# LARGE FACILITIES MANUAL


## September 2009

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# I. Introduction

Facilities are an essential part of the science and engineering enterprise, and supporting them is one major responsibility of the National Science Foundation (NSF).

Facilities may be centralized or may consist of distributed 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, awards have been made for such diverse projects as accelerators, telescopes, vessels, aircraft and geographically distributed but networked earthquake engineering simulation equipment.

NSF makes awards to external entities – primarily universities, consortia of universities or non-profit organizations – to undertake construction, management and operation of facilities. Such awards frequently take the form of cooperative agreements.[1] With the sole exception of NSF's facilities in Antarctica, for which the Foundation acquires construction, operating, and maintenance services, NSF does not directly construct or operate the facilities it supports. However, NSF retains responsibility for overseeing their development, management and successful performance, and this Manual is intended to:

- Provide step-by-step guidance for NSF staff and awardees to carry out effective project planning, management and oversight of large facilities, recognizing that different kinds of projects may require different approaches;
- Clearly state the policies, requirements and recommended procedures pertinent at each stage of a facility's life cycle – from conception to construction/acquisition, operations, renewal and/or phase-out and termination; and
- Document the best practices identified over many years so that NSF program officials can ensure accountability and carry out their responsibilities more effectively.

Various provisions of this Manual apply to the following kinds of projects:

- Large facilities that have been or will be constructed or acquired with funds from the Major Research Equipment and Facility Construction (MREFC) Account;
- Facilities or infrastructure projects that have been or will be constructed or acquired with funds provided through the Research and Related Activities (R&RA) and/or Education and Human Resources (EHR) Accounts and that require National Science Board (NSB) approval;
- Existing facilities for which operation and replacement cost would be similar in size to MREFC-funded and MREFC-eligible projects.

[1] See NSF Grant Proposal Guide at http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpg, and NSF Grant Policy Manual at http://www.nsf.gov/pubs/manuals/gpm05_131/index.jsp for detailed information on awards. NSF staff should also be familiar with the Proposal and Award Manual.

NSF supports facility construction from two appropriations accounts: the MREFC Account and the R&RA Account.[2] The MREFC Account was created in 1995 to fund the acquisition, construction, commissioning, and upgrading of major science and engineering infrastructure projects. Generally MREFC projects range in cost from tens of millions to hundreds of millions of dollars expended over a multi-year period. The R&RA account can be used to support other activities involving an MREFC-funded facility that the MREFC Account cannot support, including planning, conceptual design, development, 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.

This Manual replaces the *Facilities Management and Oversight Guide* (Guide), published in 2003, and reflects recent changes to requirements and recommended procedures by which MREFC candidate projects are identified, developed, prioritized and selected.[3] The principles motivating these changes also apply to smaller-scale facilities funded through the R&RA Account. Procedures should be modified appropriately to fit the needs of each facility.

The Manual does not replace existing formal procedures required for all NSF awards, which are described in the *Grant Proposal Guide* and *Grant Policy Manual*. 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 and approvals. But the level of approval varies substantially, as does the level of oversight needed to ensure appropriate proper accountability for federal funds. The requirements, recommended procedures and best practices presented here 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 of the Originating Organization(s)[4]. For all other facilities, NSF staff members should use their judgment in proportionately scaling the requirements and recommended procedures for specific projects.

This Manual will be updated periodically to reflect changes in requirements and/or policies. Program Officers (PO) are encouraged and expected to continue to identify and adopt best practices aimed at improving management and oversight of large facilities projects and at enabling the most efficient and cost-effective delivery of tools to the research and education communities.

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[2] Funding for facility or large scale infrastructure construction/acquisition could come from the Education and Human Resources (EHR) Account. There are no current or pending requests. Nevertheless, EHR often works in partnership with the various NSF Science and Engineering Directorates and Offices to leverage their investments in infrastructure development and research activities to support education and promote access to science and engineering facilities for educational purposes.

[3] 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 http://www.nsf.gov/pubs/2005/nsb0577/index.jsp.

[4] See Appendix 1 for definition of this and other key terms. Appendix 1 describes the NSF organizations and officers that are involved throughout the conception, development, approval and implementation of an MREFC project. Readers not familiar with NSF and its processes should review this material before proceeding.

## USING THIS DOCUMENT

The Manual is organized as follows:

- Chapter II describes the process and principles NSF uses to plan, construct and operate large facilities funded using the MREFC Account. An earlier version of this chapter was released as a stand-alone document in November 2005.
- Chapter III applies the basic principles and process described in Chapter II to the (usually smaller scale) facilities constructed or acquired with funding from the R&RA account, and highlights differences from MREFC procedures. The intent here is to allow significant flexibility to adapt the underlying principles to meet the requirements and scope of any particular project.
- Chapter IV is a compendium of detailed requirements and considerations NSF uses to implement the principles and procedures described in Chapters II and III. It is adapted and updated from the materials contained in the *Facilities Management and Oversight Guide* published in July 2003.
- Chapter V contains extensive supplementary information on specific topics concerning NSF's role in the planning and oversight of large facility projects. It consists of hyperlinked sections containing important explanatory and procedural information, presented in a tutorial format that should be of particular benefit to individuals who are newly involved with large facility projects.[5]

This Manual is intended for use by NSF staff and by external proponents of large facility projects for use in planning. However, there are occasional references to materials, such as the *Proposal and Award Manual*[6] (PAM), that 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 marked.

Owing to the rigor of merit review, constraints on funds, changing priorities and competing interests of NSF and the research community, only a limited number of projects will proceed successfully through all stages described below. To improve the possibility of success, facility advocates should be thoroughly familiar with the entire contents of this manual even if the proposed project is in the earliest stages of formulation. Anticipating downstream requirements will dramatically improve the efficiency of the process.

[5] Chapter 5 will be further updated to include additional modules, with the intent to provide to NSF and the research communities a single reference location for all relevant policies and procedures.
[6] The *Proposal and Award Manual*, http://www.inside.nsf.gov/pubs/pam/pam805/11.htm, is a compendium of internal policies and procedures, available only on NSF's internal website, related to the proposal and award process.

# II. Planning and Managing for the MREFC Account

## INTRODUCTION

NSF investments provide state-of-the art infrastructure for research and education, such as laboratory and field instrumentation and equipment, multi-user research facilities, 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.[7]

The MREFC Account supports a subset of these investments, and this chapter provides guidelines for planning and managing facilities supported through that account. Because each facility has unique aspects, each project necessarily requires a unique 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 described below.

## DEFINITION OF THE MREFC ACCOUNT

The MREFC Account is an agency-wide account, created in 1995 with Congressional approval, that provides funding to establish major science and engineering infrastructure projects with total construction costs ranging from several tens to hundreds of millions of dollars. Specifically, the MREFC Account is intended to:

- Provide a special account to fund acquisition, construction and commissioning of major facilities and other infrastructure projects;[8]
- 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.[9]

[7] These resources, many of which are now in development, are collectively known as “cyberinfrastructure.”
[8] In some cases, MREFC funds may be used to support development after construction of a facility begins.
[9] Reliable long-term funding commitments are essential to maintaining partnerships and for preventing cost overruns due to schedule delays.

## 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:

(i) Be consistent with the goals, strategies and priorities of the NSF Strategic Plan;
(ii) Establish a long-term tools capability accessible to an appropriately broad community of users on the basis of merit;
(iii) 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;
(iv) 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 S&E communities, (4) technical and engineering feasibility, and (5) management, cost, and schedule issues;
(v) Be of sufficient importance that the Originating Organization[10] 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
(vi) 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.

**Eligibility Rule:** The total cost of construction and/or acquisition of a proposed MREFC project should represent an investment greater than *10 percent* of the Originating Organization's Current Plan, adjusted to exclude activities (such as SBIR and SRS) that cannot be reasonably expected to contribute to or benefit from the development of the facility.

[10] See Appendix 1 for definition of this and other key terms. Appendix 1 describes the NSF organizations and officers that are involved throughout the conception, development, approval and implementation of an MREFC project. Readers not familiar with NSF and its processes should review this material before proceeding.

**Important Note:**

The National Science Foundation Authorization Act of 2002, Public Law 107-368. section 14(c), restricts the choice of POs overseeing MREFC-funded activities to permanent NSF employees.

"Rotators" and other individuals on temporary appointments are not eligible.

## THE MREFC PROCESS

As the diagram on Page 11 (Figure 1) indicates, pre-construction planning and development for MREFC candidate projects progress through a sequence of stages of increasing investment, planning, assessment and oversight. Among other uses, these stages ensure that the technical evolution of a candidate project is coordinated with NSF requirements, thus increasing the likelihood that it will be able to qualify for funding for further planning and eventual construction.

MREFC projects cover a wide range of disciplines and activities in science and engineering, and they can require rather different approaches to the development and ultimate acquisition of facilities, equipment and/or infrastructure. The approach described in this Manual is derived largely from experience with construction projects defined by the following characteristics:

- They serve a relatively large community or a large collaboration, whose members have organized and agree on the basic parameters of the project; and
- They result from proposals to NSF, either unsolicited or through an NSF solicitation, proposing to construct the particular equipment or infrastructure; and
- Operations of the equipment or infrastructure are carried out by the entity that proposes its construction, or by some other entity in cases where the operations expertise may not necessarily reside with the construction team.

However, because NSF supports investigation at the frontiers of understanding, where specific research targets and methodology often are not firmly established, some candidate projects may need to progress in ways that are less neatly well-defined than the prototypical cases described above. The guidelines in this Manual allow for such cases. For example:

- Because NSF is responsible for nurturing the various sciences and engineering disciplines that it supports, it may provide researchers access to funding sufficient to develop compelling research agendas, to refine and prioritize their facility requirements, and to complete research and development on facility designs and needed technologies, without assuming a direct role in managing either construction or operation. Such projects should nevertheless be sanctioned by, and ultimately driven by, the community through merit review that establishes that candidate new facilities represent a high priority of the researchers in that discipline.

- Following successful concept development, the entire project may be best developed and implemented by an award directly to industry – for example, in the case of IT infrastructure. In such cases, provision should nevertheless be made for proper pre-

construction planning, with thorough community input and merit review, followed by proper oversight throughout the implementation phase of the project.

In all cases, NSF is committed to the principle that flexibility does not preclude rigor. Every MREFC candidate project – including those that call for novel treatment – is subject to the highest standards of merit review and evaluation.

A project's lifetime is characterized by the following life-cycle stages:

(i) facility/infrastructure concept development,
(ii) project development,
(iii) project construction/acquisition,
(iv) facility/infrastructure operation,
(v) facility/infrastructure renewal, upgrade, or phaseout/termination.

(Points at which there may be departure from the MREFC process outlined here should be identified early in the project development through an NSF Internal Management Plan, described below on page 13.)

Each life-cycle stage entails different actions appropriate to the development of the project, the review and approval needed to obtain NSF funding, and the development of NSF budgets to support these activities. Entry and exit from each stage are clearly defined including required documents and deliverables.

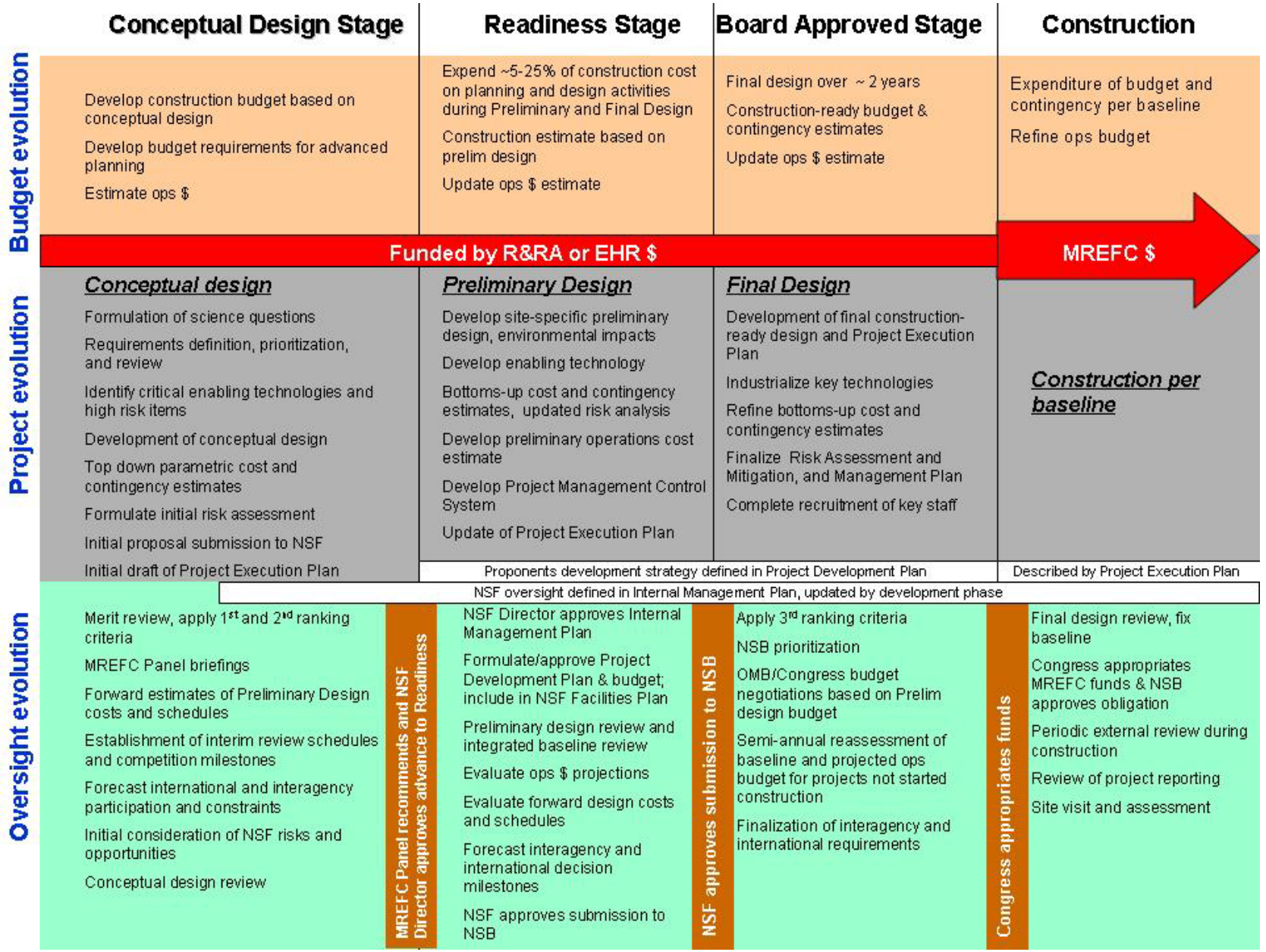
In the early stages of a project, there should be sufficient investment so that the project is well defined when proposed by NSF for construction funding. Careful planning minimizes the risk of significant alterations to the initial budget, scope, and schedule after the National Science Board (NSB or "Board") approves the project for inclusion in a future NSF budget request.

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 five- to 20-year forward look and are brought to NSF in a submitted proposal. 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 comes from the community, which also participates in the merit review process – the major contributing factor in funding decisions.


Conceptual Design Stage
Readiness Stage
Board Approved Stage
Construction
Budget evolution
Develop construction budget based on conceptual design
Develop budget requirements for advanced planning
Estimate ops $
Expend ~5-25% of construction cost on planning and design activities during Preliminary and Final Design
Construction estimate based on prelim design
Update ops $ estimate
Final design over ~2 years
Construction-ready budget & contingency estimates
Update ops $ estimate
Expenditure of budget and contingency per baseline
Refine ops budget
Funded by R&RA or EHR $
MREFC $
Project evolution
Conceptual design
Formulation of science questions
Requirements definition, prioritization, and review
Identify critical enabling technologies and high risk items
Development of conceptual design
Top down parametric cost and contingency estimates
Formulate initial risk assessment
Initial proposal submission to NSF
Initial draft of Project Execution Plan
Preliminary Design
Develop site-specific preliminary design, environmental impacts
Develop enabling technology
Bottoms-up cost and contingency estimates, updated risk analysis
Develop preliminary operations cost estimate
Develop Project Management Control System
Update of Project Execution Plan
Final Design
Development of final construction-ready design and Project Execution Plan
Industrialize key technologies
Refine bottoms-up cost and contingency estimates
Finalize Risk Assessment and Mitigation, and Management Plan
Complete recruitment of key staff
Construction per baseline
Proponents development strategy defined in Project Development Plan
Described by Project Execution Plan
NSF oversight defined in Internal Management Plan, updated by development phase
Oversight evolution
Merit review, apply 1st and 2nd ranking criteria
MREFC Panel briefings
Forward estimates of Preliminary Design costs and schedules
Establishment of interim review schedules and competition milestones
Forecast international and interagency participation and constraints
Initial consideration of NSF risks and opportunities
Conceptual design review
MREFC Panel recommends and NSF Director approves advance to Readiness
NSF Director approves Internal Management Plan
Formulate/approve Project Development Plan & budget; include in NSF Facilities Plan
Preliminary design review and integrated baseline review
Evaluate ops $ projections
Evaluate forward design costs and schedules
Forecast interagency and international decision milestones
NSF approves submission to NSB
NSF approves submission to NSB
Apply 3rd ranking criteria
NSB prioritization
OMB/Congress budget negotiations based on Prelim design budget
Semi-annual reassessment of baseline and projected ops budget for projects not started construction
Finalization of interagency and international requirements
Congress appropriates funds
Final design review, fix baseline
Congress appropriates MREFC funds & NSB approves obligation
Periodic external review during construction
Review of project reporting
Site visit and assessment

## CONCEPTUAL DESIGN STAGE

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

- Definition and relative prioritization of the research objectives and science questions the proposed facility will address;
- Site-independent description of the research infrastructure and technical requirements needed to meet the science (technical requirements normally flow down from the science );
- System-level design, including definition of all functional requirements and major systems;
- Budget and contingency estimates appropriate to a Conceptual Design;[11]
- Initial concept for a construction and commissioning schedule;
- Initial risk analysis and mitigation strategy for construction, identifying enabling technologies, high-risk or long-lead items, and 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," page 19 below);
- Description of the scope of work, budget and schedule needed to continue planning the project to bring it to the next stage, Preliminary Design;
- Plan for project management, including description of possibilities for international and interagency partnering; and
- Initial estimate of annual operations and maintenance funding that will be needed if the facility is constructed and operated.

Completion of the Conceptual Design Stage also requires production of a draft Project Execution Plan (PEP),[12] described in detail on Page 15 below. The entire process typically takes several years, during which there are different – but complementary and coordinated – responsibilities and activities for the community, NSF program staff and various funding sources.

### Conceptual Design Stage Activities:

(1) *Community Activities*. As soon as possible, 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.

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[11] 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.

[12] The PEP, like the corresponding Project Development Plan (PDP) described below, is an evolving document that usually passes through a succession of revisions as project scope and requirements are refined and cost estimates become more accurate.

These earliest plans 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 a to the Conceptual Design level of maturity.

Early in this stage, an NSF PO[13] will be assigned to be the primary point of contact with the research community to ensure that NSF reacts appropriately to community needs. At the earliest opportunity, the PO should organize a Project Advisory Team (PAT)[14] to provide advice and counsel on project oversight.

The NSF PO conducts a merit review of the proponents' Early Concept Proposal, and encourages further development by the proponents of a Conceptual Design if the reviews are favorable. As the project evolves, the PO and others report on the status of activities to NSF's MREFC Panel – a committee consisting of agency senior management and other relevant staff – on a regular basis.

Proponents should acquaint themselves with NSF's expectations for the essential elements of a construction-ready PEP as described in Appendix 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 Appendix 3, but with little or no supporting information provided. This serves simply to inform all parties of the range and magnitude of the tasks ahead.

(2) *NSF Staff Activities*. In response to the development of an early version of a PEP, the PO, with the advice of the PAT, develops an Internal Management Plan (IMP).[15]

This internal document specifies how NSF will conduct management and oversight of a 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, completing essential R&D activities, partnership agreements, termination liabilities) and lays out a strategy for financing these activities as well as concomitant NSF oversight requirements.

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[13] 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 originating or sponsoring Directorate or Office, a Section Head, Division Director, Assistant Director, or Office Head may assign the PO 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 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 Appendix I for a brief description of the duties of the PO, Assistant Director, and others referred to in the Large Facilities Manual, and see also the ***Roles and Responsibilities Module*** where more detail is provided.

[14] See Appendix 1 for a description of Project Advisory Teams. See also "Roles and Responsibilities of NSF Staff Involved in the Management and Oversight of Large Facilities."

[15] See the "Guidelines for Development of Internal Management Plans for Large Facilities" on the internal NSF Web site for a full description of the IMP and what is included within it.

The PO develops the IMP with advice and assistance from the Deputy Director for Large Facility Projects (DDLFP),[16] the PAT, the Contracting Officer or Agreements Officer, and other NSF staff. Following consultation, review and approval within the sponsoring NSF Division and Directorate or Office, and upon approval of the IMP by the cognizant NSF Assistant Director (AD) or Office Head, the IMP is formally reviewed by the Facilities Panel.[17] The Facilities Panel is chaired by the DDLFP and includes other NSF staff members experienced in the technical and administrative aspects of large project oversight. The Facilities Panel provides written comments on the IMP, which become part of the review record and are available to the PO, the Originating Organization, the MREFC Panel and the Director.

The IMP describes the plan for NSF funding the project to Conceptual Design Review (CDR), proposes transitional steps to be taken if the project is admitted to the Preliminary Design/Readiness Stage, and lays out NSF's plan to oversee development of the project through CDR and internal review.

The IMP is an internal document that informs NSF of how the principles for sound project management and effective NSF oversight will be applied to a particular project. However, each large project undertaken by NSF has unique characteristics. Accordingly, these principles should be flexibly adapted to meet the specific needs of a particular project. The IMP states the justification for pursuing alternatives to the guidelines contained in this chapter.

3) *Funding Considerations*. Early in the Conceptual Design stage, NSF and/or other institutions begin to invest research and development funds in conceptual development and design, 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.[18]

The cumulative pre-construction investment in research, planning and development that occurs during Conceptual Design, Preliminary Design, and Final Design 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. The technology needed to construct a facility may be uncertain, unproven or immature, requiring substantial R&D over a period of years.

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[16] Located in NSF's Office of Budget, Finance and Award Management, the DDLFP and the Large Facilities Office staff are resources to all NSF Directorates and Offices on issues relating to project management. While the DDLFP has specific responsibilities and authority, described within this document and the accompanying Roles and Responsibilities Manual, contributions of the DDLFP to oversight of large facility projects most productively occur through participation in broad intramural partnerships, headed by cognizant Program Officers, which broadly engage the DDLFP and all of the other resources and expertise available within the NSF to effectively steward projects through their life-cycle phases. Refer to Appendix 1 and to the Roles and Responsibilities Module for, respectively, a brief overview and a fuller description of the DDLFP and staff of the Large Facilities Office, and the other individuals referred to in the Large Facilities Manual..

[17] The composition of the Facilities Panel described below in Appendix 1.

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

Upon merit review of unsolicited and/or solicited proposals, NSF may fund planning and other development efforts for particularly promising concepts.[19] Such activities might include workshops in one or more disciplines, National Academies' studies, and research projects related to the development of new technologies.[20] NSF funding opportunities may extend to a proposal (or proposals) for development and completion of the project Conceptual Design.

**Exit from the Conceptual Design Stage:**

This stage is complete when a proposal containing the Conceptual Design and a plan and funding request leading to a Preliminary Design is received, reviewed and approved for funding.

The proposal should include: the conceptual design, analyses of how the design satisfies science requirements, the supporting infrastructure description, a management plan, budget and contingency estimates, risk analysis, potential environmental impacts, description of partnering opportunities, and other relevant information. As in the initial "skeletal plan," developed contemporaneously with the Early Concept Proposal, every topic contained in a full construction proposal should be addressed at the completion of Conceptual Design, even if only to identify what is not known at that point.[21]

The proposal should also include a preliminary PEP. NSF will subject the proposal to external merit review, applying the first ranking criteria (scientific and technical merit) as well as NSF's standard merit review criteria. 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 2 for discussion of ranking criteria.)

At a minimum, the following components of a PEP should be included within the proposal:

- Definition and relative prioritization of the research objectives and science questions that the proposed facility will address;
- Comprehensive statement of the science requirements to be fulfilled by the proposed facility (to the extent possible identifying minimum essential as well as desirable quantitative requirements), providing a basis for determining the project's design goals and the associated infrastructure requirements;
- Description of the research infrastructure needed to meet the science objectives;
- System-level, site-independent design, including definition of all functional requirements and major systems;
- Analysis of technical feasibility;

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

[20] 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 MREFC projects needed for breakthrough advances.

[21] Components of a construction-ready Project Execution Plan, which should be fully completed by the time a final design is reached, are provided in appendix 4.

- Budget and contingency estimates appropriate to a Conceptual Design[22] level of detail. The budget should be presented in a Work Breakdown Structure (WBS)[23] format and include a WBS dictionary describing the intended scope of each WBS element and the basis for each estimate. Contingency budgeting, also presented in a WBS format, should result from an initial risk analysis of each WBS element. The risk analysis methodology should be described.
- Initial estimates of the budget required for future operation of the proposed facility; and
- Description of the scope of work, budget and schedule needed to continue planning the project to arrive at a Preliminary Design. This plan should include the proponents' intended course of action to obtain and apply suitable project management expertise to direct the proposed design, development and construction planning activities.

Other topics that should be included, depending on the specific nature of the project, are:

- Description of work that should be done to establish technical feasibility, including description of high-risk technologies;
- Identification of long-lead-time items that pace the development of the design or construction of the facility;
- Role of interagency, non-governmental, or international partners in future planning and development and/or construction;
- Configuration management (maintaining the project baseline and monitoring carefully all changes that may provide at best marginal gains, but may result in delaying the project) and change control (the formal process by which changes to the cost, schedule and technical baseline scope are approved) during design evolution;
- Plans for system integration, commissioning, testing and acceptance of the facility;
- Plans for transitioning from construction and commissioning into operation;
- Liabilities at the end of facility life for site remediation, decontamination, etc. where appropriate;
- Environmental, safety and health issues that may arise in all project phases; and
- Quality assurance and quality control requirements and description of processes.

In addition, the following topics may be applicable and/or useful to NSF in its assessment of a project's suitability for advancement to the Preliminary Design/Readiness Stage:

- Initial concept for a construction and commissioning schedule;
- Initial risk analysis and mitigation strategy for construction;
- Potential environmental and safety impacts to be considered in site selection;
- Anticipated funding profile and cash-flow analysis during construction;

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[22] The budget information should be provided using a Work Breakdown Structure (WBS) format, identify the basis for estimate, and include 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.

[23] A work breakdown structure (WBS) contains a product-oriented grouping of project tasks that organizes and defines the total scope of the project. The WBS is a hierarchical framework that organizes and documents individual project components representing work to be accomplished, aggregating the smallest levels of detail into a unified project description. WBS integrates and relates all project work (cost, schedule and scope) and is used throughout the project management to identify and monitor project process. The project budget and contingency are defined by WBS element. A WBS dictionary describes the intended scope of each element, the basis of estimate for budget entries, and the methodology for calculating contingency for that element.

- Plan for project management during construction; and
- Initial estimate of annual operations and maintenance funding that will be needed if the facility is constructed and operated.

Finally, projects completing the Conceptual Design Stage will also be required to produce a Project Development Plan (PDP)[24] that describes the work to be undertaken by the proponents to bring the project to the Readiness Stage.

Formal exit from the Conceptual Design Stage typically entails three NSF actions.

(1) *Review and Approval of the Conceptual Design*:

NSF will conduct a CDR,[25] which may, 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 NSF PO in consultation with the DDLFP. The PO has overall responsibility for organizing the review, and throughout the review process acts as the interface between the NSF and the project's proponents. The PO authors the review charge and organizes the review panel. The DDLFP 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 and the DDLFP concur on the implementation of these DDLFP recommendations, appealing through their respective supervisors in the event of disagreement. Following the review, the PO and the DDLFP 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 Directorate or Office and the DDLFP via the NSF CFO.

At this point, the conceptual design baseline is likely to have significant uncertainties. 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.

(2) *Assessment and Prioritization of the proposed facility by the AD or Office Head of the sponsoring Directorate or Office:*

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[24] In general, a PDP provides a work plan for the development phase of a project, including budget, schedule, scope of work and risk assessment.

[25] NSF uses the same definition of CDR as the research community proposing the facility, recognizing that there are discipline-specific differences in this definition. It is generally understood to mean a definition of the research questions the facility is intended to answer, the functional requirements of the proposed facility, definition of the major subsystems included in the facility, and a site-independent design with parametric cost and contingency estimates.

The AD or Office Head 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 or Office Head, the scientific merit and relative importance of the proposed facility are sufficiently strong to justify advancement of the project into the Readiness Stage, the PO is authorized to proceed with organizing the development of a PDP and with updating the IMP to lay out how NSF will oversee and fund further development.

- The PDP describes in detail the scope of work to be undertaken by the proponents to bring the project to a "Preliminary Design" level of maturity, a schedule for doing so, the project proponents' estimates for the required budget, and an assessment of risk.
- The IMP describes plans for oversight, key decision points, and a budget plan for supporting the activity during the Readiness Stage where the Preliminary Design is developed. The PO also includes an analysis of development risks to the project. In addition to technical, environmental and programmatic risks, these include analysis of partnering opportunities, competition from other programs, and other NSF-specific issues. "Not-to-exceed" cost guidance for construction and anticipated operating costs are defined by NSF during ongoing development of the PDP and IMP.[26]

When (1) a candidate MREFC project has undergone a successful review of the formal proposal(s), conceptual design and the PEP, (2) NSF has conducted merit review of the PDP, and (3) the IMP has been endorsed by the AD or Head of the sponsoring Directorate or Office, the project may be considered for entry into the Preliminary Design/Readiness Stage.

(3) *Formal Recommendation for Support*:

The Directorate or Office is required to submit a memorandum to the MREFC Panel recommending the project for support, explaining how it meets the requirements for MREFC funding and how it satisfies the following criteria:

- The project's science (research) program addresses one or more science objectives in the current NSF *Facility Plan,*[27] clearly demonstrating a significant 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;[28]

[26] At each subsequent stage in the MREFC process (i.e., at Preliminary Design and Final Design completion), the IMP is updated to define NSF's project-specific expectations for readiness – including budget, schedule, decision points, and "not-to-exceed" cost guidance that are determining factors in continued NSF support.
[27] The current *Facility Plan* is available at http://www.nsf.gov/attachments/102806/public/NSFFacilityPlan.pdf
[28] Evaluation by NSF includes external merit review, using the NSF merit review criteria and the 1st ranking Criteria in Appendix 3 and evaluation by the MREFC Panel, using the 2nd ranking Criteria.

- 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 PDP for further development to the Preliminary Design/Readiness Stage; (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 PDP;[29] 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.

Copies of the approved CDR – along with the IMP, PDP, Facilities Panel memoranda and proposal merit review evaluations – should accompany this memorandum. All materials are transmitted to the MREFC Panel by the AD or Office Head of the sponsoring Directorate or Office. On the basis of this documentation, and discussions with NSF program staff, the MREFC Panel reviews candidate projects, assessing the relative merit of the candidate scientific or engineering research facility in comparison to other projects and opportunities competing for NSF resources, and recommends to the Director those projects that should move into the Preliminary Design/Readiness Stage.[30]

The Director evaluates the Internal Management Plan to ensure that the resources NSF proposes to commit towards further development are adequately matched to the anticipated scope of work, risks, partnering possibilities and other considerations related to further development. If satisfied, the Director approves the Preliminary Design Stage IMP and then decides which projects should move into this stage. These projects are then included in the *Facility Plan*, which is released annually. The NSB is asked to concur with the Director's decisions by approving the annual *Facility Plan*.

At its May meeting, the NSB's Committee on Strategy and Budget reviews the portfolio of projects that have recently completed CDR, which are being considered for further funding to develop Preliminary Designs, to set relative priorities that guide NSF's investment in their further development. NSB considers these candidate facilities and prioritizes their relative importance for further development, 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 large facility projects is available in Section 7 of the Roles and Responsibilities Module.

[29] This judgment is based upon information supplied by the PO, the Originating Organization, and the DDLFP.
[30] When an Originating Organization(s) proposes more than one candidate project for consideration by the Panel within a two-year time frame, it should prioritize its slate of projects and provide a rationale for its recommendations to the Director.

**Compliance with Environmental and Historical Statutes**

NSF's funding of Awardees for the construction or modification of facilities, vessels or research structures constitutes a Federal Action that triggers compliance with several statutes designed to protect the Nation's environmental, cultural and historic resources.

These laws include, but are not limited to, the National Environmental Policy Act (NEPA), the National Historic Preservation Act (NHPA) and the Endangered Species Act. Furthermore, there are international agreements and treaties that deal with environmental impacts. Determining the required level of compliance activities – including what documentation, consultation and/or permits may be required – is a complex task. The PO should not attempt to determine the extent of compliance requirements without consulting NSF's Office of the General Counsel. Failure to take necessary steps can cause undue delays in a project's schedule, significant cost escalation and potential federal litigation.

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. The preparation costs of such documents can range from $25,000 to more than $1 million and may take six months to more than one year to complete (exclusive of NSF's defense of any lawsuit filed challenging NSF's compliance with environmental statutes).

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 NHPA. 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 R&RA funds. Given these factors, the following guidance is offered:

1. It is imperative that the PO contact NSF's Office of the General Counsel early in the conceptual design stage to seek guidance on specific requirements for compliance.

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 known by Preliminary Design Review (PDR) since the PDR budget and risk assessment provide the basis for the construction funding request.

## PRELIMINARY DESIGN/READINESS STAGE

The Preliminary Design/Readiness Stage 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 PDP that addresses 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.

NSF has implemented a "no cost overrun policy" for cost overruns on new MREFC-funded construction projects. This policy requires that the total project 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.[31]

To satisfy these requirements, the project is developed to a Preliminary Design[32] level of maturity. Results of this development are reflected in a revised and updated PEP.[33] Components of the updated PEP that deserve particular emphasis at this stage include:

- 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, presented using a WBS structure and supported by a WBS dictionary defining the scope of individual elements;
- Updated construction schedule;

**"Off-ramps"**

Projects may be removed from the Preliminary Design/Readiness stage by the NSF Director due to:

* insufficient priority over the long term;
* failure to satisfy milestones or other criteria defined in the IMP/PDP;
* eclipse by other projects;
* collapse of major external agreements;
* extensive estimated or actual cost overruns;
* significant changes in schedule for development;
* unexpected technical challenges;
* changes in the research community that indicate eroding support for the project;
* or any other reason that the Director deems sufficiently well-founded.

Specific reasons for removing an MREFC project from this stage will be made public via the NSF *Facility Plan*.

[31] See the MREFC Section of the NSF's 2009 Budget Request to Congress, page 3, available on-line at http://www.nsf.gov/about/budget/fy2009/pdf/29_fy2009.pdf

[32] 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.

[33] See Appendix 4.

- Implementation of a Project Management Control System (PMCS) [34] and inclusion within the preliminary design of a resource-loaded schedule; and
- 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/Readiness 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;
- Definition of budget and schedule needed to go from preliminary design to final design (updated PDP);
- Plans for management of the project during construction, including preliminary partnership arrangements and international participation, oversight of major sub-awards and subcontracts, organizational structure and management of change control;[35] and
- Updated estimates for future operating costs, anticipated future upgrades, or possible decommissioning costs of the facility at the end of its operating life.

**Preliminary Design/Readiness Stage Activities:**

Budgeted contingency funds are re-allocated to defined WBS elements that result from planning activity. Consequently, budget uncertainty for projected construction is much reduced relative to the earlier conceptual design. (Additional planning and development during the final pre-construction design stage will result in further transfers of contingency budget to the detailed work scope.) Typically, a significant proportion (often one-third or more) of the total pre-construction planning budget is expended achieving the preliminary baseline.

Projects in this stage will be reviewed semiannually by the MREFC Panel, based upon updated IMP and PDP documents and the PO's analysis, in consultation with the DDLFP, of how the project has progressed. Interim reviews[36] during development 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 MREFC Panel to the Director for decision on forwarding to the NSB.

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[34] The Project Management Body of Knowledge (PMBOK) defines the PMCS as an information system consisting of the tools and techniques used to gather, integrate and disseminate the output of project management processes. It is used to support all aspects of the project from initiating through closing, and can include both manual and automated systems. (See *A Guide to the Project Management Body of Knowledge*, Third Ed., Project Management Institute, Newtown, PA, 2004). 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. The PMCS is utilized by management to: schedule and optimize project resources; determine project status by comparing the work accomplished and resources expended by a particular date to the anticipated accomplishments of the baseline plan; compute and track Earned Value, and evaluate project risk factors by simulating various "what if" scenarios; and manage the change process by evaluating the effects of alterations to the baseline on the project's planned budget and schedule.

[35] These plans are a preliminary version of the Project Execution Plan that defines how the project will conduct itself during the construction phase – see Appendix 4.

[36] Interim reviews are typically held semi-annually. Exceptions to this, dictated by the needs of a particular project, are justified in the IMP.

**Alternate "On-Ramps" into Readiness**

Not all projects navigate the same course through the pre-conceptual and conceptual design stages. For example, conceptual design could be funded by other agencies or non-Federal sources, or an opportunity could arise for the U.S. community to participate in a well-developed international effort. In such circumstances, where the conceptual design is complete and has been extensively reviewed to the satisfaction of NSF, admission to the Readiness Stage may be the most appropriate entry point into the MREFC process.

Prerequisites for entry are submission of a proposal that presents the science case for a project, as well as a PEP and construction budget of appropriate maturity for the project's state of development. Proposals should be submitted via the standard on-line FastLane channel only after discussions with the PO that include a request for waiver of the nominal page limits for NSF proposals (normally granted at the Directorate level). Reviews of this proposal, conducted by the PO in consultation with the DDLFP, will help to establish whether NSF will support the project's preliminary design, and to determine a schedule for future reviews and decision points.

Regardless of how or when the project enters the Preliminary Design Stage, a PDR will be conducted by NSF prior to consideration of its promotion into the Final Design Stage. The timing for such a review will be determined in consultation among the project proponents, the PO and the DDLFP.

**Preliminary Design Review:**

NSF conducts a PDR, collaboratively organized and led by the PO and the DDLFP, to assess the robustness of the technical design and completeness of the budget and construction planning. The review is organized and conducted by the NSF PO in consultation with the DDLFP. The PO has overall responsibility for organizing the review, and throughout the review process acts as the interface between the NSF and the project's proponents. The PO authors the review charge and organizes the review panel. The DDLFP 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 and the DDLFP concur on the implementation of these DDLFP recommendations, appealing through their respective supervisors in the event of disagreement. Following the review, the PO and the DDLFP 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 Directorate or Office and the DDLFP via the NSF CFO.

The review scrutinizes the effectiveness of project management through this stage 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. 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.

The MREFC Panel evaluates the findings, conclusions and recommendations for consistency and examines areas in which judgments by the PO or the DDLFP raise questions or concerns.

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

Following the PDR, the NSF 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 project's proposers to update the PDP to lay out the work scope, budget and schedule necessary to bring the project to Final Design.

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 Director is the coordinator for this critical planning activity, bringing projects forward for construction only if, in the Director's judgment, 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.

**Exit from the Preliminary Design/Readiness Stage:**

A candidate project exits from this stage and enters the Final Design/Board Approval stage after successful review by the MREFC Panel, and after the NSF Director recommends the proposed project to the NSB for approval to include in a future year budget request. The MREFC Panel and the Director should first be satisfied that the following conditions have been met:

- The AD or Office Head of the sponsoring Directorate or Office (the Originating Organization) 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 has been successfully reviewed internally and 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.
- The DDLFP concurs that the Preliminary Design is reasonable and poses an acceptable level of risk, and that anticipated costs for construction and operation are sufficiently well known.
- The NSF Chief Financial Officer certifies that the Preliminary Design budget has been satisfactorily defined.
- 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.
- Updated IMP and PDP documents have been reviewed and approved by the Facilities Panel (IMP only), the MREFC Panel and the Director.
- An appropriate Project Leadership/Management team is in place.

- The MREFC Panel asserts that the proposed MREFC project, when compared to other proposed projects – whether within the same field, across related fields, or across different fields[37] – is among the very highest priorities for potential new facilities.

Based on its review of the information provided and discussions with program and project staff, the MREFC Panel (chaired by the Deputy Director, and with the advice and recommendation of the DDLFP and the CFO) forwards one or more projects in priority order to the Director, who makes the decision to forward to the NSB for approval. The rationale and criteria used for the selection and prioritization of these projects is clearly articulated in the *Facility Plan*.

## NSB APPROVAL/FINAL DESIGN STAGE

The goal of the NSB Approval/Final Design Stage 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 approval to include the project in a future NSF budget request.

Technical requirements include:

- Delivery of designs, specifications and work scopes 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;
- Completion of recruitment of key staff and cost 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[38] for construction.

Successful exit occurs when a final, construction-ready PEP has been completed, reviewed and approved by NSF, and when Congressional appropriation of MREFC funds occurs, based upon a specific budget request to Congress.

### NSB Submission and Approval:

The Originating Organization is responsible for preparing the documentation needed for the NSB to review and approve a proposed MREFC project for inclusion in a future budget request.[39] Prior to NSB submission, the Director's Review Board (DRB)[40] reviews and approves the documentation supporting advancement of the project into the NSB Approved Stage (such

[37] In making this determination, the second and third ranking criteria in Appendix 3 are judiciously applied.
[38] Further discussion of the PEP is found in Chapter 4 of the Facilities Manual and in the supplementary material in Chapter 5: "Guidelines for Development or Project Execution Plans for Large Facility Projects."
[39] See Appendix 8 for description of required documentation.
[40] See page 58 for the composition of this group.

as prior stage reviews, committee evaluations, PDP evaluation and reviewed proposal ratings) to ensure adherence to NSF processes and policies.

As NSB considers projects for approval, NSF makes available to the NSB, upon request, the PEP and IMP, and the reviews from the community, the Facilities Panel, the DDLFP, the MREFC Panel and other relevant parties. The NSB considers the following elements, applying primarily the third ranking criteria (national priorities: see Appendix 2), as appropriate:

- The research and science enabled by the proposed facility;
- Construction plans together with their risks and degree of readiness;
- Budget justification for construction and operation of the facility;
- The likelihood that funding will be available in the next few years; and
- The priority of the project in furthering one or several objectives in the *Facility Plan*.

If NSB approves a project for future-year funding, it specifies its priority among all projects in the Board-approved stage.[41] 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/Readiness stage for further work. Projects should not languish in this stage; they are expected to be resubmitted to the NSB in the following year.

**Inclusion in an NSF Budget Request:**

The NSF Director proposes, in priority order, the NSB-approved 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 request authority to obligate funds.

Before funds are available for a new project, an approved Final Design Baseline should be in place, as described in the next section At that point, several steps remain to be taken before an MREFC award can be made: successful review of the final design baseline; internal NSF review by the DRB; Director recommendation to the NSB for making an award; NSB review and approval; and negotiation of the terms and conditions of the cooperative agreement between NSF and the Awardee institution for the activities in conformance with the final baseline.

**Final Design Review (FDR):**

NSB-approved 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, and plans for reporting technical and financial status, managing sub-awardees and working with interagency and international partners;

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

- A fully implemented PMCS, including a final version of the resource-loaded schedule and mechanisms for the project to generate reports – using the Earned Value Management System (EVMS)[42] – on a monthly basis and use them as a management tool. Path dependencies, schedule float, and critical path are defined;
- Updated budget and contingency, including risk analysis, presented in a detailed Work Breakdown Structure (WBS) format accompanied by a WBS dictionary defining the scope of all entries;
- A significant proportion of the budget based on externally provided information such as vendor estimates or quotes, publically available supplier prices, and the like;
- All necessary partnership agreements and Memoranda of Understanding;
- Fit-up and installation details of major components and commissioning strategy;
- Plans for Quality Assurance and Safety;
- Updated operating cost estimates; and
- Certification that all of the pre-construction planning topics, including those listed in Appendix 3, are fully complete and determined to be adequate.

After Congress appropriates MREFC construction funds for the project – but before such funds are released – NSF reviews and approves the Final Design Baseline to ensure that the project plans and budget are fully ready for construction and that there is a high degree of confidence that the facility can be delivered within the parameters defined in the project baseline.[43]

The PO and the DDLFP are responsible for collaboratively organizing and leading the Final Design Review (FDR). The review is conducted according to the same standards and with the same respective roles for the PO and DDLFP as described previously for the PDR The review is organized and conducted by the NSF PO in consultation with the DDLFP. The PO has overall responsibility for organizing the review, and throughout the review process acts as the interface between the NSF and the project's proponents. The PO authors the review charge and organizes the review panel. The DDLFP 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 and the DDLFP concur on the implementation of these DDLFP recommendations, appealing through their respective supervisors in the event of disagreement. Following the review, the PO and the DDLFP will each independently assess the review, confer on areas of concern, share their views, and report their observations through their respective

[42] Progress should be tracked and measured using the Earned Value method (this method is required by the Office of Management and Budget in its *Planning, Budgeting, Acquisition, and Management of Capital Assets* circular). Earned Value is an objective analysis of a project's cost and schedule progress as compared to the Baseline Project Definition (or, Rebaselined Project Definition). Tracking cost and schedule variances (as described below) enables decision makers to assess overall project performance and, when there are budget overruns or schedule slips, to implement corrective actions. Earned Value uses three "building blocks" (Planned Value (PV), Earned Value (EV), and Actual Cost (AC)) to calculate Schedule (EV – PV) and Cost (EV – AC) variances. Negative results indicate that a project is over budget and/or behind schedule. To use Earned Value, one needs to determine the percent of a task that has been completed. For purposes of Government Performance and Results Act (GPRA) reporting, a simple measure of Earned Value will be used: if a task has not been started, it is 0% complete; if a task has been started it is assumed to be 50% complete; and only when a task has been completed is the whole value earned. A discussion of Earned Value is included in the EVM section of Chapter V – Guidelines for Financial Management.

[43] This scrutiny emphasizes the importance of initial planning and definition of the technical scope, budget, and schedule, and implementation of a transparent process for management of changes to the final baseline.

supervisory chains – the PO via the administrative structure of the sponsoring Directorate or Office and the DDLFP via the NSF CFO.

The scope of the FDR includes assessment of the technical and project-management components of the proposed project. Review panel participants provide an objective view of the project and a critical evaluation of the plans and risks embodied in the proposed program. Participants provide expertise in the principal disciplines and specialties utilized by the project, balanced among scientific, engineering, business and project-management credentials. In addition, the IMP should continue to be updated and assessed annually 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 remand the project to the Preliminary Design/Readiness stage or mandate annual project status reviews to assure NSF of the continued viability of the project's plan and budget for construction.

Due to the Federal appropriations process, there may be one or more years between the PDR and the start of construction, which is predicated on successful completion of the FDR. During this time the NSF will review the project at least annually to ensure that the total project cost and basis of estimate, schedule, and risk management plan presented at the PDR are still valid. Following the same pattern as the CDR and PDR, the PO has overall responsibility for organizing the review, and throughout the review process acts as the interface between the NSF and the project's proponents. The PO authors the review charge and organizes the review panel. The DDLFP strengthens the review process by specifying language for incorporation within the charge and contributing to planning of the review agenda in areas pertaining to project management issues, and recommending panelists able to advise NSF in non-science related areas of the review. The PO and the DDLFP concur on the implementation of these DDLFP recommendations, appealing through their respective supervisors in the event of disagreement. Following the review, the PO and the DDLFP will each independently assess the review, share their views, confer on areas of concern, and report their observations through their respective supervisory chains – the PO via the administrative structure of the sponsoring Directorate or Office and the DDLFP via the NSF CFO.

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 or Office recommends this to the NSF OD after consultation with the PAT, internal deliberation, and if appropriate, consultation with the MREFC 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.

## CONSTRUCTION STAGE

After Congress appropriates funds for an MREFC project, NSF proceeds to award the contracts and/or cooperative agreements for construction of the facility. The policies and procedures in the PAM (an internal document) apply to MREFC projects. The PAM covers the internal award process from proposal generation through merit review, DRB and NSB reviews, and final award.

Following a successful review of the final design baseline, the Director recommends to NSB that it approve construction award(s).[44] NSB reviews the recommendation and authorizes the making of the award(s). Following this approval, an award instrument, generally a cooperative agreement(s), between NSF and the awardee institution(s) is negotiated, and construction activities begin in conformance with the final baseline.

The awardee(s) provides periodic financial and technical status reports to NSF according to the terms and conditions of the Cooperative Agreement. The project is subjected to periodic post-award status reviews that may examine any or all of the following topics: technical performance, cost, schedule and management performance, at least annually, and perhaps more frequently during certain periods, if justified by the project's rate of expenditure.. These reviews are typically held at the facility.

NSF appoints the review panel members directly and oversees them directly. They 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 on project direction and any needed changes. The reviews are organized and conducted by the PO in consultation with the DDLFP..The review is organized and conducted by the NSF PO in consultation with the DDLFP. The PO has overall responsibility for organizing the review, and throughout the review process acts as the interface between the NSF and the project's proponents. The PO authors the review charge and organizes the review panel. The DDLFP 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 and the DDLFP concur on the implementation of these DDLFP recommendations, appealing through their respective supervisors in the event of disagreement. Following the review, the PO and the DDLFP 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 Directorate or Office and the DDLFP via the NSF CFO. (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.)

Generally, when cost and/or schedule performance begin to deviate from plans, change control is exercised by the project through a Change Control Board (CCB)[45] action, resulting in modifications to the project's budget or schedule contingency. Whenever a project approves a change control action that results in allocating or returning contingency to the pool of contingency funds, the baseline Budgeted Cost of Work Scheduled (also referred to as the Planned Value) has changed.

It is normal practice for a project to update its Estimate to Complete (ETC), a process whereby the Actual Cost of Work Performed (ACWP) is compared to the baseline cost. The results are

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[44] See Appendix 5 for required documentation.

[45] A Change Control Board 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, cost 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.

used to revise the remaining cost estimate to determine the project's ETC. This activity also results in baseline changes.

Such budgetary adjustments do not mean that costs have exceeded the total funds appropriated (in the case of an upward adjustment); rather, they signify that contingency funds are being expended.

Similar change-control actions affect the Baseline Cost of Work Scheduled. They revise the baseline project 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.

If only small fractions of the available contingency and float are expended, the re-baselining is done unilaterally by the project. NSF approval is required only when the CCB recommends change actions that exceed the budget or schedule thresholds identified in the Cooperative Agreement between NSF and Awardee.

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

NSF approval is required if re-baselining involves changes to the NSB-approved Total Project Cost (TPC). An increase in construction cost exceeding 20 percent of the NSB-approved baseline cost or $10 million (whichever is smaller) should be reviewed and approved by the NSB on the recommendation of the MREFC Panel and the Director. In all cases where increases in the TPC beyond the NSB-approved level are foreseen, the MREFC Panel, through the NSF Deputy Director, is notified, reviews, concurs with, and/or makes alternative recommendations regarding the Originating Organization's plan for dealing with the issue.

Prior to requesting approval of such increases, a new external baseline review should be conducted to examine the nature of the problems encountered, and to determine whether de-scoping is an option or, if not, whether the problems have been solved. Upon review, cost and schedule are stabilized, and the contingency adjusted to an appropriate level.

For TPC increases below the NSB threshold, the nature and depth of the review will vary. Whenever any such cost increases are foreseen, it is most important that the DDLFP is consulted early, concurs on the details of the Originating Organization's plan, and advises and concurs on details of the external re-baselining review. Similarly, when there are indications that the project contingency will fall below reasonable standards,[46] the NSF PO should discuss plans for dealing with the variance with the Project Director. A good practice here is to note such information in the monthly status reports that go to the DDLFP, NSF's Office of Budget, Finance and Award Management (BFA), and the NSF Director's office. Also, the DDLFP is a resource for dealing with such problems and steps that can be taken to restore adequate contingency.

In addition to supplying regular status reports required in the terms and conditions of the cooperative agreement, it is essential that MREFC project staff inform NSF staff in a timely

[46] See details in Chapter IV, Detailed Considerations and Requirements: FREQUENCY AND CONTENT OF REPORTS and REQUIREMENTS FOR OVERSIGHT, REVIEWS, AND REPORTING.

manner of major issues or significant changes in project status, such as re-baselining, problems with partnerships, or surprising research and development results. NSF management, the MREFC Panel and the NSB should in turn be informed of such developments.

On rare occasions, MREFC projects under construction may encounter unforeseen budget or programmatic challenges that are of a substantial enough level to be considered grounds for termination or significant modification to the original project goals. NSF will provide NSB with appropriate information and a recommendation. NSB will decide whether termination or significant modification to the original project goals is warranted.[47]

[47] NSB/NSF *Setting Priorities for Large Research Facilities Projects Supported by the National Science Foundation*, NSB-05-77.

## POST-CONSTRUCTION STAGES

### Commissioning:

The transition from construction to operations is rarely abrupt. Many facility projects require a testing and commissioning phase, funded through the MREFC Account. The scope of these activities is defined in the PEP and included in the initial MREFC budget request. The PEP is included by reference in NSF's cooperative agreement or contract with the Awardee institution, documenting the mutual understanding of the work scope funded by MREFC funds. 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 phases overlap in time, they are budgeted and managed separately.

NSF will ask for a commissioning plan at least one year prior to initial commissioning activities. The scope of commissioning work is to undertake initial operation of the facility and bring it up to the design level of operation in accordance with the IMP. The IMP is updated prior to the operations stage to define reviews, decision points, strategies for renewal or re-competition, plan for advanced R&D or technology refresh, upgrades, etc.

The content of the commissioning plan will be adapted to the specific nature of the facility but at a minimum it should include:

- A detailed bottom-up cost estimate for operations..
- A detailed management plan for operation of the facility, including the roles of key staff and plans for advisory committees.
- Education and outreach plans and their associated costs
- The costs of an in-house research program, if applicable.
- A detailed set of acceptance criteria that establish that the facility is finished and ready to commence routine operations.
- A listing of which environmental safety and health (ES&H) standards will be followed by the awardee 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 for the project.
- A listing of which cybersecurity standards will be followed by the awardee and a description of how adherence to those standards will be verified. A policy for reporting to NSF of any breaches of cybersecurity should also be given. This may be given as a reference to an existing cybersecurity plan for the project.
- A discussion of how major maintenance issues (such as budgeting for periodic replacement of long-lived capital assets who useful life extends beyond the duration of the cooperative agreement) will be handled
- A discussion and a preliminary cost estimate for decommissioning the facility.
- A set of performance goals and metrics sufficient to establish that the facility is operating successfully. These will be updated in each year's Annual Work Plan (see below)

Once the commisioning plan is complete, an Operations Readiness Review (ORR) will be held to examine and comment on the plan. The review is organized and conducted by the NSF PO in

consultation with the DDLFP. The PO has overall responsibility for organizing the review, and throughout the review process acts as the interface between the NSF and the project's proponents. The PO authors the review charge and organizes the review panel. The DDLFP 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 and the DDLFP concur on the implementation of these DDLFP recommendations, appealing through their respective supervisors in the event of disagreement. Following the review, the PO and the DDLFP 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 Directorate or Office and the DDLFP via the NSF CFO.

**Operations:**

Although NSF does not directly manage the operations of the facilities it supports (with the exception of Antarctic activities), the agency engages in oversight 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 the Guidelines for Operations Module[48] and among the special topics found in **Chapter IV: Detailed Considerations and Requirements**.

The Awardee 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 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.

Three key aspects of NSF oversight of large facility operations are: Annual Work Plans, Annual Reports and Annual Operations Reviews.

- The Annual Work Plan describes what the facility expects to accomplish in the coming fiscal year. The Annual Work Plan should include a series of high level performance goals (clear and agreed upon goal sand objectives, performance measures and, where appropriate, performance targets) for the coming year. The goals should include both scientific and operations (i.e. installation of new equipment or commissioning of new buildings, maintenance, EOT and ES&H) issues. The goals will naturally vary from

[48] Guidelines for Operations ( in preparation )

facility to facility and should be agreed upon between the awardee and the NSF Program Officer. Goals in the Annual Work Plan should meet the standard of being specific, realistic, measurable and time based. The DDLFP will review the goals to ensure they meet this standard. The goals described in the annual work plan are in addition to those that may be required under GPRA reporting.

- The Annual Report describes in detail the activities of the facility in the previous fiscal year. This report is required to review progress on that year's performance goals (as described in the Annual Work Plan). 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 is required. The NSF PO reviews and approves the Annual Report.

- In most cases, NSF will annually conduct Operations Reviews of its major multi-user research 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 purpose. Exceptions to the annual review (or its alternate) occur when NSF partners with other entities to fund operations. In those instances, the Memorandum of Understanding 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. These reviews (or their alternates) should determine the extent to which the facility is meeting the goals of its Annual Plan, discuss any upcoming challenges for operations, and highlight best practices that could be applied to other large NSF 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. Results of the review are used by NSF to provide feedback 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 System Review[49] (BSR) which looks at business processes.)

- The review is organized and conducted by the NSF PO in consultation with the DDLFP. 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 DDLFP advises the NSF 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. In the event of disagreement, the PO and DDLFP appeal through their respective supervisors.

[49] See the Business Systems Review module for a thorough description of the BSR process. To avoid duplication of effort, the scope of the BSR is adapted to utilize relevant information stemming from other NSF reviews and audits.

Following the review, the PO and the DDLFP will each independently assess the review, share their views, confer on areas of concern, and report their observations through their respective supervisory chains – the PO via the administrative structure of the sponsoring Directorate or Office and the DDLFP via the NSF CFO.

- In most cases, observers of the review shall include the Program Officer, the cognizant Business Officer, and staff from the Large Facilities Office, and possibly other NSF staff who provide additional resources that benefit the review (for example, the Office of General Counsel, the Office of International Science and Engineering, etc.). 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.

**Renewal/Recompetition:**

The operations stage of large facilities is typically more than 10 years, with significant variation within NSF's portfolio.[50] To stay at the research frontier, upgrades and renewal of equipment are usually required. 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 cyberinfrastructure. 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, often from a portion of the operating funds designed for such purposes. Funding for more significant upgrades – the cost of which exceeds the MREFC threshold – may come from the MREFC account. In that case, the approval process is the same as that for a new MREFC project.

Most NSF facilities will be operated by a managing organization.[51] 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 large facilities after external merit review. NSB resolution 97-224 states that "*Expiring awards are to be recompeted unless it is judged to be in the interest of US science and engineering not to do so*". Consistent with NSB policy, NSF will, at appropriate intervals, consider whether or not to recompete the management.

The NSB issued a statement requiring full and open recompetition of awards for operation of major facilities upon their completion, and following an appropriate time period to bring the facility to sustainable operations.[52] 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. The determination of whether to compete the

[50] Computing facilities, for example, may have a useful lifetime of less than 10 years.
[51] Current examples include Associated Universities, Inc. (AUI) for the National Radio Astronomy Observatory (NRAO); University Corporation for Atmospheric Research (UCAR) for the National Center for Atmospheric Research (NCAR); and Cornell University for the National Astronomy and Ionosphere Center (NAIC).
[52] See NSB Statement On Competition, Recompetition, and Renewal of NSF Awards, NSF 08-16, available on-line at http://www.nsf.gov/nsb/publications/2008/nsb0816_statement.pdf.

effort is based on the expert advice of NSF staff and, where applicable, external sources using the facility, and should be presented to the NSB for approval.

**Termination:**

To remain at the research frontier and support new facilities, NSF should retire 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 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.

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

# III. Planning and Managing Large Facility Projects Not Funded by the MREFC Account

## INTRODUCTION

The project management processes and principles described in the preceding chapter are generally applicable to all large facility projects, irrespective of the source of construction funding. However, considerable flexibility is allowed in the management approach to adapt the process to the requirements and scope of any particular project.

This chapter, predicated upon an understanding of Chapter II, provides guidelines for planning and managing new facility projects that are *not* constructed with funding from MREFC accounts.[53] This is usually the case when the project does not qualify for MREFC funding[54] and/or the sponsoring Directorate or Office chooses not to apply for MREFC funding.

This chapter applies to non-MREFC facility projects that take a multi-stage design approach similar to that described in Chapter II, and that are large enough to require multiple levels of approval within NSF beyond the level of the Originating Organization. (It does not pertain to awards for centers, or other types of awards unrelated to facilities which require approval merely because of their large size). The total cost of a non-MREFC facility project generally ranges from millions to tens of millions of dollars or more. The majority of these projects will require NSB award approval.[55]

Non-MREFC projects are not subject to the same requirements for Conceptual Design, Preliminary Design, and Final Design reviews outlined in Chapter II. Nor are they required to use the three sets of ranking criteria in Appendix 2 or subject to review by the MREFC Panel. However, the elements described in Chapter II make a useful toolkit for a Directorate or Office to use in planning and managing all large facilities that proceed through these design stages. How the elements might apply is the focus of this chapter.

As in the case of MREFC projects, NSF is committed to the principle that flexibility does not preclude rigor. For projects that do not require a multi-stage design approach, the PO should explain the variation and define the management approach taken in the project's IMP.

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[53] R&RA (and possibly EHR) appropriations accounts are used to support the construction of non-MREFC large facilities. In addition, non-construction activities of MREFC-funded construction projects, including research, design, development, and operations costs, are normally funded through the R&RA and/or EHR appropriations accounts.

[54] See the previous chapter for eligibility requirements for MREFC funding.

[55] The *Proposal and Award Manual* (PAM), Chapter VI.H.3 requires the following items to be submitted to the NSB for approval: (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 approval is required when the resulting cost is expected to exceed the percentage threshold for NSB award approval; (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.

**Selection Criteria:** Both MREFC and non-MREFC facility projects should depend on a proposal-driven process with external and internal merit review. Other factors to consider might include:

- Exceptional opportunity to enable frontier S&E research & education;
- Urgent contemporary research & education need;
- High priority within the relevant S&E communities;
- Accessibility to an appropriately broad user community;
- Partnerships well defined;
- Technical feasibility and risks thoroughly addressed; and
- A well developed PEP.

**PO Oversight:** At the earliest practical point, each large-facility project is assigned an NSF PO[56] with primary responsibility for award management and project oversight. As noted in Chapter II, NSF restricts the choice of POs overseeing MREFC-funded activities to permanent NSF employees[57] to assure continuity of oversight. POs overseeing non-MREFC funded projects are exempt from this statutory requirement. However, the principle should be taken into consideration for non-MREFC projects by matching the term of assignment of the cognizant NSF oversight staff to the duration of the late-stage planning and construction activity. Alternatively, assigning a team of POs with a mix of permanent and rotating staff may help ensure continuity.

**Facilities Panel:** The Facilities Panel[58] is available to review and provide comments on the IMP for a large facility project, independent of the source of construction funds.

**Interaction with Deputy Director for Large Facility Projects:** The DDLFP is available in an advisory capacity to NSF staff working on non-MREFC funded projects as a resource for best practices for project management and business oversight. But the DDLFP's involvement is not mandatory unless so directed by the Director, the Deputy Director or the Assistant Director/Office Head of the Originating Organization(s). The DDLFP may be asked by the Director or Deputy Director to review DRB and NSB packages for non-MREFC facilities.

**Project Advisory Teams:** At the earliest opportunity, the PO should organize a PAT[59] to provide advice and counsel implementing developmental oversight. It is not mandatory that the DDLFP (or designated representative) be a member of the PAT, but he/she may be invited by the PO to participate where the complexity or magnitude of the project warrants. In the event that a PAT is formed, the participation of a Contracts and Complex Agreements Officer (or Grants Officer where applicable) is recommended.

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[56] Also referred to within NSF as Program Director or Program Manager.
[57] See Public Law 107-368, Section 14(c).
[58] See Chapter IV and the detailed explanations in the "Roles and Responsibilities" section of Chapter V for a description of the Facilities Panel.
[59] See Appendix 1 for a complete description of the Project Advisory Team. See also "Roles and Responsibilities of NSF Staff Involved in the Management and Oversight of Large Facilities".

**NSB Budget Approval:** Unlike MREFC projects, non-MREFC projects do not require formal NSB approval as part of the budget process in order to be included in future NSF budget requests. Rather, the non-MREFC projects are considered by NSB in the course of reviewing the entire NSF budget request. However, both MREFC projects and non-MREFC facility projects of large size require both DRB and NSB approval before an award is made.

**NSF Office of the Director:** Providing information early in the planning process to the Office of the Director is advisable. The Director may wish to share information items periodically with the NSB.

## PRE-CONSTRUCTION PLANNING AND DEVELOPMENT

As is the case with most MREFC projects, pre-construction planning and development of non-MREFC facility projects may progress through sequential stages of increasing investment, planning, assessment and oversight. At each stage, the technical evolution of the project and NSF's preparatory planning and budgeting are coordinated and synchronized to achieve an orderly evaluation process that results in eventual construction funding for the most meritorious projects.

The sponsoring Directorate decides upon the appropriate degree of rigor and formality in pre-construction planning necessary to ensure that the project is well defined and appropriately budgeted. These decisions are based upon the size and complexity of the proposed project, and are documented and justified in the project's IMP.

As with MREFC projects, most non-MREFC funded projects begin when NSF responds to a community initiative (exceptions may include infrastructure replacement and addition). Such initiatives may take different forms – for example, a report from a community planning activity or a formal proposal. The sponsoring Directorate or Office's decisions and strategies for project review, funding and oversight are delineated in the IMP. The IMP specifies how NSF will supervise management of a project, and provides budgetary estimates for developing, constructing and operating the facility. It also identifies termination liabilities and lays out a strategy for financing these activities as well as the concomitant NSF oversight requirements.

The PO in the sponsoring Directorate or Office prepares the IMP in the early stages of the project's conceptualization. It is reviewed and approved by the Assistant Director/Office Head of the Originating Organization(s). The Originating Organization(s) may design and adopt oversight processes and procedures that are flexibly tailored to the needs of the particular project.

Very large or complex projects will require more formalized pre-construction planning and frequent status reporting. Smaller projects will have appropriate requirements.[60] The project management approach used must be scaled to the needs of a particular project. For example, project management controls used to manage project resources, document project activity and plan alternate courses of action to mitigate risk will be much more sophisticated and costly for a large-scale project than for a small one.

[60] See the section on Internal Management Plans in Chapter V for additional details.

Budgets, schedules, risk assessments, and project management plans will be similarly scaled. The IMP defines NSF's expectations for the appropriate level of scaling that optimally matches oversight requirements to project needs. NSF conveys these expectations to the project proponents for incorporation in their PDP and PEP as appropriate.

# IV. Detailed Considerations and Requirements

This chapter provides greater detail about key management, budgeting and reporting activities that should be carried out, throughout a project's life-cycle phases, for both MREFC and non-MREFC projects to ensure adherence to principles established by NSF.

(Note: The following descriptions provide summaries. They are not a substitute for the detailed guidance in NSF's Proposal and Award Manual [PAM], an internal document. NSF POs should be thoroughly conversant with the contents of the PAM.)

## BUDGETING AND FUNDING

The Awardee is responsible for developing budgets to establish and/or operate a facility. The PO is responsible for reviewing these budgets (and the assumptions used to develop them) for completeness, appropriateness and reasonableness, and then for making a funding recommendation. The PO then develops a funding profile and a cash-flow analysis with examination of associated risks,[61] and takes the steps to secure appropriate commitments from all internal and external sources of funds.

Funding for the activity (development, construction and operation) is derived from the appropriate NSF budget account – R&RA, EHR or MREFC. Barring documented exceptions, the R&RA (and possibly EHR) account will be used to fund concept, development, operations & maintenance, renewal or termination costs. By contrast, the MREFC account, if applicable, will be used to fund implementation (construction, acquisition and commissioning) costs.

For non-MREFC projects, the R&RA (and possibly EHR) account also funds the implementation costs. In all cases, attention should be paid to the fundamental difference between creating the basic infrastructure (i.e., constructing and/or acquiring the facility and all its installed instrumentation and equipment), operating the facility and enabling others to use the infrastructure once it has been established. Construction, operations and maintenance are typically funded through a Cooperative Agreement between NSF and the managing organization. Infrastructure utilization is typically supported through grants, funded by NSF through the R&RA and/or EHR accounts and/or other agencies, to individual researchers to conduct research and education activities at the facility.

Budgets for construction are part of a construction proposal, which is subjected to review by the PO in order to obtain additional expert judgment. The construction budget is the result of developing a project baseline, as discussed in Chapter II. Proposed budgets should also include details concerning contributions from other agency or international partners. As indicated in

[61] A cash-flow analysis compares the project's anticipated expenditure rate, plus the time-phased risk exposure associated with budgeted contingency, to the NSF's planned schedule for obligating funding. Projects typically perform optimally when they are "technically limited," i.e. the rate at which the project progresses is limited by technical considerations, rather than "financially limited," where a project's progress is limited by the availability of funding.

previous chapters, before proposals for construction can be considered, funds for the project should be appropriated by Congress and allocated by the NSF Director.

When funds from separate appropriations are obligated under a single award, the Cooperative Agreement will specify the account to which various expenditures are to be charged. Awardees are expected to adhere to those specifications; the PO and the Grants Officer ensure adherence. In the case of partnerships, the PO explores options for generating proposals and develops a proposal-generating document with the project partners. It is very important that potential partners understand the NSF process.

For projects to be funded through the R&RA and/or EHR accounts, the PO recommends the making of an award in accordance with the proposal processing procedures contained in Chapter VI of the PAM. The PO, together with staff from NSF's Division of Grants and Agreements (DGA), drafts the Cooperative Agreement that will govern the project in accordance with the procedures contained in Chapter VIII of the PAM. DGA makes the award once the Cooperative Agreement is executed.

Such awards are made to the submitting institution. For awards involving property, the PO consults with the Office of General Counsel, the Division of Financial Management and the DDLFP to determine whether the value of the property should be included on NSF's financial statements. The DDLFP coordinates with other BFA management divisions as required. In circumstances where there are multiple Awardees, the PO will nominate a coordinating Awardee. Alternatively, a single Awardee could make sub-awards. In that case, POs need to be aware that NSF loses "privity" – a legal relationship conferring the ability to intervene or deal directly with the sub-awardees. The Awardee is then responsible for ensuring performance of the sub-awardee scope of work.

**Budgets for Construction Awards:**

NSF utilizes internal staff, outside experts and consulting firms and NSF-conducted external expert reviews at the Preliminary Design and Final Design stage to ensure that proposed construction budgets have the following characteristics:

- Budgets are based on the approved cost, schedule and performance requirements defined in the project baseline.
- The budget contingency and scope contingency are adequate to mitigate anticipated risk factors defined in the project's risk analysis.
- Budgets include adequate funding for project management, including the use of appropriate project management tools such as project management control software and associated staff support.
- Where budget caps are imposed, there are sound strategies to de-scope the project or, alternatively, include a scope contingency[62] in the budget.

[62] Scope contingency refers to those project objectives of lesser importance within the overall project scope, which may optionally be eliminated, if necessary, in order to accomplish the primary objectives while remaining within budget and schedule constraints.

- Adequate funds are provided for system integration. Failure to address integration issues, including appropriate staffing and funding, can lead to serious cost overruns and corresponding schedule slips.
- Funding is included for commissioning, testing and acceptance of the facility and transition from construction/acquisition to operations. The budget should include 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.
- Where partnerships are involved, monetary contributions to construction and/or acquisition and eventual operations and usage are timely and sufficient.
- All IT costs – both initial cost and continuing costs of hardware, software, maintenance, upgrades and operations – are fully considered. Rapid advances in computing may require upgrades as often as every three to five years.

**Budgets for Operations Awards:**

It is incumbent on NSF to plan and budget for effective research and educational use of facilities, as well as the costs to operate the facility.

Given funding constraints, a proper balance should be struck between support for users of facilities and the facilities themselves. In many cases, such support extends to in-house users of the facilities. Funding is through the Directorate/Office R&RA or EHR account. When an NSF Directorate proposes a facility for MREFC funding, a commitment is made by that Directorate to provide adequate funding for the operation and utilization of the facility. Other sources of support may be provided through other agency awards or partner funding. Support for education/outreach may also come through EHR, if appropriate.

In order to prepare for the operations phase of a large facility or infrastructure project, it is essential to begin to establish, in the conceptual design stage, the level of funding needed for operations. The choice of technology may impact this funding level, and the project design should be optimized with operating cost as a key element. The PO provides “not-to-exceed” guidance on expected operating costs prior to the onset of preliminary design activities, and the proposer’s preliminary facility design should contain a substantive, reviewable estimate of expected operating costs that will be considered as one of the determining factors in advancing a project for construction funding. The estimate is regularly reevaluated during final design and construction activities to ensure that the expectations of NSF and the Awardee are aligned.

NSF staff should ensure that a plan is in place to make anticipated operating funds available by the final year of construction and/or acquisition. (In some cases, initial operation of a facility will overlap with completion of construction.) The plan should specify the sources of all NSF funds and any expectation to share costs between Directorates/Offices and with external partners. If there are partners, the plan should address the conditions under which advanced payments are appropriate, and how advanced payments will be accounted for.

Proper support of end users is essential to the efficient utilization of a facility. Accordingly, the PO may have to increase the end user’s budget or redirect support within a program to support new investigators. Planning for end-user support should be started in the Concept stage and continues until operations begin.

The PO should refer to the funding profile and cash-flow analysis developed earlier in making budgeting and funding decisions. Budgets should be carefully reviewed to ensure that the assumptions used to develop them remain valid and that the estimate is complete, appropriate and reasonable. Multiyear budgets should take inflation into account, using official factors published by the Office of Management and Budget each year (available from NSF's Budget Division) or other accepted methods. However, when NSF budgets are flat, NSF may not be able to afford inflationary increases in operations funding for facilities, and reductions in staff and/or operations may be required.

Salary costs are typically the most significant component of operating budgets. Categories typically include: professionals and technicians to operate and maintain the facility; IT specialists; administrative and grounds staff; environmental, health and safety specialists; machinists; designers, engineers and software experts to support users; engineers/scientists to conduct R&D for continuous improvement to the facility and related instrumentation; liaison staff to interface with the community; project management specialists for ongoing projects; financial and budget specialists; and staff to meet reporting requirements.

Budgets should also include careful consideration of key non-salary factors. 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. Planners should assess emerging IT technologies, such as grid computing, to ensure that the research community will have appropriate resources to make best use of the data and to assume leadership roles in the field. Initial IT capital costs and the cost of software development, including software support during operations, need to be carefully evaluated.[63] Furthermore, informed estimates regarding the small- and mid-scale instrumentation needs of the facility and users of the facility should be made.

**Education and Outreach during Operation:**

NSF's large facilities present exceptional opportunities for furthering science education at many levels: education and training of graduate students and postdoctoral researchers; research experiences for undergraduate students (REU programs); K-12 education; research experiences (RET programs) and in-service training for K-12 teachers; and informal science education for the community. Pursuit of these activities can also result in broadening participation in scientific training, research and science education by individuals from underrepresented groups, strengthening diversity of participation.

The PO should encourage the facility Director, well before the operations phase, to begin planning that leads to effective programs in these areas. Exceptional programs are often the result of synergistic partnerships among scientists, formal educators and the broader community. The PO should encourage such partnerships, and may be able to utilize NSF resources to facilitate their development in some circumstances. The PO may give direction to the facility that a small percentage of the annual operations budget (on the order of one to two

[63] While specific computing costs generally drop with time (Moore's Law), the data volume is increasing at least as fast, and greater and greater bandwidth is required for the transmission of data to remote users. As a result, the time frame for IT upgrades/turnover is typically three to four years.

percent) should be used to further educational outreach, or may request a separate proposal from the facility to fund these activities. Graduate training and funding of REU and RET programs are usually funded through separate NSF awards.

**Contingency budgeting during operations:**

In accordance with OMB Circular A-21: *Cost Principles for Universities* and OMB circular A-122: *Cost Principles for Non-profit Organizations*, contingency or "Director's Reserve" funds are not an allowed component of facility operations budgets. Operating budgets should include explicitly identified allowances for repairs, maintenance and other factors such as "technology refresh" for IT infrastructure. It is recommended that each project undertake a systematic program of *formal risk assessment* to identify the potential cost and operations impacts of non-recurring events, along with an assessment of their probability of occurrence, and include this information as part of the operating plan.

For example, a PO may 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.

Operating budgets should include, when appropriate, resources to provide a continuing program of advanced R&D that will enable a facility to evolve its scientific program and best meet the needs of the research community. 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 large NSF 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.

It is important that NSF identify and devise plans to address the specific issues that arise as part of the *termination and closeout* of a facility at the end of its scientifically competitive life. It is recommended that the PO develop a process for projecting the anticipated termination of the facility along with the costs and legal requirements of this action. For example, annual review of an evolving plan for the decommissioning and disposal of the facility assets and environmental obligations needs to be systematically considered as part of the facilities operations mission. This process should create and keep current a plan for the facility's termination and closeout, along with its associated budget liability. While not part of the annual budgeting process, this information informs the longer-term strategic planning at the NSF Division and Directorate levels.

## SYSTEM INTEGRATION, COMMISSIONING, TESTING AND ACCEPTANCE

System Integration, Commissioning, Testing and Acceptance are Awardee 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 Awardee is required to describe its plans for System Integration, Commissioning, Testing and Acceptance

in the PEP. The 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 Awardee will perform, and the data it will consider prior to accepting the facility or components of the facility and declaring it ready for Operations and Maintenance. In some cases, a phased approach to acceptance will be required. For example, for distributed-but-integrated facilities or for facilities with complex instrumentation and equipment, the PO will want the Awardee 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 relevant Division Director and AD/Office Head, will determine whether the Awardee 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 Transition Plan should be developed by the Awardee and incorporated into the PEP at least one year prior to the anticipated commencement of commissioning activities. Elements of the Transition Plan 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 DDLFP.[64] The review of the Transition Plan considers 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 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 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?

[64] Optional for projects not constructed with MREFC funds.

- Do the budgets reflect a proper allocation between construction/acquisition and operations?

For projects funded through the MREFC account, even if limited operations are undertaken, the changeover from MREFC funding to R&RA and/or EHR funding does not have to occur until the facility has been accepted and the PO ensures that the budget is estimated accordingly. Where R&RA and/or EHR 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.

## PREPARATION OF PROPOSALS FOR OPERATIONS AND MAINTENANCE

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. POs 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 Awardee 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 three to five 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; and
- A detailed management plan for operations of the facility, including the roles of key staff and plans for advisory committees.

The review of the proposal includes a realistic assessment of the costs to operate and maintain the facility in a safe and effective manner, consistent with NSF's Government Performance and Results Act (GPRA) goals for facilities. The PO is also responsible for oversight of operational facilities through the various reviews and reports described in the IMP. In addition to following the procedures referenced as appropriate to Chapters V and VI of the 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 there an appropriate balance between in-house research and research of external users?
- Are safety (including IT security and security of the physical plant), environmental and health issues, if any, addressed?
- Are plans for securing human subjects clearances included, if applicable (e.g., assessments of education-related activities)?

- Have all costs been considered and estimated and is the available funding sufficient, or is some adjustment needed?

Throughout the operational stage, the Awardee operates and maintains the facility in accordance with the terms and conditions outlined in the Cooperative Agreement. The PO, together with the DGA or the Division of Acquisition and Cooperative Support (DACS), drafts the Cooperative Agreement that will govern the operational phase of the project in accordance with the procedures contained in Chapter VIII of the PAM. The Cooperative Agreement 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.

## PROCEDURES FOR RENEWAL OR TERMINATION OF AN OPERATING LARGE FACILITY

At least two years prior to the expiration of an award for operations of a facility,[65] the 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 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 and AD/Office Head, will prepare a plan for either upgrading the facility's capabilities or terminating support.

If the reviews show that the facility remains a high priority and has been successful in meeting its goals and objectives, the Originating Organization considers whether renewal of the operating agreement with the Awardee institution, or recompetition, is in the best interests of NSF and the affected community.[66]

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. In the event that a decision is made to recompete or to terminate support for a facility, the PO will give the

[65] The PO should use his or her judgment and consider the complexity of the facility in determining whether to begin the review process earlier.

[66] In deciding whether to renew or recompete, the PO should consider that the National Science Board has expressed its preference for recompeting all awards periodically. 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. Federally Funded Research and Development Centers (FFRDCs) cannot be renewed or terminated until a comprehensive review is performed. The review should meet the requirements 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, 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.

incumbent Awardee as much notice as possible, but not less than one year, so that all necessary arrangements to transfer (in the case of unsuccessful recompetition) or terminate obligations to vendors and employees can be planned and implemented.

The PO analyzes the costs and benefits of the facility, taking into consideration the following issues:

- How much does the community need the facility, and is the community strong and actively engaged in utilizing it?
- Is the facility meeting the research and education goals and objectives originally proposed?
- Will meeting the goals and objectives place the United States in a leading position within the research areas served by the facility?
- Is the facility a high priority of the field, as established by long-range planning?
- Is the facility operating in an efficient and cost-effective manner, or are there alternative, more efficient and cost-effective ways to meet the need?
- What research opportunities and education opportunities elsewhere are being lost by continued support of this facility?
- The extent to which the facility has been reaching its annual performance goals and the reasons for not meeting goals.

The PO analyzes what can and what needs to be done in light of the available funding, and considers the following options:

- 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 termination; or
- Terminate NSF support.

In the case of a recompetition, a renewal proposal is received from the Awardee institution, and possibly 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 DRB and NSB award approval apply.[67]

## DOCUMENTATION REQUIREMENTS

The Awardee 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. Awardee 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

[67] Refer to the footnote in Chapter III on award thresholds requiring DRB and NSB approval.

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.

Awardees should retain financial records, supporting documents, statistical records and other records pertinent to a grant 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 and the Comptroller General of the United States or any of their duly authorized representatives to make audits, examinations, excerpts and transcripts.

The documentation required, and the responsibility for producing and maintaining it, varies within the facility life cycle. During Development, the 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 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 jackets in the NSF-required format, the IMP, the Baseline Project Definition (typically defined in the PEP), the record of oversight (including all reviews and reports) and significant project correspondence.

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

- Memoranda of Understanding 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 log;
- Change requests and approvals; and
- System integration, commissioning, testing and acceptance plans and results.

During Operations & Maintenance, the Awardee documents facility performance in terms of

(1) 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 down time, and
(2) 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).

## REQUIREMENTS FOR OVERSIGHT, REVIEWS AND REPORTING

Oversight, reviews and reporting requirements change as a facility moves through its life cycle and differ substantially between the Construction and Operations Stages. The Awardee is responsible for complying with the reporting requirements contained in the Cooperative

Agreement, e.g., technical and financial reporting, GPRA reporting and final reporting and closeout requirements for termination of the award. The Awardee is also responsible for providing internal oversight of its own activities. This may require internal reporting and reviews by committees established by the Awardee institution for the purpose of oversight.[68]

Reviews and reporting are an important part of the oversight process that allows the PO to monitor performance and compliance with project goals. Due to the complex nature of facilities, the level of oversight will be considerably greater than for a typical NSF research grant. The PO has continuous responsibility for oversight of the facility in accordance with the IMP and through various reviews and reports, such as consultation and coordination with the DDLFP, consultation with the Facilities panel, and periodic updates to the MREFC Panel (if applicable) and 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 Awardee'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 Awardee in the Cooperative Agreement and these requirements should be noted as milestones on the project master schedule for construction. The Project Director adheres to the Awardee's institutional practices regarding financial and business operations controls,[69] 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.

**Frequency and Content of Reports:**

Reports are generally provided on a monthly and/or quarterly basis, with a comprehensive annual report provided by a predetermined date. Some projects, particularly those with construction activities or frequent changes in design, will need more frequent reporting intervals. During the Construction Stage, the Project Director, who is responsible for executing and controlling the project in accordance with the PEP and the Cooperative Agreement, reports to the PO on a periodic basis (monthly for MREFC-funded projects and no less than quarterly in other cases). Those reports should include the following:

- Summary of financial and technical status – work accomplished during the reporting period, including major scientific and/or technical accomplishments and milestones achieved;
- Comparison of actual cost and schedule to planned cost and schedule, using EVMS methodology;
- Review of current or anticipated problem areas and corrective actions;

[68] See also, the Reporting Requirements section in Chapter V for more detail on reporting requirements, and Guidelines for Planning External Reviews of NSF's Large Facilities for a description of best practices.
[69] See "Guidelines for Conducting Total Business Systems Reviews of NSF's Large Facilities" in Chapter V.

- Management information such as changes in key personnel, subcontracts and subcontractor performance, and any other information about which the PO needs to be aware; and
- Concerns, upcoming milestones or project deliverables.

For MREFC projects in the Construction Stage, the PO is responsible for providing the DDLFP a monthly written summary of this information. The DDLFP provides the information to NSF's Chief Financial Officer, and the Office of the Director. Smaller-scale projects that are not funded through the MREFC account will provide status reports to the PO with a frequency and level of detail defined in their respective IMPs. In every case, the PO is responsible for keeping the appropriate NSF staff (Grants and Agreements or Contracting Officer, Division Director, AD, PAT members, etc.) informed of the project status.

In executing and controlling the project, the Awardee manages the project to the Baseline Project Definition and cost and schedule. The Awardee will notify the PO of cost and schedule variances on a periodic basis (monthly, quarterly or annually, depending upon the project's cost, schedule and complexity).

Negative variances exceeding 10 percent should be accompanied by an explanation and a proposed plan for recovery or accommodation of the cost and schedule shortfalls (e.g., use of contingency, de-scope). If maintaining the baseline is not possible, the Awardee 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 also request approval, via a memo to the Division Director and AD/Office Head, prior to authorizing re-baselining a project. This activity may require notification to the MREFC Panel (if applicable), the Director, NSB, OMB and Congress.[70] 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 of the latter 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, weather, etc.

If additional funds or time will be requested, the review and approval process followed during pre-construction planning is repeated. Once a re-baselined Project Definition has been approved, 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 baseline has been implemented by the project management and accepted by NSF.

Use of contingency is an appropriate means to deal with project uncertainties during construction. When computing cost and schedule variances, one should compare earned value to planned value. However, when a task costs more than expected and contingency funds are needed to complete the task, the original planned value is adjusted by the addition of the

[70] See the section on Financial Management in Chapter V for more detail regarding the process involved.

contingency funds used. The adjusted planned value is then used to compute variances. This adjustment ensures that projects are not "penalized" in financial status reporting for utilizing contingency. Adjustments may also be necessary to account for approved change orders that affect the project's cost or schedule.

**Reviewing Awardee Performance:**

The Awardee is expected to provide appropriate internal oversight of its own activities and is expected to comply with the reporting requirements contained in the Cooperative Agreement (e.g., technical and financial reporting, and final reporting and closeout requirements for termination of the award). In addition, reviews and reporting are an important part of the oversight process that allows the PO to monitor performance and compliance with project goals.

Through the terms and conditions of the Cooperative Agreement, the PO requires the Awardee to participate in periodic external reviews that advise NSF on the status and anticipated future performance of the project. Each year NSF will conduct an Operations Review of the facility, or participate in an activity with the equivalent purpose, to evaluate progress and provide feedback. These reviews should determine the extent to which the facility is meeting the goals of their Annual Plan, discuss any upcoming challenges for operations and highlight best practices that could be applied to other large NSF facilities. Whenever possible, the review should be conducted at the facility itself by an external panel with expertise in the operations of large scientific facilities. The panel should produce a formal written report. The review is organized and conducted by the NSF PO in consultation with the DDLFP. Both the review committee membership and the charge to the committee require concurrence from the NSF PO and DDLFP. Invitees to the review shall include the Program Officer, the cognizant Business Officer and staff from the Large Facilities Office. Following the review, the DDFLP will produce an independent assessment of the review for the NSF Chief Financial Officer. The Operations Review is not meant to compete with the Business System Review (BSR) which looks at business processes.

The Business Systems Review (BSR) is one of NSF's advanced monitoring activities designed to provide oversight of the suite of business systems (people, processes, and technologies) that support the administrative management of a large facility. The Large Facilities Office (LFO) within the NSF's Office of Budget, Finance, and Award Management (BFA), 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.

The BSR is designed to provide reasonable assurance that business systems are capable of supporting the administrative infrastructure required for a large facility. Specifically, a BSR verifies that administrative and financial policies and procedures are written; determines if these policies and procedures conform to OMB requirements, NSF expectations, and other applicable federal regulations; and if they are used to administratively manage the large facility in each of the core functional areas.

Whenever possible, BSRs should be conducted on a five year cycle that places the BSR in the first or second year of each project period. However, BSRs might be considered more frequently based on a number of factors:

- Significant changes in funding levels, management, scope, or mission of the large facility;
- Transition in the large facility's life-cycle stage (from construction to facility operations and maintenance)

Further information and various details of the BSR process are provided in the BSR Guide.

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

The PO will typically use a standard review "template." (See Chapter V below – Guidelines for Planning and Executing External Reviews of NSF's Large Facilities.) These well-defined review formats provide a broad outline against which the project can be compared and checklists that can be used to assess the status of the project. These reviews can be particularly helpful in the pre-award phase in ensuring that the project is ready to be implemented. Exceptional circumstances may arise that necessitate some alternate format. In this case, the PO consults with the PAT to constitute a review charge and format tailored to meet the specific requirements of the review.

**Government Performance and Results Act (GPRA):**

In accordance with legislative and OMB requirements, NSF developed goals to measure construction/upgrade and operations performance. Information related to these goals is collected from Awardees via the "Performance Data Reports" module of the FastLane Project Reports system. Performance reports are currently required from all NSF-supported facilities undergoing construction/upgrade that incur total costs in excess of $5 million, and from facilities that receive more than $8 million per year in operations support. Each year, NSF uses the lessons learned from previous years to determine whether its facilities goals need to be refined. For example, the following performance goals were in effect for FY 2006 GPRA reporting:

| Activity | Performance Goal |
|---|---|
| CONSTRUCTION/UPGRADE | For 90% of completed construction, acquisition and upgrade projects, keep any negative cost and schedule variances to less than 10% of the approved project plan. |
| OPERATIONS | For 90% of operational facilities, keep scheduled operating time lost to less than 10%. |

## PARTNERSHIPS

For both MREFC and smaller projects, partnerships are an essential consideration – beginning at project inception. Partnerships may take many forms, but typically include coordinated funding from states or state institutions, other federal agencies, 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 PO needs 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 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 and the facility is to be operated. It is also important to know how agencies 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 contingency plans developed regarding potential changes in commitment. Finally, early negotiation also provides 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 NSF Office of International Science and Engineering should be advised of potential international partnerships early in the process and kept apprised of significant developments. That Office can facilitate coordination with the Department of State and the White House Office of Science and Technology Policy on foreign policy and geopolitical issues, advise on interactions between NSF and counterpart funding organizations in other countries, and provide information/contacts on matters such as visa issues for project participants and cost issues related to assessment of import duties on internationally shipped items.

**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. Memoranda of Understanding (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.

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 policy. (Note that 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, Chapter V - Risk Assessment and Management).
- 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.

**Memorandum of Understanding (MOU):**

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 PAM.

# V. Special Topics and Supplementary Materials

This chapter contains directions to extensive supplementary information on special topics having to do with NSF's role in planning and oversight of large facility projects. The hyperlinked sections contain important explanatory and procedural information. (Where no hyperlink is provided, the material is currently in preparation.) The materials are presented in a tutorial format to be of particular benefit to individuals newly involved with large facility projects.

The materials provided here are revisions to existing modules that appear on the Large Facility Projects pages of NSF's internal Web site. These modules are being revised to make them consistent with the newly released "Guidelines for Planning and Managing the Major Research Equipment and Facilities Construction Account" (Chapter II of this document), and also consistent with the material in Chapter III. As the revision of each module is completed, the hyperlink to it will be updated to make that material available outside NSF.

## ROLES AND RESPONSIBILITIES OF NSF STAFF INVOLVED IN THE MANAGEMENT AND OVERSIGHT OF LARGE FACILITIES

The roles and respective responsibilities of all NSF staff, and the Awardee Institution, are discussed in detail and by life-cycle stage. This document provides specific guidance and suggestions, elaborating on the concepts in Chapters I-IV above. It includes a detailed explanation of the primary role of the PO (also variously referred to within NSF as the "Program Manager" or "Program Director"). This module also elaborates on the roles of other individuals – such as the Grants Officer, PAT, Business Oversight Team and DDLFP – who support and work with the PO throughout the life cycle of a large facility project. As a supporting module to the rest of the Manual, the intent of this document is to avoid replication of information already provided there while adding context and breadth.

## RISK MANAGEMENT GUIDE

Risk management is concerned with future events whose exact outcomes are unknown, and how to deal with a range of possible outcomes. In general, outcomes are categorized as favorable or unfavorable, and risk management is the art and science of planning, assessing and handling future events to maximize favorable outcomes. The alternative to risk management is crisis management, a resource-intensive process that is normally constrained by a restricted set of available options.

The objective of this document is to provide an overview of the subject of project risk management from an NSF perspective. It is not intended to be a comprehensive discussion of the subject. Additional sources of information on Risk Management are included in Appendix A of the Risk Management Guide. Briefly, the objectives of this document are:

- To provide an overview of the risk-management process from an NSF perspective;
- To explain the responsibilities of NSF POs in the area of risk management;
- To enable the PO to understand how and when risk assessment should be performed and when a Risk Management Plan should be written and what it should address; and

- To help the PO understand the benefits of risk management and its importance in ensuring project success.

## DEFINITION AND USE OF CONTINGENCY RESOURCES IN NSF FACILITY CONSTRUCTION

Contingency generally falls into three categories: budget contingency, schedule contingency and scope contingency. This module defines the circumstances under which contingency planning and budget should be undertaken and the method by which contingency funds should be allocated, consistent with OMB regulations and sound project management principles.

## GUIDELINES FOR DEVELOPMENT OF PROJECT EXECUTION PLANS FOR LARGE FACILITIES

This module provides an overview of NSF's expectations about PEPs for POs, Grants and Agreements Officers and others involved in overseeing a large facility project and assessing the project management plans of an Awardee. These plans are usually provided, at least in preliminary fashion, as part of the proposal for construction of a large project. This plan can be fine-tuned during the period following approval of the award and prior to undertaking construction activities, through interactions between the Awardee, the NSF PO and the Grants and Agreements Officer that define NSF's expectations.

## GUIDELINES FOR DEVELOPMENT OF INTERNAL MANAGEMENT PLANS FOR LARGE FACILITIES

This module provides guidance to the PO on topics to be included in an IMP grouped by life-cycle stage. The IMP is the primary document that describes how NSF will oversee development, construction, operation and eventually termination of support for a major facility. The requirement to develop an IMP is described in Chapter II and Chapter III for MREFC and non-MREFC projects respectively. Two primary purposes are served by development of an IMP:

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

## GUIDELINES FOR IT SECURITY OF NSF'S LARGE FACILITIES

NSF has responsibility for oversight of facilities it constructs and operates, including associated IT Infrastructure. This module describes what NSF considers to be a fundamental set of IT security requirements that facilities should consider in developing and deploying their IT plans, policies and procedures. These minimal requirements and their associated evaluation criteria, as provided by the facility and agreed to by NSF, are used as part of NSF's facility oversight and review process. This module documents NSF's expectation for the awardee and PO oversight for the implementation and monitoring of cyber security best practices. These expectations

extend over the full life cycle of an award, and are appropriately modified as the award passes through various stages of its life cycle.

## GUIDELINES FOR PLANNING AND EXECUTING EXTERNAL REVIEWS OF NSF'S LARGE FACILITIES

This module describes the process for evaluation and review of all NSF large facility projects proposed for construction, under construction or currently in operation. This document provides assistance to the 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 contains 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 large facility project is provided as an aid to the PO or associated staff who may be unfamiliar with these processes or need a reference source on best practices.

The evaluation and reviews include assessment of management, schedules and budgets, as well as other matters relevant to a large facility project, such as scrutiny of the project baseline for construction activity. It does *not* address the intellectual merit or broader impact criteria used to select the project for support, but rather focuses on evaluation of the Awardee's planning and implementation activities.

## ENVIRONMENTAL CONSIDERATIONS IN LARGE FACILITY PLANNING

Awareness of, and strict adherence to, all relevant environmental regulations are extremely important considerations in the planning, construction and operation of facilities. This module provides guidance to POs in dealing with environmental regulations that are often encountered in planning and budgeting for new facility construction. This material contains extensive introductory information about general issues. POs are encouraged to contact OGC for project-specific guidance.

## TIMELINE FOR PLANNING AND MANAGING THE MREFC ACCOUNT

This module defines 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 module explains key features of that process that are of particular interest to those involved with MREFC projects.

## GUIDELINES FOR REPORTING REQUIREMENTS

This module summarizes the reporting requirements NSF typically imposes on a project during construction and operation. This information is provided so that proposing organizations and POs can assess the project-specific needs that should be addressed and appropriately budget so that these requirements can be satisfactorily accomplished.

## GUIDELINES FOR FINANCIAL MANAGEMENT

This module describes the NSF requirements for financial status reporting, including a detailed explanation of the processes and internal software NSF uses to track and report obligations of funding, by life-cycle stage, so that the total project cost for a facility can be tracked. A detailed explanation of earned value management reporting is also provided.

## GUIDELINES FOR CONDUCTING TOTAL BUSINESS SYSTEMS REVIEWS OF NSF'S LARGE FACILITIES

The purpose of this document is to define and establish the procedures for the planning, execution and follow-up activities associated with conducting Total Business Systems Reviews (TBSRs). The TBSR is designed to provide guidance to Awardees as well as NSF administrators in determining and employing best business practices by the Awardee Institution. These reviews are intended to ensure that the business systems of NSF awardees are effective in meeting administrative responsibilities as well as satisfying other federal requirements. The TBSR itself is a versatile assessment vehicle by which NSF can evaluate the "health" of its awardees' business systems.

The reviews are also intended to provide an opportunity for cross-fertilization of ideas through the identification of best practices, and serve to refocus awardees on the importance of administrative quality. This module also defines the roles and responsibilities of NSF staff assigned to TBSR activities and identifies core and targeted review areas.

## GUIDELINES FOR USE OF OMB INFLATORS IN PLANNING CONSTRUCTION OF LARGE FACILITY PROJECTS

In agreement with OMB, NSF has identified inflation factors for large facility projects for both the construction/acquisition phase and the operations phase. OMB provides this information to NSF approximately twice a year. This document provides hyperlinks to that information and instructions for its use in budget planning.

## GUIDELINES FOR OPERATIONS

This document provides guidelines conducting oversight of the operational phase of NSF's large facilities. It elaborates on the principles outlined in the large facilities manual, and offers additional information and examples that should be especially helpful to individuals newly involved in operational oversight.

# VI. Appendices

### Appendix 1 - NSF ROLES AND RESPONSIBILITIES

The following NSF officers and organizations are involved throughout the conception, development and implementation of an MREFC project:

**NSF Program Officer (PO)** – exercises primary oversight responsibility within NSF for all aspects of the project. The PO facilitates community development of research proposals for large facility projects. The PO also organizes external reviews of developmental research, writes and implements the IMP for oversight and financial support of a candidate facility project, and oversees facility construction, commissioning and operation. The National Science Foundation Authorization Act of 2002 *[Public Law 107-368, Section 14(c)]* restricts the choice of POs overseeing MREFC-funded activities to permanent NSF employees (i.e. individuals whose appointments are not temporary).

**Assistant Director (or Office Head) of the Originating 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, and authorizes the PO to proceed with organizing the development and external review of a PDP and with updating the IMP to explain how NSF will oversee and fund further development. The AD reviews and approves the IMP prior to its submission to the Facilities Panel. The AD determines whether to propose a project to the MREFC Panel as a candidate for future construction funding, based on the project's relative scientific importance and on the Originating 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 OD and NSB as appropriate.

**Deputy Director for Large Facility Projects (DDLFP)** – scrutinizes management aspects of large facility projects to assure the NSF Director and Chief Financial Officer that proposed projects are well planned, and that projects selected for construction are properly scoped and managed during construction and operation. The DDLFP works with the PO to plan, carry out and assess the results from external reviews of the project and assists the PO on all project management issues. In close collaboration with NSF senior management, the DDLFP also leads the development and implementation of policies, guidelines and procedures for the oversight of large facility projects.

**Project Advisory Team (PAT) –** assists the PO in the planning, review and management of the MREFC project. The PAT advises and assists the PO in creating and updating the IMP, planning and assessing internal reviews, and providing counsel on all aspects of the project as requested. The team should be composed of experts who are familiar with the technical, management, legal, legislative and administrative issues associated with various types of infrastructure projects. This team should meet regularly to review the status of the project.

**Contracting Officer/Agreements Officer –** has authority, subject to statutory limitations, to award and administer cooperative agreements and/or contracts. As a member of the PAT, this NSF officer participates in management reviews, risk assessment and issues management. Plans and coordinates development of award documents from early planning stages through award administration and closeout. The officer negotiates terms and conditions, interprets NSF policy, reviews business proposals and budgets, significant sub-awards, MOUs and partnership agreements. The officer also monitors awards for compliance with the most current NSF financial and administrative policies and procedures.

**Originating Organization(s)** – are NSF Directorates or Offices, and by extension their Divisions or Sections, that propose projects for funding through the MREFC Account or other sources. The Divisions have primary responsibility for overseeing planning, review, oversight and funding of Large Facilities. Their responsibilities include 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.

**Facilities Panel** – reviews and provides feedback on the initial IMP for each MREFC project or large facility project (as requested), as well as subsequent IMP revisions. The panel provides written comments to the Originating Organization and may share the comments with the MREFC Panel and/or the Office of the Director. The role of the Facilities Panel is primarily advisory. The Facilities Panel is chaired by the DDLFP. The other members of the panel are typically three experienced business operations personnel and three experienced programmatic personnel, all of whom have prior experience in the technical and administrative aspects of large project oversight. The Facilities Panel also provides preliminary review of the materials submitted to the MREFC Panel, DRB and NSB when requested.

**MREFC Panel** – provides governance of the overall MREFC process and reviews specific cases as presented by the Originating Organization(s). The Panel consists of the NSF Deputy Director (Chair), the ADs, Program Office Heads, the Chief Financial Officer, and in non-voting capacity the DDLFP, the General Counsel, and the Directors of the Office of International Science and Engineering, Office of Legislative and Public Affairs, and the Office of Institutional Resource Management.

**Director's Review Board (DRB) –** reviews and approves the documentation associated with all projects proposed to the NSB for funding, including MREFC projects. The DRB is composed of the NSF Deputy Director, three Assistant Directors/Office Heads serving on a rotating basis, the Chief Financial Officer, a representative from the OGC, a staff advisor from the Office of the Director and a DRB Executive Secretary.

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

**National Science Board (NSB) –** establishes policy, reviews and approves MREFC Account budgets, and reviews and approves specific MREFC projects for funding. NSB is an independent body established by Congress in 1950 to establish policies for NSF. Within NSB, the Committee on Programs and Plans (CPP) oversees NSF program initiatives and major new projects and facilities. The NSB sets the priority order of projects recommended for construction.

## Appendix 2 - RANKING CRITERIA FOR PRIORITIZING MREFC PROJECTS

First Ranking: Scientific and Technical Criteria Assessed by Researchers in a Field or Interdisciplinary Area (e.g., at the NSF Division level)

- 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 (e.g., at the NSF Directorate level)

- 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 (e.g., at the overall NSF level)

- 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?
- 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?

## Appendix 3 - PROJECT MANAGEMENT COMPONENTS OF A CONSTRUCTION-READY PROJECT EXECUTION PLAN

Essential components of a construction-ready Project Execution Plan, common to most plans for construction of large facilities, are listed below, as an example of the extensive nature of the pre-construction planning that should be conducted prior to expending MREFC funds to execute the project. Additions or alterations to this list are likely, due to the unique nature of each specific 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 well defined.

- Description of the research objectives motivating the facility proposal
- Comprehensive statement of the 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;
- Description of the infrastructure necessary to obtain the research objectives
- Work breakdown structure (WBS)
- Work breakdown structure dictionary defining scope of WBS elements
- Project budget, by WBS element
- Description of the basis of estimate for budget components
- Project risk analysis and description analysis methodology
- Contingency budget and description of method for calculating contingency
- Project schedule (and eventually a resource-loaded schedule)
- Organizational structure
- Plans and commitments for interagency and international partnerships
- Acquisition plans, sub-awards and subcontracting strategy
- Project technical and financial status reporting, function of the PMCS, and description of financial and business controls
- Project governance
- Configuration control plans
- Contingency management
- Internal and institutional oversight plans, advisory committees, and plans for building and maintaining effective relationships with the broader research community that will eventually utilize the facility to conduct research
- Quality control and quality assurance plans
- Environmental plans, permitting and assessment
- Safety and health issues
- Systems engineering requirements
- Systems integration, testing, acceptance, commissioning and operational readiness criteria
- Plans for transitioning to operational status
- Estimates of operational cost for the facility

## Appendix 4 - NSF *FACILITY PLAN*

The NSF *Facility Plan* – updated annually and made public – serves as valuable planning tool within and outside NSF. It also provides a comprehensive exposition of needs and plans to inform decision-making in the Executive Branch and Congress, and serves as an important vehicle for communicating with research communities.

The first section of the *Facility Plan* provides an extensive discussion of the frontier research objectives and opportunities that provide the context and compelling need for major facilities. The contents of this section derive from workshops, advisory committees, NRC reports, expertise of visiting and permanent scientific staff, and unsolicited proposals from the community. The *Plan's* second section provides annual updates on the status and progress of each MREFC project and candidate project. It also maps these projects against the objectives and opportunities contained in the first section. In particular, this section addresses:

*Preliminary Design/Readiness Stage Projects:* Projects in various stages of readiness, including those that will be ready to go the NSB for approval within approximately the next year, and those that the MREFC panel has recommended for advancement to the *Preliminary Design/Readiness Stage*.

*NSB Approved Projects:* Projects that the NSB has approved for funding in a future budget request.

*Possible New Starts:* Facilities for which initial MREFC funding is requested in NSF's annual budget request.

*Ongoing MREFC Projects*: Facilities already in operation or under construction.

In addition to providing regular status reports, the *Facility Plan* reflects the Administration's priorities for new start projects, NSB priorities for NSB-approved projects, and the NSF Director's priorities for projects in the *Preliminary Design/Readiness Stage*. Ongoing MREFC projects are always given the highest budget priority.

Every year new science and engineering opportunities arise and new priorities assert themselves. As a result, no roster or ranking of potential MREFC projects is ever final. Responsible stewardship of public funds demands that all candidate efforts be evaluated and reevaluated constantly in the context of the latest, most pressing research goals and the most profoundly important unanswered questions.

It is the responsibility of the MREFC Panel to develop and maintain the *Facility Plan*. The plan is approved by the Director and submitted to the NSB in March.

## Appendix 5 – OTHER DOCUMENTATION RELEVANT TO REVIEW OF MREFC PROJECTS

For MREFC Projects requesting NSB approval (for inclusion in a future budget request):

In addition to the NSF Form 10 (for clearance) and the AD/Office Head endorsement(s), two items should be prepared and clearly marked as "pre-decisional – Do Not Distribute."

(1) A Director's Memorandum to Members of the NSB, briefly summarizing the project, the need for the project and a cost estimate. The Director's Memorandum should include the following statement:

"With the Board's concurrence that this project is meritorious and that its planning is sufficiently advanced, the Director will take appropriate action in preparation of a budget request. Board approval of this project for planning purposes does not imply NSB approval of project implementation. Any such approval will be requested from the NSB at the appropriate time."

The Director's Memorandum should conclude with the following resolution:

"RESOLVED, that the National Science Board concurs that planning for the <project title> is sufficiently advanced, and the intellectual value of the project sufficiently well demonstrated, to justify consideration by the Director and the Board for funding in the FY 20XX or a future NSF budget request."

(2) A project report (usually six to eight pages) providing an update of the documentation provided to the MREFC Panel.

For NSB approval of MREFC project implementation:

Before project construction can be initiated, project implementation approval should be granted by the NSB. First, the Director should prepare a *Memorandum for NSB Action*[71]. The Director's memorandum to the NSB should summarize information and issues related to the proposed implementation of the project, potential policy issues/implications, precedents involved, prior NSB discussion and any other factors that could be considered non-routine.

It should normally contain: a brief science/engineering overview; a description of connections to any national and international programs; a description of the project; a summary of the review process and a short statement of response to any major concerns raised by reviewers; a schedule; budget totals including consideration of contingencies; the impact that technological advances would have on the project during construction; the percentage of program or division budgets that the proposed award represents and out-year implications; and a description of plans for project management.

[71] See PAM VI.H.3.b.

The Memorandum should also include a statement regarding plans for the end of the award period, consistent with the policies set forth in NSB-97-216, "NSB Statement on Competition and Renewal of NSF Awards" and the accompanying Resolution passed by the NSB at its meeting of November 13, 1997. The Memorandum should conclude with the following resolution:

"RESOLVED, that the National Science Board authorizes the Director at his/her discretion to make an award for implementation of < Title > to < Institution or Entity > in an amount not to exceed $XXX, XXX, XXX for XX months."[72]

For Project Management Documentation:

In addition to the other required materials (described in PAM VI.H.3.b.), MREFC project implementation approvals should include a PEP and IMP, as detailed in Appendices B and C. Other documentation that may be relevant to preparation of MREFC projects is included in Appendix D.

For procurements:

*Federal Acquisition Regulations*. Staff should consult with the Contracts Branch of the Division of Acquisition and Cooperative Support when considering issuing a Request for Proposals (RFP). Note that NSB approval is required for all programmatic RFPs that will result in contracts that meet the NSB review threshold.

For program design:

*Activity Design, Review and Management Protocol* (O/D 93-02; January 5, 1993). This design and review protocol covers newly proposed funding activities and applies to any proposed programmatic activity that has budget or management impact. It is designed to apply more generically to the initiation of new programmatic research thrusts, especially those new "programs" that require National Science Board review and approval.

For Environmental Assessment (EA) or Environmental Impact Statement (EIS):

*Proposal and Award Manual*, Chapter VIII, section 800 – Environmental Impact Statements. This section of the PAM describes the policy and procedures applicable to NSF actions requiring the preparation of an Environmental Impact Statement in accordance with the National Environmental Policy Act.

[72] The resolution should be modified if there are any special conditions (e.g. "pending congressional approval" or "pending the availability of funds.")

# VII. REFERENCES

*Science and Engineering Infrastructure Report for the 21st Century -The Role of the National Science Foundation*, February 8, 2003. NSB-02-190; http://www.nsf.gov/nsb/documents/2002/nsb02190/nsb02190.pdf

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

*Setting Priorities for Large Research Facility Projects Supported by the National Science Foundation*, a 2004 National Academies report, http://books.nap.edu/catalog/10895.html.

NSF Government Performance and Results Act (GPRA) *Strategic Plan* contains the basic rationale for all NSF support. http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf0648

*Grant Policy Manual* http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpm

*General Conditions for Grants* http://www.nsf.gov/pubs/2001/gc101/gc101rev1.pdf

*Director's Review Board Procedures* (O/D 97-07; June 10, 1997): O/D 97-07 sets forth the function of the Director's Review Board (DRB) and establishes procedures to be followed for items requiring DRB review. As part of its responsibilities, the DRB reviews actions and information items prepared for the National Science Board (NSB) and items to be considered for delegation of authority by the Director.

*Proposal and Award Manual*, available on NSF's internal website at: http://www.inside.nsf.gov/pubs/pam/pam805/11.htm, is a compendium of internal policies and procedures related to the proposal and award process. Chapter III, section 300-Program and Award Recommendations and Information Items to the National Science Board: This section of the PAM sets forth the policy and procedures governing the preparation and review of action and information items for the National Science Board and the DRB.

*Proposal and Award Manual*, in turn, supplements guidelines relevant to grants and other assistance agreements; e.g., the *Grant Proposal Guide,* available at: http://www.nsf.gov/pubs/2003/nsf03041/start.htm.

## VIII. List of Acronyms

| | |
|---|---|
| AC | Actual Cost |
| CDR | Conceptual Design Review |
| CFO | Chief Financial Officer |
| DDLFP | Deputy Director for Large Facility Projects |
| DRB | Director's Review Board |
| EHR | Education and Human Resources |
| EV | Earned Value |
| EVMS | Earned Value Management System |
| FDR | Final Design Review |
| FFRDC | Federally Funded Research and Development Center |
| G7 | Group of Seven leading individual nations – Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States |
| G8 | Group of Eight leading individual nations – Canada, France, Germany, Italy, Japan, the United Kingdom, the United States and the Russian Federation |
| GPG | Grant Proposal Guide |
| GPRA | Government Performance and Results Act |
| IMP | Internal Management Plan |
| IT | Information Technology |
| IUPAP | International Union of Pure and Applied Physics |
| MOU | Memorandum of Understanding |
| MREFC | Major Research Equipment and Facility Construction |
| NAR | Non-Advocate Review |
| NRC | National Research Council |
| NSB | National Science Board |
| NSF | National Science Foundation |
| OAS | Organization of American States |
| OCED | Organization of Economic Cooperation and Development |
| OMB | Office of Management and Budget |
| OSTP | Office of Science and Technology Policy |
| PAM | Proposal and Award Manual |
| PAT | Project Advisory Team |
| PDP | Project Development Plan |
| PDR | Preliminary Design Review |
| PEP | Project Execution Plan |
| PO | Project Officer |
| PV | Planned Value |
| R&D | Research and Development |
| R&RA | Research and Related Activities |
| RFP | Request for Proposals |
| S&E | Science and Engineering |
| SBIR | Small Business Innovative Research |
| SRS | Science Resource Statistics |
| TPC | Total Project Cost |
| WBS | Work Breakdown Structure |