of the MPSAC Subcommittee, found here[5], showcased the strengths of the existing MPS facilities, which have resulted in thousands of published papers, Nobel-prize-winning science, industrial innovation, and generations of trained scientists. It also articulated the critical importance of future facilities for the U.S. economy and U.S. scientific and technological leadership.

While other agencies, such as the Department of Energy (DOE), also have an exceptional record of building and supporting major facilities, the NSF model differs in key ways from the models used by these agencies. NSF is traditionally responsive to proposals coming from the community, including both individuals and teams of investigators, often at universities. This commitment to responsiveness is one factor in the scale and scope of the demand and the challenges that NSF now faces in developing the facilities of the future. In contrast, the DOE relies heavily on its network of established national laboratories with core infrastructure that builds and supports facilities as part of its mission. Though the DOE and NSF both seek community input in selecting projects, differences in the agency's missions mean that there will be differences in the methods they use to identify, prioritize, and execute major research facilities.

NSF's evaluation of and response to proposals have always required review and prioritization processes that are merit-based and transparent. Application of these processes has been very effective in prioritizing projects within specific scientific disciplines. However, for evaluation of large facility projects across multiple disciplines,

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[2] https://www.nsf.gov/pubs/2005/nsb0577/nsb0577.pdf
[3] https://www.nsf.gov/nsb/publications/2020/nsb202015.pdf
[4] https://www.nsf.gov/pubs/2019/nsf19068/nsf19068.pdf
[5]
https://www.nsf.gov/mps/advisory/mpsac_subcommittee_reports/MPS_Facilities_and_Major_Research_Infrastructure_Report_1.pdf

additional considerations of the criteria used to evaluate and compare proposals are required.

The 2004 NAS Report recommended that NSF produce a “roadmap” and “rankings” of proposed projects. In response to this recommendation, the NSB noted that NSF would develop a “facility plan” that would be updated annually by the Director. Benefits of a ranked project list include: (1) clear communication of agency plans to the scientific community, so stakeholders can fully and productively engage in approved projects, (2) signaling to all potential funders the importance of projects that went through a deliberative process, and have the support of the agency, and (3) promotion of goals associated with transparent decision processes. However, the Subcommittee suggests that an actively managed portfolio of potential projects rather than a rigid, ranked roadmap would allow for clear and balanced responses to needs and opportunities.

- *The U.S. must invest in infrastructure, including data, software, computation, and networking capabilities, across all S&E disciplines.*

- *To catalyze regional scientific and innovation networks, America must strategically build S&E infrastructure and capacity in the nation’s underserved areas and institutions, while retaining excellence and capacity where it already exists.*

- *For the most complex and costly facilities, for which only one or two of a kind are needed worldwide, the U.S. must cooperate with other countries, such that U.S. researchers can participate fully, help set the agenda, and share equitably in the results.*

The NSB Vision 2030 Report identified *three infrastructure imperatives* for the future: These imperatives are currently addressed through a variety of funding mechanisms available at NSF, many of which are division-level mechanisms such as center or institute programs.

These other mechanisms within NSF should be used whenever possible and appropriate, since MREFC projects are managed according to strict project management protocols and NSF oversight, adding significantly to cost and staffing burdens. With respect to MREFC funding, project prioritization should include consideration of whether the MREFC budget is the most appropriate funding mechanism. Importantly, project prioritization should take into account that MREFC is the unique budget source for large facilities, such as those featured in the Subcommittee's First Interim Report.

This Report offers considerations that may be used in prioritizing competing MREFC projects, and should also allow ongoing evaluation of project proposals in the context of evolving conditions.

VI. Current Processes for Evaluation and Prioritization of Research Facilities

The 2004 NAS Report considered funding in the MREFC budget line; it noted then-currently-used criteria to prioritize large facility projects (found in Appendix I of this report). Briefly, those criteria included: the impact of the facility on the field; the opinion of the scientific community on the importance of the project; the accessibility of the facility; partnership possibilities; feasibility and risk; and readiness to proceed. After these considerations were addressed, the project was then further ranked on how transformative the project is; how broadly the project will benefit the scientific community; and how timely or pressing the need for the facility is.

The report presented these criteria as (i) a set of overlapping scientific and technical, agency strategic, and national criteria, (ii) with roles for the community, the Foundation, and the NSB, and (iii) a process for approval and execution. The operative approval process the Report outlined included: *Advisory structure/Origin of projects; Strategic planning; Project evaluation criteria; Community involvement;* and *Prioritization process.*

The 2005 NSB Report built on and expanded the findings of the 2004 NAS Report. It served as a guide to developing a facility plan and the processes for selecting MREFC projects. The 2005 NSB Report used criteria for developing a large facility roadmap from the 2004 NAS Report and presented criteria for NSB approval and prioritization of large facility projects and developing a large facility roadmap in its Appendix ii: Criteria for developing large facilities roadmaps and budgets (found in Appendix II of this report).

The criteria outlined include: *scientific and technical criteria*, including scientific merit, technological readiness, and the credentials and project-management skills of the proposers; *agency strategic criteria*, including impact on scientific advancement, broadest range of research needs served, major commitments from other agencies/countries, potential for workforce development, and readiness to proceed; and *national criteria*, including transformative projects in new and emerging fields; likelihood to maintain U.S. leadership in science and engineering; greatest benefit to researchers, educators, and students; and window of opportunity.

In addition to establishing well-defined criteria, the 2005 NSB Report called for maximizing the opportunity for community input and documenting the final prioritization, including those processes that were discussed with the community of interest.

VII. Current Policies for Development of Major Facilities

NSF has developed the Research Infrastructure Guide[6] (RIG) to document the policies and processes applicable to Major Facilities. The RIG defines the path projects currently must follow as they move from development into design, and from design into construction.

This path is as follows: once the concept for a new Major Facility has been developed and recognized as a priority for the responsible Division and Directorate, the sponsoring Directorate must request approval from the NSF Director to formally enter the Design Stage. The Design Stage at NSF has three standard phases (shown in Fig. 1 below). Only after a project has passed the Final Design Review is the decision made whether or not to advance the project into Construction. Once the Director has approved the decision to take this step, the project becomes eligible for construction funding and a request for the necessary funds is entered into the budget.

As indicated in Figure 1, prioritization is relevant throughout the process. It continues as projects advance through the Design Stage, both at the Directorate level (as the projects are better defined and community needs are better understood) as well as at the Agency level (as projects from different Directorates advance and the necessary funding is added to budget requests).

[6] https://www.nsf.gov/pubs/2021/nsf21107/nsf21107.pdf

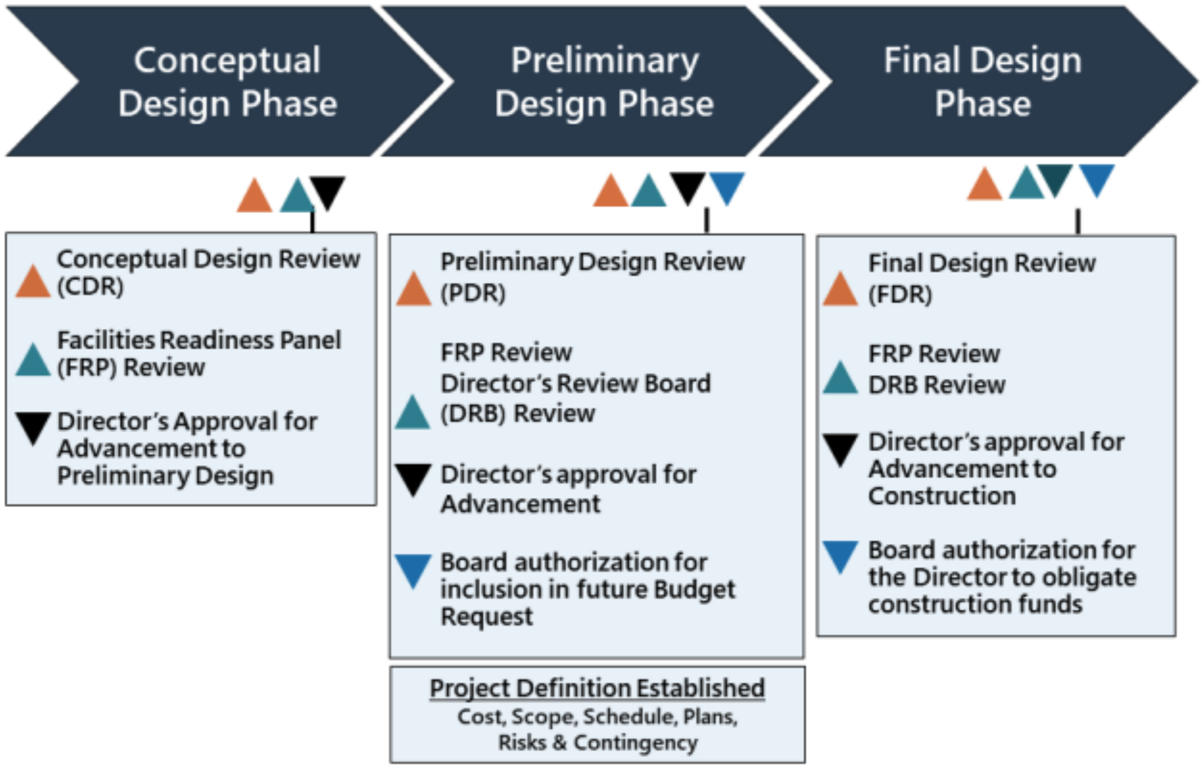

Figure 1: The reviews and approvals required as a Major Facilities project moves through the Design Stage at NSF[7].

In addition to the processes outlined by the RIG, MPS must also consider the influence and concerns of key stakeholders beyond the scientific communities that are promoting these facilities. Within NSF, the Office of the Director holds the final approval authority (pending authorization by the NSB) and *applies its own prioritization.* The NSB weighs in with its views and exercises its role through its power to authorize the Director to make the large investments involved in MREFC-funded projects. Beyond the bounds of the NSF, OMB closely guides and monitors NSF's budget preparation. Congress has the final determination through its appropriations of funding for the MREFC account. Each of these stakeholders may have very different perspectives on the importance of a project, and it will be important to understand those perspectives and take them into account in developing the MPS strategy for moving projects forward.

Additionally, it is important to understand that in the NSF budgeting model, while the capital costs of construction are funded from the MREFC account (appropriated by Congress), the costs of developing a project concept and a detailed design of the

[7] https://www.nsf.gov/pubs/2021/nsf21107/nsf21107.pdf

project (both pre-construction), as well as the operations of the facility after construction, all must be funded through Division and Directorate budgets. These investments by the Division and Directorates could represent a significant fraction of their overall budget, underscoring the need for a new strategic approach to handling these various phases of major facility costs.

VIII. What Has Changed in Two Decades Since the NAS and NSB Reports

The first interim Subcommittee Report made the case that leading-edge research instruments and facilities are essential components in, and drivers of, the *science and technology that will define our future and power our economy*. While scientific excellence is still the most important consideration in the prioritization of large facility projects, additional considerations have evolved and become more relevant since the Brinkman and NSB reports. These include:

1) Role of partnerships

e.g., the leadership facility in particle accelerators is in Europe, at CERN; U.S. agencies acknowledge the need to plan and act with international partners; and early technical developments to reduce risk for telescope projects are often supported by philanthropy; partnerships include international entities, other agencies, and philanthropic organizations.

2) Societal considerations

e.g., greater focus on workforce development, inclusion of the broadest spectrum of participants and institutions, sensitivity to the importance of international allies and competitors, and impacts of projects on communities.

3) Divisional responsibility for ongoing funding

e.g., operations, upgrades, and renewal following facility construction, and potential decommissioning.

4) Evolution of metrics

e.g., translation of fundamental science to commercialization for economic impacts and societal needs.

5) Contributions of discipline-specific facilities to broader fields

e.g., synchrotron beam lines, and telescopes for multi-messenger astronomy.

6) Focus on sustainability

e.g., environmental impacts, including energy consumption.

7) The scale of large facility requests
e.g., numbers of proposals and costs of individual projects, potential impact on Division and Directorate budgets for design and operational costs.

IX. Recommended Considerations for Evaluation of Major Research Facilities:

Our considerations fall into three categories, detailed below. While all three categories are essential, they are listed in the following tiered ordering: after **Scientific and Technical Need and Impact** is established, the **Readiness to Proceed** is considered**,** followed by **Alignment with Broader Missions** and consideration of broader impacts. Evaluation metrics and guidelines for their evaluation are given below.

1) Scientific and Technological Need and Impact

NSF's mission is "*to address the most compelling scientific questions, educate the future advanced high-tech workforce, and promote discoveries to meet the needs of the Nation.*" Investments in both current and cutting-edge future facilities will ensure that the U.S. maintains leadership in critical research activities, and has the ability to partner in advanced infrastructure wherever that may be located. As the leading category, scientific and technological need and impact can be measured by evaluation of:

- Broad community support and endorsement, demonstrated by studies and in reports. These include, for example:
    - Reports commissioned by Federal entities and led by independent groups, e.g., Federal Advisory Committees; National Academies of Science, Engineering, and Medicine; independent science advisory group JASON;
    - Reports commissioned by Federal entities and led by the scientific community, e.g., Basic Research Needs Workshops of the Department of Energy Office of Science;
    - Reports, generally on the decadal scale, resulting from large-scale, open, community planning processes, e.g., the Snowmass Process in particle physics;
    - Reports from professional societies or workshops and conferences.

- Potential for innovation and major science and technology discoveries or advancements. For example, such facilities have enabled: 1960s – observation of neutrino oscillations and the observation of the cosmic microwave background; 1982 – discovery of the fractional quantum Hall effect at the National Magnet Lab; 2009 – the first demonstration of hard x-ray Free Electron Lasers; 2012 – discovery of the Higgs boson; and 2016 – observation of gravitational waves. The potential for innovation may also impact a broad range of scientific areas.

- Importance and uniqueness of NSF as a funder. Importance may be measured in terms of a facility opening a new field of science, ensuring future U.S. leadership in a critical scientific field, significantly extending or broadening the capabilities of predecessor facilities, or leveraging a partnership opportunity. A high threshold for approval as the sole funder should be applied if there is another agency or institution whose mission could include funding for that facility, or if there are facilities existing or planned in the U.S. (or in other countries that offer access to U.S. investigators).

- Timeliness, and opportunity costs associated with not moving forward. The costs associated with not moving forward with, or postponing, a proposed facility could include: loss to the scientific enterprise nationally or globally; loss of economic and technological impact; reduced global competitiveness; increased national security risks; and other societal consequences, including training a highly skilled workforce.

- Uniqueness of capabilities. The special attributes of existing, as well as competing, facilities should be considered. Some facilities provide a critical capability, yet have a smaller user base. Some facilities might be duplicative of capabilities outside the U.S. Further, the decommissioning of existing facilities, and any consequent gaps or needs created, could be a factor in this consideration.

- Clear indications of potential use. Consideration may be given to a specific facility that has a narrower user base, but uniquely addresses key scientific goals or national interests. Evaluation requires the development of relevant metrics regarding use and impact.

2) Readiness to Proceed

"Readiness to proceed" applies to each stage of a project; it should be consistent with the Research Infrastructure Guide, and not be taken to mean readiness to proceed to full project execution. For example, there may be a unique window of opportunity for a project - such as when a scientific opportunity is uncovered, or domestic and international partnerships are developed. This could create an additional scientific opportunity that may not have been included in longer term budgetary planning, and may require special consideration of timelines. The maturity level of a project, as well as the opportunity created by partnership, can be evaluated through the following set of criteria:

- Existence of a well-defined plan. This includes plans for technology demonstration, construction, operation, and potential decommissioning, and appropriate project oversight. Agency projects have well-defined stages and detailed requirements for advancing through the stages (e.g., R&D, Conceptual Design Report [CDR] development, Execution, D&D, etc.). A clear understanding of lifecycle costs and how each stage is funded, displayed in the budget, and communicated to stakeholders, is needed.

- The advantage and value of a potential partnership could be considered at every stage of a project, from its inception throughout the design phase. This includes the potential to reduce risk, the external validation of the scientific and technological need, and the construction cost considerations.

As the agency proceeds to a commitment to construction, considerations for decision makers at this important juncture should include the following:

- Satisfaction of the requirements of the Agency's project management office. This includes, for example, establishment of a cost and schedule baseline, completion of a technical readiness assessment including a technical maturation plan for both hardware and software, a National Environmental Policy Act (NEPA) determination as necessary, sustainability requirements, etc.

- Feasibility of the project cost and schedule baseline within the Agency's overall budget. While an essential project may be deferred or the schedule stretched to meet feasibility requirements, this may lead to cost increases.

- Partnerships. Any potential partnering funding sources, and their readiness, should be identified for each stage of a project. These partnerships should be established with formal documentation specifying roles, responsibilities, and deliverables of each partner. Mechanisms should be in place to track partner performance and to timely address issues that may arise.

- Siting and environmental issues. A plan to investigate and determine appropriate siting of the project is needed.

Agency decision-makers at the appropriate level for each decision approve a project's advancement through these stages, usually in consultation with program staff and project-management staff.

3) Alignment with Broader Missions

Alignment with broader missions involves multiple considerations, from those that have been foundational within science agencies from their beginning, to the federal government goals and national priorities of the present day. Expanded and broader missions have evolved since the creation of the post-WWII S&T agencies, and in particular since the release of the 2005 NSB Report. They address multiple factors that may impact national competitiveness and leadership. This suggests that the following considerations be used in evaluating broader missions:

- Foundational goals of science and technology funding agencies. These long-term and well-established goals include: ensuring that the U.S. leads in exploring the frontiers of science and technology; maintaining and increasing national competitiveness; and training the next generation of science and technology leaders for the nation.

- Alignment with current government goals. These include Executive Branch (Agency & Administration) and Legislative Branch (Congressional) directions and goals.

- Broader societal impacts. These include a variety of issues, which may resonate in part or in whole with current government goals, such as competitiveness and leadership in the international sphere, national security, economic security, environmental impact, energy independence, global change, open access, DEI (diversity, equity, and inclusion), S&T workforce development and expansion, democratization of participation and geographic distribution of resources, and the potential for public inspiration, appreciation, and engagement.

X. Implementation and Transparency

Looking ahead, it will be essential for NSF to effectively communicate its priorities in a transparent and public manner, with structured, two-way communication between the research community and NSF. Success in building and operating major facilities will not rely solely on the agency's investments. It will also depend on the cooperation and willingness of the research community to engage with NSF regarding infrastructure needs and to work across disciplinary boundaries. Additionally, especially at the preliminary phase of idea generation, it is recommended to consider the plans of other agencies and nations while assessing and prioritizing project ideas. Funding to support idea generation within the agency's disciplines - including conceptual development, planning, engineering, and design - was highlighted in the 2004 NAS Report. Such funding can be considered to go hand-in-hand with, and enables, effective communication among stakeholders within the research community.

Although review of the internal NSF process for selecting, developing, and operating facilities is not explicitly mentioned in the Charge to the Subcommittee, effective implementation of any such process should include transparency at each stage of the decision process. Considerations of transparency become increasingly important with the increase in the number of facilities competing for limited resources.

Therefore, the Subcommittee suggests:

- **MPS maintain a portfolio of projects that are reviewed as a group.** This will ensure that project prioritization includes consideration of and comparison among competing facilities and needs across fields and is updated to reflect changing conditions. In light of the increasing number and magnitude of requests, there is an unprecedented need to organize the current ensemble of existing and potential projects into a managed portfolio. A decision process that involves a portfolio of facilities will enable MPS to balance risk: the cost of large facilities makes it challenging to consider investing in a high-risk facility when viewed on its own and not balanced by other, less risky projects. The portfolio approach also offers MPS an opportunity to balance the needs of disciplines, compare technical readiness, eliminate redundancies, and identify and address gaps. Adopting this suggestion requires a significant modification of the existing process at NSF and a new vision for infrastructure.

- **Prioritization should occur within Divisions and across Divisions as well as at the Directorate.** This will minimize the investment of resources and time on projects that are not likely to survive the full process. The Division directors will be best positioned to communicate the potential loss to the scientific community should a project not be selected. We note that facilities that serve multiple disciplines are particularly important; the Directorate should ensure that these receive appropriate consideration.

- **All three of the tiered prioritization categories are essential.** However, the relative weights of the items within each category may vary depending on changing conditions. Moreover, it may not be necessary to meet the criteria of every one of the items. The NSF should develop and communicate its weighting of the various considerations used to establish prioritization.

- **To ensure community participation and endorsement, all stages of the process should be open and transparent.** A successful process to develop new facilities should include broad input, an understanding of community consensus, a transparent narrowing and prioritization process, and a final decision made by NSF leadership. We acknowledge that, ultimately, decisions will rest with single individuals, but the steps, ingredients, and justifications leading to those decisions must be readily understood.

XI. Conclusion

A dramatic increase in the number of proposals for large research facilities, and their associated increased costs, has presented a challenge for allocating limited NSF's MREFC funds. This challenge is also a sign of the importance and health of the nation's scientific enterprise, which offers so many promising opportunities for investigation and discovery. It requires a new look at the criteria used for prioritizing projects. Through its funding of facilities, NSF is in the unique position of being able to prioritize among a wealth of options to determine which projects will deliver the greatest benefits. The considerations suggested in this Report, informed by previous work and advice from current stakeholders, aims to help guide the direction of scientific research, technology development, and innovation enabled by NSF-MPS facilities for decades to come.

Appendix I

Excerpt from the National Academy of Sciences 2004 Report, *Setting Priorities for Large Research Facility Projects Supported by the National Science Foundation*

On receipt by NSF, large facility proposals are first subjected to rigorous external peer review that focuses on the criteria of intellectual merit and broad (probable) impacts. Only the highest rated proposals—those rated outstanding on both criteria—survive this process. These are recommended for further review by an MREFC panel that comprises the NSF assistant directors and office heads, who serve as stewards for their fields and are chosen for their breadth of understanding, and is chaired by the NSF deputy director acting in consultation with the director and later for review by the NSB.

Both the MREFC panel and the NSB look for a consistent set of attributes in each project that they recommend:

- The project represents an exceptional opportunity to enable frontier research and education.
- The impact on a particular field of research is expected to be transformational.
- The relevant research community places a high priority on the project.
- The resulting facility will be accessible to an appropriately broad user community.
- Partnership possibilities for development and operation are fully exploited.
- The project is technically feasible, and potential risks are thoroughly addressed.
- There is a high state of readiness—with respect to engineering cost effectiveness, interagency and international partnerships, and management—to proceed with development.

The MREFC review panel evaluates the merit of a proposed project and then ranks it against other projects under consideration. It first selects the new projects that it will recommend to the director for future NSF support on the basis of a discussion of the merits of the science in the context of all sciences that NSF supports. Projects that are not highly rated according to the above criteria are returned to the initiating directorates and may be reconsidered later. Highly rated projects are placed in priority order by the panel in consultation with the NSF director. The review panel and the director emphasize the following criteria to determine the priority order of the projects:

- How “transformative” is the project? Will it change how research is conducted or alter fundamental science and engineering concepts or research frontiers?
- How great are the benefits of the project? How many researchers, educators, and students will it enable? Does it broadly serve many disciplines?

- How pressing is the need? Is there a window of opportunity? Are there interagency and international commitments that must be met?

Those criteria are not assigned relative weights, because each project has its own unique attributes and circumstances. For example, timeliness may be crucial for one project and relatively unimportant for another. And the director must weigh the impact of a proposed facility on the balance between scientific fields, the importance of the project with respect to national priorities, and possible societal benefits."

Appendix II

Excerpt from the 2005 National Science Board Report, *Setting Priorities for Large Research Facility Projects Supported by the National Science Foundation, Appendix ii: Criteria for Developing Large Facilities Roadmaps and Budgets*

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 by Using the Advice of Directorate Advisory Committees

- 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 by the National Science Board

- 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 must be met?”

● Which projects will have the greatest impact on current national priorities and needs?

● 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?

Excerpt from the 2005 National Science Board Report, *Setting Priorities for Large Research Facility Projects Supported by the National Science Foundation, Appendix iii: National Science Board Criteria for Approving and Prioritizing Large Facility Projects (LFPs)**

The Board will utilize the following criteria as part of its consideration to provide Board approval to each LFP:

● scientific and technical assessment within field or interdisciplinary area,

● community and advisory committee support,

● address reviews,

● potential to be transformative,

● essential for U.S. leadership in S&E,

● greatest leverage of researchers, educators and students enabled,

● time sensitive window of opportunity and commitments,

● impact national priorities and needs (include social),

- impact across fields and NSF,
- and balanced portfolio.

*Not all criteria will be appropriate for every project under consideration, and additional criteria may be appropriate for some projects.