Introduction/Background

The MPS AC Subcommittee on MPS Facilities & Major Research Infrastructure ("subcommittee") supports the MPS AC in providing strategic advice to MPS on opportunities and challenges posed by the research infrastructure portfolio. The subcommittee is charged with the preparation of a strategic report over five years that will provide advice to guide the next decade of infrastructure investments. Several interim reports will be requested during this period to dive into specific topics or proposed facilities, all of which will inform the final report.

In March 2021, the subcommittee was charged with producing an initial report articulating the importance of major research infrastructure both to MPS' scientific leadership and to MPS' ability to enable the current and future cutting-edge science of the Directorate. In its first report, the subcommittee noted to the MPS AC that research infrastructure, from mid- to large-scale, was **essential** to sustain U.S. leadership in the mathematical and physical sciences, while also identifying several challenges to efforts to maintain that leadership.

Among those challenges was the need for clear guidelines to help MPS prioritize which major facility projects to pursue. This particular challenge is the subject of this addendum to the original charge, which outlines a request for the subcommittee's second study.

MPSAC Subcommittee on MPS Facilities & Major Research Infrastructure

Charge Addendum #2: MPS Prioritization Considerations

(Version 03.18.2022)

Background/Context for this Addendum

There is strong demand for MPS to support an increasing number of infrastructure projects at all scales, each of which may be considered mission-critical for different communities and types of science. As previously identified by the subcommittee, MPS is thus faced with the formidable challenge of prioritizing these diverse projects.

Looking forward to the next decade of infrastructure investments, we recognize the need for a strategic framework for prioritization that will fully satisfy the criteria established by the National Science Board (See Setting Priorities for Large Research Facilities Projects Supported by NSF in Appendix II) while at the same time be applicable to the current circumstances of research and broader impacts across the MPS disciplines. This framework must allow the Directorate to evaluate community recommendations in the context of opportunity costs for future major research infrastructure projects, and strategic priorities, as well as scientific and societal needs at multiple scales (i.e., mid-scale and large projects).

Interim Report Request/Charge #2:
MPS Large Infrastructure Prioritization Considerations

Given how critical large research infrastructure is for MPS leadership, the imperative to deliver tangible benefits to society, and the established criteria for ranking research infrastructure initiatives provided in the National Academies' 2004 report, the subcommittee is asked to produce an interim report that addresses the following charge:

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.

In developing its response, the subcommittee should consider the following contexts as a starting point:

- **Multi-level strategic considerations**: MPS' prioritization framework must be responsive to the multifaceted landscape of strategic priorities in which MPS is situated, including both agency-wide and federal priorities, individual and multiple

scientific communities' priorities, and those motivated by broader societal benefits, along with both long-term (decade timescale) priorities and shorter-term (1-5 year timescale) priorities that may present time-sensitive opportunities.

- **Partnerships and discipline context:** Given the large investments involved, MPS must incorporate the national and international context of potential facilities into account, exploring how such investments can best the fields forward with potential inter-agency and international partnerships and how they may complement current or planned facilities elsewhere.
- **Current investments and future opportunities**: Given that construction projects often represent major investment commitments over five to ten years, when considering investing in the construction/implementation of an infrastructure project, MPS must weigh the opportunity costs of starting and then supporting large projects now with respect to potential future projects on the longer-term horizon.
- **Societal realities**: Scientific investments today are expected to incorporate a broader range of societal impacts than ever before; MPS must take a more holistic view of broader impacts in evaluating the large investments required for new generations of major research infrastructure, including diversity, equity, inclusion, and cultural aspects/impacts, as well as technology translation and environmental, climate, and geopolitical issues.
- **Balance of risk and reward**: Given the diversity of MPS facilities and infrastructure in access models (multi-user facilities or large collaborations), risk profiles, breadth of scientific case, multidisciplinary impacts, etc., MPS must apply these prioritization principles and considerations in a manner that is both internally consistent and adaptable to this diversity.

This request is focused on the prioritization of aspirational new Major Facilities projects (defined as those in which construction is estimated to cost more than $100M). Future O&M costs should be considered in the subcommittee's deliberations. A similar discussion of prioritization considerations for midscale projects will be undertaken in a future report, specifically in the context of both the NSF-wide Mid-Scale Research Infrastructure programs and the Division-level programs.

While resource constraints do serve to motivate this request, the subcommittee should treat the associated concerns of rising operations and maintenance costs of existing facilities, as well as the balance of infrastructure investments and grants, as beyond the scope of this interim study; these issues will be also the subject of later requests.

The subcommittee is expected to produce a report communicating its findings and recommendations for presentation of an interim draft by October 1, 2022, in order to brief the MPS AC at its November 2022 meeting, and submission a final report to the MPS AC no later than February 1, 2023.

APPENDIX I

To provide context for this report, the subcommittee should consider the following frameworks and guidance for prioritization and strategic decision-making:

- In 2004, the National Academy of Sciences issued a report[1] regarding NSF's process for identifying, approving, constructing, and managing large research facility projects. The report included several recommendations for actions by NSF, including a set of criteria for the evaluation and selection of large projects for construction at the division, directorate, and agency levels (See Appendix I on pp. 5-6 of this document for summarized criteria).
- In 2020, the National Science Board (NSB), in its Vision 2030 Report,[2] identified Infrastructure as one of four elements of Science and Engineering (S&E) leadership and laid out a four-pronged strategy to ensure U.S. innovation leadership: Deliver Benefits from research, Develop STEM talent for America, Expand the geography of innovation, and Foster a global S&E community. This report will guide NSF's strategic planning for the coming decade.
- NSF's Major Facilities Guide lays out the criteria that are currently in place at the agency level to determine eligibility for major facility construction funding.[3]

[1] https://www.nap.edu/catalog/10895/setting-priorities-for-large-research-facility-projects-supported-by-the-national-science-foundation.
[2] https://www.nsf.gov/nsb/publications/2020/nsb202015.pdf.
[3] https://www.nsf.gov/pubs/2019/nsf19068/nsf19068.pdf, Sec. 2.1.2 (p. 26).

APPENDIX II

The following criteria have been excerpted from the National Academies' 2004 report, *Setting Priorities for Large Facility Projects supported by the National Science Foundation.* These criteria may serve as a guideline for the work of this Subcommittee.

Criteria for Developing Large Facilities Roadmaps and Budgets

Overlapping categories of criteria should guide the preparation of the large facilities roadmap and NSF's annual budget submissions. Scientific and technical quality must be at the core of these criteria. Because these are large facility projects, they must have the potential to have a major impact on the science involved; otherwise, they should not reach the next step.

The rankings show what we would expect to happen first within a field, then within a directorate of NSF, and then across NSF. The criteria from earlier stages must continue to be used as the ranking proceeds from one stage to the next.

- **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 inter- national 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?

Ranking projects across disciplines is inherently not an exact science; nevertheless, these criteria, as illustrated by the questions, provide a framework for a discussion of why one project is accorded a higher priority than another and a mechanism for the discussion to be as objective as possible in ranking projects across fields.

Within the ranking categories, the questions might change as governmentwide initiatives and unexpected occurrences shift priorities. Similarly, at times, some questions might have greater weight than others in the judgment of the NSB. The key element is for the questions and weighting to be identified before the ranking process begins and for a clear rationalization to be provided when proposed large research facility projects are ranked.