National Science Foundation

WHERE DISCOVERIES BEGIN

LARGE FACILITIES MANUAL

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

NSF 15-xxx

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SUMMARY OF SIGNIFICANT CHANGES

The purpose of this revision is to update the material and to improve the clarity and legibility of the manual for the targeted audience of users both inside and outside NSF.

1. Existing content was re-organized into logical units that follow the stages of a facility's life cycle. Several new placeholder sections were created, with the expectation that content will be provided in future revisions of this document.
2. The format of the re-organized content was changed to outline style, with some additional section headings provided and some previous headings re-named for clarity and ease of use.
3. The material in Section 3 on managing non-MREFC funded projects and facilities was incorporated into Section 2, and Section 3 now covers the various plans required for management throughout the Major Research Equipment and Facilities Construction (MREFC) life-cycle stages.
4. Roles and Responsibilities in Section 2.1.6 were revised to include the replacement of the Program Advisory Team (PAT) and Business Oversight Team (BOT) with the Integrated Project Team (IPT) and the Facility Panel with the Large Facilities Working Group (LFWG). Definitions for the Director's Review Board were updated to match the *NSF Proposal and Award Manual*. All references to changed roles and responsibilities were edited throughout the manual for consistency.
5. The material in the separate document, NSF 12-048 Risk Management Guide for Large Facilities, was rewritten and incorporated in the manual as Section 5.2, Risk Management Guidelines.
6. Section 4.2.5, Budget Contingency Planning for the Construction Stage, was added with processes and requirements for managing budget contingency.
7. A new section, 1.1.1.1, Management Fees, was added on allowability of management fees for projects.
8. The list of components in a Project Execution plan (PEP) was updated and placed into a table in Section 3.4.1. The Project Development Plan (PDP) is now included as a component of the PEP.
9. Two new sections, 2.4.3.1 and 2.4.3.2, were added with material on Construction Award Close-out and No-Cost Extensions.
10. A new section, 4.5.5, Re-Baselining, was added to clarify the process for modifying project baselines.

11. The language for the definitions of facility life cycle was adjusted to be more in line with common usage in project management and was applied consistently across the document. A summary process flowchart was added to illustrate life cycle stages and phases.

12. Several appendices with material pertinent to the new logical groupings were moved into relevant main manual sections. The appendix on Federal Acquisitions Regulations was deleted.

13. References were revised to indicate publication status and which documents are internal to NSF and which are available to the public. For this revision of the manual, all hyperlinks to documents were removed. Section 6, References, was updated to an alphabetized list of all documents referenced in the manual.

14. Acronyms were spelled out at the first instance in each section and elsewhere in order to improve readability and understanding, particularly for readers outside NSF, and Section 7, List of Acronyms, was updated.

15. A Lexicon of common terms related to NSF management of large facilities was added as Section 8.

16. Corrections were made to various minor typographical errors and formatting errors.

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1 INTRODUCTION

1.1 PURPOSE AND SCOPE

A major responsibility of the National Science Foundation (NSF) is the support of scientific facilities as an essential part of science and engineering enterprise. NSF makes awards to external Recipient 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] Generally speaking, NSF does not directly construct or operate the facilities it supports. However, NSF retains responsibility for overseeing the Recipient's development and management of the facility as well as assuring the successful performance of the funded activities.

Facilities are defined as shared-use infrastructure, instrumentation and equipment that are accessible to a broad community of researchers and/or educators. Facilities supported by NSF may be centralized or may consist of distributed-but-integrated installations. They may incorporate large-scale networking or computational infrastructure, multi-user instruments or networks of such instruments, or other infrastructure, instrumentation, and equipment having a major impact on a broad segment of a scientific or engineering discipline. Historically, awards have been made for such diverse projects as accelerators, telescopes, research vessels, aircraft, and geographically distributed but networked observatory systems.

The *Large Facilities Manual* contains NSF policy on the planning and management of large facilities. The purpose of the Manual is to provide guidance for NSF staff and awardees to:

- Carry out effective project planning, management, assistance, assurance, and oversight of large facilities,
- Clearly state the policies, requirements, and recommended procedures pertinent at each stage of a facility's life cycle, and
- Document best practices that ensure accountability and effectiveness of the program.

The policies in the *Large Facilities Manual* apply to all large facility projects funded by NSF, including:

- 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 leveraged with Education and Human Resources (EHR) Accounts and that require National Science Board (NSB) approval; and

[1] See *NSF Proposal and Award Policies and Procedures Guide* for detailed information on awards. NSF staff should also be consulted for material contained in the internal NSF document, *Proposal and Award Manual*.

- Existing facilities for which operation and replacement cost would be similar in size to MREFC-funded and MREFC-eligible projects.

NSF typically supports facility construction from two appropriations accounts: the MREFC Account and the R&RA Account. The MREFC Account was created in 1995 to fund the acquisition, construction, commissioning, and upgrading of major science and engineering infrastructure projects that could not be otherwise supported by Directorate level budgets without a severe negative impact on funded science. MREFC projects generally range in cost from one hundred to several hundred million 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. The provisions and principles in the *Large Facilities Manual* also apply to these smaller-scale facilities funded through the R&RA Account, but procedures should be modified appropriately to fit the needs of each facility.

1.2 PRECEDENCE

The *Large Facilities Manual* comprises Chapter XIII of the *Proposal and Award Manual* (PAM), but is published under separate title. It replaces the *Large Facilities Manual*, NSF 13-38, published in 2013, and incorporates changes in organization and content intended to clarify the policies and procedures by which MREFC candidate projects are identified, developed, prioritized and selected.[1]

The *Large Facilities Manual* is a public document owned and managed by the Office of Budget, Finance and Award Management's (BFA) Large Facilities Office (LFO). It is available on the LFO public website (http://nsf.gov/bfa/lfo/index.jsp) as well as through the internal LFO website.

The Manual does not replace existing formal procedures required for all NSF awards, which are described in the publically available *Proposal and Award Policies and Procedures Guide* and in the NSF internal *Proposal and Award 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, programmatic/technical review, and a substantial approval process. This level of review and approval differs substantially from standard grants, as does the level of oversight needed to ensure appropriate and proper accountability for federal funds. The policies, requirements, recommended procedures, and best practices presented herein apply to any facility large enough to require interaction with the NSB or any facility so designated by the Director, the Deputy Director, or the Assistant Director/Office Head of the Originating Organization(s).[2] 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 NSF oversight and Recipient management of large facilities projects and at enabling the most efficient and cost-effective delivery of tools to the research and education communities.

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

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

1.3 DOCUMENT STRUCTURE

The Manual is organized as follows:

- Section 1 introduces the purpose, scope, and historical perspective of this document.
- Section 2 describes the life cycle stages and the process and principles NSF uses to plan, construct and operate large facilities. The steps for approval and execution of projects funded using the MREFC Account and the roles and responsibilities of NSF staff are detailed.
- Section 3 describes the requirements for preparing and following the various detailed management plans required during the life cycle of a large facility.
- Section 4 is an expanded compendium of several NSF key requirements and principles listed in Sections 2 and 3. It includes detailed descriptions of processes used to plan, acquire, and manage large facilities.
- Section 5 contains extensive supplementary information on specific topics concerning NSF's role in the planning, oversight, and assurance of large facility projects. It consists of sections containing important explanatory and procedural information and pointers to separate documents (or modules) with similar information. The information in the documents is presented in a tutorial format that should be of particular benefit to individuals who are newly involved with large facility projects.[1]
- The appendices contain other information relevant to MREFC projects and large facilities.

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 NSF *Proposal and Award Manual*[2] (PAM), which are available only internally to NSF staff and refer to details of NSF administrative practices and procedures that are not relevant to external project proponents. Wherever these internal references are included, they are clearly noted as such.

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

[1] Section 5 will be further updated to include additional information, with the intent to provide to NSF and the research communities a single reference location for all relevant policies and procedures.

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

2 LARGE FACILITY LIFE CYCLE AND THE MREFC PROCESS

2.1 MREFC PROCESS INTRODUCTION

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

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

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

2.1.1 Definition of the MREFC Account

The MREFC Account is an agency-wide account, created in 1995 with Congressional approval, which provides funding to establish major science and engineering infrastructure projects that exceed 10% of the Directorate's annual budget, or roughly one hundred million dollars or greater. Specifically, the MREFC Account is intended to:

- Provide a special account to fund acquisition, construction and commissioning of major facilities and other infrastructure projects;[1]
- 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.[2]

The MREFC Account funding is specifically for construction related activities; it cannot be used to support other activities involving an MREFC-funded facility, such as planning, conceptual design, development, operations and maintenance, or scientific research.

[1] In some cases, MREFC funds may be used to support development after construction of a facility begins.

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

2.1.2 Eligibility for MREFC Funding

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

In addition, a candidate project should:

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

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

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

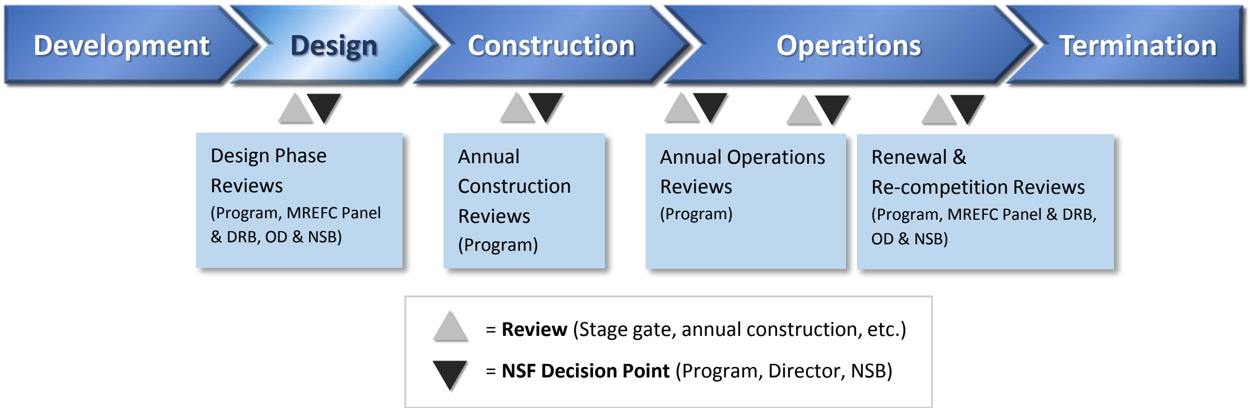
2.1.3 Facility Life Cycle

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

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

Each life cycle stage entails different actions appropriate to the advancement of the project, the review and approval needed to obtain NSF funding, and the creation of NSF budgets to support these activities. Entry and exit from each life cycle stage are clearly defined including required documents and deliverables. A high-level graphic of the progression through the stages is given below in Figure 2.1.3-1.

Figure 2.1.3-1 Progressive Steps in the MREFC Life Cycle, Showing Review and Decision Points for Exit and Entry into Each Stage. The Design Stage is highlighted to indicate that it is further broken down into phases.



Points at which there may be departure from the MREFC process outlined here should be identified early in the project development and documented as part of the NSF Internal Management Plan (IMP) Individuals should discuss any proposed departures with the cognizant Program Officer.

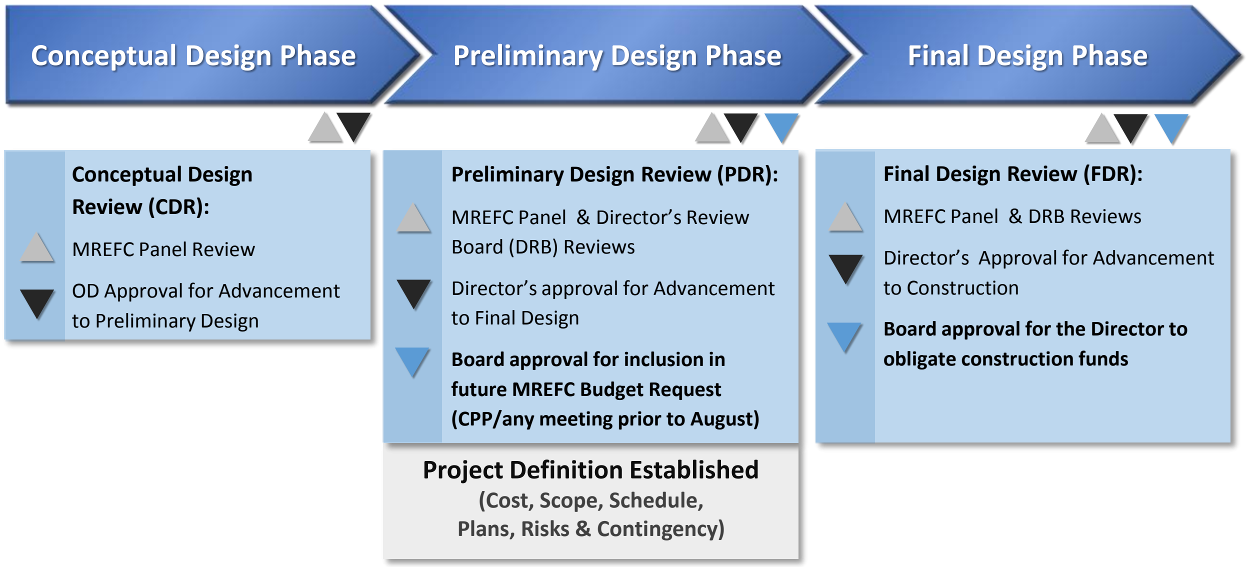
The Design Stage is further divided into three phases, each with defined entry and exit points, as shown in Figure 2.1.3-2 below:

1. Conceptual Design

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

2. Preliminary Design
3. Final Design

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



Summary definitions of each stage and phase are given below. See sub-sections 2.2 to 2.6 for detailed discussions of the various procedures and deliverables for each step in the facility life cycle.

Development Stage

The life cycle stage in which initial ideas emerge and a broad consensus built for the potential long-term needs, priorities, and general requirements for Research Infrastructure (RI) of interest to NSF. Investments in development by NSF, other government agencies, or private interests can be focused or sporadic but are generally smaller annual investments than in the Design Stage. The effort is focused on the high-level ideas and building community consensus on requirements and setting priorities across a broad landscape of potential needs. This stage can last 10 years or more. The cumulative investment over this period can be quite substantial. Next to the Termination Stage, the Development Stage is often the most challenging to navigate depending upon how federal agencies and science communities are organized. The exit process from this stage begins, once the issues have coalesced, with a proposal from a Division (via its Directorate) to the NSF Director that a project is ready to begin the Conceptual Design Phase. At that point a formal senior-level agency internal review takes place and the NSF Director may approve this transition to the first phase in the Design Stage, with the provision that no commitment to advance the project beyond the approved design phase is implied.

Design Stage

This is the life cycle stage for detailed planning of RI which is formally approved by the NSF Director and funded by the sponsoring Directorate or Division as a candidate MREFC (or other) project. It is divided into the Conceptual, Preliminary, and Final Design Phases; with a formal and rigorous review gate at the end of each phase to show readiness for advancement to a higher level of design readiness. Entrance into this stage occurs when the NSF Director approves the proposed Research Infrastructure as a national priority and the Directorate obligates funding to detailed cost, scope and schedule development for possible construction. This stage includes a series of readiness reviews to assure proper design progress and advancement through the defined phases. This Stage generally lasts 3-5 years and costs 10% or more of the estimated construction cost depending on the nature of the infrastructure. It is also the stage where construction funds are identified and (ideally) were partnerships are formalized.

> Conceptual Design Phase: Advances the definition of the scope and requirements, determines feasibility, and produces updated drafts of most elements of the Project Execution Plan, including parametric cost and schedule range estimates and a preliminary risk analysis.
>
> Preliminary Design Phase: Further advances the project baseline definition and the Project Execution Plan. It produces a bottom-up scope, cost, schedule, and risk analysis of sufficient maturity to allow determination of the Project Total Cost and overall duration for a given Fiscal Year start and to establish the MREFC budget request to congress.
>
> Final Design Phase: Further refines the project baseline definition and the Project Execution Plan and demonstrates that project planning and management meet requirements for readiness to receive funding. The Final Design phase ends after review and NSF recommendation to approve the obligation of construction funds.

Construction Stage

This stage begins when MREFC funds are obligated for acquisition and/or construction of RI that fulfills the terms and conditions set forth in an award instrument between NSF and the recipient(s). Depending on the nature and scale of the facility, construction typically lasts 2-6 years and costs between $100M and $800M. This stage has the most stringent requirements for managing the scope, cost, schedule, and performance; for reporting progress; and for formality of oversight and assurance by NSF. Progress is reported against the approved Project Execution Plan and project status is reviewed periodically to ensure that the project is capable of finishing within budget and schedule. The Construction Stage normally includes activities to transition to operations. It ends after final delivery and acceptance of the defined scope of work and facility performance per the terms of the award agreement.

Operations Stage

This life cycle stage includes the day-to-day work to operate and maintain the RI and to perform research. During this stage, the facility is actively collecting and distributing data for use by the science community. Operations may include activities to transition from construction to operations, refurbishment or upgrade activities, and activities that support planning for and transition to the Termination Stage. This stage typically lasts 20-40 years, the total cost of which often greatly exceeds the cost of construction. It normally includes a series of periodic status reviews but may also include reviews and decisions on further investment, capability up-grades, and refurbishments and eventually the final decision on termination. Annual operating costs and Concept of Operations Plans (including operational agreements between parties for funding, data sharing, etc.) should already be well established before entering this stage. The decision to terminate is generally made when NSF and/or the scientific community determine that the facility is no longer considered an operational priority with regard to advancing science. This final decision is often the most challenging.

Termination Stage

Entrance into this stage occurs when the first financial investment is made to divest or decommission the RI. The decision to terminate happens at the end of the Operations Stage. Termination could include divestment to another entity's operational and financial control or decommissioning, including complete de-construction and removal of the infrastructure. Cost of decommissioning can be substantial and must be thoroughly considered in terms of process and costs as part of termination planning.

2.1.4 Summary of the MREFC Process

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 a targeted NSF solicitation, proposing to construct the particular equipment or infrastructure; and
- Operation of the equipment or infrastructure is carried out by the entity or community that proposes construction (or by some other entity in cases where the operations expertise may not necessarily reside with the construction team).

As the diagram in Figure 2.1.4-1 indicates, pre-construction planning and development for MREFC candidate projects progress through a sequence of stages of increasing investment, planning, assessment, oversight, and assurance. 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.

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 not as neatly well-defined as the prototypical cases described above. The guidelines in this Manual allow for such cases. For example:

- Because NSF is responsible for nurturing the various science 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 overseeing 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 cyber-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 stage 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 technical evaluation.

Figure 2.1.4-1 Summary Timeline for MREFC Projects

	Conceptual Design Phase	Preliminary Design (Readiness) Phase	Final Design (Board Approved) Phase	Construction	Operations
Funding	Preconstruction Planning Funded via R&RA and EHR funds	Preconstruction Planning Funded via R&RA and EHR funds	Preconstruction Planning Funded via R&RA and EHR funds	MREFC funds	R&RA, EHR funds
		Expend ~5-25% of construction cost on planning & design activities	Expend ~5-25% of construction cost on planning & design activities		
Budget evolution	Develop construction budget based on conceptual design Develop budget requirements for advanced planning Estimate ops $	Construction estimate based on prelim design Update ops $ estimate	Final design over ~ 2 years Construction-ready budget & contingency estimates Update ops $ estimate	Expend budget & contingency per baseline Refine ops budget	Yearly budgets with out-year projects
		Proponents development strategy defined in Project Development Plan	Proponents development strategy defined in Project Development Plan		
Project evolution	Formulate science goals; define requirements, prioritize, review Develop conceptual design; identify critical technologies, high risk items Formulate initial risk assessment Develop top-down parametric cost and contingency estimates Initial proposal submission to NSF Initial Project Execution Plan (PEP)	Develop site-specific preliminary design, environmental impacts Develop enabling technologies Bottom-up cost and contingency estimates, updated risk analysis Develop Project Management Control System Develop preliminary operations cost estimate Update PEP	Develop final construction-ready design & PEP Industrialize key technologies Refine bottom-up cost and contingency estimates Finalize Risk Assessment & Mitigation, Management Plans Complete key staff recruitment	Construction per baseline and PEP	Annual Work Plans with goal setting Annual Reports that track progress relative to goals
	NSF oversight defined in Internal Management Plan, updated by development phase	NSF oversight defined in Internal Management Plan, updated by development phase	NSF oversight defined in Internal Management Plan, updated by development phase	NSF oversight defined in Internal Management Plan, updated by development phase	NSF oversight defined in Internal Management Plan, updated by development phase
Phase transitions		**NSF Director approves PD phase** (at start)	**NSF approves submission to NSB** (at start)	**Congress appropriates funds** (at start)	
Program & Oversight evolution	Merit review, apply 1st and 2nd ranking criteria MREFC Panel recommendation → Director approval for CD start Develop Internal Management Plan (IMP), est. PD costs, timeline Establish interim review plan and competition milestones Forecast international and interagency participation, issues Initial analysis of NSF opportunities, risks **Conceptual Design Review (CDR)**	NSF Director approves PD start, Internal Mgmt Plan (IMP) Approve Project Development Plan (PDP) & budget Evaluate design costs, schedules; and ops costs est. Forecast external partner decision milestones **Preliminary Design Review (PDR)** & integrated baseline review, cap total project budget NSF Director requests NSB approval for MREFC request NSB prioritization	OMB/Congress negotiations on proposed project and budget profile Semi-annual assessment of baseline and projected ops budget for projects not in construction Finalization of interagency and international requirements, agreements **Final Design Review (FDR)**, fix baseline	Congress appropriates MREFC funds & NSB approves obligation Periodic external review during construction Review of project reporting Site visit and assessment	Annual or regular reviews of operations Preparation for facility re-competition, renewal or disposal/termination

2.1.5 Timeline and Flowcharts for the MREFC Approval Process

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

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

2.1.6.1 Overview

The Large Facilities Manual (LFM) describes the actions NSF takes to carry out its oversight and assurance responsibilities for large facility projects. One key element is the definition of the roles and responsibilities of the NSF participants who carry out those actions. The main participants are:

- **Program Officer (PO)** – A scientist or engineer having primary oversight responsibility within NSF for all aspects of the project.[1]
- **Originating Organization** – The NSF Division, Directorate, or Office which proposes projects for funding through the MREFC Account or other funding source and is committed to pre-construction planning activities and eventual facility operation and use.
- **Senior Management of the Originating Organization** – The leadership individuals who utilize community inputs, discipline-specific studies, advisory committee recommendations and internal NSF considerations to prioritize the opportunities represented by the candidate project relative to competing opportunities and demands for available resources.
- **Grants and Agreements Officer or Contracting Officer (G/AO)** – NSF administrative staff from the Division of Grants and Agreements (DGA) or the Division of Acquisition and Cooperative Support (DACS), located within the Office of Budget, Finance, and Award Management (BFA).
- **Deputy Director for Large Facility Projects, (DDLFP), also known as the Head, Large Facilities Office (HLFO)** – The individual who heads the Large Facilities Office (LFO). The LFO provides an NSF-wide resource for assistance with project oversight and assurance. The LFO is administratively located in BFA.
- **Large Facilities Office Liaison** – The designated project management advisor from the LFO, who is assigned as project liaison by the DDLFP. This individual is the PO's primary resource for assistance with all policy, process, and procedural issues related to the development, implementation, and oversight of MREFC projects.

Within NSF, various bodies provide coordination, assistance, assurance, and advice to the main participants and to the agency as a whole:

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

- **Integrated Project Team (IPT)**[1] – Comprised of NSF personnel with knowledge and expertise in areas related to the scientific and technical, award management, and strategic aspects of a particular MREFC project. The IPT is a coordinating body that provides internal agency assurance and guidance to the PO in the planning, review, and oversight of that project. The members of the IPT are selected by the management of the cognizant directorates and offices, in consultation with the PO, at the beginning of the Conceptual Design Phase. The IPT is chaired by the PO.
- **Large Facilities Working Group (LFWG)**[2] – An advisory group composed of internal NSF staff and administrators that reviews and provides feedback to the LFO on draft policies, processes and procedures related to NSF Large Facilities (including but not limited to the Large Facilities Manual); raises and provides inputs on issues related to NSF Large Facilities; and reviews and comments on IMPs prior to the Conceptual Design Review (CDR).
- **Advisory Committee of the originating Directorate or Office** – Comprised of researchers from the community (and external to NSF), it advises the originating Directorate or Office in a wide variety of programmatic areas, including large facilities.

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

- **MREFC Panel** – Comprised of Senior Management representatives from the Directorates and Offices of NSF, it reviews and recommends projects for advancement through the MREFC process, as presented by the Originating Organization(s), and makes recommendations to the NSF Director on priorities and use of NSF resources.
- **Director's Review Board** – Comprised of Senior Management Representatives from the Directorates and Offices of NSF, it reviews and approves the package of materials associated with all topics to be submitted to the National Science Board (NSB) for information or action, including MREFC projects.

Finally, there are entities that set NSF policy and that approve the advancement, funding requests, and obligation of funds for the development, construction, and operation of large facility projects:

- **NSF Director** – Has ultimate responsibility for the obligation of funds from the MREFC Account and for proposing new MREFC projects to the NSB, the Office of Management and Budget (OMB), and Congress.

[1] The IPT replaces the Program Advisory Team (PAT) and the Business Oversight Team (BOT).

[2] The LFWG replaces the Facilities Panel.

- **NSB** – Establishes policy, reviews and approves MREFC Account budgets, and reviews and approves specific MREFC projects for funding.

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

Table 2.1.6-1 Summary of Principal Roles and Responsibilities of PO, G/AO, and LFO Liaison by Facility Life Cycle Stage

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

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

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

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

2.1.6.2 Main Participants

Program Officer (PO)

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

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

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

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

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

> *"PROJECT MANAGEMENT. No national research facility project funded under the major research equipment and facilities construction account shall be managed by an individual whose appointment to NSF is temporary."*

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

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

- Project planning, both internally and in coordination with the relevant research community;
- Serving as the NSF interface with the research community to nurture concepts for development and utilization by the community of a facility;
- Formulating an IMP that defines NSF strategy for conducting project oversight, managing NSF risk, and providing project funding;
- Coordinating contact between the project proponents and other NSF staff members that may need to have direct contact with the project or that the project may wish to contact;
- Chairing the IPT;

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

- Conducting merit and programmatic/technical reviews of proposals for development, implementation, operation, and utilization of a facility (CDR, Preliminary Design Review, Final Design Review (FDR), construction and operational reviews);
- Preparing all required documentation for internal project review and approval within the NSF;
- Participating in developing the estimated costs of planning, construction, operations, maintenance and related programmatic activities, and, under management direction of the originating Division, Directorate, or Office, assigns budgets to these tasks; and
- Overseeing implementation, operation, and eventual termination of NSF support for the project.

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

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

The AD (or Office Head) of the 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 (i.e., ready to begin Preliminary Design activities), and authorizes the PO to proceed with organizing the development and external review of a Project Execution Plan and with updating the IMP to explain how NSF will oversee and fund further development. The AD reviews and approves the IMP prior to its submission to the LFWG for review and comment. 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 Office of the Director (OD) and NSB as appropriate.

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

The AD oversees development of MOUs with other agencies, international partners, private foundations, and other entities and, with the approval of the NSF OD, enters into negotiations with those parties and signs these agreements on behalf of NSF when authority to do so is delegated by NSF OD.

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

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

Specific responsibilities include, but are not limited to:

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

<u>Division Director</u>

The Division Director (DD), assisted by Divisional Staff, has primary responsibility for overseeing planning, review, oversight and funding of Large Facilities. This responsibility 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.

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

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

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

<u>Grants and Agreements Officer or Contracting Officer</u>

The Grants and Agreements Officer or Contracting Officer (G/AO) has authority, subject to statutory limitations, to award and administer CAs and/or contracts. As a member of the IPT, this NSF officer participates in management reviews, risk assessment and issues management. The G/AO plans and coordinates development of award instruments from early planning stages through award administration and closeout. The G/AO negotiates terms and conditions, interprets NSF policy, and reviews business proposals and budgets, significant sub-awards,

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

MOUs, and partnership agreements. The G/AO also monitors awards for compliance with the most current NSF financial and administrative policies and procedures.

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

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

The G/AO is appointed by, and is administratively part of the DGA or DACS within the BFA. The timing of this assignment is at the discretion of the DGA or DACS DD in response to a request from the PO, but should be early enough in the planning stage of a large project to allow the participation of the G/AO in the strategic planning and development of the IMP for a large project (i.e., during the Conceptual Design Stage when NSF begins to consider strategies for the business aspects of managing oversight of the proposed project).

The G/AO is responsible for oversight of the financial and administrative terms of the assistance agreement,[1] just as the PO is responsible for scientific and technical oversight. Unlike the PO, he/she holds the warrant to obligate government funds. The G/AO and the PO jointly share the principal technical and financial responsibilities for the oversight and assurance of a large facility project. In this capacity, the G/AO is jointly responsible with the PO for the success of a project.

The G/AO is an integral member of the IPT for a facility project in order to expedite NSF action on business and administrative issues related to the project.

The G/AO confers with the PO and other relevant offices to ensure that the NSF's technical and administrative oversight activities are well coordinated. The G/AO and the PO collaborate on the preparation of solicitations and the proposal and award process. The G/AO has individual responsibility for developing and overseeing the implementation of financial and administrative aspects of the award process, and joint responsibility with the PO for recompetition planning and execution, and award termination and closeout.

The G/AO develops the CAs or contracts that establish a business relationship between the NSF and the recipient. Consequently, the G/AO has an oversight responsibility that extends to the

[1] An assistance agreement is a grant or CA to an institution with fiduciary responsibility for the project or facility.

business practices of that recipient, in addition to the specific business operations and oversight practices of the particular project that may be based with that recipient.[1]

The G/AO, with the assistance of BFA resources, establishes that the financial stewardship and reporting practices of the awardee institution, as they pertain to NSF instruments, are consistent with NSF requirements, OMB circulars, or Federal Acquisition Rules.[2]

Deputy Director for Large Facility Projects and BFA's Large Facilities Office

The NSF's Deputy Director for Large Facilities Projects (DDLFP), who is also the Head, Large Facilities Office (HLFO), and the LFO supporting staff are the NSF's primary resource for all policies or processes related to the development, implementation, and oversight of MREFC projects. They are the NSF-wide resource on project management. The DDLFP has the institutional authority and resources to effectively develop mandatory policies, which are approved by Senior Management, for all project stages. The DDLFP works closely with the BFA and NSF Senior Management Officers, providing expert opinion on non-scientific and non-technical aspects of project planning, budgeting, implementation, and assurance to further strengthen the oversight capabilities of NSF. The DDLFP also facilitates coordination and collaboration throughout NSF fosters the sharing of lessons learned and the use of best practices from prior projects.

The DDLFP develops and implements processes for insuring that all facility award instruments include, at a minimum, four performance evaluation and measurement components:

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

Prior to NSF requesting NSB approval to include a proposed project in a future budget request, the DDLFP contributes to agency assurance that the project plans are construction ready, and that the construction and operations budgets are satisfactorily justified.[3] This assurance comes through assignment of the LFO Liaison to the IPT and membership (as assigned) on various governance bodies such as the Director's Review Board and MREFC Panel.

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[1] Refer to *the Business Systems Review (BSR) Guide* described in Section 5.8 for discussion on this point. When NSF is not the cognizant audit agency for the awardee institution, its oversight of awardee business practices is narrowly defined.

[2] Refer to the *NSF -Award Monitoring and Business Assistance Program* [AMBAP] and *Business Systems Review [BSR] Guides* for more details on the criteria and processes for this assessment.

[3] See "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.

The DDLFP prepares a monthly status report for NSF Leadership on all ongoing MREFC projects, candidate MREFC projects in planning, and other large facility projects designated by the originating Directorate or Office. Inputs to the monthly report are provided by each cognizant PO and their associated Directorate/Division. The PO provides a monthly report that summarizes the technical and financial status of the project, pending near-term milestones, and any other issues that should be brought to the attention of the LFO. The DDLFP combines all of these inputs into a single report, summarizes the key technical and financial status information, and provides an independent commentary on project management issues as necessary.

Under the direction of the NSF Senior Management, the DDLFP prepares an annual *National Science Foundation Facility Plan* and presents it to the National Science Board (NSB), usually at the NSB's February meeting. The Facility Plan describes the status and plans for the portfolio of major multi-user facility projects that are either receiving or are candidates for receiving MREFC funds. The Facility Plan supplements information contained in the NSF's annual Budget Request to Congress.

<u>LFO Liaison</u>

For each large facility project, the DDLFP designates an LFO Liaison to work closely with the PO and the Grants and Agreements Officers or Contracting Officer (G/AO), providing expert assistance on non-scientific and non-technical aspects of project planning, budgeting, implementation, and management to further strengthen the oversight capabilities of NSF. The LFO Liaison participates in each project IPT and also advises the cognizant PO of mitigating steps when project management challenges arise. The LFO Liaison works with the PO and the G/AO, not directly with the recipient or their project staff.

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

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

LFO also carries out BSRs of awardee business systems for large facilities in design, construction or operation based on a regular review cycle and other potential risks, such as building institutional capacity in advance of an MREFC award. BSRs may also be conducted at smaller scale facilities at the request of NSF Leadership or the originating organization. BSR objectives and processes are described in detail in NSF's *Business Systems Review (BSR) Guide*, described in Section 5.8.

2.1.6.3 Coordinating and Advisory Bodies

The Integrated Project Team

The Integrated Project Team (IPT) replaces the Project Advisory Team (PAT) and the BOT. The PAT and BOT were advisory in nature, whereas the IPT serves as a formal coordinating body for Large Facilities throughout the Design and Construction Stages. The IPT consists of three primary groups:

1. Science and Technical Group led by Program and primary responsible for oversight. May include other Staff from the Division and/or Directorate as deemed appropriate by Program (budget, science program, etc.).
2. Award Management Group comprised of various Offices and Divisions within the BFA. This group is primary responsible for assurance. The linkage with the Science and Technical Group is with the review and monitoring of cost, scope and schedule as well as the Project Execution Plan. The linkage with the Strategic Group is with internal NSF processes and procedures related to Large Facilities.
3. Strategic Group comprised of various offices within the OD. This group's role is primarily with assurance. The linkage with the Science and Technical Group is with communication with external stakeholders.

The IPT is chaired by the PO. Members are appointed by the ADs or Office Heads, in consultation with the PO. Appointments shall be for the duration of the project or until new appointments are made by the Office Heads. The PO will convene the IPT at least quarterly to discuss any project-related issues.

Large Facilities Working Group

The Large Facilities Working Group (LFWG), previously known as the Large Facilities Panel, serves in an advisory capacity to the LFO and is charged with:

1. Reviewing and providing comment on draft policies, processes and procedures related to NSF Large Facilities including, but not limited to, the LFM
2. Raising, discussing and providing inputs on issues related to NSF Large Facilities
3. Review and comment on IMPS prior to the CDR

The Working Group is chaired by the Deputy Director, Large Facilities Projects (DDLFP) (also known as the Head, Large Facilities Office). Members are appointed by the ADs, in consultation with the DDLPF, to ensure that the overall make-up provides a diverse range of perspectives from programmatic and project management to Directorate-level interests. Appointments shall be for a term of one (1) year.

A member of the LFO staff will serve as the Group's executive secretary. Ex-officio members include representatives from the OD, the Cooperative Support and Contracts Branches of the Division of Acquisition and Cooperative Support, and the Office of the General Counsel (OGC).

The DDLFP will convene the Group at least quarterly to discuss issues raised by the Group or the agency, and set priorities related to review of documentation related to Large Facilities.

Advisory Committee of the Originating Directorate or Office

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

2.1.6.4 Governing Bodies

MREFC Panel

The MREFC Panel ensures that the overall MREFC process is followed. It reviews specific cases as presented by the Originating Organization(s) and makes recommendations to the Director. The Panel consists of the NSF Deputy Director (Chair), the Ads, Program Office Heads, the Chief Financial Officer, the other Senior Management of NSF, and (in non-voting capacity) the DDLFP.

The MREFC Panel assesses and prioritizes major research infrastructure projects funded through the MREFC account.[1] The Panel reviews specific on-going and candidate projects as presented by the Originating Organization and makes recommendations to the NSF Director. In particular, because the Panel is composed of administrators with responsibility for every area of science and engineering supported by NSF, it applies the third ranking criteria[2] for prioritizing MREFC projects, which pertain to overall NSF priorities:

[1] For example, the MREFC Panel reviews the Large Facilities Manual and supporting information, such as this document. The Large Facilities Manual and its supporting materials are "living materials" that are periodically updated to reflect additional requirements and/or policy changes as they are reviewed by the MREFC Panel, NSF Director and the National Science Board.

[2] See Appendix A of the Large Facilities Manual – Ranking Criteria for Prioritizing MREFC Projects.

- Which projects are in new and emerging fields that have the most potential to be transformative? Which projects have the most potential to change how research is conducted or to expand fundamental science and engineering frontiers?
- Which projects have the greatest potential for maintaining U.S. leadership in key science and engineering fields?
- Which projects produce the greatest benefits in numbers of researchers, educators and students enabled?
- Which projects most need to be undertaken in the near term? Which ones have the most current windows of opportunity, pressing needs and international or 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?

Under the guidance of the NSF Director and Deputy Director, the MREFC Panel reviews the current status, planning and implementation, challenges and concerns, and any policy issues concerning MREFC projects throughout the year. The MREFC Panel recommends advancement of projects into successive stages of development, and may provide other review and assessment as directed by the Deputy Director.

Director's Review Board

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

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

Members of the DRB may include:

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

Joint meetings between the DRB and MREFC Panel may be scheduled as the particular situation warrants, but keeping in mind their distinct roles and responsibilities.

NSF Director

The 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 materials submitted to the NSB, OMB or Congress.

National Science Board

The National Science Board (NSB) establishes policy, reviews and approves MREFC Account budgets, and reviews and approves specific large awards for funding, including MREFC projects.[1] NSB is an independent body established by Congress in 1950 to set 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.

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

The NSB has established a process for reviewing and approving recommended actions and funding requests from NSF regarding large facility projects during facility development.[3] The NSB performs certain reviews and approvals, including an annual review of facilities, and prioritizes projects as necessary. NSB involvement at each life cycle stage includes:

- Sets policies of NSF that determine the administrative framework for overseeing all life cycle stages s of NSF's large facilities;

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[1] The *Proposal and Award Manual* (PAM) 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.

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

[3] See the internal NSF document "NSB MREFC Process" (graphic, NSB-/CPP – 12-18, approved May 4, 2012). See also NSB's meeting minutes with "Annual Timeline for Integration of Board MREFC Process with NSF Budget Process" (NSB-10-66, approved August 2010).

- Is kept apprised of the status of all large facilities funded by NSF through oral and written information items, particularly projects in the development and construction stages. Approves awards for advancement through design phases if above the NSB threshold;
- Approves the release of NSF's annual Facility Plan;
- May provide guidance or expectations for pursuing further development of a project, which, if not realized, could result in terminating further NSF support; and concurs in any recommendation to terminate support;
- May recommend augmentation of the budget of the Division originating a candidate new facility, to partially offset the impact on other programs resulting from the need to fully support pre-construction planning;
- Recommends inclusion of a candidate project in a future NSF Budget Request to Congress, after a PDR and NSF Director approval;
- Prioritizes the order of construction start among projects similarly approved for inclusion and not yet started;
- Authorizes the Director to obligate appropriated MREFC construction funding to the recipient;
- Reviews all recommendations for awarding funds to operate large facilities if above the NSB approval threshold; and
- Approves recompetition strategies for operations awards if above the NSB approval threshold.

2.2 DEVELOPMENT STAGE

2.2.1 Initiation of a Potential MREFC Project

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

NSF POs, who work closely with those communities, should be attentive to the emergence of breakthrough concepts and actively encourage discussion and planning. In addition, NSF uses National Academies' studies, community workshop reports, professional society activities, Directorate advisory committees and many other methods to identify opportunities and ensure continuous community input.

Ideas and opportunities identified by the research communities typically have a 5- to 20-year forward look and are brought to NSF in the form of a submitted proposal requesting funding for development. When there are competing concepts, it may be appropriate for NSF to issue a solicitation inviting proposals.

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

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

2.2.2 Exit from Development to Design Stage

Formal start of the Design Stage for a facility project occurs once a recommendation of the MREFC Panel and approval by the NSF Director is received. This process is initiated by a request from the sponsoring Directorate and/or Division to the Director's Office once a project is determined to be ready for the Conceptual Design Phase and potential construction with MREFC funds. Generally, such a request is made when the sponsoring organization has determined that: (1) the project is a high priority for further development, (2) the project is eligible for MREFC funding (see criteria) and the MREFC funding route is preferred, and (3) the sponsoring organization is committed to begin explicit investment in more detailed design activities in the current or upcoming budget cycle using Directorate or Divisional funding (R&RA).

The MREFC Panel's recommendation will focus on providing the Director with answers to the following questions:

Science

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

Planning

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

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

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

2.3.1 Conceptual Design Phase

2.3.1.1 Introduction – Conceptual Design Phase

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

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

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

2.3.1.2 Conceptual Design Phase Activities

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

[1] 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.

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

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

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

For example, proponents may wish to develop a "straw man" PEP that contains sections labeled using each of the entries in Section 3.5, with as much supporting information provided based on the outputs from the Development Stage (if any) and/or the requirements in the solicitation. This serves to illustrate an understanding to all parties of the range and magnitude of the tasks ahead.

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

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

[2] See the NSF cognizant PO for a discussion of the internal document "Guidelines for Development of Internal Management Plans for Large Facilities."

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

The PO develops the IMP with advice and assistance from the IPT. Following consultation, review and approval within the sponsoring NSF Division and/or Directorate, and upon approval of the IMP by the cognizant NSF AD, the IMP is formally reviewed by the LFWG.[1] The LFWG is chaired by the DDLFP and includes other NSF staff members experienced in the technical and administrative aspects of large project oversight. The LFWG 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 management and funding of the project to CDR, proposes transitional steps to be taken if the project is admitted to the Preliminary Design Phase, and lays out NSF's plan to oversee development of the project including internal and external review. Each large project undertaken by NSF has unique characteristics. Accordingly, the IMP should be adapted to meet the specific needs of a particular project. The IMP should state the justification for pursuing alternatives to the guidelines contained in the Large Facilities Manual.

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

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

NSF may decide to fund additional planning and development efforts for particular projects depending on the outcomes of the review and whether or not the Conceptual Design Phase was

[1] The composition of the LFWG is given in Section 2.1.6.

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

funded.[1] Such activities might include workshops in one or more disciplines, National Academies' studies, and research projects related to the development of new technologies.[2] These activities might be funded as part of the Conceptual Design Phase award, or through a separate proposal submission.

2.3.1.3 Conceptual Design Review (CDR)

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

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

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

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

The review is organized and conducted by the PO in consultation with the LFO Liaison. The PO has overall responsibility for organizing the review, and throughout the review process acts as the interface between the NSF and the recipient. The PO authors the review charge and organizes the review panel. The LFO Liaison 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 LFO Liaison concur on the implementation of these

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

[2] 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.

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

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

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

2.3.1.4 Exit from the Conceptual Design Phase

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

1. Successful completion of the CDR as described above,
2. Recommendation for advancement by the sponsoring Directorate, and
3. Approval for advancement to the Preliminary Design Phase by the OD

Recommendation for Advancement by the Sponsoring Directorate

The AD relies on community inputs, discipline-specific studies, advisory committee recommendations and internal NSF considerations to prioritize the opportunities represented by the project relative to competing opportunities and demands for resources. If, in the judgment of the AD, the scientific merit and relative importance of the proposed facility are sufficiently strong to justify advancement of the project into the Preliminary Design Phase, the AD will submit a memorandum to the MREFC Panel recommending the project for support, that explains 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, clearly demonstrating a compelling need for the project;

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

Supporting documentation, including the approved IMP, relevant review evaluations, and any other supporting information should accompany this memorandum. All materials are transmitted to the MREFC Panel by the AD or Office Head of the sponsoring Directorate or Office. On the basis of this documentation, a presentation by 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 Phase.[3]

<u>Approval by the Office of the Director (OD)</u>

The Director evaluates the MREFC Panel recommendation and, if satisfied, approves advancement to the Preliminary Design Phase. The project is then included in the Facility Plan, which is released annually.

At its May meeting, the NSB's Committee on Strategy and Budget reviews the portfolio of projects which are being considered for future funding and evaluates relative priorities that guide NSF's investment looking across the entire range of disciplines served by NSF within the constellation of other competing opportunities, existing facilities, and the balance of support for infrastructure, its utilization, and individual investigator-led research. The NSB is asked to concur with the Director's decisions by approving the annual Facility Plan.

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

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

[3] 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.

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

2.3.2 Preliminary Design Phase

2.3.2.1 Introduction – Preliminary Design Phase

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

NSF has implemented a "no cost overrun policy" on MREFC-funded construction projects. This policy requires that the Total Project Cost (TPC) estimate developed at the Preliminary Design Stage has adequate contingency to cover all foreseeable risks, and that any cost increases not covered by contingency be accommodated by reductions in scope.[1]

To satisfy these requirements, the project is developed to a Preliminary Design[2] level of maturity. Results of this development are reflected in a revised and updated PEP.[3] Components of the updated PEP that deserve particular emphasis at this stage include:

- Update of the project development plan budget and timeline, with major anticipated risks in the completion of design and development activities;
- Refinement of the research objectives and priorities of the proposed facility;

"Off-ramps"

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

- Insufficient priority over the long term;
- Failure to satisfy milestones or other criteria defined in the imp/pep;
- Eclipse by other projects;
- Collapse of major external agreements;
- Extensive estimated or actual cost 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 phase will be made public via the NSF Facility Plan.

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

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

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

- Update of the description of the required infrastructure, site-specific design, and definition of interconnections of all major subsystems;
- Environmental Assessments or Environmental Impact Statement (if applicable);
- Bottom-up budget and contingency estimates for construction, presented using a Work Breakdown Structure (WBS) structure and supported by a WBS dictionary defining the scope of individual elements;
- Updated construction schedule with contingency estimate;
- Updated Educational Outreach and Broader Societal Impact plan that includes the scope of work, required budget and schedule to implement the plan, plus the budget and schedule needed to develop the plan from preliminary design to final design;
- Implementation of a Project Management Control System (PMCS) [1] and inclusion within the preliminary design of a resource-loaded schedule;
- Updated risk analysis, including regulatory issues affecting construction or operation, and time-dependent factors such as inflation indices, price volatility of commodities, etc. (The preliminary design budget estimate will be the basis for a future NSF budget request to Congress if the project successfully emerges from the Preliminary Design/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;
- 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;[2] and
- Updated estimates for future operating costs, anticipated future upgrades, or possible decommissioning costs of the facility at the end of its operating life.

2.3.2.2 Preliminary Design Phase Activities

During the Preliminary Design Phase, the earlier conceptual design evolves into a more mature plan with respect to the baseline and contingency definitions. The WBS elements and resource estimates benefit from additional knowledge and planning. Consequently, budget uncertainty for projected construction is much reduced relative to the earlier conceptual design. At the end of the Preliminary Design Phase, the approved total project cost (performance baseline estimate plus contingency) is capped. (Additional planning and development during the final pre-construction design stage may result in exchanges between contingency budget and

[1] The PMCS involves both the software tools for development of the project databases and the processes and procedures needed to organize and manage the project; schedule and optimize project resources;; compute and track Earned Value and evaluate project risk factors; and manage the change process by evaluating the effects of alterations to the baseline on the project's planned budget and schedule.

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

performance baseline, but the total project cost does not change.) Typically, a significant proportion (often one-third or more) of the total pre-construction planning budget is expended achieving the preliminary baseline.

Interim reviews[1] during the Preliminary Design Phase will be conducted by NSF as described in the IMP. This stage culminates in a Preliminary Design Review (PDR), conducted by NSF, to ensure that all aspects of the project definition and planning are robust. The results of the PDR are reported by the MREFC Panel, followed by a recommendation to the Director for decision on forwarding to the NSB for possible inclusion in a future MREFC budget request.

2.3.2.3 Preliminary Design Review (PDR)

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

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

Once the project has satisfied any recommendations made by NSF as a result of external review, and resolved any outstanding issues, the Directorate recommends to the MREFC Panel that the project is ready for advancement to the Final Design Phase 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 OD may request further external review.

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

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

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

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

2.3.2.4 Exit from Preliminary Design Phase

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

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

2.3.2.5 NSF Director's Recommendation for Advancement to Final Design

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

- The AD of the sponsoring Directorate continues to assert the high scientific merit and importance of the project and has a sound financial plan for supporting the remaining pre-construction planning activities and the future operations and use of the facility.
- The Preliminary Design 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 MREFC Panel 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.
- An appropriate Integrated Project Team (IPT) is in place and has provided assurance that the Preliminary Design Total Project Cost has been satisfactorily analyzed at a high degree of confidence to support the budget request.
- 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 PEP have been reviewed and approved by the Large Facilities Working Group (IMP only) and the IPT.
- 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[1] – is among the very highest priorities for potential new facilities.

Based on its review of the information provided and discussions with Program and the sponsoring Directorate, the MREFC Panel forwards one or more projects in priority order to the Director, who makes the decision on advancement and whether or not 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.

2.3.2.6 National Science Board Approval

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

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

As NSB considers projects for advancement to Final Design, NSF makes available to the NSB, upon request, the PEP and IMP, and the reviews from the community, the Large Facilities Working Group, the LFO, the MREFC Panel and other relevant parties. The NSB considers the following elements, applying primarily the third ranking criteria (national priorities: see Appendix B), as appropriate:

[1] In making this determination, the second and third ranking criteria in Appendix A are judiciously applied.

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

- 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.

As with all NSF proposals, the quality of the Intellectual Merit and Broader Impact activities, including educational outreach, play an important role in funding decisions. If NSB approves a project for future-year funding, it specifies its priority among all projects in the Board-approved stage.[1] If a project is not approved, or if an approved project's plans are no longer deemed to be clearly and fully construction-ready, NSB will remand that project to the Preliminary Design phase for further work, or recommend that the project be terminated.

2.3.2.7 Inclusion in an NSF Budget Request

Each year, the NSF Director proposes, in priority order, the NSB-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.

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

2.3.3 Final Design Phase

2.3.3.1 Introduction – Final Design Phase

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

Technical requirements include:

- Delivery of designs, specifications and work scope that can be placed for bid to industry;
- Refined bottom-up cost estimates and contingency estimates;
- Implementation of a PMCS for project technical and financial status reporting;
- 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[1] for construction.

Successful exit occurs after the following steps are completed:

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

2.3.3.2 Final Design Review (FDR)

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

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

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

System (EVMS)[1] – 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 WBS format accompanied by a WBS dictionary defining the scope of all entries;
- An updated Educational Outreach and Broader Societal Impact plan (including the scope of work, budget and schedule) that also includes the capital investment required to meet the needs of the proposed Educational Outreach and Broader Societal Impact plan;
- 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 MOUs;
- 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 Section 3, are fully complete and determined to be adequate.

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 (BOE), acquisition strategies, schedule, and risk management plan presented at the PDR are still valid.

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

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

[1] During construction, progress should be tracked and measured using the Earned Value method (this method is required by OMB in *Planning, Budgeting, Acquisition, and Management of Capital Assets, OMB Circular No. A–11 (2014)*. A discussion of Earned Value is included in the Earned Value Management (EVM) section of Section 5.7, Guidelines for Financial Management.

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

In the event the project's construction plans are determined to be inconsistent with the pending budget request, NSF will undertake remedial action. Should remedial action be necessary following the review, the sponsoring Directorate recommends this to the OD after consultation with the IPT, internal deliberation, and if appropriate, consultation with the 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 (off ramp).

2.3.3.3 Exit from the Final Design Phase

Following a successful review of the final design baseline, the Director recommends to NSB that it approve construction award(s).[1] NSB reviews the recommendation and authorizes the making of the award(s). Following this approval, an award instrument, generally a CA (s), between NSF and the awardee institution(s) is negotiated, and construction activities begin in conformance with the final baseline.

Following the approval to obligate funds and as part of NSF's final negotiation of the award instrument, the award-level NSF Cost Analysis will be initiated and conducted jointly with key assurance members of the IPT; namely the Division of Acquisition and Cooperative Support (DACS), DIAS, and the LFO. The analysis will encompass such things as negotiated sub-awards/contracts associated with initiating construction and negotiation of final indirect cost and labor rates. The Cost Analysis will be conducted following NSF internal Standard Operating Guidance.

[1] See Appendix B for documentation required for recommendations.

2.4 CONSTRUCTION STAGE

2.4.1 Construction Award Management and Oversight

After Congress appropriates funds for an MREFC project, NSF proceeds to award the contracts and/or CAs for construction of the facility. The policies and procedures in the publically available *NSF Proposal and Awards Policy and Procedures Guide*, and in the internal document *NSF Proposal and Award Manual* (PAM), apply to MREFC projects. The PAM (available to the PO) covers the internal award process from proposal generation through merit review, DRB and NSB reviews, and final award. The awardee(s) provides periodic financial and technical status reports to NSF according to the terms and conditions of the CA. The project is subjected to periodic post-award reviews that may examine any or all of the following topics: technical performance, cost, schedule, and management performance. These reviews are typically held at the facility and are conducted at least annually. More frequent reviews may take be scheduled based on the project's expenditure rate or due to any other technical or management issues that arise.

NSF selects the annual review panel members who are typically external experts covering all aspects of the project, and assess technical progress, cost, schedule, and management performance. These panels report directly to NSF and provide advice on project direction and any needed changes. The reviews are organized and conducted by the PO in consultation with the LFO Liaison. The PO has overall responsibility for organizing the review, and throughout the review process acts as the interface between the NSF and the awardee. The PO authors the review charge and organizes the review panel. The LFO Liaison strengthens the review process by specifying language for incorporation within the charge and for aspects of the review agenda pertaining to project management issues, and recommending panelists able to advise NSF in non-science related areas of the review. Following the review, the PO and the LFO Liaison will each independently assess the review, confer on areas of concern, share their views, and report their observations through their respective supervisory. (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)[1] action, resulting in modifications to the project's budget or schedule contingency. It is also normal practice for a project to update its budget and schedule Estimates to Complete (ETC), which also may result in baseline changes.

[1] A CCB comprises the senior project managers responsible for defining the project's resource requirements and allocating or expending those resources. It typically consists of the Project Director, Project Manager, Business Manager, 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.

Whenever a project approves a change control action that results in allocating or returning contingency to the pool of contingency funds, the Performance Measurement Baseline (PMB) budget may also change.

Similar change-control actions affect the PMB schedule. 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.

Modifications to the performance baseline that are within the defined scope and do not change the project end date or total project cost are referred to as "re-planning". Re-planning may be due to adjustments or re-organization of the project plan and/or may signify that contingency funds are being expended in an expected manner. If the allocations of budget and schedule contingency are below the budget or schedule thresholds identified in the CA between NSF and Awardee, the change requests are approved unilaterally by the project. NSF approval is required when the CCB recommends re-planning change actions that exceed the budget or schedule thresholds identified in the CA between NSF and Awardee. Each will have a different threshold for approval. Approval levels for scope changes are generally outlined in the CA.

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.

"Re-baselining" occurs when the changes involve:

1. Increases in the NSB-approved TPC,
2. An extension beyond the approved end date, and/or
3. Major changes in scope.

When the proposed changes reach the re-baselining level, the approval process involves NSF and may involve the NSB. Changes in end date follow NSF's No-Cost Extension (NCE) policies. An increase in TPC exceeding 20 percent of the NSB-approved baseline cost or $10 million (whichever is smaller) must be reviewed and approved by the NSB following a recommendation by the MREFC Panel and the Director.[1] Prior to requesting approval to re-baseline, a new external baseline review should be conducted to examine the nature of the problems encountered, and to determine whether de-scoping should be exercised per the approved scope contingency plan in the PEP or, if not, whether the problems can be solved by use of

[1] Open Session Approved Minutes, 418th Meeting of the National Science Board, Resolution NSB-11-1, Adopted February 16, 2011.

budget contingency or other means. Upon review and approval, cost and schedule are stabilized, and the contingency adjusted to an appropriate level.

Whenever significant cost increases are foreseen, it is most important that the LFO Liaison is consulted early, concurs with the PO 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,[1] the PO should discuss plans for dealing with the variance with the Project Director. This information should be clearly noted in the monthly status report that goes to the DDLFP. The LFO is a resource for helping to deal with such problems and for helping to identify steps that can be taken to restore adequate contingency.

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

On rare occasions, 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 the NSB with appropriate information and a recommendation via the MREFC Panel and the Director. The NSB will decide whether termination or significant modification to the original project goals is warranted.[2]

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[1] See details in Section 4.5, Requirements for Performance Oversight, Reviews and Reporting.

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

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2.4.2 Commissioning Plan

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 as part of the performance baseline. The PEP is included by reference in NSF's CA 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 must be budgeted and managed separately due to segregation of funds requirements.

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 recompetition, 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, including the scope to work, associated budget and schedule.
- 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 cyber-security 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 cyber-security should also be given. This may be given as a reference to an existing cyber-security 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 CA) 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 commissioning plan is complete, an Operations Readiness Review (ORR) will be held to examine and comment on the plan. This can be considered as one of the required annual reviews. The review is organized and conducted by the PO in consultation with the LFO Liaison similarly to other reviews described above.

2.4.3 Construction Award Close-out

2.4.3.1 Project Close-out Process

(Intentionally left blank – this section to be written)

2.4.3.2 Request for No-Cost Extension

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

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

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

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

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

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

1. List of the tasks to be completed during the extension period and justification that they are within project scope.

    a. Link the tasks to the associated WBS element and give a short justification of how they fit within existing project scope. Risk mitigation effort should be associated with an identified and documented risk element.
    b. Provide the total burdened estimated cost for each task. Detailed cost estimates do not have to be provided, but should be documented and available if requested.
    c. The justification for each task will typically fall into one or more of several categories: (1) open purchase orders and invoices associated with items whose delivery is delayed beyond the current period of performance, for example due to subcontractor performance, (2) rework of existing tasks within the approved scope, for example due to workmanship or performance issues, (3) existing tasks within the approved scope that have not yet been completed, and (4) risk mitigation to address in-scope performance issues. An example of a task list with justifications is given in the sample Table 2.4.3-1 on the following page.

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

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

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

[1] Scope contingency is defined in Section 5.2.3.

Table 2.4.3-1 Sample of a No-Cost Extension Tasks Table

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

2.5 OPERATIONS STAGE

2.5.1 Operations Management and Oversight

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

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

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

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

Three key aspects of NSF oversight and assurance of large facility operations, *which (if applicable) are referenced in and required by the CA,* are: (1) Annual Work Plans, (2) Annual Reports, and (3) Annual Operations Reviews. NSF or the cognizant agency may also conduct periodic audits.

[1] These sections are in preparation.

Annual Work Plan

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 goals and objectives, performance measures and, where appropriate, performance targets) for the coming year. The goals should include both scientific and operations issues (i.e., installation of new equipment or commissioning of new buildings, maintenance, Education and Oversight Training [EOT] and ES&H). The goals will naturally vary from facility to facility and should be agreed upon between the awardee and the NSF Program Officer (PO). Goals in the Annual Work Plan should meet the standard of being specific, realistic, measurable and time-based. The LFO Liaison will review the goals to ensure they meet this standard.

Annual Report

The Annual Report describes in detail the activities of the facility in the previous twelve months. 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 PO reviews and approves the Annual Report.

Annual Operations Reviews

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 MOU between the partners defines the process for monitoring: (1) identification and accomplishment of programmatic goals; (2) fiscal accountability; (3) stewardship of NSF assets; and (4) compliance with laws and regulations. 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 Systems Review[1] (BSR) which looks at business processes.)

- The review is organized and conducted by the PO in consultation with the LFO Liaison. The PO has overall responsibility for organizing the review (or representing NSF's interests in the case of a partnership), and for acting as the interface between the NSF and the project's proponents throughout the review process. The LFO Liaison advises the PO during the planning and execution of the review to ensure that there is consistent practice across NSF in the formulation of performance goals, that goals and objectives are clearly stated and represent quantifiable performance measures or targets where practical, are periodically reported, and that an evaluation and feedback mechanism is implemented as an essential part of an ongoing program of continual performance enhancement.

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

- In most cases, observers of the review shall include the Program Officer, the Grants and Agreements Officer, the LFO Liaison and other staff from the Large Facilities Office, and possibly other NSF staff from the Integrated Project Team. Budget considerations, logistical constraints, or alternate processes for review agreed to by NSF and its funding partners may result in exceptions to the number and range of NSF staff participating.

[1] See Section 5.8 for discussion of the BSR process as well as the NSF BSR Guide. To avoid duplication of effort, the scope of the BSR is adapted to utilize relevant information stemming from other reviews and audits.

2.5.2 Renewal/Recompetition

Most NSF facilities will be operated by a managing organization. Because facility lifetimes are long (some current facilities have operated in excess of 40 years), recompetition of management is appropriate at intervals. Whenever practical, NSF seeks to make competitive renewal awards for operation of large facilities after external merit review. See Section 3.5.2 for procedures for Renewal and Recompetition. The NSB issued a statement requiring full and open recompetition of awards for operation of major facilities upon their completion and after an appropriate time period to bring the facility to sustainable operations.[1] The goal of competition is to stimulate new approaches toward more effective management that may offset any potential for increased costs, and ideally may achieve some cost savings. Important considerations beyond performance of current management include how recompetition might affect the scientific productivity of the facility and the burden it would place on the community. Even in cases where the existing management has been explicitly and rigorously reviewed and found to be effective, the benefits of competition may outweigh any short-term disadvantages of recompetition. The determination of whether to compete the effort is based on the expert advice of NSF staff and, where applicable, external sources using the facility, and should be presented to the NSB for approval.

[1] See NSB Statement on Competition, Recompetition, and Renewal of NSF Awards, NSB 08-16, https://www.nsf.gov/nsb/publications/2008/nsb0816_statement.pdf.

2.6 TERMINATION STAGE

To remain at the research frontier and support new facilities, NSF will consider retiring existing facilities when the science they enable is of a lower strategic priority than science that could be enabled by alternate use of the funds. Such decisions will be difficult to make, in part because of the number of stakeholders and interested parties, and will require extensive community consultation and input, which may come from “blue ribbon” panels, National Academies committees and professional societies. In some cases in which a facility can continue to be productive, it may be possible to transfer ownership 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.

2.7 APPLICATION OF MREFC PROCESS TO NON-MREFC FUNDED PROJECTS

2.7.1 Flexible Requirements for Non-MREFC Facility Projects

The project management processes and principles described in the preceding section 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 section provides guidelines for planning and managing new facility projects that are *not* constructed with funding from MREFC accounts.[1] This is usually the case when the project does not qualify for MREFC funding[2] and/or the sponsoring Directorate or Office chooses not to apply for MREFC funding.

This section applies to non-MREFC facility projects that take a multi-stage design approach similar to that described in Section 2, 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.[3]

Non-MREFC projects are not subject to the same requirements for Conceptual Design, Preliminary Design, and Final Design reviews outlined in Section 2. Nor are they required to use the three sets of ranking criteria in Appendix A or subject to review by the MREFC Panel. However, the elements described in Section 2 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 section.

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.

[1] 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.

[2] See the previous Section 2.1.2 for eligibility requirements for MREFC funding.

[3] See the description of NSB roles and responsibilities in Section 2.1.6.

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 science and engineering (S&E) research and education;
- Urgent contemporary research and 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[1] with primary responsibility for award management and project oversight. As noted in Section 2, NSF restricts the choice of POs overseeing MREFC-funded activities to permanent NSF employees[2] 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.

Large Facilities Working Group: The Large Facilities Working Group[3] 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 AD/ 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.

Integrated Project Teams: At the earliest opportunity, the originating Directorate or Office should coordinate with the PO to organize an IPT[4] to provide advice and help coordinate NSF's oversight and assurance.

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

[2] See Public Law 107-368, Section 14(c).

[3] The functions of the Large Facilities Working Group are described in "Roles and Responsibilities" in Section 2.1.6.

[4] Ibid.

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 above the NSB approval threshold 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.

2.7.2 Pre-construction Planning and Development of Non-MREFC Projects

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/or 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 AD/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.[1] 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.

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 PEP as appropriate.

[1] Refer to Section 3.3 "Guidelines for Development of Internal Management Plans for Large Facilities" (an internal NSF document).

3 LIFE CYCLE MANAGEMENT PLANS FOR LARGE FACILITIES

3.1 INTRODUCTION TO MANAGEMENT PLANS

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

The NSF Facility Plan, as described in Section 3.2, is a yearly exposition of the status and intentions for the NSF portfolio of existing and candidate MREFC facility projects, in the context of the current climate of science opportunities and priorities. It also lays out the objectives and compelling needs for major facilities, given the frontier research opportunities of the time. The NSF Facility Plan informs decision-making in the Executive Branch and Congress, as well as serving as a vehicle for communication with scientific communities. It is available to the public on the NSF web site.

Section 3.3 describes and points to an internal NSF document with guidelines on creating an Internal Management Plan (IMP), the NSF document that captures how NSF will oversee awards for large facilities throughout the life cycle, from candidate MREFC facility projects in design, through construction and operation, and ultimately, through termination. An IMP also provides financial strategies for funding given the estimated budgetary estimates. Both the guidelines and the created IMPs are internal NSF documents.

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

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

Guidelines for plans to terminate operations under NSF awards are in development, with Section 3.6 provided as a placeholder. Termination of NSF funding and oversight of a facility may be accomplished through divestment or transfer to another agency or funding source or through decommissioning and deconstruction.

3.2 NSF FACILITY PLAN

The NSF *Facility Plan*, which is updated annually and publicly available, serves as valuable planning tool both 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, National Research Council (NRC) reports, expertise of visiting and permanent scientific staff, and unsolicited proposals from the community. The Facility Plan's second section provides annual updates on the status and progress of each Major Research Equipment and Facilities Construction (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 National Science Board (NSB) for approval within approximately the next year, and those that the MREFC panel has recommended for advancement to the Preliminary Design Phase.
- **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 Phase. 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 Deputy Directory for Large Facility Projects (DDLFP) to develop and maintain the Facility Plan. The plan is approved by the Director and submitted to the NSB in March of each year.

3.3 INTERNAL MANAGEMENT PLANS FOR THE LARGE FACILITY LIFE CYCLE

Please contact the cognizant NSF program officer for details, which are given in the internal NSF document *Guidelines for Development of Internal Management Plans for Large Facilities*.

This document provides guidance to the PO on topics to be included in an Internal Management Plan (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 Section 2.3.1 for MREFC and in Section 2.7 for non-MREFC projects. 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.

3.4 PROJECT EXECUTION PLAN

3.4.1 Components of a Construction-ready Project Execution Plan

Essential components of a construction-ready Project Execution Plan (PEP), common to most plans for construction of large facilities, are listed in Table 3.4.1-1 below, as an example of the extensive nature of the pre-construction planning that should be conducted prior to expending 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 better defined.

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

Component	Sub-Topics	Description of Sub-Section Requirements
1. Introduction	1.1 Scientific Objectives	Description of the research objectives motivating the facility proposal.
	1.2 Scientific Requirements	Comprehensive statement of the Requirements Matrix/ Key Science Requirements to be fulfilled by the proposed facility (to the extent possible identifying minimum essential as well as desirable quantitative requirements), which provide a basis for determining the scope of the associated infrastructure requirements.
	1.3 Facility / Infrastructure	Description of the infrastructure necessary to obtain the research and education objectives.
	1.4 Community Outreach and Impacts	Description of the Educational Outreach and Broader Societal Impacts associated with the purpose of the facility, including the scope of work, budget and schedule related to community or society related actions or interactions.

Component	Sub-Topics	Description of Sub-Section Requirements
2. Organization	2.1 Project Governance	Project Governance, showing Oversight and Advisory Plans with clear lines of authority, responsibility, and communication between Internal and institutional governance and oversight and advisory committees.
	2.2 Project Organization	Project Organizational Structure, showing clear lines of authority, responsibility, and communication between NSF, any partners, and the Awardee.
	2.3 Partnerships	Role of interagency or international partners in future planning and development and/or construction. Plans, agreements, and commitments for interagency and international partnerships. Description of the project's stakeholders and their roles, responsibilities and meeting schedules.
	2.4 Roles and Responsibilities	Roles and Responsibilities of key project personnel and governance groups.
	2.5 Community Relations and Outreach	Community Relations and Outreach plans for building and maintaining effective relationships with the broader research community that will eventually utilize the facility to conduct research. Description of scientific and educational outreach programs.
3. Design and Development	3.1 Project Development Plan	Description of activities that will be undertaken in order to achieve readiness for construction, such as design, prototyping, manufacturing process validation, vendor qualification, modeling and simulation, creation of required project management plans, forming partnerships, etc.
	3.2 Development Budget and Funding Sources	Estimate of total budget required to perform Design and Development, including NSF funding and any contributions from partners and other outside sources.
	3.3 Development Schedule	Schedule of design and development activities and milestones, at a level of detail appropriate to the maturity and complexity of the work.

Component	Sub-Topics	Description of Sub-Section Requirements
4. Construction Project Definition	4.1 Summary of Total Project Definition	Summary at Work Breakdown Structure (WBS) level II of total construction project scope, cost, and schedule required to complete the construction or implementation project, indicating the Performance Measurement Baseline (PMB) and contingencies funded by NSF as well as any associated scope supported by other funding sources.
	4.2 Work Breakdown Structure (WBS)	WBS contains a product-oriented, hierarchical framework that organizes and defines the total scope of the project into individual project component that represent work to be accomplished, aggregating the smallest levels of detail into a unified project description. The WBS integrates and relates all project work (cost, schedule and scope) and is used throughout the project management to identify and monitor project progress.
	4.3 WBS Dictionary	WBS dictionary defining scope of each WBS element, through all levels.
	4.4 Scope Contingency	Scope Contingency from potential de-scoping options; decision points for exercising options; time-phased potential savings in cost and schedule from de-scoping.
	4.5 Baseline Budget	Budget for the PMB, by WBS element.
	4.6 Budget Contingency	Contingency budget and description of method for calculating contingency, including confidence level for completing within budget.
	4.7 Cost Book and Basis of Estimate	The Cost Book budget is the tool used to collect and track budgets. It is organized by the WBS format, identifies the estimated cost and the basis of estimate (BOE) for each cost item, and includes the WBS dictionary definition of the scope associated with each WBS element. Typically the Cost Book also provides NSF cost categories and other project specific group categories such as charge accounts.
	4.8 Funding Profile	Show the proposed NSF Funding Profile by year with baseline commitment and anticipated contingency allocation profiles. Also provide a total funding profile from all sources if applicable.
	4.9 Baseline Schedule	Schedule (without contingency) for the overall project and each major subsystem, including system integration, commissioning, acceptance, testing and transition activities; as well as major milestones and milestones for reviews, critical decisions and deliverables. It uses formal scheduling programs, is based on the WBS hierarchy, and is resource-loaded before the construction/implementation stage. Baseline schedule does not include schedule contingency.
	4.10 Schedule Contingency	Schedule contingency amounts and project end date with contingency; state method of calculating contingency, including confidence level for meeting project end date.

Component	Sub-Topics	Description of Sub-Section Requirements
5. Staffing	5.1 Staffing Plan	Staffing FTE plan, per NSF and other project-specific job categories, over time.
	5.2 Hiring and Staff Transition Plan	Schedule and requirements for hiring and training staff, including timelines for increasing or decreasing staffing levels. Required qualifications for key staff.
6. Risk and Opportunity Mgt	6.1 Risk Management Plan	Risk Management Plan describes the methodology/process for identifying, ranking, analyzing, tracking, controlling, and mitigating risks.
	6.2 Risk Register	A tracking document or tool that provides a ranked list of identified risks, with risk impact analysis and prioritization, responsibilities, mitigation plans and opportunities of risk reduction, and risk status over time.
	6.3 Contingency Management	Contingency management plans and approval process using change control. Describe NSF approval requirements per cooperative agreements (CAs).
7. Systems Engineering	7.1 Systems Engineering Plan	Systems Engineering Management Plan; roles and responsibilities.
	7.2 Systems Engineering Requirements	System-level design and technical feasibility study, including definition of all functional requirements and major systems.
	7.3 Interface Management Plan	Identification of interfaces between major components or WBS elements and plans for managing communication, interferences, and interactions. Interface Management Plan and Documentation.
	7. 4 QA/QC Plans	Quality assurance and quality control requirements and description of processes.
8. Configuration Control	8.1 Configuration Control Plan	Configuration Control plans.
	8.2 Change Control Plan	Change Control Plan to manage accounting changes and changes in the baseline plan: changes in scope, modifications to budget or schedule, and movement of contingencies into or out of the baseline. Includes approval and documentation processes plus roles and responsibilities.
	8.3 Document Control Plan	Document Control Plan for managing version control, access, and archiving of project related documentation.
9. Acquisitions	9.1 Acquisition Plans	Describe acquisition plans, processes, sub-awards, and subcontracting strategy. Provide a time based list of acquisitions and procurement actions.
	9.2 Acquisition Approval Process	Describe the approval process for acquisitions (NSF, internal), and create a year by year Acquisition Plan of actions that are estimated to require NSF approval.

Component	Sub-Topics	Description of Sub-Section Requirements
10. Project Mgt. Controls	10.1 Project Manage-ment Control Systems	Description of the project management organization and processes.
	10.2 Earned Value Management System (EVMS)	Description of the EVMS plans, processes, software, and tools.
	10.3 Financial and Business Controls	Description of Financial and Business processes and controls.
11. Site and Environment	11.1 Site Selection	Site selection criteria and description of selected site(s).
	11.2 Environmental Aspects	List need for any Environmental Impact Statements, permitting, site assessments, etc.
12. Cyber-Infrastructure	12.1 Cyber-Security Plan	Plan for maintaining security of data, hardware, and networks during all stages of project life cycle.
	12.2 Code Development Plan	Plans for writing, testing and verifying, deploying, and documenting software, including configuration control during the stages of development.
	12.3 Data Management Plan	Plans for managing data, including infrastructure, archiving, open data access plans, etc.
13. Health and Safety	13.1 Health and Safety Plans	Safety and Health plans.
14. Review and Reporting	14.1 Reporting Requirements	Statement of reporting requirements, including notifications for specific events and periodic reports on progress and project technical and financial status per NSF requirements or CAs.
	14.2 Audits and Reviews	Statement of the required and proposed reviews, audits, and assessments for progressing during project life cycle through project close-out.
15. Integration and Commissioning	15.1 Integration and Commissioning Plan	Plans for systems integration, testing, and commissioning.
	15.2 Acceptance / Operational Readiness Plan	Plan for operational readiness, including acceptance criteria and acceptance procedures.
16. Project Close-out	16.1 Close-out Plan	Procedures and criteria for closing out the project. Includes acceptance of verification of technical performance as well as documented completion of all scope contained in the WBS dictionary. Includes procedures documentation for closing out all acquisitions and financial accounting.
	16.2 Transition to Operations Plan	Plans for transitioning to operational status.
	16.3 Operations Plan	Estimate of annual operations and maintenance staffing and funding that will be needed when the facility is constructed and operated.
17. Facility Termination	17.1 Facility Retirement Plan	Description and estimate of liabilities at the end of facility life for demolition, site remediation, decontamination, etc., where appropriate.

3.4.2 Detailed Guidelines for Project Execution Plans

Please contact the cognizant NSF program officer for details, which are given in the internal NSF draft document, *Guidelines for Development of Project Execution Plans for Large Facilities*.

This document provides an overview of NSF's expectations about Project Execution Plans (PEP) for Program Officers (POs), Grants and Agreements Officers (G/AOs) 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 G/AO that define NSF's expectations.

3.5 OPERATIONS PLAN

3.5.1 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. Program Officers (PO) and Directorates/Offices are encouraged to take into account the time needed for internal NSF review, including NSB review, and offer guidance to the community. Estimates of the funds for operations and maintenance are provided even in the planning stages of a facility. The potential 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 3 to 5 years);
- The costs of an in-house research program (as a separate line item in the budget), if applicable, including an indication of how the overall research program will be managed and how research program resources will be allocated;
- Education and outreach plans and costs;
- A detailed management plan for operations of the facility, including the roles of key staff and plans for advisory committees.

Note that cost estimating methods should follow the Government Accountability Office (GAO) Cost Estimating Guidelines, per Section 4.2.

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

- Is the facility ready for reliable operations and is the infrastructure (including personnel requirements) adequate to execute the proposed work plan?
- Do the operations and maintenance plans allow for optimal utilization of the facility by users (e.g., scheduled operating time versus down-time)?
- Is 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 and/or vertebrate animal clearances included, if applicable (e.g., assessments of education-related activities)?
- Are the Educational Outreach and Broader Societal Impact plan and cost reasonable and include an appropriate strategy to evaluate the outcomes?
- Have all costs been considered and estimated and is the available funding sufficient, or is some adjustment needed?

Throughout the operational stage, the Awardee operates and maintains the facility in accordance with the terms and conditions outlined in the CA. The PO, together with the Division of Grants and Agreements (DGA) or the Division of Acquisition and Cooperative Support (DACS), drafts the CA that will govern the operational phase of the project in accordance with the procedures contained in Chapter VIII of the PAM. The CA will include plans for NSF oversight, reflect the needs of the facility users, and address how the user program will be managed and how user time will be allocated. The PO provides oversight for all aspects of operations, maintenance and the research and education program. The PO also maintains an awareness of emerging technical, managerial and financial issues through contact with the facility managers and users, and through oversight, reviews and reports.

3.5.2 Procedures for Renewal or Recompetition of an Operating Large Facility

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

The review should analyze 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, educational outreach and broader societal Impact goals and objectives originally proposed?
- Has the facility reached its annual performance goals, and if not, what are the reasons for not meeting any goals?
- 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?

Federally Funded Research and Development Centers (FFRDCs) follow a slightly different process and 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

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

management in ensuring a cost-effective operation; and (5) a determination that the criteria for establishing the FFRDC continue to be satisfied and that the sponsoring agreement is in compliance with FAR 35.017-1.

If the reviews show that the facility remains a high priority and has been successful in meeting its goals and objectives, the 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. In deciding whether to renew or recompete, the PO will take into consideration that the NSB 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).

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

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

In the event that a decision is made to recompete or to terminate support for a facility, the PO will give the 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 by the incumbent management entity) or terminate obligations to vendors and employees can be planned and implemented.

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

[1] Refer to the footnotes in Section 2.1.6 and 2.7.1 on award thresholds requiring DRB and NSB approval.

3.5.3 Detailed Guidelines for Oversight of Operations

Please contact the cognizant NSF program officer for details, which are given in the internal NSF draft document *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.

3.6 TERMINATION, TRANSFER, OR DIVESTMENT PLAN

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4 KEY MANAGEMENT PRINCIPLES AND REQUIREMENTS FOR LARGE FACILITIES

4.1 INTRODUCTION

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

(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 Program Officers [POs] should be thoroughly conversant with the contents of the PAM.)

4.2 COST ESTIMATING AND ANALYSIS

4.2.1 Cost Estimating, Budgeting, and Funding Overview

The Recipient is responsible for developing the cost estimates to design, construct, establish and/or operate a facility. NSF is responsible for conducting a detailed cost analysis of these estimates (and all assumptions used to develop them) for completeness, appropriateness and reasonableness, establishing the budget in collaboration with the Recipient, and then making the award based on the availability of funds. The PO assists with developing the required funding profile based on a cash-flow analysis by the Recipient with examination of associated risks,[1] and takes the steps to secure appropriate commitments from all internal and external sources of funds as articulated in the IMP. The cost analysis is an iterative process with inputs being refined following each major Design Review as described in Section 2.

For large facilities projects, the Recipient shall follow Government Accountability Office (GAO) cost and schedule estimating guidelines in creating the cost estimates in support of the budget requests, taking into consideration NSF policy and practice as given in the Large Facilities Manual. Proposing organizations and/or Recipients should consult with their PO for detailed guidance on Cost Book preparation.

For most large facilities costs, funding for the various activities is derived from the appropriate NSF budget account; typically Research and Related Activities (R&RA), Education and Human Resources (EHR) or MREFC accounts. Barring documented exceptions, the R&RA (and possibly EHR) account will be used to fund development, design, operations & maintenance, and renewal or termination stage costs. The MREFC account will be used to fund construction, acquisition and commissioning costs as part of the construction stage.

For non-MREFC projects, the R&RA (and possibly EHR) account also funds the construction stage 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 funded through the appropriate award instrument (typically a Cooperative Agreement [CA]) between NSF and the managing organization. Infrastructure utilization is typically supported through grants R&RA or EHR), funded by NSF and/or other agencies, to individual researchers to conduct research and education activities at the facility.

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[1] 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).

Cost estimates for construction are part of a construction proposal, which is subjected to internal and external review by NSF. External review may consist of a combination of panels to obtain expert advice and/or commissioning of independent cost estimates. The resulting construction budget is the result of developing the approved performance project baseline and contingency from all of these inputs. Proposed budgets should also include contributions from other agency or international partners. As indicated in previous sections, before proposals for large facilities construction can be awarded, funds for the project must be appropriated by Congress and approved by NSF at the appropriate level.

When funds from separate appropriations are obligated under a single award, the award instrument (assistance award or contract) will specify the account to which various expenditures are to be charged. Recipients are expected to adhere to those specifications; the PO and the Grants and Agreements or Contracting 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 assistance awards (CAs or grants), the PO recommends the making of an award in accordance with the proposal processing procedures contained in Chapter VI of the *Proposal and Award Manual* (PAM). The PO, together with staff from NSF's Division of Acquisition and Cooperative Support (DACS), drafts the award instrument that will govern the project in accordance with the procedures contained in Chapter VIII of the PAM or the FAR as appropriate.

For awards involving property, the PO consults with the OGC, the Division of Financial Management, and the Large Facilities Office at NSF (LFO) Liaison to determine whether the value of the property should be included on NSF's financial statements. The LFO Liaison coordinates with other BFA management divisions as required. In circumstances where there are multiple recipients, the award instrument may designate one which coordinates the others. Alternatively, a single recipient could make sub-awards. In that case, POs need to be aware that NSF may lose "privity" – a legal relationship conferring the ability to intervene or deal directly with the sub-awardees. The recipient is then responsible for ensuring performance of the sub-awardee scope of work.

4.2.2 Cost Estimating and Analysis for Construction Awards

4.2.2.1 Characteristics of Construction Cost Estimating and Budgets

As part of its oversight and assurance roles, NSF utilizes a combination of internal staff, outside experts and consulting firms, and panel reviews at the Conceptual Design, Preliminary Design and Final Design phases to assure that proposed construction cost estimates and budgets have the following characteristics:

- Performance baseline and contingency estimates have a sound, supportable and well documented basis of estimate (BOE).
- Subsequent budgets are based on the approved cost, schedule and performance requirements defined in the project baseline.
- The budget, schedule, and scope contingencies are adequate to mitigate anticipated risk factors defined in the project risk analysis. This includes estimated inflation factors specific to the project.
- Cost estimates include adequate funding for project management, including the use of appropriate project management tools such as project management control software and associated staff support.
- There are sound strategies to de-scope the project, such as a time-phased scope contingency[1] plan in the budget.
- The cost estimate includes system integration. Failure to address integration issues, including appropriate staffing and funding, can lead to serious cost overruns and corresponding schedule slips.
- The cost estimate includes commissioning, testing and acceptance of the facility and transition from construction/acquisition to operations. The subsequent budget includes 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, sufficient, and well documented in the PEP and IMP.
- All cyber-infrastructure 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 3 to 5 years.

[1] Scope contingency is defined in Section 5.2.3.

4.2.2.2 Management Fees

Management fee is an amount of money paid to a recipient in excess of a cooperative agreement's or cooperative support agreement's allowable costs. Generally, NSF does not permit the payment of fee (profit) to organizations under financial assistance. However, a management fee may be authorized for awards in the limited circumstances of construction or operations of a large facility as the responsible organization is likely to incur certain legitimate business expenses that may not be reimbursable under the governing cost principles. NSF provides for a management fee in these limited circumstances, as appropriate, recognizing that the awardee would only incur such expenses as a result of its support of the NSF-funded activity.

Prior Approval of Management Fees - A management fee proposal must be submitted to NSF that provides sufficient visibility into each expense category to identify its intended purpose. Agreement on management fee amounts shall be completed and a specific dollar amount established prior to the initiation of work under an award, or any subsequent period not authorized as part of the initial award. Any amount negotiated shall be expressly set forth in the terms and conditions of the award. Awardees may draw down the management fee in proportion to the amount incurred during the performance period. Fee established for a period longer than one year shall be subject to adjustment in the event of a significant change to the budget or work scope.

The following expense categories will be used in the negotiation and award of a management fee:

- **Working capital necessary to fund operations under an award** - An amount for working capital may be necessary to ensure a level of retained earnings available to the organization in order to secure credit and borrowing to assure the financial health of the organization.

- **Facilities capital necessary to acquire assets for performance** - An amount for facilities capital may be necessary to allow the organization to acquire major assets and to address expenses that require immediate substantive financial outlays but that are only reimbursed through depreciation or amortization over a period of years.

- **Other ordinary and necessary expenses for business operations that are not otherwise reimbursable under the governing cost principles** – An amount for other expenses that are ordinary and necessary but not otherwise reimbursable may be necessary to provide a reasonable allowance for management initiative and investments that will directly or indirectly benefit the NSF-funded activity. Inclusion of amounts under this category warrants careful consideration of the benefits that may be obtained when providing management fee. Examples of potential appropriate needs include expenses related to contract terminations and losses, certain appropriate educational and public outreach activities, and financial incentives to obtain and retain high caliber staff.

- **Prohibited Use of Management Fees** - Although not an exhaustive list, the following are examples of expenses that are not appropriate uses of a management fee:
  - Alcoholic beverages
  - Tickets to concerts, sporting and other events
  - Vacation or other travel for non-business purposes
  - Social or sporting club memberships
  - Meals or social activities for non-business purposes
  - Meals or social activities for business purposes that are so extravagant as to constitute entertainment
  - Luxury or personal items
  - Lobbying as set forth at 2 CFR § 200.450 and FAR 31.205-22, as appropriate to the recipient type

In addition, costs incurred under the award that are otherwise allowable under the governing cost principles must be classified as direct or indirect charges to the award and shall not be included as proposed management fee elements.

Documentation Requirements on Use of Management Fees - Even though the management fee represents an amount in excess of allowable cost and is therefore not subject to the governing cost principles, NSF, as a matter of policy, has determined that review of appropriate use of such funds is necessary. Information available on actual uses of management fee previously awarded by NSF in the preceding five-year period under any award shall be included in the proposing organization’s fee proposal. As a term and condition of the award, the awardee will be required to provide information (typically annually) on the actual use(s) of the management fee. NSF will conduct reviews of this information regarding the extent to which the awardee fee proposals have proven reliable when compared with actual uses of management fee (both as to the fee amount as well as the planned uses of the fee). Unexplained failure to reasonably adhere to planned uses of fee will result in reduction of future management fee amounts under the award.

4.2.3 Cost Estimating and Analysis 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 real-world funding constraints, a proper balance should be struck between support for the scientific users of facilities and the construction and maintenance of the facilities themselves. In many cases, such scientific support extends to in-house users of the facilities. 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 stage of a large facility or infrastructure project, it is essential to begin to establish the level of funding needed for operations as early as the Conceptual Design Phase. The choice of technology during construction may impact the eventual funding level for operations, and the project design should be optimized with operating cost as a key element. The Program Officer (PO) should provide "not-to-exceed" guidance on expected operating budgets 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. The estimate is regularly reevaluated during the final design phase and the construction stage to ensure that the expectations of NSF and the recipient are aligned.

NSF staff should ensure that a plan is in place to make anticipated operating funds available when as the project transitions form construction and/or acquisition to operations. In many 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 external 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 as early as the Development Stage and continue 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 (OMB) 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 and cyber-infrastructure specialists; administrative and grounds staff; environmental, health and safety specialists; machinists; designers, engineers and software experts to support users; engineers/scientists to conduct research and development (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 and cyber-infrastructure 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.[1] Furthermore, informed estimates regarding the small- and mid-scale instrumentation needs of the facility and users of the facility should be made.

[1] 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.

4.2.4 Education and Outreach Budgeting 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 (Research Experiences for Undergraduates [REU] programs); K-12 education; research experiences and in-service training for K-12 teachers (Research Experiences for Teachers [RET] programs); 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 Program Officer (PO) should encourage the Principle Investigators and/or eventual 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 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.

4.2.5 Budget Contingency Planning for the Construction Stage

4.2.5.1 NSF Policy Positions

1. "Management reserve" is not allowable in the risk-adjusted Total Project Cost (TPC) estimate; only "contingency."
2. Directorates shall be responsible for the first 10% of cost overruns which exceed the Board approved TPC.
3. At the Preliminary Design Review (PDR), projects shall have a prioritized de-scoping plan that equates to at least 10% of the performance baseline.
4. In support of NSF's "No Cost Overrun" policy, projects shall use a confidence level for contingency estimates between 70 and 90 percent (under a probabilistic approach) based on the particulars of the project and the inherent ability to de-scope.

4.2.5.2 Introduction

NSF's "No Cost Overrun" policy was originally codified in the Fiscal Year (FY) 2009 budget request to Congress which reads:

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

The policy has been continually reinforced in subsequent budget requests to Congress and although the wording has changed slightly, the intent has remained the same.

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

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

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

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

In contrast, "Management Reserve"[4] is often used by industry and other organizations to cover the unforeseen risks, or the "unknown unknowns." **However, NSF has no mechanism for holding management reserve. As a result, the Directorate is responsible for the first 10% of costs which exceed the approved TPC.** To mitigate this risk, the project's prioritized and time-phased de-scoping plan must equal **at least 10%** of the performance baseline when established at PDR. The ability to de-scope varies widely by project and the impacts on the eventual scientific capabilities of the facility will also vary. The scope contingency plan should be well

[1] NSF terminology aligns with that of AACE International, the Association for the Advancement of Cost Engineering, and of the Project Management Institute's ***Project Management Body of Knowledge (PMBOK Guide).*** See Section 5.2.3 for NSF definitions of contingency and management reserve.

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

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

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

considered and strive to minimize negative impacts. The Directorate may also choose to cover the cost overrun from programmatic funding (and increase the TPC) in lieu of de-scoping if it deems the science-support capabilities of the facility would be too severely impacted.[1] See Section 2.4.1 of this manual for required approvals.

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

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

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

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

Since development of contingency is statistically-based, there is a chance that not every risk will be realized at its maximum impact. Therefore, even when properly managed, it is possible that contingency dollars will remain at the end of the project. Once project objectives are met and the project completed, **any residual funds must be de-obligated and returned to NSF** at which time NSF will request possible re-allocation of those dollars to other agency priorities. Awarded contingency shall be held by the Recipient until project completion, but no later. Budget, Finance and Award Management (BFA), the Large Facilities Office (LFO), and the Program Office will conduct a project close-out with the Recipient in accordance with NSF policy and as described in Section 2.4.3 of this manual.

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

- Contingency budgets are developed in accordance with widely accepted standards for risk assessment and planning. Contingency budget, scope, and schedule are similarly derived from probabilistic, bottom-up assessments of the entire project scope.
- Contingency budgets are evaluated for reasonableness by NSF through use of expert review panels convened by the Program that examine the BOE and methodology, and compare the cumulative contingency reserve amounts with historical experience on similar projects. This happens at each phase of the project (Conceptual, Preliminary, and Final Design) at increasing levels of refinement. Other divisions within NSF, and potentially contracted experts, will also evaluate the contingency estimate as part of the total project cost assessment as it moves through these phases.
- The overall status of remaining contingency, future liens on contingency, and all allocations and returns of contingency funds (as risks are realized or retired) are reported on a periodic basis as specified in the award instrument. This is part of the standard project reporting and requires archiving in the permanent electronic record used by NSF (FastLane/e-Jacket).
- Management and use of contingency is documented separately through the configuration and change control process and must reference the associated Work Breakdown Structure (WBS) elements and/or the previously identified Risk. The Earned Value Management (EVM) framework for financial status reporting will eventually reflect movement of contingency into the baseline budget (increase or decrease in Budget at Completion; BAC). Although traceable as allocations or returns to the contingency budget, contingency dollars become part of the baseline and are no longer separately identifiable as contingency once incorporated.
- All project expenditures must be used only for scope as defined by the elements of the NSF approved performance baseline, and all are subject to financial audit.
- Budgets submitted on NSF SF 424C in lieu of SF 1030 which specifically calls out contingency separately.
- Management of contingency is described in the Configuration and/or Contingency Management Plan as part of the PEP. In this plan, thresholds are established (based on

the nature of the project) on who has the authority to approve the use of contingency. These thresholds are also documented in the award instrument. Below the thresholds, the Recipient has authority to manage and allocate contingency budget to specific in-scope elements of the project WBS following the Configuration Change Control Process. Above these thresholds, approvals from NSF are required, with the level of approval corresponding to the magnitude of the proposed change.

- Financial controls prevent the cumulative Recipient cash draws from exceeding the obligated spending authority in NSF's financial system.

4.2.5.3 Contingency Planning and Assessment during Conceptual Design

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

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

[1] See Section 5.2, Risk Management Guidelines, for more information about formulating and implementing Risk Management Planning, and standard references on project management, such as the PMBOK Guide, for a detailed explanation of the individual steps in Risk Management Planning: risk identifications, qualitative and quantitative risk analysis, risk handling, and risk monitoring.

4.2.5.4 Contingency Planning and Assessment during Preliminary Design

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

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

Budget, scope, and schedule risk are usually correlated to some extent. A change in scope, for instance, may mean more costs and additional schedule. Risk analysis and budget and schedule contingency estimation methods must consider the degree of correlation in estimating an appropriate level of budget contingency.

[1] See Section 5.2, Risk Management Guidelines, for more information about formulating and implementing Risk Management Planning, and standard references on project management, such as the PMBOK Guide, for a detailed explanation of the individual steps in Risk Management Planning: risk identifications, qualitative and quantitative risk analysis, risk handling, and risk monitoring.

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

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

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

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

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

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

The budget contingency estimate will be further evaluated by NSF as part of its second internal cost analysis for the project based on the PDR deliverables. This second cost analysis will give

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

[2] See Section 5.2.3 for definitions.

assurance on the TPC brought forward to the NSB as well as help inform the cost book and other deliverables developed during the Final Design Phase in preparation for award.

4.2.5.5 Development of the Contingency Use Process

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

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

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

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

4.2.5.6 Contingency Planning and Assessment during Final Design

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

4.2.5.7 Contingency Use and NSF Oversight during Construction

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

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

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

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

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

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

4.2.5.8 Reporting Requirements

Each project in construction must report monthly to NSF on the financial status of the project, while projects in the Design stage are highly encouraged to submit a monthly report. At a minimum, the monthly report will include: (1) the amount of available budget contingency, as a total amount, and as a percentage of the estimated cost to complete (ETC) the project; (2), EVM reporting, at least at the second level of detail in the WBS; (3) an updated BAC and Estimate at Completion (EAC) for each second level element; and (4) an updated change log indicating all contingency allocations ("puts and takes") and a "liens" list of projected amounts of possible future calls on contingency. Projects are expected to periodically compute and update the ETC and EAC, and compare these quantities to the BAC and TPC. NSF will monitor the financial information provided and compare the available contingency to the estimated remaining risk exposure. NSF may request corrective action if the contingency budget appears inadequate to manage remaining risk.

All CCB actions, irrespective of amount, or whether they increase or decrease the BAC, must be reported directly to Program Officer at least quarterly. All CCB actions exceeding defined thresholds for allocation of budget, schedule, or scope contingency shall be approved by NSF as codified in the PEP and the CA. NSF-approved CCB actions must be made part of the award's permanent record. For assistance awards (CAs or grants), CCB documentation is maintained in NSF's electronic record system (e-jacket) in accordance with the award terms and conditions.

NSF's financial system controls prevent the cumulative Recipient cash draws from exceeding the obligated spending authority. All funds are retained within NSF's obligated award amount to be drawn down by the Recipient for allowable expenses once needed. NSF conducts various post-award monitoring activities, such as periodic external reviews (whose scope includes financial as well as technical status), site visits, and single and program-specific audits to monitor compliance.

4.2.5.9 Partnership Considerations

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

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

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

Sample Change Control Request

Change Request #: CR-

All change requests, whether approved or not, should be assigned a number, entered into a change log, and archived. NSF must be notified of all pending and approved change requests.

Date: ______________

Change Request Title: ______________

Impacted WBS: ______________

List the WBS IDs and titles for the elements impacted by this change, using the most appropriate summary levels as necessary.

Associated Risk ID #: ______________

List the Risk Register IDs and titles of the risks or opportunities associated with this change.

Originator Name: ______________

Name and signature of the person making the request for this change.

Originator Signature: ______________

Project Controls Rep: ______________

Identify any other personnel instrumental to this change, as desired. Examples are: management sponsor, preparer, the project controls implementers, etc.

Summary Change Description:

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

☐ NSF approval required
☐ Technical Review Board approval required

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

Scope or Technical Impact:

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

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

Budget Impact:

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

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

Budget Impacts by WBS and Control Account

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

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Sample Change Control Request

Schedule Impact:

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

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

Changes to Project Milestones

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

Project Acknowledgement and Concurrence Signatures:

Title/Name	Signature	Date

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

Project Management Approval and Disposition:

☐ Change Approved Signature:___________________________ Date ______________
☐ Change Rejected (CCB Chair)

Disposition:

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

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Sample Change Control Request

NSF Program Officer Approval (If required):

Program Officer Signature______________________________________ Review Date_________________

Comments:

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

Project Controls Implementation:

(Describe Actions Taken in Cost and Schedule Baseline)

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

Project Controls Staff ___________________________ Implementation Date ________________

Additional Documentation:

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

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4.2.6 Budget Contingency Planning during the Operations Stage

Any request for contingency must comply with paragraph 200.433 of the Uniform Guidance. As a result, it is generally more appropriate for operating budgets to include only explicitly identified allowances for repairs, maintenance and other factors such as “technology refresh” for cyber-infrastructure or other similar up-grades. Unless a formal risk assessment is conducted and a Risk Management Plan for operations implemented, it is recommended that each project have in place a systematic program to identify the potential cost and operations impacts of both recurring and non-recurring events to develop these allowances and include this information as part of the operating plan.

A Program Officer (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. For example, the Academic Fleet utilizes the Major Overhaul Stabilization Account (MOSA) as part of the operating budget development process to distribute regular and periodic maintenance costs evenly over a series of five-year cycles.

Operating budgets should include, when appropriate, resources to provide a continuing program of advanced research and development (R&D) that will enable a facility to evolve its scientific program and best meet the needs of the research community. Funding for these kinds of up-grades may also come from separate equipment and/or instrumentation programs within the Directorate or Division. 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.

4.3 SYSTEM INTEGRATION, COMMISSIONING, TESTING AND ACCEPTANCE

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

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

Frequently, some aspects of construction and/or acquisition overlap with initial operation. A detailed Transition Plan should be developed by the Recipient 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 Large Facilities Office.[1] 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?

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

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

For projects funded through the MREFC account, even if limited operations are undertaken, the changeover from MREFC funding to Research and Related Activities (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.

4.4 DOCUMENTATION REQUIREMENTS

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

Recipients should retain financial records, supporting documents, statistical records and other records pertinent to the award instrument (CA, grant or contract) 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 in accordance with either the Uniform Guidance or FAR requirements.

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

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

- Memorandum of Understanding (MOU) and any other project agreements or deals;
- Architectural, engineering, shop and as-built drawings;
- Correspondence identifying problems, the resolution process, and the final decision;
- Contingency use log;

- Change requests and approvals; and
- System integration, commissioning, testing and acceptance plans and results.

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

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

4.5 REQUIREMENTS FOR PERFORMANCE OVERSIGHT, REVIEWS AND REPORTING

4.5.1 Introduction to 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 Recipient is responsible for complying with the reporting requirements contained in the award instrument (e.g., technical and financial reporting), Government Performance and Results Act (GPRA) reporting and final reporting and closeout requirements for termination of the award. The Recipient 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.[1]

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 Program Officer (PO) has continuous responsibility for oversight of the facility in accordance with the Internal Management Plan (IMP) and through various reviews and reports, such as consultation and coordination with the Large Facilities Office, coordination of assurance through the NSF Integrated Project Team (IPT), and periodic updates to the MREFC Panel (if applicable) and the NSB.

Reviews and reporting incur certain costs. Depending on the size of the project and the distribution of the information, these costs may be significant enough to warrant explicit inclusion in the project budget. Review and reporting plans and costs should be identified in the PO's IMP and in the Recipient's PEP so that they can be adequately considered in the project budget and schedule. The PO should clearly define the reporting requirements that are the responsibility of the Recipient in the award instrument and these requirements should be noted as milestones on the project master schedule for construction. The Recipient's Project Director adheres to their internal practices regarding financial and business operations controls,[2] 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.

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[1] Please contact the cognizant NSF PO for details and a description of best practices, which are given in "Guidelines for Reporting to NSF during Planning, Construction, and Operation of MREFC Funded Projects" and the internal NSF draft document "Guidelines for Planning External Reviews of NSF's Large Facilities."

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

4.5.2 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. For example, providing the written minutes from a weekly construction meeting is common practice. During the Construction Stage, the Project Director, who is responsible for executing and controlling the project in accordance with the PEP and the award instrument, reports to the Program Officer (PO) on a periodic basis (monthly for MREFC-funded projects and no less than quarterly in other cases). Those reports should include the following:

- 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 Earned Value Management System (EVMS) methodology;
- Review of current or anticipated problem areas and corrective actions;
- 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 LFO a written monthly summary of this information in a standard format provided by the Deputy Directory for Large Facility Projects (DDLFP). 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 Internal Management Plans (IMPs). In every case, the PO is responsible for keeping the appropriate NSF staff (Grants and Agreements or Contracting Officer, Division Director (DD), Assistant Directors (ADs), Integrated Project Team [IPT] members, etc.) informed of the project status.

In executing and controlling the project, the Recipient manages the project to the Baseline Project Definition and cost and schedule. The Recipient will notify the PO of cost and schedule variances as part of the routine reporting process.

4.5.3 Reviewing Recipient Performance

The Recipient is expected to provide appropriate internal management of its own activities and is expected to comply with the reporting requirements contained in the award instrument (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 NSF's oversight and assurance process that allows the Program Officer (PO) to monitor performance and compliance with project goals.

Through the terms and conditions of the award instrument, the PO requires the Recipient 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 PO in consultation with the LFO Liaison. Both the review committee membership and the charge to the committee require concurrence from the PO and LFO Liaison. Invitees to the review shall include the PO, the cognizant Business Officer, and staff from the Large Facilities Office. Following the review, the LFO Liaison will produce an independent assessment of the review for the DDLFP. The Operations Review is not meant to compete with the Business Systems Review (BSR), which looks at business processes.

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."[1] 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

[1] Please contact the cognizant NSF PO for details and a description of best practices, which are given in the internal NSF draft document "Guidelines for Planning External Reviews of NSF's Large Facilities."

with the LFO Liaison to constitute a review charge and format tailored to meet the specific requirements of the review.

The BSR is one of NSF's advanced monitoring activities designed to assist with oversight and provide assurance of the suite of business systems (people, processes, and technologies) that support the administrative management of a large facility. The LFO has the lead role in coordinating the assessment of these systems by using desk reviews and site visits to determine if the administrative business systems used in managing the facility meet NSF expectations and are in compliance with federal regulations.

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.

BSRs are generally conducted on a five-year cycle for all facilities. For new MREFC projects, the BSR is ideally conducted prior to the construction award. The LFO uses an internal risk assessment process to decide which facilities will have a BSR conducted in any given year. Risk factors include:

- When the last BSR on the facility was conducted;
- New MREFC project being proposed;
- Other identified risks such as audit finding, significant changes in funding levels, management, scope, operational performance or mission of the large facility;

Further information and various details of the BSR process are provided in the BSR guide.[1]

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

4.5.4 NSF's Performance Metric for Construction

In accordance with the GPRA Modernization Act of 2010 (P.L.111-352); *Empowering the Nation Through Discovery and Innovation: NSF Strategic Plan for Fiscal Years (FY) 2011-2016;* and OMB requirements, NSF developed goals to measure construction/upgrade performance based on EVM systems used to monitor project cost and schedule. **For all MREFC facilities under construction, the NSF performance metric goal is that negative EVM cost and schedule variances for projects more than 10 percent complete will be kept at, or less than, negative 10 percent.** (Projects that are less than 10 percent complete are not held to this goal because EVM data is less meaningful statistically in the very early stages of a project.)

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).

4.5.5 Re-Baselining

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

The PO should consult with the NSF Integrated Project Team and the Directorate/Division Leadership, prior to authorizing re-baselining a project. Variances may result from many factors – for example, inadequate project planning or management, or factors not within the Project Director's (or manager's) control. Examples 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, unusually severe weather, etc.

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

1. Increases in the NSB-approved Total Project Cost (TPC),
2. A change in the approved project end date, and/or
3. Major changes in scope.

The LFO, the MREFC Panel, and the Director should be kept informed of any pending re-baselining discussions. NSF approvals are required per Section 2.4.1 of this manual. If only the schedule is extended without an increase in TPC, the terms and conditions of the award instrument apply (i.e. NSF policy on No-Cost Extension for CAs). 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.

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

4.6 PARTNERSHIPS

4.6.1 Partnerships Overview

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,[1] non-governmental entities, and foreign funding agencies. International partnerships are generally the most complex.

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

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

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

A second important issue is early negotiation with international partners. There is a need to start with a clear understanding by all partners as to how the construction project is to be managed 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

[1] See "Best Practices for Federal Research and Development Facility Partnerships," IDA Science & Technology Policy Institute, IDA Paper P-5148 Log: H 14-000676, for guidance or models on forming interagency federal partnerships.

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 and Integrative Activities (OIIA) 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.

4.6.2 Partnership Funding

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

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

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

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

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

- Evaluate NSF's role (NSF's authority and responsibility vary depending on its status as executive agent or as a majority, equal or minority partner). Assess risks and develop a plan to address them, e.g., implementation of controls that limit NSF's exposure to overruns (see Section 5.2, Risk Management Guidelines).
- Ensure that all partners understand the review and approval processes of the other partners.
- Prior to entering into a partnership, develop and execute an MOU.

4.6.3 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 *Proposal and Award Manual* (PAM).

5 SPECIAL TOPICS AND SUPPLEMENTARY MATERIALS

5.1 INTRODUCTION

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

5.2 RISK MANAGEMENT GUIDELINES

5.2.1 Introduction

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

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

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

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

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

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

NSF requires large facility awardees to develop and follow formalized Risk Management during the design and construction stages of sponsored Major Research Equipment and Facilities Construction (MREFC) projects.

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

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

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

The Risk Management Plan (RMP) is a required element of the Project Execution Plan (PEP) described in Section 3 of this manual (often as a separate document). A RMP should be included in the project planning and proposals no later than the start of the conceptual design phase. The Plan should identify the responsibilities for risk management and describe the Risk Management process that will be followed— including roles and responsibilities, procedures, criteria, tools, and techniques to be used to identify, analyze, respond to, and track project risks. The level of detail in the plan, and the scope, timing, and level of risk analysis should be commensurate with the maturity and complexity of the project and may evolve and change over time. An example of an acceptable RMP outline is shown in Table 5.2.5-1.

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

The Risk Register – typically a spreadsheet or data base – is a tracking tool that includes a description of all risks that are deemed to be important to achieving project success, along with an assessment of those risks that allows them to be prioritized for effective management. The Risk Register also includes the risk handling strategy, the person to whom each risk has been assigned for accountability purposes, the current status of the risk handling strategy, and comments. An example of a commonly used style for a Risk Register is given in Table 5.2.5-1. It should be noted that appropriate tracking tools will vary among projects because the types of information and indicators being monitored vary from project to project. The selection and definition of a tracking system to be used in a project should be commensurate with the size and complexity of the project and should be defined in the project's RMP.

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

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

5.2.2 Definition of Project Risk and Risk Exposure

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

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

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

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

5.2.3 Definition of Allowable Contingencies

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

5.2.3.1 Allowable Contingency

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

> **Contingency:** *"a planned amount of money or time which is added to a baseline estimate to address specific, identified risks."*[1]
>
> **Management reserve:** *"a planned amount of money or time which is added to a baseline estimate to address unforeseeable events."*[2]

NSF does not carry management reserves as defined above. For NSF projects, only the first type, **Contingency**, is allowed. This means that the estimation of contingency amounts must be tied to risks identified at the time the total budget and duration are set, and that such contingency can only be used to mitigate those pre-identified risks. Use of contingency to cover unforeseen events is not allowed. See Section 5.2.7 for using proper quantitative estimating methodologies for determining risk based contingencies.

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

5.2.3.2 Contingency Definitions

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

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

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

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

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

For MREFC construction projects, the amount of budget contingency is determined by performing a probabilistic risk analysis on the baseline cost and schedule and selecting a Total Project Cost with an acceptable confidence level (typically between 70%-90%). See Section 4.2.5 for details on Total Project Cost requirements and caps. Thus Total Project Cost is the sum of the baseline budget and the selected contingency amount. Budget contingency is held separately from the PMB and allocations of budget contingency to and from the PMB are managed through formal change control.

Schedule contingency: *An amount added to a baseline schedule estimate to allow for identified delays, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional project duration. Typically estimated using statistical analysis or judgment based on past asset or project experience.*

For MREFC construction projects, the amount of schedule contingency is determined by performing a probabilistic risk analysis on the baseline schedule of activities and selecting a commitment finish date with a confidence level between 70%-90%. The overall project duration is the sum of the baseline duration and the selected contingency amount. Schedule contingency is held separately from the PMB and allocations of schedule contingency to and from the PMB are managed through formal change control.

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

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

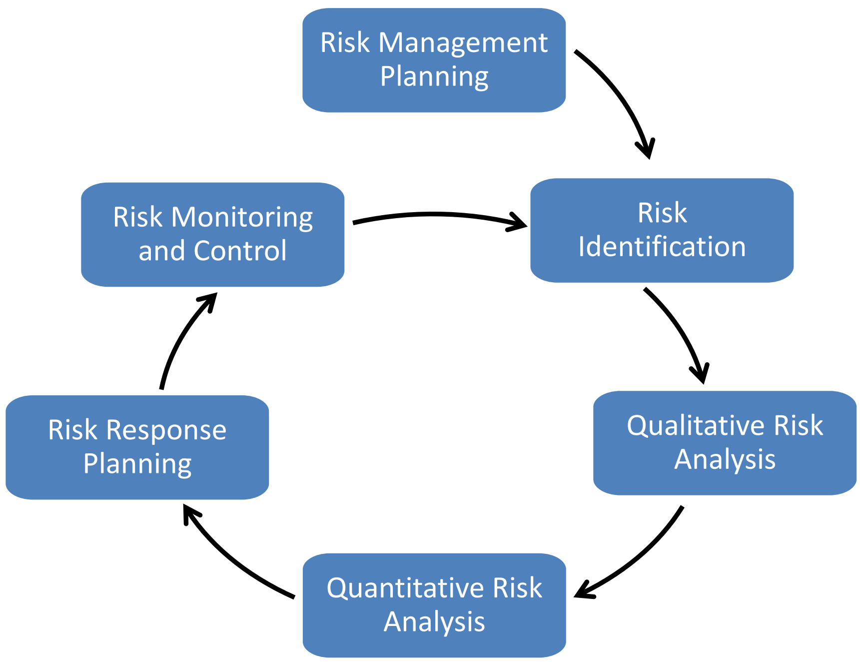
5.2.4 Risk Management Steps and Methodology

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

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

The relationship between these steps is shown in Figure 5.2.4-1.

Figure 5.2.4-1 Picture of Six Risk Management Processes (According to PMI)[2]



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

[2] Risk Handling and the Project Management Institute's Risk Response Planning process are somewhat equivalent. Risk Handling includes implementing the risk mitigation and other responses, whereas Risk Response Planning envisions that these actions will be included in the Project Execution Plan and implemented as part of the PEP.

The Risk Management steps outlined above are iterative and continuous and any one step, or all of the steps, could be active at any given time. Risk analysis is performed continuously throughout the project life cycle. For example, a conceptual risk analysis may be conducted to facilitate selection between alternative options, to determine the level of project management required, to identify where the challenges lie, and to determine the level of technical information and development activity necessary to achieve project success. That risk analysis is then updated during each of the life cycle phases of the project. Performing risk analysis is particularly necessary in preparing for key project decisions. Periodic reviews of the risks at appropriate intervals should be performed to identify new risks, to evaluate progress in risk handling strategies, as well as to evaluate changes during the project development and implementation cycles. Risk Management Planning, and the RMP, may also need to be re-addressed at times of significant change, such as transitions from one project life cycle to another or during a re-baselining with significant modifications to the project baseline.

5.2.5 Risk Management Planning

Planning begins by developing and documenting a Risk Management strategy. Early efforts establish the purpose and objectives, assign responsibilities for specific areas, identify additional technical expertise needed, describe the assessment process and areas to consider, delineate considerations for mitigation planning, define a rating scheme, dictate the reporting and documentation needs, and establish report requirements. The strategy to manage root causes provides the program team with direction and a basis for planning. The output of risk management planning is a written document – the Risk Management Plan (RMP) – containing the details of how risk will be managed through application of tools and processes defined in the plan. See the next subsection for a description of requirements for the RMP.

One key strategic decision that should be made early in the Risk Management planning is the selection and assignment of personnel with appropriate capability in Risk Management to lead and/or guide the planning and analyses. As will be seen from the topics presented in the analysis portion of the section, the art and science of risk management can be extremely complicated for complex, high risk projects. While project managers, scientists and engineers may have expert knowledge and judgment for identifying, estimating impacts from, and defining mitigation for individual risks, they are usually not expert in estimating the overall or aggregate risk exposure to the project from the combined impact of many individual risks. Finding qualified resources to meet the risk management requirements of the project, particularly for establishing the amount of contingency, should be a high priority for early planning in order to ensure that methodologies and programming tools can be selected and implemented in a timely manner. Options include sending existing staff for specialized training in risk management and tool usage, directly hiring risk management experts, contracting with industry, or some combination of the above.

A second early key decision is the determination of what risk assessment methodologies and tools will be used, from first estimates through construction. The sophistication of the appropriate risk assessment tools typically increases with advancing planning detail and maturity, as well as with increasing project complexity. A project that includes a high number of procurements and in-house tasks typically requires software applications and methods that use a fully resource loaded schedule for risk assessment and contingency estimation, while a project entailing management of a single large contract may be adequately served by tools and methods that use cost spreadsheets and summary level schedules. Choosing the appropriate tools and methods at the outset can avoid the need and the burden of changing to different systems as the project planning matures.

Risk Management planning is iterative. Normally, the risk management methodology and procedures are defined as part of the risk management process planning early in the design stage, but they may be extended or modified during design and execution as long as the efforts remain within approved scope.

5.2.5.1 Risk Management Plan (RMP)

The Risk Management Plan (RMP) describes how risk management will be applied on the project. It is an integral part of the PEP, as outlined in Section 3.4 of this manual. The level of detail in the plan and the scope, timing, and level of risk analysis should be commensurate with the complexity and maturity of the project as it advances through design and construction stages. The plan is a living document used throughout design and implementation and should therefore be under configuration management. The Risk Management Plan should include the following elements:

- Risk Management Strategy and Approach
- Roles and Responsibilities
- Processes used to apply the Risk Management process
- Baseline definition for Calculating Risk Exposure and Contingency needs
- Contingency Estimating and Management
- Resources assigned to and schedule, cost, and timing of risk management activities

The Recipient should periodically review the RMP and revise it, if necessary. Some events may drive the need to update an existing RMP, such as: (1) the baselining of a project, (2) preparation for a major decision point, (3) technical audits and reviews, (4) an update of other project plans, and (5) a change in major project assumptions. A sample format with the expected content for a Risk Management Plan (RMP) is outlined in Table 5.2.5-1.

Table 5.2.5-1 Sample Format for a Risk Management Plan

Section	Description
1. Introduction	This section should address the purpose and objective of the plan, and provide a brief summary of the project, to include the approach being used to manage the project, and the acquisition strategy.
2. Definitions	Definitions used by the Recipient should be consistent with NSF definitions for ease of understanding and consistency. However, the NSF definitions allow program officers flexibility in constructing their risk management programs. Therefore, each Recipient's RMP may include definitions that expand the NSF definitions to fit its particular needs. For example, each plan should include, among other things, definitions for the ratings used for technical, schedule, and cost risk in qualitative risk analysis.
3. Risk Management Strategy and Approach	Provide an overview of the risk management approach, to include the status of the risk management effort to date, and a description of the project risk management strategy.
4. Organization	Describe the risk management organization of the Recipient and list the roles and responsibilities of each of the risk management participants.
5. Resources Implications of the Plan	The resources to be used in managing risk on the project should include the time of management and project team members as well as risk specialists and contractors if appropriate, to manage effectively the risks on the project. These risk management costs should appear specifically in the project budget.

Section	Description
6. Schedule Implications of the Plan	The time periods in the project schedule when risk management activities are planned to occur. Activities providing sufficient time to perform the tasks and milestones to record their completion should be inserted in the project schedule and statused along with the schedule statusing plan.
7. Risk Management Process and Procedures	Describe the project risk management process to be employed, i.e., risk planning, qualitative and quantitative risk assessment, handling, monitoring and documentation, and a basic explanation of these components. Also provide application guidance for each of the risk management functions in the process. If possible, the guidance should be as general as possible to allow the project's risk management organization flexibility in managing the project risk, yet specific enough to ensure a common and coordinated approach to risk management. It should address how the information associated with each element of the risk management process will be documented and communicated to all participants in the process, and how risks will be tracked to include the identification of specific metrics if possible.
8. Risk Planning	This section describes the relationship between continuous risk planning and this RMP. Guidance on updates of the RMP and the approval process to be followed should be included.
9. Risk Identification	This section of the plan describes the identification process. It includes procedures to be used for examining the critical risk areas and processes to identify and document the associated risks.
10. Risk Register Analysis and Ranking	This section summarizes the analyses process for developing a qualitative or quantitative risk rating and populating the Risk Register. This rating is a reflection of the potential probability of each risk and the impact of each risk on the project schedule, cost, scope and quality. It also describes how the risk analysis data will be collected and maintained throughout the project's life cycle.
11. Probabilistic Risk Analysis and Contingency	This section describes the way the project will analyze the implications of identified and quantified risks on the total project schedule and cost objectives or major milestones. Typically a Monte Carlo simulation is used based on the project resource-loaded schedule or on the cost estimate if a schedule is not available. This section also describes the use of the risk analysis results for setting contingency amounts and prioritizing risks for risk mitigation.
12. Risk Handling	This section describes the risk handling options, and identifies tools that can assist in implementing the risk handling process. It also provides guidance on the use of the various handling options for specific risks.
13. Risk Monitoring	This section describes the process and procedures that will be followed to monitor the status of the various risk events identified including the frequency and organizational level of risk review. It provides for identification and calibration of new risks should they arise. It should provide criteria for the selection of risks and risk mitigations to be reported on, and the frequency of reporting. Guidance on the selection of metrics should also be included.
14. Risk Management Information System, Documentation and Reports	This section describes the management information system structure, rules, and procedures that will be used to document the results of the risk management process. It also identifies the risk management documentation and reports that will be prepared; specifies the format and frequency of the reports; and assigns responsibility for their preparation and dissemination.

Section	Description
15. Risk Exposure and Contingency Management	This section describes the specific process and procedures used to determine construction project risk exposures and the concomitant contingencies for scope, cost, and schedule. It describes contingency management plans and processes and ensures that contingency use is linked to both an identified risk and an appropriate Work Breakdown Structure (WBS) element within project scope.

5.2.5.2 Roles and Responsibilities

Typically, the Project Manager or a designated Risk Manager (RM) is responsible for leading the identification and analysis of project risks. All stakeholders (e.g., users, designers, and sponsors) involved in the project are asked to provide input on what they deem to be the risks for the project, possible risk mitigations, and ways to capture potential opportunities. The RM consolidates the information collected and creates the list of risks with accompanying attributes, and manages the response to the risks. An example of a Roles and Responsibilities table for key stakeholders and project staff that meets requirements is shown below in Table 5.2.5-2.

Table 5.2.5-2 Example of a Risk Management Roles and Responsibilities Table

Roles	Responsibilities
Organization Management	• Support the risk management process. Encourage all levels of the project organization to participate fully and openly in the process. • Make project decisions based in part on the results of risk analysis. • Provide the culture that supports risk management and welcomes honest and realistic results.
Risk Manager	• Oversee the Identification and documentation of new risks (threats and opportunities) in the risk register • Oversee the analysis of risks by the project team and work with them to develop risk response plans (mitigate, avoid, accept, and transfer). • Oversee reporting and tracking of risk activities during project status meetings • Document and communicate risk activities frequently with stakeholders • Review risks as they are concluded, and identify lessons learned • Recommend and champion mitigation strategies to the Change control Board (CCB) on behalf of the risk management team.
Project Team Members	• Assist the RM with the risk identification, qualitative and quantitative risk analysis and development of risk response plans (mitigate, avoid, accept, and transfer). Participate in risk workshops and interviews to provide risk data. • Submit new threats, opportunities, and mitigations into the risk system as they arise. • Assist the RM with the development and execution of risk response plans • Attend project risk status meetings, as needed, and assist RM with the reporting and tracking of risk activities • Assist the RM with documenting and communicating the risk (threats and opportunities) activities frequently with stakeholders • Review risks as they are concluded, and identify lessons learned

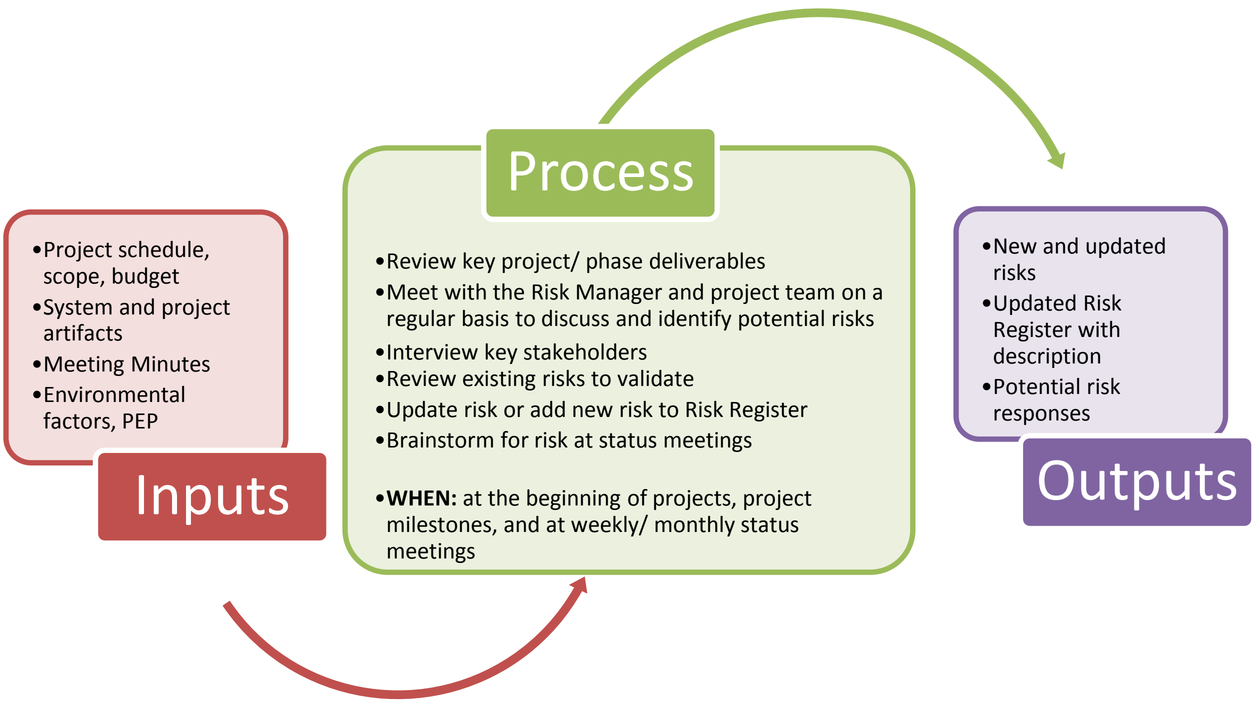
Roles	Responsibilities
Risk Owner	• Assist the risk originator (PM, RM, project team member, etc.) with development of the risk descriptions • Assist the RM and project team with the analysis development of risk response plans (mitigate, avoid, accept, and transfer) contingency plans • Update the risk register with modifications to risks • Monitor the risk triggers and update the risk register • Attend project status meetings, as needed, and assist the PM with reporting and tracking risk activities • Assist the RM and project team with documenting and communicating risk activities with stakeholders • Capture risk closure notes in the risk register and lessons learned

5.2.6 Risk Identification

5.2.6.1 Risk Identification Process

Risk identification is an organized approach for determining, listing, and describing events that might impact a project's objectives (for example, time, cost, scope, and performance). It is an iterative process that is conducted throughout the entire project life cycle. The risks are described with a basis as to why this event is considered a risk. Identification relies on the skill, experience, and insight of project personnel and subject matter experts (SMEs), as well as the Awardee's project manager, the NSF Program Officer, and the NSF Grants and Agreements Officer. The objective of risk identification is to describe all the relevant risks so that the group can focus on uncovering the probability and impact of the risks on project objectives (used in qualitative risk analysis) or activities / costs affected (used in quantitative risk analysis). The process for performing Risk Identification, along with inputs and outputs, is given in Figure 5.2.6-1.

Figure 5.2.6-1 Risk Identification Process



Techniques used in identifying risks include leveraging existing project artifacts and guidance documents, as well as proactively searching and gathering information to assist in that identification. The quality and completeness of risk identification is primarily dependent upon the knowledge and experience of the project team and its commitment to risk management processes. For example, the following basic methods can be used to assist in the identification of risks:

- Brainstorming
- Diagramming
- Interviewing
- Analysis of existing project artifacts
- Comparison to historical information

Formal risk identification is performed in the early part of the project life cycle and as part of a continuous effort during the project life cycle. Any person associated with the project should be encouraged to continually identify potential project risks. Risk Identification, whether in workshops or in interviews, should include at least the following participants:

- Project managers
- Project team leaders
- Project team members
- Business stakeholders
- SMEs
- Contractors
- SMEs outside the project team, for unbiased perspective
- Project partners (e.g., foreign agencies, organizations with diverse objectives)

One immediate outcome of risk identification is the populating of the Risk Register, or tracking tool, with the identified risks. The priorities based on impacts to project objectives and plans for handling and reducing impacts will be added after analysis and risk handling planning, as described in later sections. The Risk Register provides a means of tracking and reporting status as risks occur and migration strategies are implemented, and is an important tool for Risk Management implementation.

5.2.6.2 Risk Identification and the Risk Register

The Risk Register includes a description of all risks that are deemed to be important to achieving project success (from the Risk Identification process) along with an assessment of those risks (using Qualitative Risk Analysis) that allows risks to be prioritized for effective risk management. The results of identification, qualitative analysis, and risk handling – the major components in the Risk Register – can lead to further analysis (Quantitative Risk Analysis, for example).

Each risk should be assigned a unique identification number or code. Once a risk is entered in to the Register, it is never deleted. Its state may be changed to inactive (for example, retired, closed, or merged with another risk), but it should never be deleted from the register. Risk IDs are never reused.

The Register should be accessible (read-access) to all project members – the primary objective of the Register is to keep the project team thinking pro-actively about how to avoid or mitigate threats and take advantage of opportunities. It can be a spreadsheet, data base, or a specialized risk management software tool. Changes to the Register should be managed through the risk process, which often may restrict ability to make changes (write-access) to a small team or to the Risk Manager. The mechanism for all project members to read, comment on, and submit new risks and mitigations should be established in the RMP.

The examples shown here and in Section 5.2.7, Qualitative Risk Analysis, lead to a Risk Register containing a ranked subset or summarized set of risks based on individual, qualitative impact analysis. Note that numeric impacts determined by the qualitative method for individual risks may not be summed or combined to give a value for overall project risk exposure.

Further discussion of Risk Register content is given in Section 5.2.7, Qualitative Risk Analysis, with a sample Risk Register shown in Figure 5.2.7-6.

5.2.6.3 Risk Description

The risk description serves as a key point in the Risk Register, and will be generated and updated as needed. If there is a trigger event that causes the risk or foretells the risk's occurring it should be described since it will specify what condition(s) would launch the risk and maybe activate a contingency plan.

Risks (both threats and opportunities) are typically identified and tracked using the following sentence structure for the Risk Description:

> *"Because of (some cause) a (risk) may occur, and (consequences) will happen."*

Example:

> *"Because foreign exchange rates may change, the cost of components in WBS 3.1 and 2.6 may increase or decrease, causing cost variances which affect contingency use."*

Using this format helps to distinguish the uncertainty or risk from its cause and its consequence, a distinction which is important for mitigation planning. For instance, a statement that "we have 5 schedule risks" is focused on an objective (schedule) that is impacted, not the root cause of the risk or uncertainty. Alternatively, a statement that "the risk is that the technology is really hard" does not lend itself to mitigation efforts. Difficulty of technology is a fact or a "cause" in this format, which cannot be changed. The risk may be that "we do not have the right skills on the project to handle the complexity" or "we may have to rely on third parties to gain control of this technology." That is a risk that can perhaps be mitigated. A possible risk description for this scenario may be:

> *Because the technology for the major components in WBS 2.7 is very advanced, we may have to rely on third parties for design, with the consequence that we have less control over cost and schedule and an added burden of increased communication efforts.*

Risks should be identified that are both internal, perhaps under project control, and external, likely to be beyond project control. Risks for which there are no plans for mitigation should also be included in the register.[1] However, note that NSF does not allow the use of contingency for risks that are commonly referred to as "unknown unknowns"[2] such as exceptional events or major changes in scope. These exceptional events may not be included in quantitative risk analyses used in determining contingency amounts.

5.2.6.4 Risk Identification Concerns

Efforts should be made to identify all risks to the project as early as possible, employing all stakeholders identified in and using the techniques listed in Section 5.2.6.1, Risk Identification Process. At the time of the risk analysis there are likely to be risks that are currently unknown but may be revealed at a later date. When they become apparent, they can be then analyzed and a "corrective action" can be specified and implemented. The objective of the Risk Management program is to minimize the number of unanticipated issues and to address them when possible and prudent.

Some people believe that project risk is often underestimated in both cost and schedule, leading to well-known, sometimes notorious, overruns.[3, 4] Historical experience suggests that mega-projects suffer from such problems systematically.[5] Strategic or overarching risks are often missed in the risk identification process since the participants do not think globally, only locally. Systemic or overarching risks are often not discussed or even considered during risk identification. There may be cultural bias that leads to optimistic thinking in which threats are systematically underestimated, outcomes are assumed to be achievable with less than realistic effort and the potential for set-backs and rework is ignored. Any tool or technique that will encourage people to "think outside of the box" when identifying project risk will help identify the possibility of large overruns – when caught early, these risks may be manageable.

One common issue in identifying and collecting project risks is that people's response and participation in the identification process may be "stove-piped." That means that people will

[1] The fact that "we cannot do anything about it" or "we choose to accept the risk" does not disqualify it as a risk to the project. One can argue that these risks must be in the Risk Register and certainly in the Quantitative Risk Analysis.

[2] In many Risk Management guides, a portion of contingency is designated as management reserve for "unknown unknowns." NSF does not allow what is normally referred to as management reserve. The current NSF budget cap policy and scope decrease plans of 10% of the Project Management Baseline replaces reserve.

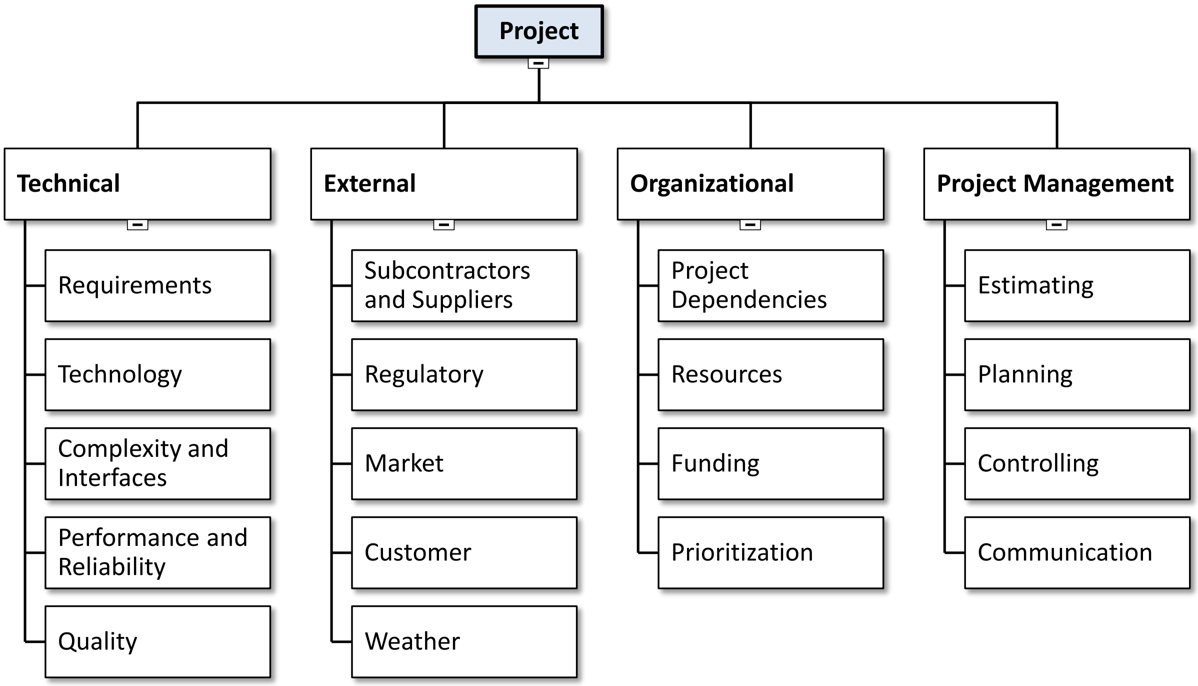
[3] See Bent Flyvbjerg, Nils Bruzelius, and Werner Rothengatter, Megaprojects and Risk: An Anatomy of Ambition, 2003 Cambridge University Press, and Glenn Butts and Kent Linton, "NASA the Joint Confidence Level Paradox – a History of Denial," NASA Cost Symposium, April 28, 2009.

[4] Challenges to Meeting cost, Schedule, and Performance Goals, NASA IG-12-21

[5] Edward W. Merrow, Industrial Megaprojects, 2011, Wiley.

ordinarily discuss threats and opportunities that have to do with their own area of concentration. In practice the project teams and other SMEs have experience and knowledge outside these narrow areas, so the data collection method used should encourage them to think broadly and strategically when identifying risks. Reminding risk identification participants of external, organizational and project management source-areas of risks can help elucidate strategic risks that they know about but that are outside their narrow area of technical expertise or their work assignment. Often the use of a standard Risk Breakdown Structure shown in Figure 5.2.6-2 will encourage risk identification participants to think more broadly about risks to the project.

Figure 5.2.6-2 Typical Risk Breakdown Structure (RBS)[1]



Different approaches to Risk Management may subdivide risks into various categories for analysis. For illustrative purposes, this guide will use cost, schedule, and technical or performance risk as the categories used in examples. Other risk categories commonly in use are programmatic, business or economic, design requirements, software, and technology risks. Alternatively, the OMB Risk Categories shown in Figure 5.2.6-3 could be used as guidelines for identifying the various types of risk that apply to the project (refer to “OMB Risk Categories” document in Critical Infrastructure Protection (CIP) for detailed descriptions and examples of these categories). See the Government Accountability Office (GAO) Cost Estimating and

[1] This RBS was the initial model for the RBS in the PMBOK® Guide, Chapter 11 of the Project Management Institute

Assessment Guide, GAO-09-3SP, Chapter 14, for more examples. Some projects may also decide to differentiate between internal and external risks. In many cases, it may be advisable to use different categories for various parts of a project. For instance, categories of risk may be different for software development than for hardware procurement. Each project should decide which categories are most appropriate for its use while establishing the Risk Management Plan and processes.

Figure 5.2.6-3 OMB Risk Categories: to be used as a starting point for projects to select their own categories

1) Schedule
2) Initial Costs
3) Life Cycle Costs
4) Technical Obsolescence
5) Feasibility
6) Reliability of Systems
7) Dependencies and Interoperability
8) Surety (Asset Protection)
9) Risk of Creating a Monopoly
10) Capability of Agency to Manage the Investment
11) Overall Risk of Project Failure
12) Organizational and Change Management
13) Business
14) Data/Info
15) Technology
16) Strategic
17) Security
18) Privacy
19) Project Resources

Another related social or cultural issue in identifying project risks is that people are often uneasy about (or even afraid to be) discussing risks that can be embarrassing or harmful to the project. This unease is often experienced during risk workshops or in other group settings. Social pressures to conform ("groupthink") – to suppress dissenting opinions clearly unpopular to the group, including management, to agree with others against personal opinion just to move the workshop along, and to defer to people perceived to have greater expertise even when in disagreement – often make it difficult for some people to speak out.[1] A possible solution to the impacts of social pressure is to conduct one-on-one, in-depth interviews with SMEs in which the interviewee is promised confidentiality. Such interviews often yield honest opinions about what might affect the project's success. Usually some or most of the risks revealed and discussed in these sessions are not on the organization's risk register and would not be analyzed in qualitative or quantitative risk analysis in the absence of the interviews. For these reasons it is important to provide a safe environment for project team members and others to identify and discuss project risks.

Risk identifiers may have concerns about including risks that are 100% likely to happen (sometimes these are called "uncertainties or issues") in the Risk Register. If the risks are 100%

[1] These phenomena are discussed in Understanding and Managing Risk Attitude, David Hillson and Ruth Murray-Webster, Gower, 2005.

likely to happen and their impacts are known, they should be included in the PMB. Often, however, a risk that is certain to occur will have an impact that is not already included in the project execution plan and that needs to be handled somewhere else, such as in the risk analysis. Or the risk may have an uncertain impact on project objectives. These situations call for the risk to be identified, even if it is already happening or certainly will happen, so the risk can be included in the Risk Register and the subsequent quantitative risk analysis. The objective of risk identification is to describe all the relevant risks so that the group can focus on uncovering the probability and impact of the risks on project objectives (used in qualitative risk analysis) or activities / costs affected (used in quantitative risk analysis). Once a risk that is certain to occur has been included in the PMB it can be removed from the Risk Register.

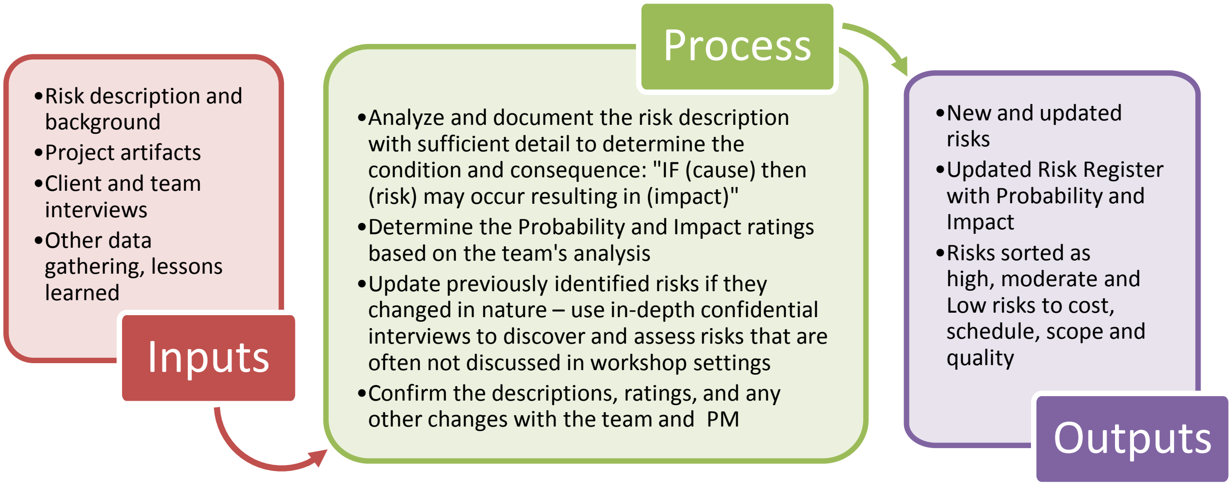
Care must be taken to provide the same thoroughness of identification for events far in the future as well as for the near term for projects that have an execution period of several years. Project team members usually find that it is easier to identify and discuss the risks that are current or on the near horizon than those that may occur much later in the project. Adding to the difficulty is the fact that future events may not be well defined at the time of risk analysis. The risk identification exercise should take special care to encourage the participants to look into the future, maybe with the help of lessons learned documents or their own experiences on prior projects, to see what risks are far down the project life cycle. Another useful technique is to “walk through” the activities planned for later execution. Examples of unidentified risks may include unexpected legal changes, technical performance issues, resource losses, etc. Other sources of future risks might include the reliance on unproven or even just conceptualized technology or on doing business with an organization or in a country unknown to the sponsors. The risk identification should include thinking about risks that have happened on other similar projects or might occur in later phases of this project. If the team spends some time discussing these down-stream risks they can perhaps remember other projects or conceptualize the existence of risks that would otherwise go unreported.

5.2.7 Qualitative Risk Analysis – Risk Register Ranking

5.2.7.1 Purpose of Qualitative Risk Analysis

Qualitative risk analysis involves determining the probability of the occurrence of a risk, assessing the consequences of this risk on specific project objectives (time, cost, scope and quality) if it occurs, and using the two dimensions of a risk (probability and consequence) to identify a rank or "risk level." This risk level represents a judgment as to the relative risk to the project objectives and the project as a whole and is categorized as *Low*, *Moderate,* or *High*. Based on the risk level, risks can be prioritized for mitigation to responses. The results of Risk Identification, Qualitative Risk Analysis, and Risk Response Planning comprise the main elements of the Risk Register. The process for performing Qualitative Risk Analysis, along with inputs and outputs, is given in Figure 5.2.7-1 below.

Figure 5.2.7-1 Qualitative Risk Analysis Process



Achieving risk reduction is an integral part of setting priorities, sequencing project work, and responding to the most serious risks first. Thus, the identified risks must be prioritized. Note that Qualitative Risk Analysis is applied only to individual risks and is not used in estimating overall project risk exposure or in determining contingency amounts. The analysis of impact or consequence, however, may serve as input to Quantitative Analysis used to estimate overall risk exposure.

5.2.7.2 Considerations When Performing Qualitative Risk Analysis

A number of factors complicate qualitative risk analysis, including:

- Risk data, like data about the future contained in cost estimates or project schedules, have a significant content based on subjective, expert judgment. The evaluation of risks to cost and schedule therefore generate approximate rather than precise results. "There are no facts about the future."[1]

- The term "risk" includes both "threats" and "opportunities" for NSF purposes. Project risk team members should look for uncertainties that could help improve the project's results or offset threats. Both threats and opportunities should be examined for total project impact, since opportunities for one project participant may be considered threats by another, and vice versa.
- The probability that a risk may occur and the impact if the risk were to occur should be evaluated separately before combining the two parameters in a risk matrix. The idea that "the risk is unlikely so its impact must be low" confuses the two parameters of probability and impact. SMEs should be asked to estimate the impacts as if the risk has occurred. Probability and impact will be considered together in the combined risk matrix approach.
- It is good practice to assess risks' impact on separate objectives such as time, cost, scope or quality/performance Impact ranges rather than creating a single, overall risk level for the risk. Thus, ranking levels are defined for each of these objectives. For instance, a risk can be judged to have a high impact on time but a moderate impact on cost and a low impact on scope.
- The definitions of impact on each project objective (very low, low, moderate, high and very high) are set by the Risk Manager and documented in the RMP.
- The definitions of combined risk level for probability and impact taken together (low, moderate or high; or green, yellow or red) in the Risk Matrix are set by the Risk Manager and documented in the RMP.
- The impact of an individual risk may be modest and still be considered a high or very high priority for mitigation. This is because the combined or aggregate risk of many moderate risks may be high. The project may want to mitigate some low or moderate risk in order to reduce the combined threat from many risks.
- The risk register should include only root cause risks. Risks as defined in the plan may not be mutually exclusive, that is, they may have the same root cause risk. Put another way, if two or more risks are not mutually exclusive as written, their common root cause risk should be identified and used instead.

[1] Lincoln E. Moses, Administrator of the Energy Information Administration, Administrator's Message to the Annual Report To Congress, 1977, Volume Three.

5.2.7.3 Limitations of Qualitative Analysis

There are some limitations to the practice of qualitative risk analysis. Recognizing these will help the organization appreciate and use the results correctly:

- Qualitative Risk Analysis addresses the impact of individual risks on project objectives one at a time. As such it is dedicated to prioritizing individual risks based on subjective estimates of probability and subjective estimates of the impact to the project objectives. It is not equipped to forecast or estimate overall project results such as the finish date or total cost.
- Qualitative Risk Analysis is unlikely to yield valid quantitative results since it usually does not include all possible correlations and outcomes for impacted activities from a single risk. SMEs must consider the risk with its probability of occurring and all the activities in the schedule it would affect if it occurred, whether or not those activities are on the risk critical path (the risk equivalent to the critical path in CPM scheduling). They must also evaluate whether other risks might keep that risk from creating much improvement if it were mitigated. All of this analysis is being done in the individual SME's head. Such complex calculations are best handled by the Quantitative Risk Analysis simulation method described in Section 5.2.7.
- The estimation of the impact of a risk on cost must consider the impact of that risk directly on cost plus the impact indirectly on the cost of time-dependent resources if the risk also affects time. This is another calculation that individuals are not well-equipped to make without a computer but is handled well by Quantitative Risk Analysis.
- Judging whether a risk has a high-priority for the project would involve reviewing the conclusions on each objective and asking the risk manager to prioritize the objectives. Some projects are time sensitive and some are budget driven, others have a fixed scope or could be de-scoped. These factors would need to be considered to determine whether the risk is low, moderate or high priority for the project as a whole. Some software packages that perform qualitative risk analysis assume that if a risk is "high" for any objective it should be judged to be "high" for the entire project. There is no real basis for doing so, since the risk may be judged to be high for an objective that is not the most important for the specific project under consideration.

5.2.7.4 Qualitative Risk Analysis – Probability and Impact Assessment

Risk level determination can be done using a variety of techniques. The method given here begins by assigning qualitative values for event probability and impact/consequence(s) to each objective separately. These will then be used to determine a qualitative risk level. A key feature of this method is that it requires independent assessment of the probability and consequence of a risk.

The probability of a risk occurring is usually given to a range of possible probabilities of occurring. Similarly, consequences are usually expressed in levels that represent ranges of impacts judged by the risk manager to be of very low, low, moderate, high or very high impact as the result of one risk among many. The ranking of a risk as it is applied to a particular objective (e.g., time) is determined by the combination of probability and impact ranges, where the project manager or some other stakeholder (e.g., the customer) determines which combinations would indicate that the risk is high, moderate of low priority for further study, quantitative risk analysis or handling.

The following steps provide the details of this Qualitative Analysis method:

1. Address each risk statement from the Risk Identification process individually.

2. Determine the qualitative probability of occurrence value (P) range that best describes the probability for each risk with appropriate basis and justification. Discuss the probability that the risk might occur on the project with some noticeable effect on the objective being discussed. Estimate the probability for the risk without regard to which objective(s) the risk affects if it occurs. The probability of occurrence is for the duration of all project phases. Table 5.2.7-1 provides an example of typical criteria for establishing probability values.

3. Determine the qualitative consequence or impact of occurrence value I range that best describes the impact for the objective such as time, cost, scope or performance for each risk with appropriate basis and justification. In the evaluation, assume that the risk has occurred and determine the recovery time, the cost of recovery, and the impact on scope or quality. The consequence of occurrence is for the duration of all project phases and for the objective being assessed. Table 5.2.7-2 provides typical criteria for establishing consequence values. This table illustrates the different definitions that are applied to the implications for time, cost, scope and quality. Of course these definitions should be tailored to the project by the project manager or some other stakeholder (e.g., the owner or customer).

Table 5.2.7-1 Sample Risk Probabilities Table

Each project should determine the appropriate number of levels and their definitions that match that project's circumstances.

Probability of Occurrence Descriptor	Probability of Occurrence Numerical Ranges equivalent levels[1]	Criteria in Words
Very Low	<0.1	Will not likely occur anytime in life cycle of the facilities; or the probability of occurrence is less than equal to 10%.
Low	>0.1 but <0.4	Will not very likely occur in the life cycle of the project or its facilities; or the probability of occurrence is greater than 10% but less than or equal to 40%.
Moderate	>0.4 but <0.6	Will likely with middling probability (e.g., a coin flip) to occur sometime during the life cycle of the project or its facilities; or the probability of occurrence is greater than 40% but less than 60%.
High	>.6 but <.8	Likely to occur with more than 60 percent chance during the project, or the probability of occurrence is between 60% and 80%
Very High	>0.8	Will likely occur sometime during the life cycle of the project; or the probability of occurrence is greater than or equal to 80%.

Table 5.2.7-2 Sample Risk Consequences[2] Table

The descriptors for the objectives of cost and time are explicitly given as numbers while those for scope and quality are expressed in narrative descriptions.

Defined Conditions for Impact Scales of a Risk on Major Project Objectives, e.g., Time Definition for Threats Only					
Project Objective	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
Cost	Insignificant Cost Increase	<5% Cost Increase	<5 - 10% Cost Increase	<0 - 20% Cost Increase	>20% Cost Increase
Time	Insignificant Time Increase	<5% Time Increase	<5 - 10 % Time Increase	<0 - 20 % Time Increase	>20% Time Increase
Scope	Scope Decreases are Barely Noticeable	Minor Areas of Scope Affected	Major Areas of Scope Affected	Scope Reduction Unacceptable to Sponsor	Project End Item is Effectively Useless
Quality	Quality Degradation Barely Noticeable	Only Very Demanding Applications are Affected	Quality Reduction Requires Sponsor Approval	Quality Reduction Unacceptable to Sponsor	Project End Item is Effectively Useless

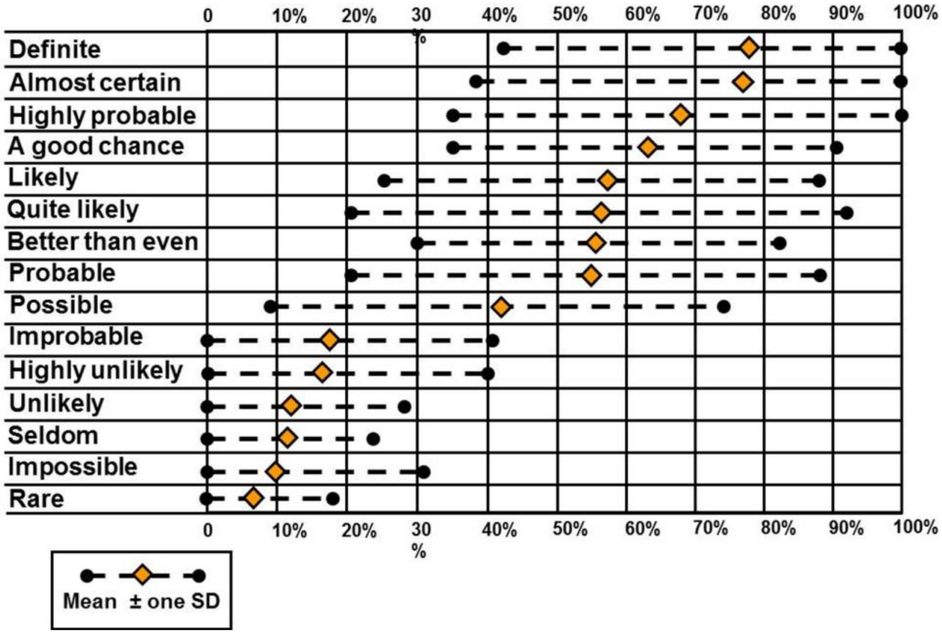
[1] The scales still must be calibrated per the discussion and reference in Section 5.2.9.

[2] An earlier version of this table was used in the PMBOK® Guide. The percentage ranges should be adjusted by the project manager for the project and translated into days and dollars for ease of use.

Notice that the definitions for time and cost can be quantitative but that those for scope and quality are generally descriptive. Sometimes a project's scopes can be quantified, though it may have several dimensions. Quality or performance might be measurable in terms of failure rates or number of "fixes" that would be needed. The more the impact levels can be quantified the more the responses by different people will be comparable. The project manager can calibrate the numerical ranges for the specific project. The consequence definitions of very low, low, moderate, high or very high (or *Negligibl*e, *Margina*l, *Significan*t, *Critica*l, and *Crisis*) may vary considerably from a small to a large project. These tables should be provided as part of the RMP.

It is preferable to refer to the numerical levels when gathering qualitative risk data since definitions in words are often misleading. For instance, two people may use the term "Likely" but mean different values. Or, one may say the risk is "likely" to occur and another may say "unlikely" but mean the same numerical value, or at least in the same "bucket" or range of values. Research has shown that the overlap in probability values with common word definitions is severe.[1] (See Figure 5.2.7-2.)

Figure 5.2.7-2 Overlap in Risk Probability of Occurring When Descriptors Are Used



Expert judgment is required in risk analysis, just as it is for project scheduling and project cost estimating. That is why several or many people need to be involved in providing their opinions

[1] Private research conducted by Dr. David Hillson in 2004 and presented at a PMI EMEA conference.

and experiences when assessing project risks. With multiple people assessing the probability and impact of each risk against each objective, such as in the recommended in-depth confidential interviews, there will be differences of opinion between them. The risk analyst has to consolidate the data from different sources into one set of parameters for each risk and objective from the dissimilar responses. This process uses expert judgment.

5.2.7.5 Alternative Approach to Qualitative Risk Impact Analysis – Maxwell

An alternative approach is that proposed by F. D. Maxwell for projects such as those supported by the Aerospace Corporation or the Space & Missile Systems Center of the US Air Force in Los Angeles. The "risk driver category" is not the same as the project objectives, but rather describes where the risks might be originating. This was not used by Maxwell in conjunction with the probability before 1990, but it does illustrate definitions of impact that were used on many aerospace and scientific projects. Maxwell stated that:

> *Special attention must be given to first-of-a-kind risks because they are often associated with project failure. First-of-a-kind risks should receive a critical or crisis consequence estimate unless there is a compelling argument for a lesser consequence value determination.*

Table 5.2.7-3 Maxwell Risk Driver Assessment Framework[1]

		Risk Levels				
	Risk Driver Category	**Very Low**	**Low**	**Medium**	**High**	**Very High**
1	Required Technical Advancement	Nothing New	Minor Modifications Only	Major Modifications	State of the Art	Beyond State of the Air
2	Technology Status	Currently in Use	Prototype Exists	Under Development	In Design	Concept State
3	Complexity	Simple	Somewhat Complex	Moderately Complex	Highly Complex	Highly Complex with Uncertainties
4	Interaction/ Dependencies	Independent of Other Risk Drivers	Dependent on One Additional Risk Driver	Dependent on Two Additional Risk Drivers	Dependent on Three Additional Risk Drivers	Dependent on more than Three Additional Risk Drivers
5	Producability	Established	Demonstrated	Feasible	Known Difficulties	Infeasible
6	Process Controls	Statistical Process Controls (SPC)	Documented Controls (No SPC)	Limited Controls	Adequate Controls	No Known Controls

[1] Developed by F. D. Maxwell at the Aerospace Corporation. Included in "Estimating Cost Uncertainty when only Baseline Cost is Available," quoting R.L. Abramson and S. A. Book, "A Quantification Structure for Assessing Risk-Impact Drivers," Laserlight Networks, briefing presented to the 24th Annual DOD Cost Symposium (Leesburg, VA, September 5-7, 1990).

	Risk Driver Category	Very Low	Low	Medium	High	Very High
7	Manufacturing Precision	High	Adequate	Limited Margins	Known but Inadequate	Unknown
8	Reliability	Historically High	Average	Known Limited Problems	Serious Problems of Unknown Scope	Infeasible
9	Criticality to Mission	Nonessential	Minimum Impact	Known Alternatives Available	Possible Alternatives Exist	"Show Stopper"
10	Cost	Established	Known History or Close Analogies	Predicted by Calibrated Model	Out of Range of Experience	Unknown or Unsupported Estimate
11	Schedule	Demonstrated	Historical Similarity	Validated Analysis	Inadequate Analysis	Unknown or Unsupported Estimate

5.2.7.6 Qualitative Risk Analysis – Risk Level Matrix

Once the probability and impact level of each identified risk is agreed to, the risk's position is determined on the probability and impact matrix shown in the following figures. The vertical matrix axis labels in the figures correspond to the definitions for probability levels given in Table 5.2.7-1, and the horizontal axis labels correspond to the values for impact defined in Table 5.2.7-2. Combinations of probability and impact for a risk are shaded as red, yellow and green for high, medium, and low risk level. The risk manager, project manager, or other stakeholder should set these regions for each risk level, based on an understanding of the definitions of the axes, which would cause the risk to rise to the appropriate level of attention.

Figure 5.2.7-3 shows a risk probability and impact matrix for one objective that is symmetrical. Figure 5.2.7-4 shows a risk probability and impact matrix for an objective that emphasizes the impact of the risk on its red-yellow-green status. This asymmetrical risk matrix indicates that any risk that has a very high impact will achieve "high risk" or "red risk" status without regard to the probability that the risk will occur on the project. Of course the definitions of risk impact and probability buckets defined in the RMP will determine the relative score that the risk achieves.

Figure 5.2.7-3 Symmetrical Risk Level Matrix

Probability and Impact Matrix for a Specific Objective (Time, Cost, Scope or Quality)					
Probability	Symmetrical				
Very High	Mod	Mod	High	High	High
High	Low	Mod	High	High	High
Mod	Low	Mod	Mod	High	High
Low	Low	Low	Mod	Mod	Mod
Very Low	Low	Low	Low	Low	Mod
	Very Low	Low	Moderate	High	Very High
	Impact				

Figure 5.2.7-4 Asymmetrical Risk Level Matrix

Probability and Impact Matrix for an Objective (Time, Cost, Scope)					
Probability	Impact Averse				
Very High	Low	Mod	High	High	High
High	Low	Mod	Mod	High	High
Mod	Low	Low	Mod	High	High
Low	Low	Low	Mod	Mod	High
Very Low	Low	Low	Low	Mod	High
	Very Low	Low	Moderate	High	Very High
	Impact				

The Risk Level for each objective for a defined risk depends upon where it falls in the Risk Level Matrix according to the axes definitions. For example, a cost risk with an estimated probability of 70% of occurrence and an estimated impact of $280K, or cost increase of 9% for the item at risk, would fall into the High probability range and the Moderate cost impact range, according to Table 5.2.7-1 and Table 5.2.7-2. Thus the Risk Level for cost for this particular risk occurring falls into the High, or “red” range in Figure 5.2.7-3.

It is important to scale probability and impact so that the risks can be distinguished. On the one hand, if the lower bound for an impact score of very high is easy to reach there will be many risks with the same “red” assessment and the method will not distinguish risks for priority Risk Handling. On the other hand, definitions of high or very high impacts that are very difficult to reach will lead to very few or no “red” risks. While that may be true for some projects it would be unusual for an NSF project with a high scientific impact.

The objective of the matrix is to communicate the choice of priorities for monitoring and response, which may best be done with the 2-D diagrams (5x5) shown herein. Depending upon the activity and the ability to differentiate the risk levels, other matrices may be chosen by the risk analysis team. For example, a 5x5x4 risk level (the fourth level represents the 4 objectives) matrix would then have five values for probability, five for consequence and four for objectives.

Recall that Risk Management entails the identification and ranking of opportunities as well as threats.[1] Opportunities that are assessed to be in the "High" category are viewed as "low-hanging fruit" that can be easily claimed for the project if sought. For instance, if people are coming off another similar project where they have had a good result, our project will benefit if we can encourage or otherwise get them to join our project team. However, if such an opportunity is not recognized in a timely manner, those productive people will go to other projects. Another example is a potential cost saving if older but acceptable technologies can be used in place of cutting edge solutions without impacting performance or quality. This type of cost savings is common in data acquisition and storage systems, for instance.

The butterfly or mirror risk probability and impact matrix below shows scoring threats and opportunities in similar ways. The red-yellow-green ranges for threats have been discussed. The red risks for opportunities are those that have a high likelihood of occurring and if they occur they help the project achieve its objectives, if only by offsetting threats. Risk Response of opportunities needs to be proactive in order to secure these opportunities for the project.

Figure 5.2.7-5 Probability and Impact Matrix including Threats and Opportunities

Mirror or Butterfly Probability and Impact Matrix for Threats and Opportunities											
Project Objective (e.g., time, cost, scope, quality)											
Prob.	Threats					Opportunities					Prob.
VH	L	M	M	H	H	H	H	M	M	L	V
H	L	L	M	H	H	H	H	M	L	L	H
M	L	L	M	H	H	H	H	M	L	L	M
L	L	L	L	M	H	H	M	L	L	L	L
VL	L	L	L	L	M	M	L	L	L	L	VL
	VL	L	M	H	VH	VH	H	M	L	VL	
	Impact (threats)					Impact (opportunities)					

5.2.7.7 Risk Level Input to the Risk Register

The Risk Levels per each objective for all identified risks are entered into the Risk Register. See the sample Risk Register in Figure 5.2.7-6. It is common practice to also include a column in the matrix for the probability descriptor for ease of reference. As mentioned before, it is good practice to list the Risk Level for each project objective separately and not combine them into a single risk level for the stated risk. Projects may choose, however, to designate a flag to identify

[1] An early discussion of the use of opportunities in project management can be found in: Effective Opportunity Management for Projects: Exploiting Positive Risk, David Hillson, Marcel Dekker, 2004.

some risks as "Major" or "Top" risks. These Top Risks are judged by the project management to call for more aggressive management and more frequent monitoring than other risks.

Communicating and tracking the status of the top project risks is a key element of project management. The Risk Management Plan should address the frequency with which these significant risks are tracked. Top risks should be reviewed and evaluated during standard sub-system team meetings and reviews as well as at project status meetings.

Projects should also include a status report for the top risks in the various required reports to NSF, including the monthly report, as well as for reviews. One simple method for communicating the summary status of top risks to various stakeholders is shown in the sample Top Risk Matrix shown in Figure 5.2.7-6, which shows risk level and trend data for selected risks.

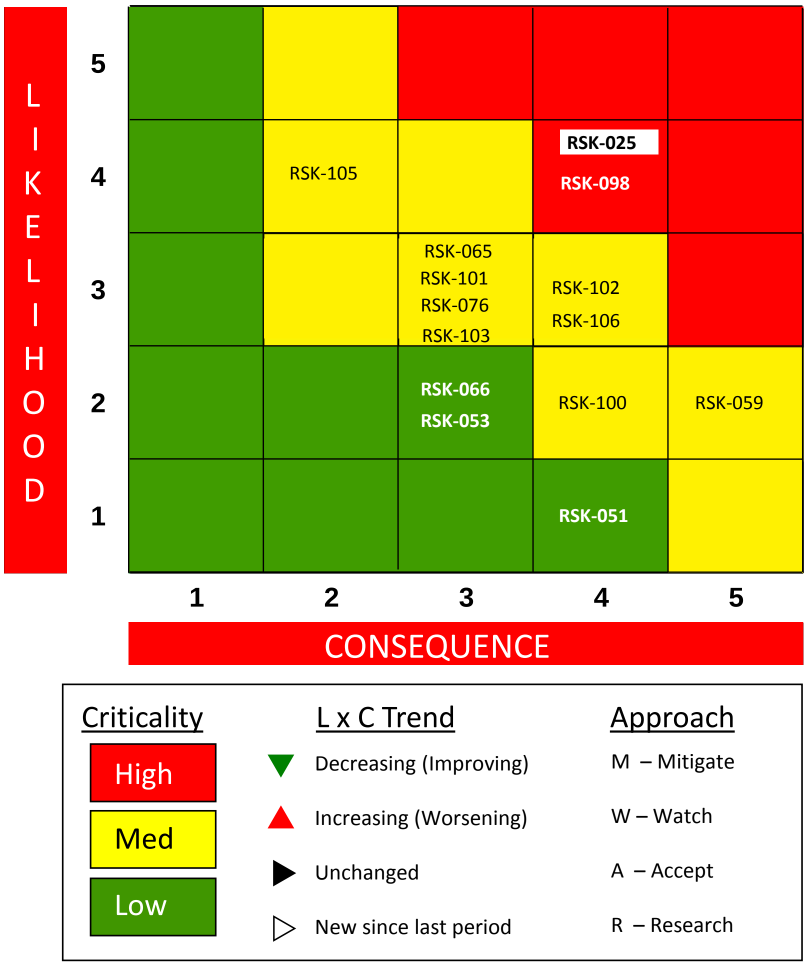
Figure 5.2.7-6 Sample Risk Register with Risk ID Number, Associated WBS Identification, Qualitative Probability and Impact for Initial and Post-mitigation States, and Mitigation Actions

			Pre-Mitigated Scores											Post-Mitigated Scores						
			Probability and Impacts				Resulting Risk Score			Risk Action				Probability and Impacts				Resulting Risk Score		
Risk ID	Risk Description	Associated WBS	Prob. Risk Occurs	On Sched.	On Cost	On Scope/Quality/Perform-ance	Risk on Sched.	Risk on Cost	Risk on Scope/ Quality/ Perform-ance	Risk Owner	Risk Mitigation Actions	Trigger or Watch date	Major Risk Flag	Prob. Risk Occurs	On Schedule	On Cost	On Scope/ Quality/ Perform-ance	Risk on Sched.	Risk on Cost	Risk on Scope/ Quality/ Perform-ance
PM1	If ...., then ...	2.2	H	VH	H	M	H	H	M					M	M	M	L	M	M	M
TECH1	If ...., then ...	3.2.5	H	VH	H	M	H	H	H					M	M	L	L	M	M	M
EXT8	If ...., then ...	3.1.3	M	VH	H	M	H	H	M					L	H	M	L	H	M	L
ORG4		5.6	M	H	M	M	H	M	M					L	M	M	L	M	M	M
PM4		7.8	M	H	H	M	H	H	M					L	L	L	L	L	L	L
TECH5		0.2	M	VH	H	M	H	M	M					VL	M	M	M	L	M	L
TECH6			L	H	M	M	M	M	M					VL	L	L	M	L	M	L
EXT6			L	H	H	L	M	M	L					VL	VL	L	L	M	L	L
PM2			M	L	H	L	M	H	M					L	VL	VL	VL	L	H	L
TECH9			VL	VH	VH	L	M	M	L					VL	H	VH	L	M	L	L
TECH10			VL	VH	M	VL	M	L	L					VL	M	L	VL	L	L	L

Figure 5.2.7-7 Sample Top Risk Matrix and Status Report, showing list of project risks selected as most significant to monitor on a frequent basis, with ranking and trend data

Note that top risks include some with Low and Medium criticality (or ranking), as well as those evaluated as High criticality.

Project Top Risk Matrix



Trend	Rank	LxC	Risk ID	Approach	Title
▶	1	(4X4)	RSK-025	M	Inadequate Observatory Performance for initial operations
▲	1	(4x4)	RSK-098	M	Operations Staff Fatigue
▼	2	(3X4)	RSK-102	M	Lack of Adequate Planning for data analysis pipeline
▼	4	(3x3)	RSK-103	M	Lack of Data Extraction and Analysis Tools
▶	5	(4x2)	RSK-105	M	Scientist support staff resources
▶	6	(2x5)	RSK-059	M	Loss of single-point-failure component
▶	7	(3x3)	RSK-076	M	Maintaining Science Instruments
▶	8	(2X4)	RSK-100	M	Instrument support structural Integrity
▶	9	(3x3)	RSK-101	M	Undocumented Hardware Requirements
▷	3	(3X4)	RSK-106	M	Science Instrument Hardware Change Control
▶	10	(2x3)	RSK-066	W	Operations Staff Retention
▶	11	(2x3)	RSK-053	W	Changes in Safety and Reliability Requirements

5.2.7.8 Other Qualitative Risk Analysis Methods

Expected monetary value, simulation, Bayesian probability theory, reliability, and the use of decision trees or its inverse, failure mode effects and criticality analysis (FMECA) are other risk analysis methods that are used in project management. They are not described in detail here but may be researched using the given references.

Expected monetary value is the product of the risk event probability multiplied by the value of the gain or loss that will be incurred. Schedule impacts and intangibles (i.e., a loss may put the organization out of business) must be considered when using this approach. This method for scaling contingency amounts does not take advantage of information about the range of possible impacts or probabilities. It can only provide a mean value of the contingency, not some other target level of confidence. It is not good for time risks or cost risks that have time risk components.[1]

Any schedule of a real project can easily be handled using Monte Carlo simulation techniques,[2] discussed in the next section on Quantitative Risk Analysis. Simulation uses a model of a system such as the project schedule to simulate a project using Monte Carlo analysis. Monte Carlo "performs" the project many times so as to provide a statistical distribution of calculated results under many different scenarios, since in each scenario different risks may occur with different combinations of impact. The use of Monte Carlo analysis to estimate the risk schedule or cost distribution by statistically combining risk costs is illustrated in the next section.

A decision tree is a diagram depicting key interactions between decisions and associated events and uncertainties as understood by the decision-maker.[3] A FMECA is a bottoms-up version of a decision tree, building up from the elements to the decisions. Either approach helps the analyst to divide a problem into a series of smaller, simpler, and more manageable events that more accurately represent reality to simplify decision-making.

Bayesian probability theory treats probability as a degree of belief or uncertainty in a given statement. More information may be found in Foundations of Risk Analysis. [4]

[1] Integrated cost-schedule risk analysis is presented in Section 5.2.8, Quantitative Risk Analysis.

[2] For schedule impact the organization should not use the Program Evaluation and Review Technique (PERT or the Method of Moments) to represent project risk in schedules. This method underestimates risk for the type of projects addressed herein. Refer to "Project Schedule Risk Analysis: Monte Carlo Simulation or PERT?" David T. Hulett, PM Network published by the Project Management Institute, February 2000, pp. 43 ff

[3] See Recommended Practice 85R-14, Use of Decision Trees in Decision Making, Association for the Advancement of Cost Engineering International (AACEI), 2014, David T. Hulett principal author. Also, "Use Decision Trees to Make Important Project Decisions," David T. Hulett, Cost Engineering (published by AACEI, July / August 2014.

[4] Pages 62 and 64 of Foundations of Risk Analysis by Aven.

5.2.8 Quantitative Risk Analysis – Estimating Contingency

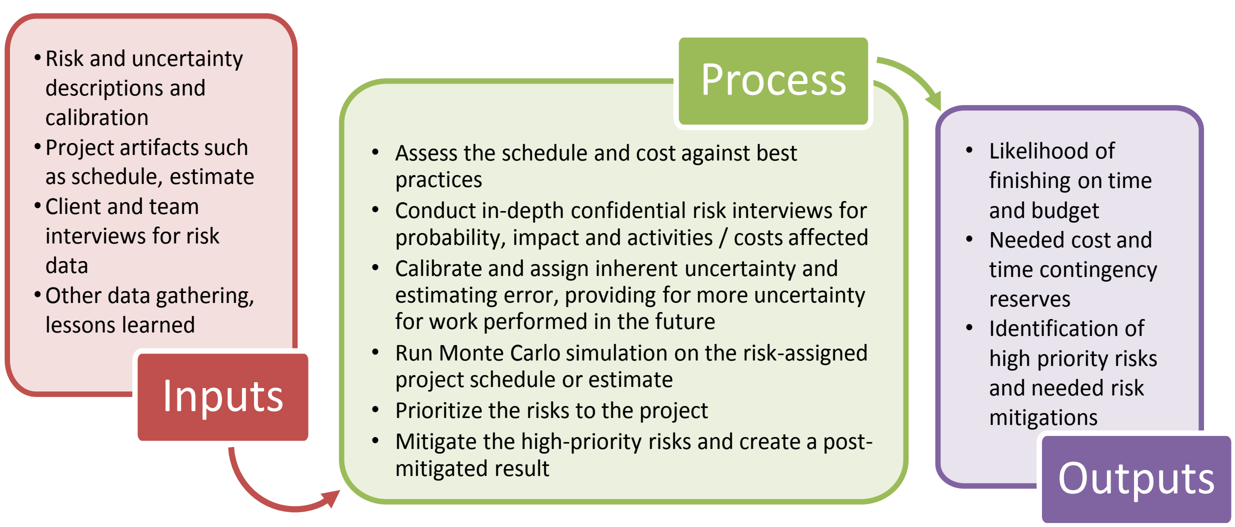
5.2.8.1 The Purpose of Quantitative Risk Analysis

Quantitative risk analysis can analyze the impact of all of the risks and uncertainties on the project objectives of overall time and cost. Hence quantitative risk analysis can derive results that qualitative risk analysis cannot provide, i.e. the likely finish date and project cost when all risks are considered within a model of the entire project.
Quantitative risk analysis allows the risk analyst to estimate:

- How likely is the project to meet its schedule and cost goals?
- How much schedule and cost contingency is needed to achieve the project's desired level of certainty?
- Which risks are causing any potential overrun and are thus high priority for risk mitigation?

Quantitative risk analysis allows the analyst to estimate the finish date and cost of the project based on a probability distribution created by applying Monte Carlo simulation to a project plan such as the schedule, cost estimate or cost-loaded schedule. The inputs are uncertainty and discrete risk events, although there may also be probabilistic branches, weather / calendar effects and even conditional branches. The process for performing Quantitative Risk Analysis is shown in Figure 5.2.8-1 below. Outputs are the estimated total cost and finish date and associated contingency amounts above the baseline input cost and finish date.

Figure 5.2.8-1 Quantitative Risk Analysis Process



A quantitative risk analysis requires an accurate, up-to-date schedule as well as up-to-date risk data to be useful. The schedule used for analysis is often not the detailed Integrated Master Schedule (IMS), but is a summary schedule that can be resource loaded.

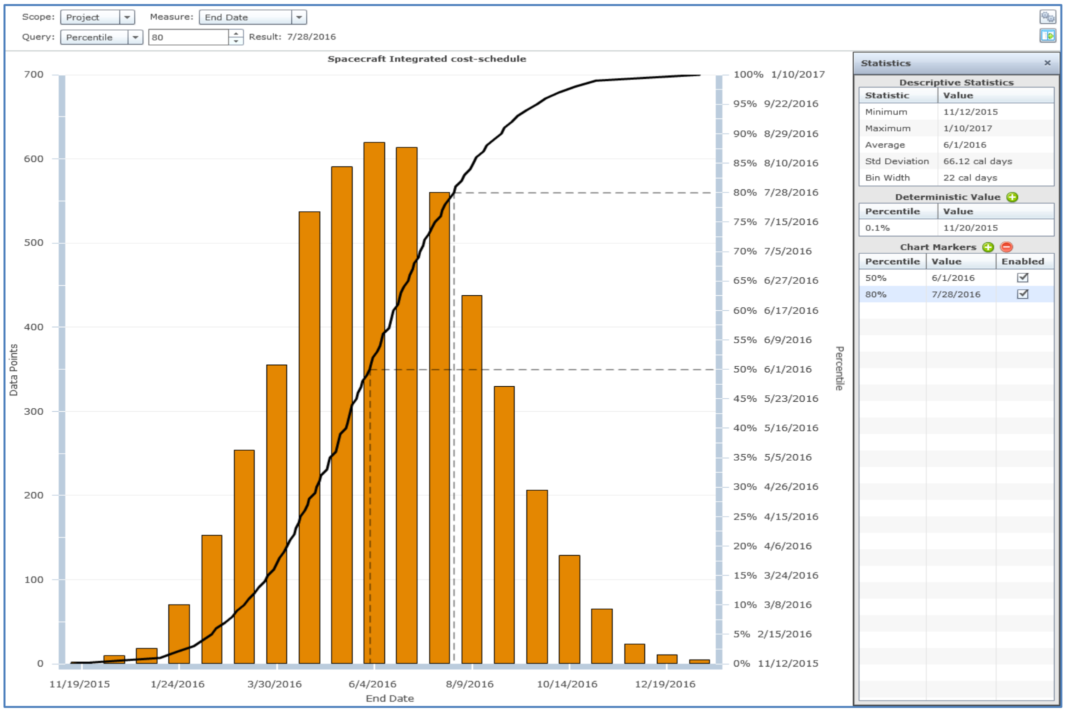
While software tools have made it relatively simple to run a Quantitative Analysis, the preparation work for a simulation run can take significant time and effort. Often, projects use Qualitative Analysis for month-to-month risk management and use Quantitative Analysis for establishing a new baseline or calculating an updated Estimate at Complete (EAC).

There are several commercial packages available that provide tools and programs for performing Quantitative Analysis using cost estimates and/or resource loaded schedules. While NSF strongly recommends probabilistic analysis methods for estimating total project risks and contingency amounts, it does not endorse or recommend any particular program or product.

A typical result of a quantitative schedule risk analysis using one such commercial tool, in this case a schedule risk analysis histogram of possible end dates, is shown in Figure 5.2.8-2. The estimated ranges of impact of risks and uncertainties on the duration of scheduled activities were fed into a Monte Carlo simulation program that generated a distribution of possible end dates based on a resource loaded schedule. For the histogram below, the horizontal axis shows the possible end dates. The right vertical axis shows the end dates for the confidence level curve.[1] The dotted lines on the plot represent the end dates for which the confidence level for completion by that date is 50% and 80% respectively. For this example, the PMB end date is 11/20/2015. If the project elects to use the 80% confidence level, then the chosen project finish date is 7/28/2016, indicating that the project needs to mitigate or provide contingency for an additional 8.3 months of project duration beyond the baseline date.

[1] NSF sets a required range for the confidence level unless an exception is requested and approved by NSF. See Section 4.2.5 for details.

Figure 5.2.8-2 Typical Result of a Quantitative Schedule Risk Analysis



Another typical output, from quantitative analysis of a resource-loaded schedule, is a time-cost scatter diagram. Figure 5.2.8-3 plots cost on the y-axis against end date on the x-axis. A line is drawn through the slope of the distribution. The plot illustrates the important fact that time and cost are related. In this case, longer schedule activities with labor-type resources generate higher cost.

Figure 5.2.8-3 Time-Cost Scatter Diagram: Each data point represents one realization of the simulation

5.2.8.2 Key Elements in Quantitative Risk Analysis

The platform for quantitative risk analysis is the project cost estimate or project schedule. Since most cost estimates are developed in a spreadsheet, a risk analysis of the project's cost estimate alone is often conducted using a software package that simulates a spreadsheet model.[1] Schedule risk analyses simulate a project schedule, so software that is able to simulate schedules developed in the organization's preferred scheduling package must be used.[2] Integrated cost-schedule risk analyses involve a good-quality PMB schedule (i.e., without cost

[1] Two commonly-used packages are @RISK from Palisade Corporation and Crystal Ball from Oracle. (NSF does not endorse or recommend any particular package.)

[2] There are several schedule simulation packages available. Two of the schedule simulation packages with the most capabilities are Polaris from Booz Allen Hamilton and Primavera Risk Analysis from Oracle. Others include Acumen RISK from Deltek, Risky Project from Intaver Institute, @RISK for Project from Palisades, JACS from Tecolote and Full Monte from Barbecana. (NSF does not endorse or recommend any particular package.)

or schedule contingency) with loaded resources representing the cost estimate attached to the activities they support.

The elements of risk that may affect the cost, duration, or both cost and duration of a project include uncertainty, identified discrete risk events, and possible discontinuous events.

- Uncertainty represents inherent variability in predicting the outcome of future events. The uncertainty may be from people and organizations' inability to do the same thing the same way reliably or from the fact that future events cannot be predicted with complete accuracy. Uncertainty has a probability of 100% (since it is always present) and an estimated range for duration or cost. The range often has a positive tail (opportunity) and a negative tail (threat) such as -5% and +10%. These ranges represent the confidence in the estimates of activity duration or cost element actually occurring as estimated. The uncertainty ranges are often specified as a 3-point estimate with low, most likely and high values for a specified distribution shape, often a triangular distribution. For every iteration in a simulation, the software pulls a random impact multiplier for each duration and/or each cost item from within the chosen distributions. That value, say 1.07, is then multiplied by the activity duration or element cost in the model to get the value to be used for that iteration.
    - There may be asymmetry in the range of uncertainty since it is often easier to overrun than underrun an estimated value. Hence the optimistic tail of the distribution may not have as much probability as the pessimistic tail has. Also, the most likely value may not be the assigned value in the schedule or estimate. Hence a fairly typical uncertainty range could be .95, 1.05, and 1.15 – the middle value implies that the duration or cost is most likely 5% higher than in the baseline model.
    - The range of uncertainty can also be used to cover potential, but as yet unidentified, discrete risks that may surface later in the project than at the time of analysis. The inability to identify discrete risks is common for events that occur significantly later in the project or for activities that cannot yet be well defined. Most often these uncertain risks can be addressed by allocating a wider range of uncertainty to these durations or costs than to those assigned to better understood activities occurring in the early years of the project. In this way the generally higher level of uncertainty for durations and costs in the later years of the project can be included in the risk analysis leading to the size of the contingency reserve.
    - Some types of activities have more inherent uncertainty than others. It may be more difficult to make estimates of duration and cost for testing than for design, whereas fabrication may be somewhere in between. Therefore, some categories of activities may have wider uncertainty ranges than others. These activity-type specific uncertainty bands are sometimes termed reference ranges.

- Discrete Risk Events include those already identified and quantified in the Risk Register as well as any that may be discovered when interviewing for risk data to use in the quantitative risk analysis. Discrete risks are specified by their probability and range of impact if they happen to activity durations or cost elements.
    - The probability determines the fraction of the Monte Carlo iterations that they appear in.
    - The impact range is related to the duration of the individual activities or size of cost line items that they are assigned to. Hence the concept of impact range for quantitative analysis is not the same as that used for qualitative risk analysis, which is impact on the final date or total cost for the entire project.
    - A risk can affect many activities or cost elements. Activities or cost elements can be affected by more than one, sometimes many, discrete risks.
    - Discrete risks can be represented by adding a risk to a cost element or schedule activity or by specifying a multiplicative factor to apply to the estimated cost (risk register method) or activity duration (risk driver method).

- Discontinuous Risk Events are discrete events that can have consequences beyond adding duration to existing activities or cost to an existing budget element. Technically challenging projects such as NSF facilities typically have numerous discontinuous risks. Capturing a complete list of these risks is critical to effective RM and project success. For example, failing a qualifying test (or other discontinuous event) may require adding new activities and cost to the schedule in order to recover from the event. These activities and cost elements are almost certain not to be in the baseline schedule or cost estimate since those artifacts are usually based upon success of the baseline plan.

5.2.8.3 Platforms for a Project Quantitative Risk Analysis

A project schedule risk analysis starts with a good-quality Critical Path Method (CPM) schedule:

- The schedule can be a summary or roll-up of the detailed schedule of the project and should not have any padding or contingency for risk. Estimated project end date and schedule contingency duration are outputs of the risk analysis. The detailed project schedule is not always a good candidate for risk analysis input since it usually has several thousand activities and may be difficult to debug. That is, the detailed project schedule, perhaps a contractor's schedule, may not conform to scheduling best practices.[1] Hence, and in recognition that a schedule risk analysis is a strategic analysis of the project, summary or "analytical" schedules may be used instead of the detailed schedule. This analytical schedule needs to represent all the work of the project (including contractor and other participants such as the customer) and be validated against best CPM best

[1] One source of complete scheduling best practices is the Government Accountability Office (GAO) Schedule Assessment Guide, expected to be revised in 2015.

practices. It is recommended that the summary or analytical schedule format adheres to the project WBS to facilitate reporting of contingency usage.

Characteristics of a schedule used for Quantitative Risk Analysis are:

1) It represents all the work of the project,
2) All logic links are established,
3) All constraints are appropriate, and
4) It is resource loaded.

Since the schedule validation process can require significant effort by project leaders, some references[1] recommend creating a 300-1000 line summary schedule from the project IMS and resource loading it with a minimal number of summary resources. (Some multi-billion dollar projects have been known to use as few as eight summary resources.) That methodology is followed in the exercise demonstrated in the following case study.

A cost risk analysis starts with a complete, PMB cost estimate:

- The PMB cost estimate is complete for all in-scope work but does not include any built-in “padding” or contingency for risk. The estimated cost contingency amount is an output of the risk analysis. The cost estimate is usually specified in spreadsheet format and may be simple or detailed. It is recommended that the summary or analytical schedule format adheres to the project WBS to facilitate reporting of contingency usage.

An integrated cost-schedule risk analysis starts with a resource loaded schedule for a PMB with cost and schedule estimates:

- A schedule, either analysis or detailed level, that is loaded with resources. For the purpose of a risk analysis the resources do not have to be detailed at the same level as the Cost Book, but they do have to distinguish between time-dependent (e.g., labor, rented equipment) resources that will cost more if their activities are longer and time-independent (e.g., materials, purchased equipment) resources that may have variable cost but not because of uncertainty in duration. Again, it is recommended that the summary or analytical schedule format adheres to the project WBS to facilitate reporting of contingency usage.

[1] David T. Hulett, principal author, Recommended Practice 57R-09, Integrated Cost and Schedule Risk Analysis Using Monte Carlo Simulation of a CPM Model, AACEI, 2011.

All quantitative risk analyses require:

- Good quality risk data collected in the Risk Register but usually enhanced using good interview techniques. Note that SMEs are often more willing to talk freely about extreme good and bad possible risk results in confidential interviews.
- A professional schedule risk simulation package[1] that can perform a Monte Carlo risk analysis simulation on a risk-loaded schedule.
- An organizational culture that is committed to conducting an unbiased and realistic risk analysis and to use its output, such as total risk to objectives or prioritized risk events to be mitigated in order to improve the prospects of the project.

5.2.8.4 Case Study: Quantitative Risk Analysis[2] Exercise

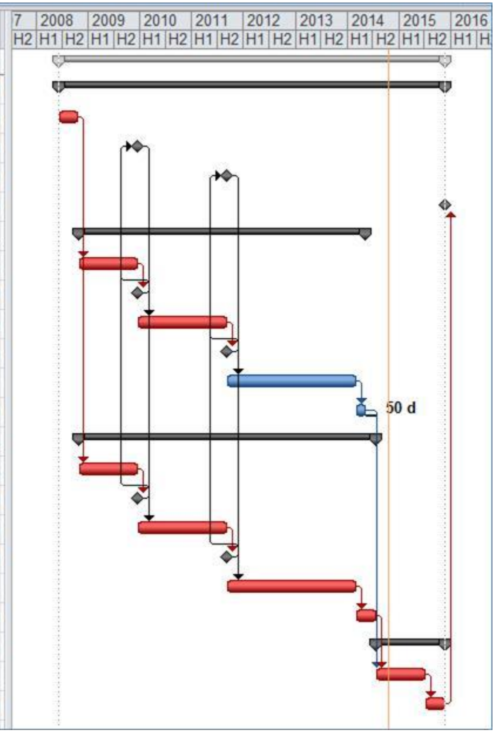
These steps will be illustrated with a simple case study of an integrated cost-schedule risk analysis of design and fabrication of a space vehicle, as shown in the resource-loaded Gantt chart schedule shown in Figure 5.2.8-4.

[1] There are several different software packages that can do this analysis. The package used for these charts and tables is Polaris® from Booz Allen Hamilton.

2 David T. Hulett, principal author, Recommended Practice 57R-09, Integrated Cost and Schedule Risk Analysis Using Monte Carlo Simulation of a CPM Model, AACEI, 2011.

Figure 5.2.8-4 Resource Loaded Schedule Used for a Simple Case Study of an Integrated Cost-Schedule Risk Analysis for Design, Fabrication, Testing, and Delivery of a Space Vehicle

ID	Name	Duration	Start	Finish	Cost
0	**Spacecraft Integrat**	**1950 d**	**6/1/08**	**11/20/15**	**$651,599,953**
1	**Spacecraft Project**	**1950 d**	**6/1/08**	**11/20/15**	**$4,000,000**
2	Requirements De	100 d	6/1/08	10/17/08	$4,000,000
3	PDR Spacecraft	0 d	12/11/09	12/11/09	$0
4	CDR Spacecraft	0 d	9/2/11	9/2/11	$0
5	Ship to Launch Si	0 d	11/20/15	11/20/15	$0
6	**First Stage**	**1450 d**	**10/20/08**	**5/9/14**	**$331,599,994**
7	FS Preliminary De	300 d	10/20/08	12/11/09	$19,199,998
8	FS PDR	0 d	12/11/09	12/11/09	$0
9	FS Detailed Desig	450 d	12/14/09	9/2/11	$129,599,989
10	FS CDR	0 d	9/2/11	9/2/11	$0
11	FS Fabrication	650 d	9/5/11	2/28/14	$178,800,005
12	Test FS Engine	50 d	3/3/14	5/9/14	$4,000,000
13	**Upper Stage**	**1500 d**	**10/20/08**	**7/18/14**	**$261,999,984**
14	US Preliminary D	300 d	10/20/08	12/11/09	$19,199,998
15	US PDR	0 d	12/11/09	12/11/09	$0
16	US Detailed Des	450 d	12/14/09	9/2/11	$86,400,000
17	US CDR	0 d	9/2/11	9/2/11	$0
18	US Fabrication	650 d	9/5/11	2/28/14	$152,400,005
19	US Test	100 d	3/3/14	7/18/14	$4,000,000
20	**Integration**	**350 d**	**7/21/14**	**11/20/15**	**$54,000,005**
21	Integration	250 d	7/21/14	7/3/15	$45,000,002
22	Integration Testi	100 d	7/6/15	11/20/15	$9,000,000



This is a project starting June 1, 2008, with a ship to launch site end date of November 20, 2015. The project cost is estimated at $651.6 million.[1] Resources are shown on the bar chart and include mostly labor, with some equipment in the First Stage and Upper Stage Fabrication activities.

In this case study the resources are few and summary.

[1] This schedule has been developed in Microsoft Project. Another popular scheduling package is Primavera P6 from Oracle. Most schedule simulation packages can import projects from these two scheduling packages.

Table 5.2.8-1 Resources for Quantitative Risk Analysis Example

Resource Name	Type
Preliminary Designers	Work
Detail Engineers	Work
Fabrication	Material
Integrators	Work
Integration Testers	Work
Specification Writers	Work
Unit Testers	Work
Fabricators	Work

5.2.8.5 Schedule Risk Analysis – Uncertainty

The schedule risk analysis starts with uncertainty reference ranges, estimated by the project SMEs. Recall that the probability for uncertainty occurring is 100%, and thus occurs for all simulation iterations for all assigned durations. The ranges are the SMEs' estimates of uncertainty in the task durations. Note that three of these imply that the SME interviewees assess the "Most Likely" value to be greater than the durations in the schedule. This may be because they view the schedule as being built with optimistic durations or that more has been learned about activity durations, leading to a higher estimate of the "most likely" durations. Although not shown here, their evaluation could also have resulted in lower, mostly durations. The use of Risk Drivers allows these distributions to have both threat and opportunity tails.

Table 5.2.8-2 Schedule Duration Risk Reference Ranges

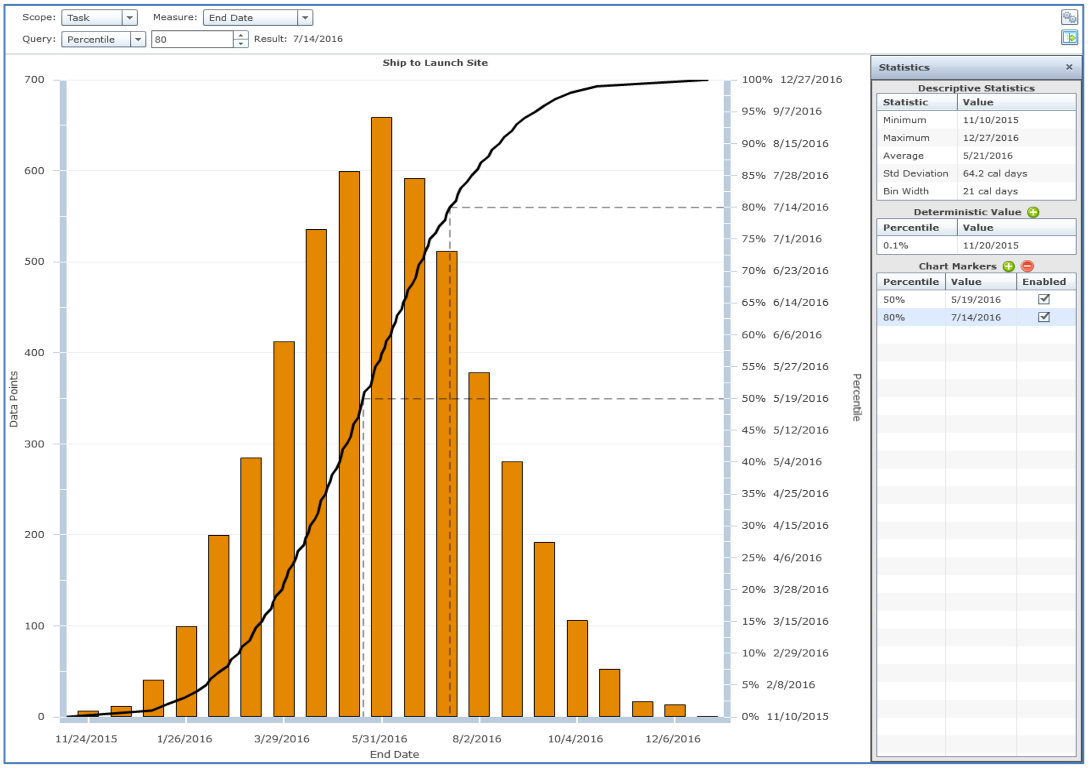
Activity Category	Low	Most Likely	High
Designers	0.90	1.00	1.20
Fabricators	0.95	1.05	1.20
Integrators	0.95	1.05	1.20
Requirement Writers	0.90	1.00	1.15
Testers	0.85	1.10	1.25

Notice that these are fairly narrow ranges that represent inherent variability, for instance, but do not represent the impact of discrete risks on the activity durations. These ranges are applied to the activities in the named categories by a triangular distribution, in this case, from which the computer pulls at random a multiplicative factor that is applied to the schedule duration. The example exercise demonstrated here uses 5,000 iterations because the software is fast, but 3,000 iterations would generally be enough.

Uncertainty ranges should be wider the further out into the future the work is being planned and estimated. This is because it is harder to estimate durations or costs several years into the future, since the work has not been contracted yet and may not actually be detailed with any specificity. Also, there will be risks in the future that cannot be identified today as discrete risks but should be provided for with wider uncertainty ranges.

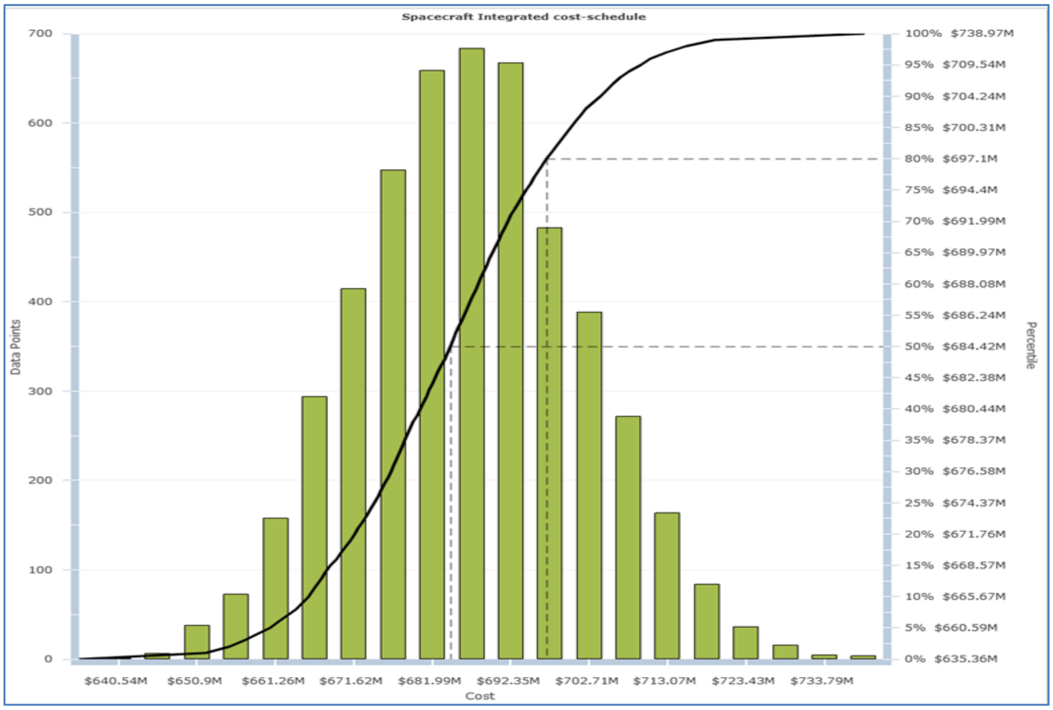
The analysis is performed using the reference ranges. If the analysis stopped at this point with just uncertainties, the schedule results would look like the histogram shown in Figure 5.2.8-5 below. The 80th percentile has been chosen as the target level of confidence for this example. The target confidence level for actual projects is chosen by the project or the customer.[1] The related cost risk histogram shown in Figure 5.2.8-6 represents the effect of duration uncertainty alone on the costs for time-dependent resource.

Figure 5.2.8-5 End Date Results for Schedule Duration Uncertainties



[1] To show these results one software package, Polaris, was chosen. However these results can be achieved using Primavera Risk Analysis, JACS, Risky Project and others.

Figure 5.2.8-6 Cost Result for Schedule Duration Uncertainties



The results can also be shown in tabular form, with the 5% and 95% values included to determine if the total range is believable. For uncertainties alone, the results in Table 5.2.8-3 are believable.

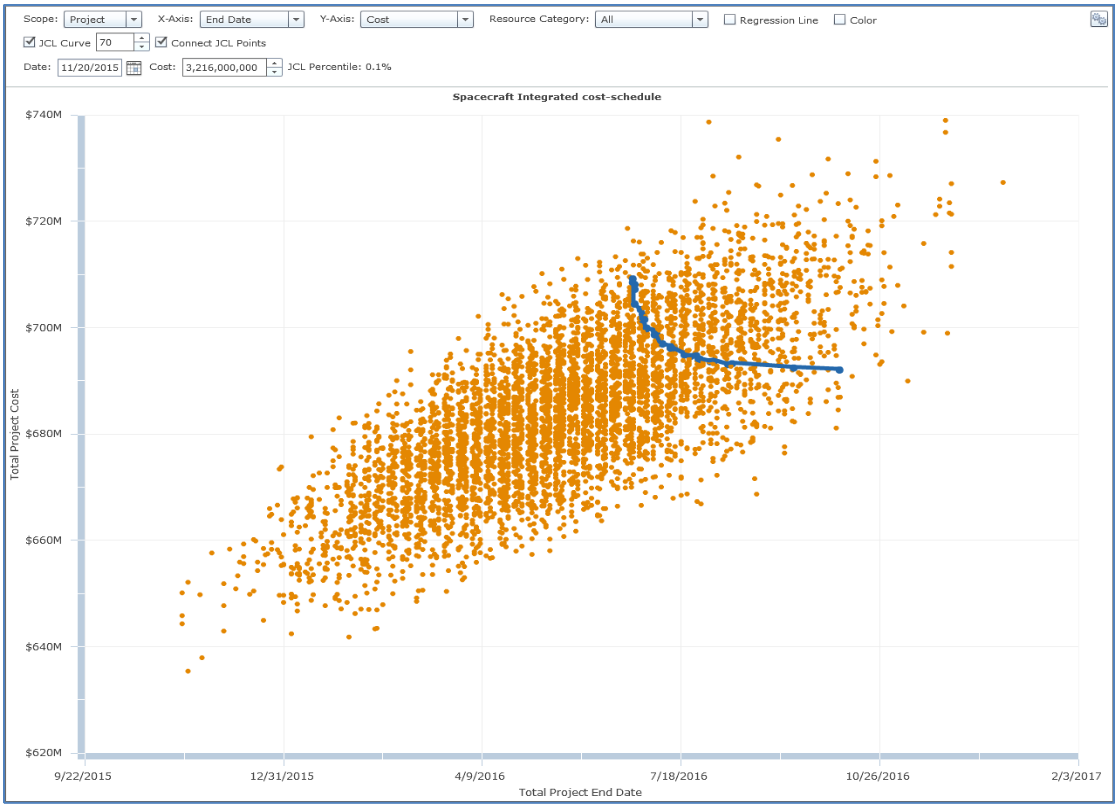
Table 5.2.8-3 Results with Schedule Uncertainties Assigned

Schedule	Baseline	5%	50%	80%	95%
Dates	20-Nov-15	8-Feb-16	19-May-16	14-Jul-16	7-Sep-16
Months from Base		2.6	6.0	7.8	9.6

Cost	Baseline	5%	50%	80%	95%
Dollars (millions)	651.6	660.6	684.4	697.1	709.5
% above Base		1%	5%	7%	9%

Because this is an integrated cost-schedule risk analysis there is interest in the relationship between time and cost. This is shown in a finish date – total cost scatter diagram shown in Figure 5.2.8-7. The scatter plot has a dot for each of all 5,000 iterations. The scatter slope indicates the positive relationship between time on the horizontal axis and cost on the vertical axis. The curved line toward the top right of the scatter represents those combinations of cost and schedule results that exhibit a 70% probability of meeting both objectives, given the uncertainties applied to the cost-loaded schedule. The target of 70% confidence level for budgeting and scheduling was chosen in this case since it is often used by several government funded agencies, such as NASA.[1]

Figure 5.2.8-7 Total Cost and End Date Scatterplot for Schedule Uncertainties



Note that the schedule uncertainty data in this example are assumed to be not correlated. If they were correlated (i.e. if one is high in its range then the others would also be high in their ranges), the extremes in cost and time would be greater and the correlation between time and cost would be tighter than shown above. The analyst should explore whether the uncertainty distributions should exhibit correlation or not. If so, then the analyst will want to exploit the capabilities of the chosen analysis package to handle correlations.

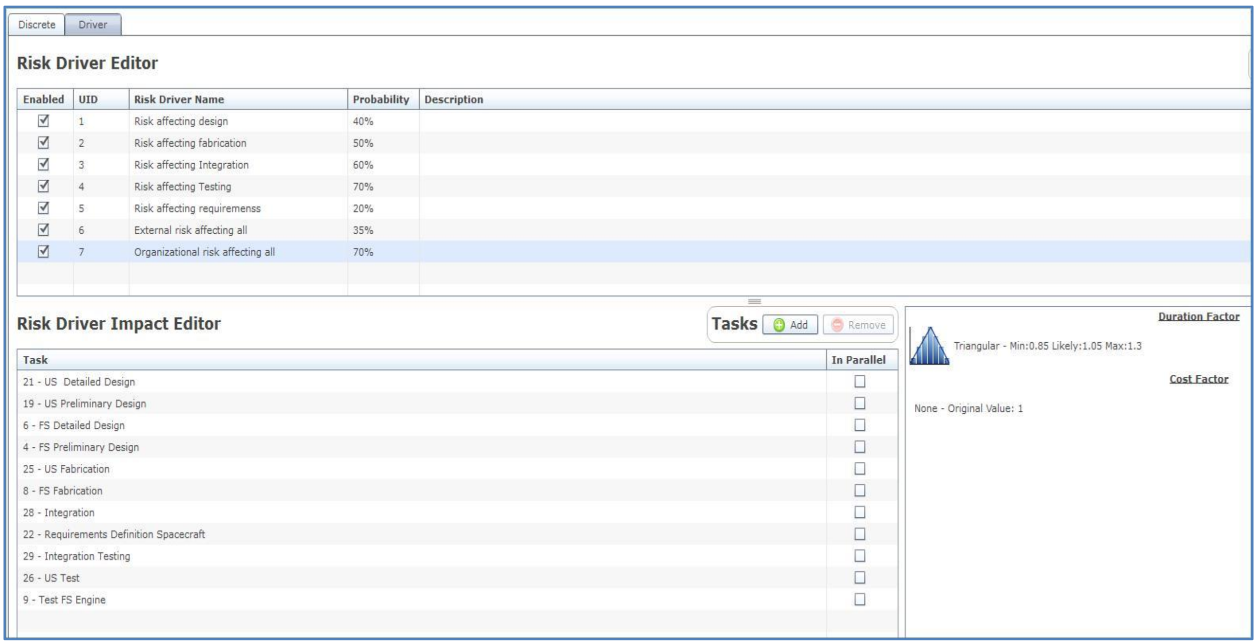
5.2.8.6 Schedule Risk Analysis – Discrete Risks Added as Drivers

The second step is to identify, calibrate and assign discrete risks to the project schedule. The risks used in this example are applied to the categories of activities, including design, fabrication, integration, testing and requirements. For this exercise the risks are given generic

[1] See: "Understanding the Joint Confidence Level (JCL) at NASA," NASA Office of Evaluation at 9/4/14.

names, but in an actual analysis the risks would be taken from the Risk Register and augmented by risks discussed in the confidential risk interviews. The generic risks for this exercise, with their probabilities are shown in the top section in Figure 5.2.8-8. One risk, "Organizational risk affecting all," has been selected to show its assigned impact range next to the triangle symbol on the right: Min 0.85, mode 1.05, Max 1.3. The Organizational risk has a probability of 70% and is assigned to all tasks since its impact is felt on everything. Although the description has not been filled in for this exercise, the organizational risk could stem from "lack of ready access to key decision makers that can increase durations" or to "organizational red tape that could slow decision making," for example.

Figure 5.2.8-8 Schedule Risk Drivers – Organizational Risk



When these risk drivers are assigned to multiple tasks or activities, those activities' durations become correlated since (1) if the risk occurs it occurs for all activities to which it is assigned, and (2) the multiplicative factor chosen for that iteration is applied to all of those activities. If only one risk is involved the activities become 100% correlated. If other risks are also assigned the correlation between activity durations is reduced. In this way the risk driver method models how correlation occurs so SMEs do not have to guess at the correlation matrix. With the addition of discrete risks to the analysis, the schedule impacts are more pronounced and the results show a later start (by 15.4 months) and higher cost (by $100 million) than with just the uncertainties for the 80% confidence level. See Table 5.2.8-4 below. Note that the cost increase is due to schedule duration risk drivers alone, and not to any cost uncertainty or risk.

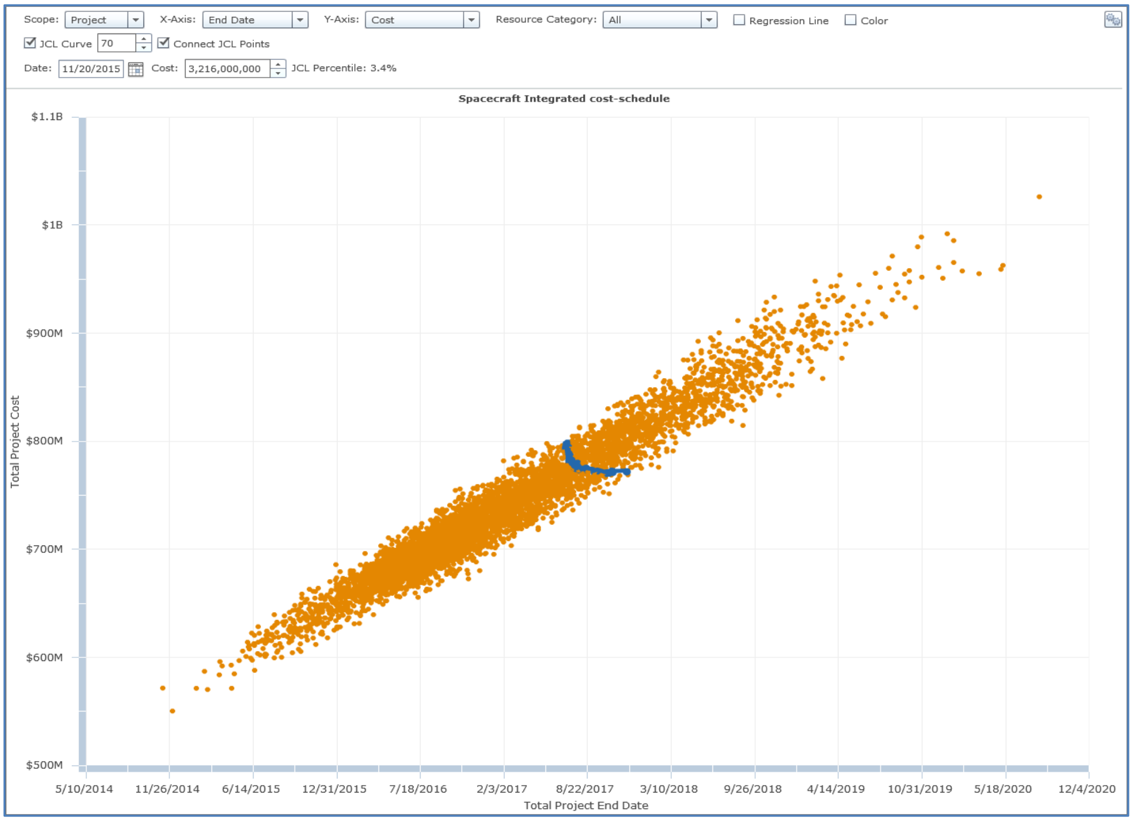
The scatterplot in Figure 5.2.8-9 shows greater correlation of time and cost risk than the previous plot showing uncertainties only, since the Organizational risk driver was assigned to all activities.

Table 5.2.8-4 Results with Schedule Uncertainties and Discrete Risks Assigned

Schedule	Baseline	5%	50%	80%	95%
Dates	20-Nov-15	5-Jan-16	28-Dec-16	26-Oct-17	16-Aug-18
Months from Base		1.5	13.3	23.2	32.9

Cost	Baseline	5%	50%	80%	95%
Dollars (millions)	651.6	650.7	730.6	797.6	865
% above Base		0%	12%	22%	33%

Figure 5.2.8-9 Total Cost and End Date Scatterplot Showing Greater Correlation of Time and Cost Risk



5.2.8.7 Cost Risk Analysis – Uncertainty and Discrete Risk Drivers

The last consideration in this simple example is whether there are uncertainties and discrete risks for cost which would cause cost variations that are independent of schedule.

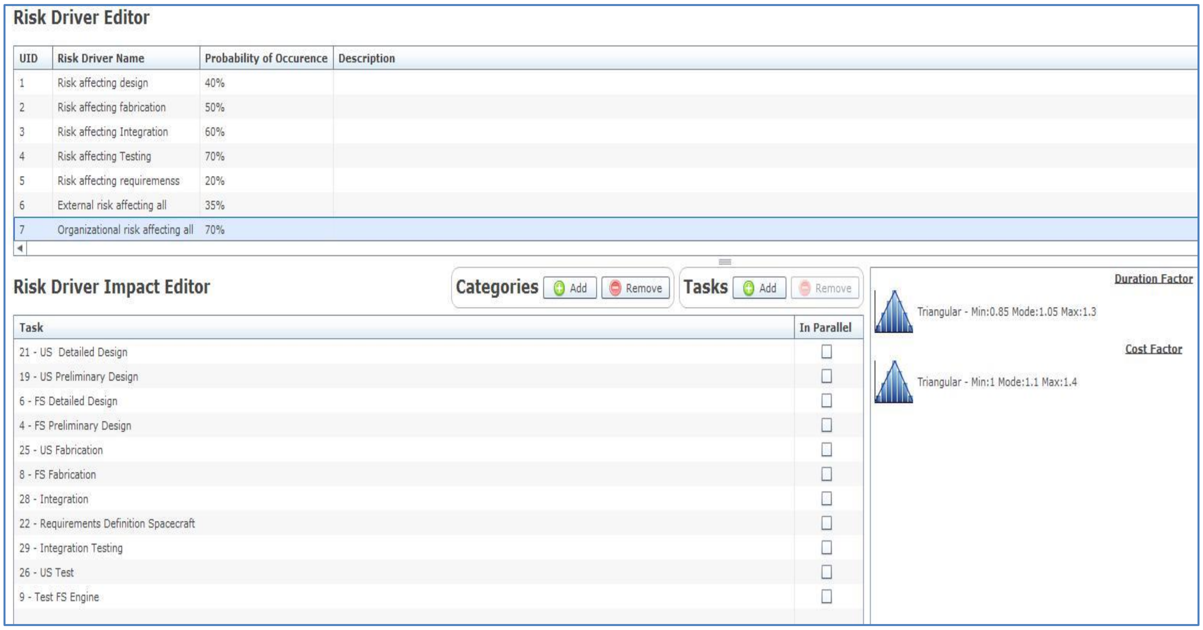
Examples of uncertainty could be errors in the time independent cost of fabrication, variances in the time-dependent activities' daily "burn rate" due to uncertainty in the number of hours/workers needed per day, and/or uncertainty in the estimated salaries. These risks, if they occur, are in addition to the cost impact from schedule duration risks already discussed in the previous material. The cost estimating error on the burn rate of labor or total cost of equipment can be entered by resource as uncertainties, with probability of 100% and a range of impact. Example uncertainty reference ranges for cost uncertainty as applied to different resources for this exercise are shown in Figure 5.2.8-10.

Figure 5.2.8-10 Uncertainty in the Burn Rate and Total Cost

Resources and Their Utilization Uncertainty				
UID	**Resource**	**Type**	**Planned Units per Unit or Day**	**Rate Per Unit or Day Min - Most Likely - Max**
1	Preliminary Engineers	Time Dependent	640	600 - 650 - 700
2	Detail Engineers	Time Dependent	960	900 - 960 - 1,020
3	Fabrication	Time Independent	1	0.9 - 1.05 - 1.15
4	Integrators	Time Dependent	1,200	1,100 - 1,250 - 1,500
5	Integration Testers	Time Dependent	1,200	1,150 - 1,250 - 1,550
6	Specification Writers	Time Dependent	800	750 - 800 - 850
7	Unit Testers	Time Dependent	800	700 - 825 - 950
8	Fabricators	Time Dependent	720	680 - 720 - 760

Discrete Risk drivers affecting cost can also be included to the analysis, in addition to the uncertainty factors. These cost factors can be entered as the implication of identified risk drivers, just as in the previous exercise for schedule drivers. If both cost and schedule risks occur, the burn rate, cost estimate, and duration will vary, and each driver will cost to vary. While new risks may be entered that just affect the burn rate or total cost of equipment, the existing risks with schedule drivers already included can have those impacts as well. For example, a cost factor has been added to the Risk Driver Editor for the previously identified Organizational risk affecting all tasks, as shown in the Figure 5.2.8-11.

Figure 5.2.8-11 Screenshot of Risk Driver Editor



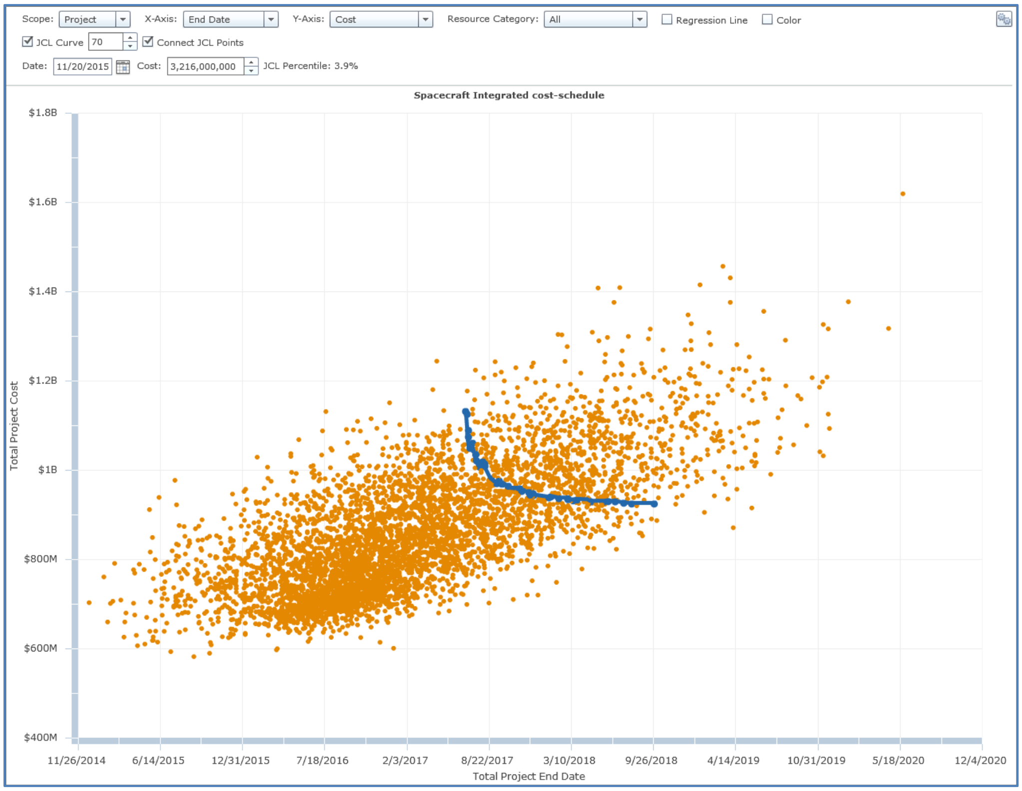
After running the program with the addition of cost uncertainties to resources and allowing risk drivers to affect costs directly rather than only through schedule risk, there is a direct impact on cost, as can be seen in Table 5.2.8-5 below. The schedule table is not shown, since the cost drivers included in the exercise do not by themselves impact duration. Note that some risks will have just schedule duration uncertainties and risk drivers, some will have just cost uncertainties and drivers, and some will have both. Cost will be affected in all cases, but schedule is affected only for those risks with duration uncertainties and drivers.

Table 5.2.8-5 Results with Uncertainties and Cost Risks Assigned

Cost	Baseline	5%	50%	80%	95%
Dollars (millions)	651.6	679	838.6	975	1100
% above Base		4%	29%	50%	69%

Adding the uncertainty and risks affecting the costs independently of time to the simulations results in a time-cost scatterplot shows less connection between time and cost, as shown in Figure 5.2.8-12.

Figure 5.2.8-12 Scatterplot Showing Less Connection between Time and Cost

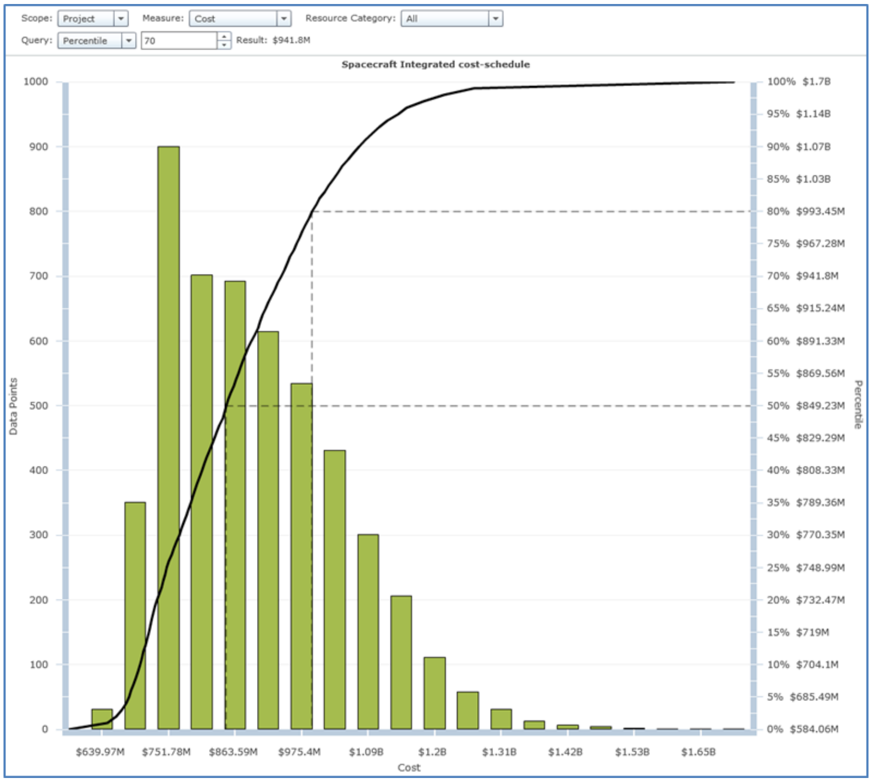


5.2.8.8 Handling Inflation

Inflation is a part of the NSF budgeting and project planning. The program should select an acceptable source for the future inflation rate and use it in the baseline and the risk analysis of that baseline. For the case study in this exercise, the baseline cost is projected at $651.6 million in base year dollars, that is, without inflation. With risks but no inflation the risk analysis simulation shows a cost in base year dollars of $975 million at the 80th percentile of certainty.

The analysis program can be used to factor in inflation if the cost estimating has been performed in base year dollars. Adding the factor of cost inflation and setting it at the rate of 3% causes the risked cost at the P-80 level to increase to $993 million in then-year dollars as shown below:

Figure 5.2.8-13 Scatterplot with Addition of Cost Inflation Factor



The value of 3% inflation may be a most likely number, but the software used in this exercise does not support an uncertain inflation level in simulation. A suggestion is to perform two scenarios where the inflation rate is either lower or higher than 3%.

- At 2% inflation the cost is estimated at $987 million
- At 4% inflation the cost is estimated at $1 billion.

These scenarios can help understand the total “then dollar” cost of the project that is risk adjusted, and the impact of the inflation assumption on that number.

5.2.8.9 Prioritizing the Discrete Risks – Risk Mitigation Workshop

The organization is encouraged to use these results to help improve the prospects of the project by mitigating the important risks. To do this the risks are prioritized. This prioritization method uses the Monte Carlo simulation, a 60-year old method, and the schedule which the project team is using to manage or at least summarize the project. It is thought that this prioritization of risks is more realistic than that using qualitative methods resulting in the risk register, in part because it recognizes the structure of the schedule and handles correlations.

Figure 5.2.8-14 Savings and Days Saved

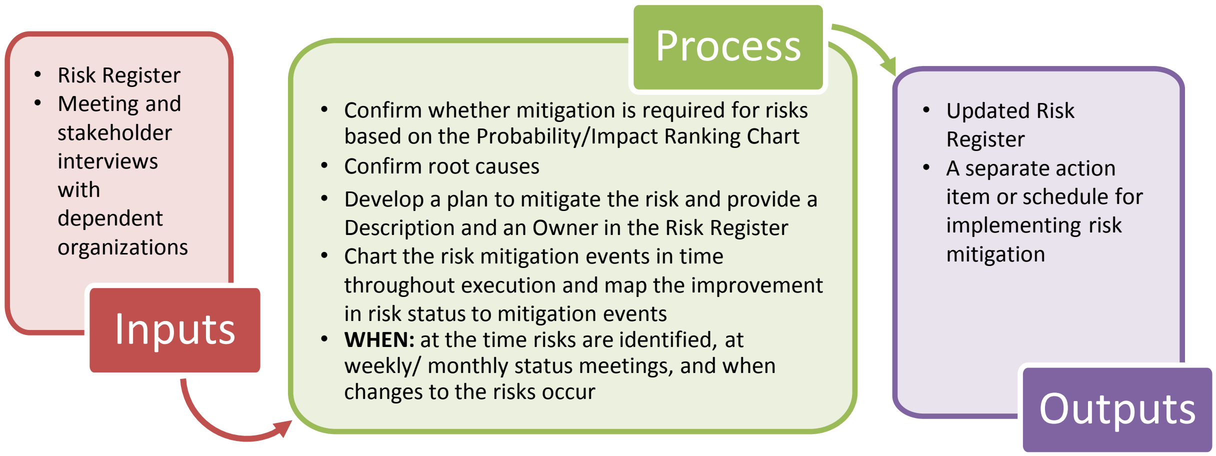
ID	Name	Cost Savings	Days Saved
7	Organizational risk affecting all	$196.15M	207
	Uncertainty	$48.03M	152
6	External risk affecting all	$34.97M	41
2	Risk affecting fabrication	$23.8M	31
4	Risk affecting Testing	$4.28M	34
3	Risk affecting Integration	$10.86M	32
1	Risk affecting design	$5.35M	10
5	Risk affecting requiremenss	$0	0

The risk mitigation exercise must be done in a workshop setting since many people have to contribute and commit to the mitigations.

- This workshop includes the PM, DPM, team leads and others involved in mitigation of risk.
- Given the prioritized list of risks for a project that may overrun cost and schedule targets, the project team can develop risk mitigation actions. The mitigation workshop estimates the improvement in the probability and impact parameters is expected to result from the various mitigations planned for each identified risk (uncertainty cannot be mitigated in concept).
- For the mitigation actions to "count" against the project risk management must commit to them as evidenced by their post-mitigation budget, schedule and assignment of people to monitor the risks and their mitigations. These risks should be added to the risk register as well so they are reviewed frequently.
- Each risk mitigation action accepted is modeled and the post-mitigation amount of risk to time and cost is recorded, along with the cost of the risk mitigation. A post-mitigation simulation will determine how much benefit is expected from the mitigations.
- The final report includes post-risk mitigation results and the overall project cost and schedule risk if those risk mitigation actions are taken and mitigate the risks. Note that the original cost and schedule target will generally not be met since that would require complete mitigation of the risks that caused the estimate of overrun in the risk analysis itself.

5.2.9 Risk Response Planning

Figure 5.2.9-1 Risk Response Planning Process



A known risk (often referred to as a "known unknown") is a risk that has been identified and can be calibrated (probability and impact) and analyzed. Examples of known risks may include strategic or overriding aspects of the project environment such as poor project management practices, lack of resources, multiple projects, external dependencies, relationships between project participants, technical complexity etc. Identified risks need to be proactively managed throughout the project life cycle by identifying who owns the management of that risk and by outlining risk symptoms, triggers, and contingency plans that would prevent the risk from occurring or that would lessen the project impact should it occur.

The Risk Response Planning step includes considerations related to risk mitigation and response planning. This includes the assignment of one or more persons to take responsibility for each identified risk and the development of measures and action plans to respond to the risk should it become an issue. PMI PMBOK® Guide defines Risk Response Planning as the process of developing options and actions to enhance opportunities and to reduce threats to project objectives.

Risk response actions for threats are generally categorized as:[1]

- **Avoid** – This strategy involves changing the project to eliminate the threat from identified risk
- **Mitigate** – This strategy involves taking early action to reduce the likelihood and/or impact of risk

[1] This listing and these descriptions are described in the PBMOK® Guide, 5th Edition, 2013 PMI

- **Transfer** – This strategy involves shifting the responsibility and ownership of the risk to another party. Although this strategy is seldom used for NSF projects, it typically involves purchasing insurance against the type of risk or requiring vendors to assume more risk.
- **Accept** – This strategy involves acknowledging the threat as part of the project and accepting the consequences of its occurrence. An example of this is political or legislative risk that is out of the control of the project team. The consequence of acceptance may mean that contingency resources may need to be applied if the risk is realized.

Risk response actions for opportunities are generally categorized as:

- **Exploit** – This strategy seeks to eliminate the uncertainty associated with this opportunity to ensure it happens. This is similar to Avoid threats.
- **Enhance** – This strategy seeks to increase the probability and / or the positive impacts of the opportunity. This is similar to Mitigate threats.
- **Share** – This strategy seeks to share the benefits of the opportunity with another organization that is in the best position to secure the opportunity for the project. This is similar to Transfer for threats.
- **Accept** – This strategy accepts an opportunity if it arises but does not envision pursuing it, similar to Accept for threats.

For the most part, project risk response planning will consist of defining risk thresholds for action, confirming risk triggers, and then planning a mitigation strategy and/or developing backup plans if risks occur. A risk trigger is an event or events that activate the execution of a backup plan, should the risk become an issue. Triggers should be specified in the Risk Definition in the Risk Register, as well as the date that risk resolution is required for each risk. Mitigation strategies identify actions that may minimize or eliminate project risks before the risk occurs or document decisions to accept the consequences of risks without action. A risk may have several mitigation activities that attempt to balance the reduction in the probability and/or the severity of the risk occurrence with the cost-effectiveness of the mitigation strategy. Mitigation planning requires that the root cause(s) of the risk be identified and that the mitigation strategy and plans be aligned accordingly. Backup plans define actions to be taken in response to identified risk triggers in hopes of reducing potential project impact as a result of a realized risk (often defined in the literature as an "issue").

A tabulated example of the impact of Risk Response evaluation is given below in Table 5.2.9-1.

Table 5.2.9-1 Impact of Risk Handling on Project Cost

	Before Handling				After Handling			
						Residual Risk Cost Estimates ($K)		
Risk Item or Basis	Risk Level	Worst Case Cost ($K)	Handling Strategy	Cost Implement Handling	Risk Level	Best Case	Most Likely	Worst Case
Redesign to solve problems identified during reviews	Moderate	3,360	Mitigate	75	Low	0	150	500
Do analyses or design per external comments	Moderate	390	Avoid	0	--	N/A	N/A	N/A
Rework design documents during concept evolution	Moderate	5,720	Mitigate	0	Moderate	0	750	2,500
Redesign for add'l equipment for ops or pretreat interface	Moderate	160	Mitigate	0	Low	0	40	100
Design for sintering equipment	High	500	Mitigate	308	Moderate	0	0	200
Redo design for SNF re-sizing	Moderate	200	Accept	0	Moderate	0	50	200
Redesign; contamination control in process room	Moderate	5,000	Mitigate	361	Moderate	0	300	3,000
Change design basis, due to scale-up impact	Low	50	Accept	0	Low	0	15	50
Redesign, for SC furnace	Low	800	Mitigate	0	Low	0	0	50
Redesign to add gas-trapping system	Low	1,550	Accept	0	Low	0	0	1,550
Rework to add waste streams to design	High	3,000	Mitigate	0	Moderate	0	250	2,300
Rework robotic features design	High	7,440	Mitigate	53	Moderate	0	500	2,000
Redesign for characterization	High	5,000	Mitigate	176	Moderate	0	600	3,000
Redesign to meet canister requirements	Moderate	3,000	Accept	0	Moderate	0	100	3,000
Design for new cables	Moderate	400	Mitigate	0	Low	0	0	50
Redesign for additional MC&A equipment	Moderate	400	Mitigate	0	Low	0	0	50
Redesign, to apply new structural criteria to 105L	Moderate	1,500	Mitigate	300	Low	0	0	700
Redesign, per SGS inputs	Low	500	Accept	0	Low	0	0	500
Redesign for changes, per NRC interface	Moderate	200	Mitigate	0	Low	0	0	150
Additional utility design features	Moderate	500	Accept	0	Moderate	0	300	500
Delays initiating design, awaiting R&D completion	High	5,360	Mitigate	0	Moderate	0	240	720
Delays redesigning for classified process control system	Low	60	Avoid	0	--	N/A	N/A	N/A
Add features to meet IAEA	Moderate	500	Mitigate	0	Low	0	0	50
Uncertainty in obtaining contingency funds	Moderate	2,000	Avoid	0	--	N/A	N/A	N/A
Disposal of bundling tubes	Moderate	100	Avoid	75	--	N/A	N/A	N/A
Decontamination of final-product canister	Moderate	500	Avoid	341	--	N/A	N/A	N/A
Storage location for depleted uranium	Moderate	100	Avoid	75	--	N/A	N/A	N/A
Availability of emergency generator and fuel tank	Moderate	40	Avoid	0	--	N/A	N/A	N/A
Redesign for necessary structural supports	Moderate	300	Avoid	225	--	N/A	N/A	N/A

Risk Item or Basis	Risk Level	Worst Case Cost ($K)	Handling Strategy	Cost Implement Handling	Risk Level	Best Case	Most Likely	Worst Case
Arithmetic Sums:		48,630		1,989		0	3,295	21,170

The risks with mitigation plans and risk triggers are all listed in the Risk Register with their Qualitative Risk Assessment status. After Risk Response Planning has been performed the entire entry for the risk includes:

- Its statement or definition
- Analysis and ranking of initial risk
- Assignment to a risk owner
- Risk mitigation actions and backup plans
    - Costs
    - Timing and risk triggers
    - Expected results
- Status of mitigation efforts
- Analysis and ranking of residual risk after mitigation

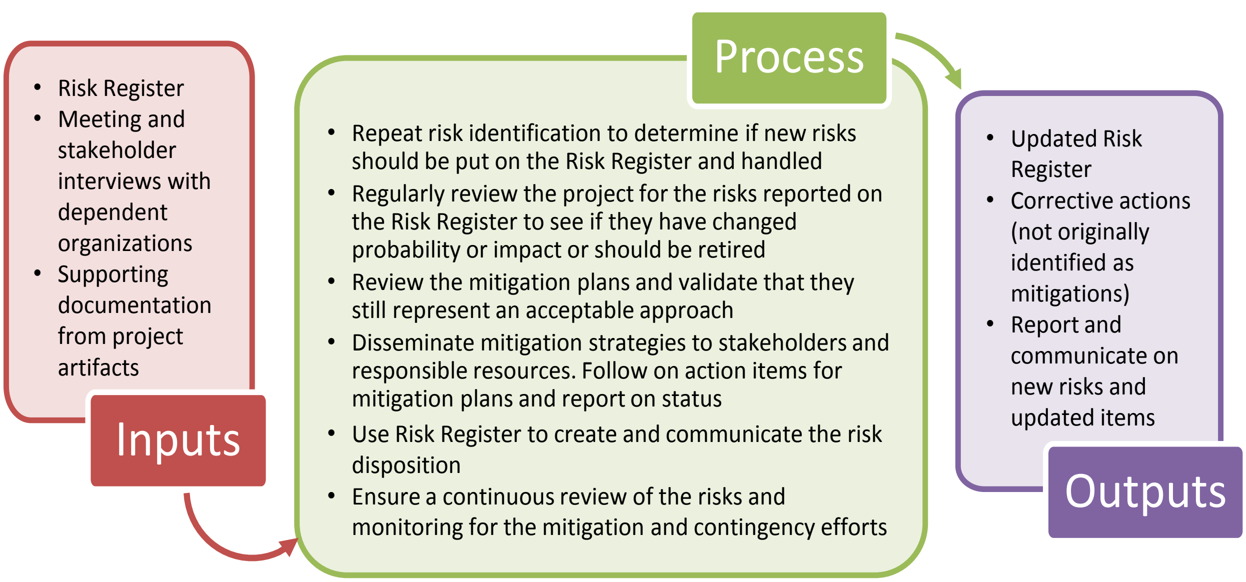
The last item listed above is the expected residual risk and ranking after mitigation has been applied. This is accomplished by repeating the analysis of probability and ranked impact on project objectives with successful mitigation assumed. Thus, the Risk Register shows “before” and “after” views of the analysis, with risks migrating down from red to yellow to green with the mitigation steps that cause the improvement in risk status and timing of those steps. The sample risk register shown in Figure 5.2.7-6 shows columns with headings for “Pre-Mitigated” and Post-Mitigated” analysis results.

5.2.10 Risk Monitoring and Control

Risk Management requires continuous monitoring of project risk and iterative application of the risk identification, analysis, and response processes. Existing risks need to be monitored, controlled, and ultimately retired, while new risks must be identified and added to the Risk Management process. Risk Monitoring and Control is the process of identifying, analyzing, and planning for new risk, keeping track of and re-analyzing identified risks, monitoring risk symptoms and triggers, reviewing the execution of risk responses strategies while evaluating their effectiveness, and reporting status to stakeholders. The Risk Register, as the tool that supports Risk Management and provides a means of communication, must be kept up to date with status and changes. The frequency and process for reviewing project risk is set out in the project Risk Management Plan.

Risk Control includes the process of regularly updating the Risk Register and communicating to stakeholders the latest risk status, with resulting impacts on the project and mitigation plans. Reporting of project and program level risks should be included as part of regularly scheduled status meetings with, and in formal status reports to, internal project members as well as eternal stakeholders and the NSF. The NSF has emphasized the need to communicate the risks at regularly scheduled status meetings to ensure that continued focus and awareness is placed on risk management.

Figure 5.2.10-1 Risk Monitoring and Control Process



When risks are resolved, they should be retired from the list of active risks. When the project ends, the risk register may be closed. If some risks pose other future threats to the program or future projects, consideration should be given to re-opening a risk with the appropriate operations management, or at the program level as an "ongoing risk."

5.2.11 Contingency Management for Risk Mitigation

5.2.11.1 Contingency Budget Timeline

NSF expects the project to refine its WBS budget estimates following the Preliminary Design Review (PDR), adding additional definition to the tasks associated with accomplishing the project's deliverable activities. At Final Design Review (FDR) the PEP budget estimate should be substantially based on externally obtained cost estimates (vendor quotes, bids, historical data, etc.). This added definition is expected to result in an increase to the project's estimated Budget at Completion (BAC) and project schedule, and a concomitant reduction in its budget and schedule contingencies, while TPC and the risk-adjusted, committed schedule finish date remain constant. The quantitative risk analysis should have a component to anticipate this increase in cost and time so that the original contingency reserves are sufficient to provide for this increase.

As a project progresses, the baseline cost estimate and schedule will typically be exceeded and contingency amounts of dollars and time will be used. Periodically the project cost estimate must be revised to reflect all new information, including actual costs and use of contingency funds, adjustments to the risk profile, learning curves for manufactured items, etc. This new estimate of the cost of the remaining work is called the Estimate to Complete (ETC), and the Actual Cost of Work Performed + ETC is equal to the latest revision of the EAC. The EAC should be compared to the sum of BAC plus remaining contingency to ensure that it is less than the TPC. If the sum of BAC plus remaining contingency is greater than the TPC, de-scoping may be necessary. See Section 4.2.5 for details on requirements for budget contingency use.

The project should create and maintain an expected contingency allocation profile. Contingency allocation profiles usually do not track the commitment or spending profiles. For many projects, the highest use of both schedule and budget contingency occurs during procurement and during final commissioning/integration phases. A contingency allocation curve for such a project would be bi-modal, with one peak for procurements activities and another for significant reserves held back until the end of the project, even though the spending curve may be low near the end of the project. Although risk does burn down over time, there may be significant reworking of hardware, for example, needed as a result of knowledge gained during integration and commissioning activities.

5.2.11.2 Change Control for Contingency Adjustments

Adjustments to cost, schedule, and scope are documented and approved under the project Change/Configuration Control Process (CCP), developed as a part of the PEP. The Risk Management Plan describes how the project uses the Change/Configuration Control Process (CCP) to assign contingency to specific WBS elements when risks materialize, and how budget contingency is de-allocated from WBS elements and returned to the contingency category when budget underruns occur. The Change Control Process should be initiated when the Total Project Cost is established at the Preliminary Design Review, and followed for the duration of the project. All change control actions that affect the use of contingency – cost, schedule, or technical performance and scope – must include a link to an identified and documented risk and indicate the affected WBS elements at the first meaningful level of technical differentiation within the project. The CCP must make provision for seeking prior approval from the NSF Program Officer for all actions exceeding thresholds as defined in the CA. All change requests are to be archived by the project, and made available for review by NSF. The Project must keep a log of all change actions such that contingency actions, including puts and takes, can be reported and summarized. See Section 4.2.5 for further details and a sample Change Request form.

Note that use of contingency does not automatically require a change to the baseline. For instance, a change control action can authorize contingency to cover a cost overrun which is tracked as a variance on the baseline Budget at Complete (BAC). In such a case the contingency can be incorporated into either the BAC or the EAC. In the first instance, the BAC is changed. In the second, the variance from the BAC remains and can be used for trending and other information. See Section 4.2.5 for further details on approval levels for use of contingency.

Adjustments to contingency should include taking advantage of opportunities to assign savings and underruns to contingency. Savings should not be left in associated WBS elements if they are above thresholds set out in the Risk Management Plan, nor should they be shifted to other tasks without going through the Change Control Process for return to contingency and subsequent allocation to a different WBS element. Budget and cost underruns should be moved to contingency as risks are retired and WBS elements are closed out and reconciled. Savings realized through the implementation of planned de-scoping options should also be placed into contingency. Returning the savings allows the best use of contingency reserves for overall project priorities.

5.2.11.3 Liens List: Forecasting and Opportunity Management

The Project should maintain a Liens List of planned future adjustments to contingency as a forecasting tool that tracks actions that have not yet been incorporated into the BAC or EAC. The list may document items such as very high probability risks with trigger points for action, deferred scope held as contingency until a decision date, realized risks needing draws on contingency that require more definition for a change control action to be implemented, and anticipated opportunities for returns to contingency. It can also be used to record the need for contingency to cover variances that will not/cannot be mitigated. It does not serve the same purpose as a watch list or major threats list from the Risk Register. It acts as an escrow or staging account for planned or near certain contingency allocations.

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

Projected amounts of possible future adjustments to contingency in the Liens List are to be periodically reported to NSF. NSF recommends including this information within the monthly status report as well.

5.2.11.4 Updates of the Estimate at Complete and Risk Exposure

The project should maintain an estimate of total costs and risk exposure by periodically updating the schedule, the Estimate at Complete (EAC), and the analysis of overall project risk. Estimated contingency amounts should be appropriate for the risk exposure throughout the project life cycle. During concept and early development stages, a qualitative risk analysis and risk register may provide an adequate estimate of risk exposure for both the design and construction planning estimates. As project planning reaches the preliminary design phase, the drawbacks of qualitative analysis – limited subset of risks, ignored correlations, and arithmetic sums of averages – do not allow that method to adequately portray total project risk.[1] Project planners must transition to quantitative risk analysis in order to establish a substantiated Total Project Cost at the time of the PDR.

For the construction stage, initial contingency is a part of project total cost, scope and schedule. As time goes by, risk exposure changes with risk mitigation, new knowledge, and new circumstances. The amount of remaining contingency budget fluctuates over time with assignments to risk mitigation and return of savings. The remaining risk exposure estimate should be compared to the remaining available contingency to determine whether the project has adequate funds to cover anticipated risks. Remaining available contingency (RAC) is defined as the difference between the combination of the EAC plus any liens and The Total Project Cost:

RAC = Total Project Cost (TPC) - (EAC + liens)

The sum of the (EAC + liens) should include variances (backward looking actuals) and updated estimates (forward looking forecasting) in the current plan, not the target baseline BAC. The EAC should equal the BAC only at project start and after major changes to the baseline from re-planning or re-baselining.

It is good practice to re-estimate EAC and Risk Exposure yearly, unless stated otherwise in the CA. Specific dates may also be appropriate times for re-evaluation, such as at major milestones dates. The Project Manager periodically re-assesses the current risk assessment to identify and address any new risks that arise as the project progresses. This assessment should result in a determination of whether cost and schedule contingency remains sufficient for project risks.

[1] Projects usually adopt a more conservative certainty target such as the 80^{th} percentile.

5.2.11.5 Contingency Use and NSF Oversight during Construction

The NSF Program Officer must concur on all CCB actions exceeding CA-defined thresholds for allocation of budget, schedule, or scope contingency. NSF will negotiate a CA with the recipient institution to fund project construction activity which will specify thresholds above which prior NSF approval[1] is required before allocation of contingency (following formal CCB review) to specific WBS elements. Contingency may only be used to support in-scope work for the approved project baseline. See Section 4.2.5.7 for additional details.

5.2.11.6 Documentation and Reporting of Contingency Use

Risk management actions involving Change Control actions fall under the following documentation and reporting requirements, as stated in more detail in Section 4.2.5:

- All Change Control Requests, irrespective of amount or whether they increase or decrease the BAC, are to be reported directly to NSF Program Officer
- The recipient will keep an archive of all Change Control Requests
- The recipient will keep a summary log of all Change Control Requests
- Projected amounts of possible future adjustments to contingency (“liens”) are to be periodically reported to NSF.

NSF recommends including this information within the monthly status report. Note that National Science Board (NSB) approvals[2] are required when Change Control actions exceed the even higher thresholds defined by NSB policy.

The required summary log of all Change Control actions should include the following:

- Change control action title,
- Change control document reference number,
- Change control approval date,
- Amounts of change in budget, scope, and/or schedule, for each affected and identified WBS element,
- Any adjustments to contingency reserves,
- WBS elements affected by the changes (at WBS Level II or at the first meaningful level of technical differentiation within the project)
- Risk Register ID number and description for the risk being addressed, and
- NSF approval date if required.

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

[2] See Section 2.4, Construction Stage, for details on NSF policy on how and when NSB approval is required.

Monthly reports must also include the status of contingency as part of the Earned Value Management (EVM) reports. See Section 4.2.5.8 for details on reporting.

5.2.12 Partnership Considerations for Contingency Management

NSF may partner with other entities to plan and construct a major facility. The guidelines within Section 4.2.5.9 of this document are applicable when NSF funds a particular scope of work within a larger overall project. Risk assessment, contingency development processes and contingency status reporting are to be applied to those WBS elements to be funded by NSF. NSF encourages the development of unified management for project planning and execution of the entire project scope wherever practical.

5.3 GUIDELINES FOR CYBER-SECURITY OF NSF'S LARGE FACILITIES

NSF has responsibility for oversight of facilities it constructs and operates, including associated IT Infrastructure. This section, to be written, will describe 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 will document NSF's expectation for the recipient 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.

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

This document, which is in preparation, will describe the process for evaluation and review of all NSF large facility projects proposed for construction, under construction or currently in operation. It will provide assistance to the Program Officer (PO) in preparing and planning a review of the *non-research related aspect* of the project's management, budgets, schedule and related activities. The information contained will offer guidance for three situations: reviews of facilities in planning; reviews of construction activity; and operational reviews of ongoing facilities. A description of the overall process of planning and carrying out an external review of a 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 covered in the document 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 the broader impact criteria used to select the project for support, but rather focuses on evaluation of the Recipient's planning and implementation activities.

5.5 ENVIRONMENTAL CONSIDERATIONS IN LARGE FACILITY PLANNING

NSF's funding for the construction or modification of facilities constitutes a Federal Action that triggers compliance with several statutes designed to protect the Nation's environmental, cultural and historic resources. Awareness of, and strict adherence to, all relevant environmental regulations are extremely important considerations in the planning, construction and operation of facilities.

These statutes include, but are not limited to, the National Environmental Policy Act (NEPA), the National Historic Preservation Act (NHPA) and the Endangered Species Act. 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 Program Officer (PO) should not attempt to determine the extent of compliance requirements without consulting the Environmental Compliance Team within NSF's Office of the General Counsel. 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). Recipients should contact the cognizant NSF PO for details, which are given in the internal NSF document *Proposal and Award Manual (PAM)*, Chapter VI. E. – Environmental Considerations. This section of the PAM describes the policy and procedures applicable to NSF actions requiring the preparation of an EIS in accordance with the National Environmental Policy Act.

Additionally, in conjunction with or independent of its NEPA compliance, NSF may be required to initiate consultations with Native Americans and other interested parties pursuant to the NHPA and/or initiate informal or formal consultation with the U.S. Fish and Wildlife Service under the Endangered Species Act. These compliance requirements can introduce significant schedule and cost risk into the project which should be considered and addressed. Furthermore, there is no special source of funding within NSF to pay for the environmental compliance process; the cost is normally borne by the program using Research and Related Activities (R&RA) funds. Given these factors, the following guidance is offered:

1. It is imperative that the PO contact the Environmental Compliance Team within NSF's Office of the General Counsel early in the conceptual design stage to seek guidance on specific requirements for compliance.
2. It is extremely important that the PO and the project get cost estimates for the compliance process and factor these into the project's scope, schedule and budget early in the design process.

The cost drivers associated with these activities (their impact on the project construction cost) need to be well understood by PDR since the PDR budget and risk assessment provide the basis for the construction funding request.

5.6 GUIDELINES FOR REPORTING REQUIREMENTS

This published guide[1] summarizes the reporting requirements NSF typically imposes on a project during construction and operation. This information is provided so that proposing organizations and Program Officers (POs) can assess the project-specific needs that should be addressed and appropriately budget so that these requirements can be satisfactorily accomplished.

[1] "Guidelines for Reporting to NSF during Planning, Construction, and Operation of MREFC Projects." Is available online.

5.7 GUIDELINES FOR FINANCIAL MANAGEMENT

This published document[1] 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.

[1] "Financial Management Module in Support of the Management and Oversight of Large Facilities" is available online.

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

The purpose of the NSF's *Business Systems Review (BSR) Guide*[1] is to define and establish the procedures for the planning, execution and follow-up activities associated with conducting BSRs. The BSR is designed to provide guidance to Awardees under assistance awards (CAs and grants) as well as NSF staff 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 BSR itself is a versatile assessment vehicle by which NSF can evaluate the "health" of its Awardees' business systems and plays an integral part in NSF's assurance role.

BSRs 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 BSR Guide defines the roles and responsibilities of NSF staff assigned to BSR activities and identifies core and targeted review areas.

[1] "Business Systems Review (BSR) Guide" is available online.

5.9 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. Please contact the cognizant NSF Program Officer or the Grants and Agreement/Contracting Officer for details.

Proposing organizations and Recipients are not limited to using the OMB inflators when doing cost estimates. NSF encourages organizations to use inflators appropriate for the known situations or a particular industry as long as they can be justified. The justification for all inflators (including use of standard OMB inflators) should be included in the basis of estimate.

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7 LIST OF ACRONYMS

AD	Assistant Director
AMBAP	Award Monitoring and Business Assistance Program
BAC	Budget at Complete
BFA	Office of Budget, Finance, and Award Management
BOE	Basis of Estimate
BOT	Business Oversight Team (Replaced by Integrated Project Team [IPT])
CA	Cooperative Agreement
CCB	Change Control Board
CCP	Change/Configuration Control Process
CDR	Conceptual Design Review
CPM	Critical Path Method
CPRD	Cost Proposal Review Document
DACS	Division of Acquisition and Cooperative Support
DD	Division Director
DDLFP	Deputy Director for Large Facility Projects
DGA	Division of Grants and Agreements
DIAS	Division of Institution and Award Support
DRB	Director's Review Board
EA	Environmental Assessment
EAC	Estimate at Complete
EHR	Education and Human Resources
EIS	Environmental Impact Statement
ES&H	environmental safety and health
ETC	Estimate to Complete (for Cost)
EVM	Earned Value Management
EVMS	Earned Value Management System
FAR	Federal Acquisition Regulations
FDR	Final Design Review
FFRDC	Federally Funded Research and Development Center
FY	Fiscal Years
GAO	Government Accountability Office
G/AO	Grants and Agreements Officer
GPRA	Government Performance and Results Act
HLFO	Head, Large Facilities Office
IMP	Internal Management Plan
IMS	Integrated Master Schedule
IPT	Integrated Project Team (replaces the BOT and the PAT)
IT	Information Technology
LFM	Large Facilities Manual
LFO	Large Facilities Office at NSF
LFWG	Large Facilities Working Group

MOU	Memorandum of Understanding
MREFC	Major Research Equipment and Facilities Construction
NCE	No-Cost Extension
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NRC	National Research Council
NSB	National Science Board
NSF	National Science Foundation
O&M	Operations and Maintenance
OD	Office of the Director
OGC	Office of the General Counsel
OMB	Office of Management and Budget
ORR	Operations Readiness Review
PAM	Proposal and Award Manual
PAT	Project Advisory Team (replaced by the Integrated Project Team [IPT])
PDP	Project Development Plan
PDR	Preliminary Design Review
PEP	Project Execution Plan
PI	Principal Investigator
PMB	Performance Measurement Baseline
PMBOK	Project Management Body of Knowledge
PO	Program Officer
R&D	Research and Development
R&RA	Research and Related Activities
RAC	Remaining Available Contingency
RBS	Risk Breakdown Structure
RET	Research Experiences for Teachers
REU	Research Experiences for Undergraduates
RFP	Request for Proposals
RI	Research Infrastructure
RM	Risk Manager
RMP	Risk Management Plan
S&E	Science and Engineering
SOG	Standard Operating Guidance
SME	Subject Matter Expert
SPC	Statistical Process Control
TPC	Total Project Cost
WBS	Work Breakdown Structure

8 LEXICON

8.1 PREFACE

This Lexicon contains definitions of project and program management terms used in this Manual, as applied to NSF large facilities. It is a combination of specialized terms defined by NSF and used in the management of its large facilities, and terms and definitions commonly used in professional project and program management. A subset of common project management terms compatible with NSF usage were selected from a standard source, the *PMI Lexicon,*[1] for inclusion in this lexicon.

The Lexicon provides a common set of standard terms and definitions that should facilitate communication and understanding between stakeholders when used in documents and correspondence related to large facility management.

The terms and definitions included in this lexicon are in development and are subject to modifications in future versions.

[1] Entries in italics in this lexicon have been reproduced with permission from Project Management Institute, Inc., *[PMI Lexicon]*, *(2012)* Copyright and all rights reserved.

8.2 TERMS AND DEFINITIONS

Acceptance Criteria. *A set of conditions that is required to be met before deliverables are accepted.*

Activity. *A distinct, scheduled portion of work performed during the course of a project.*

Actual Cost. *The realized cost incurred for the work performed on an activity during a specific time period.*

Analogous Estimating. *A technique for estimating the duration or cost of an activity or a project, using historical data from a similar activity or project.*

Apportioned Effort. *An activity where effort is allotted proportionately across certain discrete efforts and not divisible into discrete efforts. (Note: Apportioned effort is one of three earned value management [EVM] types of activities used to measure work performance.)*

Approval. The act of officially accepting an idea, action, or plan.

Assistance. The act of giving support or help; making it easier for someone to do something or for something to happen.

Assumption. *A factor in the planning process that is considered to be true, real, or certain, without proof or demonstration.*

Assurance. To give a strong and/or definite statement that something will happen or that something is true; to give confidence to.

Backward Pass. *A critical path method technique for calculating the late start and late finish dates by working backward through the schedule model from the project end date.*

Baseline. *The approved version of a work product that can be changed only through formal change control procedures and is used as a basis for comparison.*

Baseline Definition. The description of the approved scope of work and resources for a construction project, including a hierarchical, product-oriented Work Breakdown Structure (WBS) and associated WBS dictionary; the cost and schedule Performance Measurement Baselines (PMB); and any contingency amounts.

Budget Contingency. An amount added to a baseline budget estimate to allow for identified items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs. Typically estimated using statistical analysis or judgment based on past asset or project experience. Budget contingency is allowed on MREFC awards.

Bottom-up Estimating. *A method of estimating project duration or cost by aggregating the estimates of the lower-level components of the work breakdown structure (WBS).*

****Budget at Completion.*** *The sum of all budgets established for the work to be performed.* (For NSF projects, contingency amounts are not included in the ETC, EAC, BAC, or PMB due to the NSF requirement that contingency is held and managed separately from the baseline.)

Change Control. *A process whereby modifications to documents, deliverables, or baselines associated with the project are identified, documented, approved, or rejected.*

Change Control Board. *A formally chartered group responsible for reviewing, evaluating, approving, delaying, or rejecting changes to the project, and for recording and communicating such decisions.*

Change Control System. *A set of procedures that describes how modifications to the project deliverables and documentation are managed and controlled.*

Change Request. *A formal proposal to modify any document, deliverable, or baseline.*

Code of Accounts. *A numbering system used to uniquely identify each component of the work breakdown structure.*

Conceptual Design Phase. The first phase of the Design Stage, after passing the gate from the Development Stage, that advances the definition of the scope and requirements, determines feasibility, and produces updated drafts of most elements of the Project Execution Plan, including parametric cost and schedule range estimates and a preliminary risk analysis.

Contingency. A planned amount of scope, budget, or time added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs. Typically estimated using statistical analysis or judgment based on past asset or project experience**.**

Contingency Report Table. A table containing a list of change control actions and allocations, with ties to associated WBS elements and identified risk events, for all Performance Measurement Baseline (PMB) changes that impact the use of contingency.

Constraint. *A limiting factor that affects the execution of a project, program, portfolio, or process.*

Construction Stage. The period of time in which funds are obligated for acquisition and/or construction of a facility that fulfills the terms and conditions set forth in an award instrument between NSF and the recipient(s). This stage ends with the start of the Operations Stage

Control Account. *A management control point where scope, budget, actual cost, and schedule are integrated and compared to earned value for performance measurement.*

Corrective Action. *An intentional activity that realigns the performance of the project work with the project management plan.*

Cost Performance Index. *A measure of the cost efficiency of budgeted resources expressed as the ratio of earned value to actual cost.*

Cost Variance. *The amount of budget deficit or surplus at a given point in time, expressed as the difference between the earned value and the actual cost.*

Crashing. *A technique used to shorten the schedule duration for the least incremental cost by adding resources.*

Critical Chain Method. *A schedule method that allows the project team to place buffers on any project schedule path to account for limited resources and project uncertainties.*

Critical Path. *The sequence of activities that represents the longest path through a project, which determines the shortest possible duration.*

Critical Path Activity. *Any activity on the critical path in a project schedule.*

Critical Path Method. *A method used to estimate the minimum project duration and determine the amount of scheduling flexibility on the logical network paths within the schedule model.*

Current Plan. The project cost and schedule plan reflecting the status of progress to date and updated estimates for completing remaining work that is compared to the approved Performance Measurement Baseline (PMB), as part of Earned Value Management.

Data Date. *A point in time when the status of the project is recorded.*

Decision Tree Analysis. *A diagramming and calculation technique for evaluating the implications of a chain of multiple options in the presence of uncertainty.*

Decomposition. *A technique used for dividing and subdividing the project scope and project deliverables into smaller, more manageable parts.*

Defect Repair. *An intentional activity to modify a nonconforming product or product component.*

Deliverable. *Any unique and verifiable product, result, or capability to perform a service that is required to be produced to complete a process, phase, or project.*

De-Scoping Options (Plan). See Scope Contingency Plan.

Design Stage. The life cycle stage for detailed planning for projects approved by the NSF Director at the end of the Development Stage and funded under the formal MREFC planning process. It is divided into the Conceptual, Preliminary, and Final Design Phases; with a formal and rigorous review gate at the end of each phase to show readiness for advancement to a higher level of refinement with regard to scope, cost, and schedule.

Development Stage. The Facility Life Cycle stage in which initial high level ideas are developed and a consensus built for the potential long-term need, priorities, and general requirements for a large research facility of interest to NSF and the broader research community.

Discrete Effort. *An activity that can be planned and measured and that yields a specific output. (Note. Discrete effort is one of three earned value management [EVM] types of activities used to measure work performance.)*

Early Finish Date. *In the critical path method, the earliest possible point in time when the uncompleted portions of a schedule activity can finish based on the schedule network logic, the data date, and any schedule constraints.*

Early Start Date. *In the critical path method, the earliest possible point in time when the uncompleted portions of a schedule activity can start based on the schedule network logic, the data date, and any schedule constraints.*

Earned Value. *The measure of work performed expressed in terms of the budget authorized for that work.*

Earned Value Management. *A methodology that combines scope, schedule, and resource measurements to assess project performance and progress.*

Effort. *The number of labor units required to complete a schedule activity or work breakdown structure component, often expressed in hours, days, or weeks.*

Enterprise Environmental Factors. *Conditions, not under the immediate control of the team, that influence, constrain, or direct the project, program, or portfolio.*

****Estimate at Completion.*** *The expected total cost of completing all work expressed as the sum of the actual cost to date and the estimate to complete.* (For NSF projects, contingency amounts are not included in the ETC, EAC, BAC, or PMB due to the NSF requirement that contingency is held and managed separately from the baseline.)

****Estimate to Complete.*** *The expected cost to finish all the remaining project work.* (For NSF projects, contingency amounts are not included in the ETC, EAC, BAC, or PMB due to the NSF requirement that contingency is held and managed separately from the baseline.)

Facility. Shared-use infrastructure, equipment, or instrument - or an integrated network and/or collection of the same – that is either acquired or constructed to collect, analyze, and provide necessary data and information in support of research having a major impact on a broad segment of a scientific or engineering discipline.

Facility Life Cycle. The sequence of steps or stages that characterize the lifetime of a facility from beginning to end. For NSF**,** the stages are Development, Design, Construction, Operations, and Termination.

Fast Tracking. *A schedule compression technique in which activities or phases normally done in sequence are performed in parallel for at least a portion of their duration.*

Final Design Phase. The third and last phase of the Design Stage, after a successful Preliminary Design Phase, that further refines the project Baseline Definition and the Project Execution Plan and demonstrates that project planning and management meet requirements for readiness to receive funding. The Final Design phase ends in a potential NSF approval to obligate construction funds.

Finish-to-Finish. *A logical relationship in which a successor activity cannot finish until a predecessor activity has finished.*

Finish-to-Start. *A logical relationship in which a successor activity cannot start until a predecessor activity has finished.*

Forward Pass. *A critical path method technique for calculating the early start and early finish dates by working forward through the schedule model from the project start date or a given point in time.*

Free Float. *The amount of time that a schedule activity can be delayed without delaying the early start date of any successor or violating a schedule constraint.*

Gantt Chart. *A bar chart of schedule information where activities are listed on the vertical axis, dates are shown on the horizontal axis, and activity durations are shown as horizontal bars placed according to start and finish dates.*

Internal Management Plan. The internal document that defines NSF strategy for conducting project oversight and assurance, managing NSF risk, and providing project funding.

Lag. *The amount of time whereby a successor activity is required to be delayed with respect to a predecessor activity.*

Late Finish Date. *In the critical path method, the latest possible point in time when the uncompleted portions of a schedule activity can finish based on the schedule network logic, the project completion date, and any schedule constraints.*

Late Start Date. *In the critical path method, the latest possible point in time when the uncompleted portions of a schedule activity can start based on the schedule network logic, the project completion date, and any schedule constraints.*

Large Facility. A facility for which the construction cost is more than a specified percentage of the sponsoring NSF organization's budget plan, and which is paid for out of MREFC funds. Construction costs for large facilities typically range between $100M and $800M.

Lead. *The amount of time whereby a successor activity can be advanced with respect to a predecessor activity.*

Lessons Learned. *The knowledge gained during a project which shows how project events were addressed or should be addressed in the future for the purpose of improving future performance.*

Level of Effort. *An activity that does not produce definitive end products and is measured by the passage of time. (Note. Level of effort is one of three earned value management [EVM] types of activities used to measure work performance.)*

Liens List. A list of expected adjustments to project scope, budget, and schedule contingency amounts that are waiting for implementation, including formal change control actions for planned baseline modifications, scope contingency options held for decision, and coverage of variances.

Logical Relationship. *A dependency between two activities or between an activity and a milestone.*

Management. The act of controlling and making decisions about an operation, organization or project; the act or process of deciding how to use something; the judicious use of means to accomplish an end.

Management Reserve. A planned amount of money or time added to a baseline estimate to address unforeseeable events (often referred to as "unknown unknowns"). Management reserves are not allowable on NSF awards.

Milestone. *A significant point or event in a project, program, or portfolio.*

Most Likely Duration. *An estimate of the most probable activity duration that takes into account all of the known variables that could affect performance.*

"No Cost Overrun" Policy. NSF policy requiring that a Total Project Cost estimate established at the Preliminary Design Stage have adequate contingency to cover all foreseeable risks, and that any cost increases not covered by contingency be accommodated by reductions in scope.

Operations Stage. The Life Cycle Stage that succeeds Construction and includes the day-to-day work to operate and maintain the facility and to perform research. Operations may also include activities to transition from construction to operations, replacement or upgrade activities, technology research and development, and activities that support planning and staging for the Termination Stage.

Opportunity. *A risk that would have a positive effect on one or more project objectives.*

Optimistic Duration. *An estimate of the shortest activity duration that takes into account all of the known variables that could affect performance.*

Organizational Breakdown Structure. *A hierarchical representation of the project organization, which illustrates the relationship between project activities and the organizational units that will perform those activities.*

Organizational Project Management Maturity. *The level of an organization's ability to deliver the desired strategic outcomes in a predictable, controllable, and reliable manner.*

Oversight. Watchful and responsible care of something or some activity; regulatory supervision.

Parametric Estimating. *An estimating technique in which an algorithm is used to calculate cost or duration based on historical data and project parameters.*

Path Convergence. *A relationship in which a schedule activity has more than one predecessor.*

Path Divergence. *A relationship in which a schedule activity has more than one successor.*

Percent Complete. *An estimate expressed as a percent of the amount of work that has been completed on an activity or a work breakdown structure component.*

Performance Measurement Baseline. (Aka target baseline or performance baseline) The approved cost and schedule plan for accomplishing project work scope that can be changed only through formal change control process and that is used as a basis of comparison for Earned Value Management. (For NSF projects, contingency amounts are not included in the Earned Value tracking amounts due to the NSF requirement that contingency is held and managed separately from the baseline.)

Pessimistic Duration. *An estimate of the longest activity duration, which takes into account all of the known variables that could affect performance.*

Phase Gate. *A review at the end of a phase in which a decision is made to continue to the next phase, to continue with modification, or to end a project or program.*

Planned Value. *The authorized budget assigned to scheduled work.*

Portfolio. *Projects, programs, subportfolios, and operations managed as a group to achieve strategic objectives.*

Portfolio Management. *The centralized management of one or more portfolios to achieve strategic objectives.*

Precedence Diagramming Method. *A technique used for constructing a schedule model in which activities are represented by nodes and are graphically linked by one or more logical relationships to show the sequence in which the activities are to be performed.*

Predecessor Activity. *An activity that logically comes before a dependent activity in a schedule.*

Preliminary Design Phase. The second phase of the Design Stage, after the Conceptual Design Phase, that further advances the project definition and the Project Execution Plan. It produces a bottom-up scope, cost, schedule, and risk analysis of sufficient maturity to allow determination of the Project Total Cost and Duration for a stated future start date and to establish the MREFC budget request.

Preventive Action. *An intentional activity that ensures the future performance of the project work is aligned with the project management plan.*

Probabilistic Risk Assessment. A quantitative risk analysis that uses probability distributions to represent the uncertainty usually present in the cost of a deliverable or the duration of a scheduled activity, in order to obtain a range of outcomes for overall project cost and finish dates that support selection of contingency amounts as part of risk management. Many commercial probabilistic risk analysis applications employ Monte Carlo simulations of project cost and schedule.

Probability and Impact Matrix. *A grid for mapping the probability of each risk occurrence and its impact on project objectives if that risk occurs.*

Procurement Management Plan. *A component of the project or program management plan that describes how a team will acquire goods and services from outside of the performing organization.*

Program. *A group of related projects, subprograms, and program activities that are managed in a coordinated way to obtain benefits not available from managing them individually.*

Program Management. *The application of knowledge, skills, tools, and techniques to a program to meet the program requirements and to obtain benefits and control not available by managing projects individually.*

Progressive Elaboration. *The iterative process of increasing the level of detail in a project management plan as greater amounts of information and more accurate estimates become available.*

Project Calendar. *A calendar that identifies working days and shifts that are available for scheduled activities.*

Project End Date. The projected date for the completion of all the project baseline schedule activities plus use of all schedule contingency. (Note that this date may be earlier than, but no later than, the end date of the award instrument.)

Project* Execution *Plan. *The document that describes how the project will be executed, monitored, and controlled.*

Project Life Cycle. *The series of phases that a project passes through from its initiation to its closure.*

Project Management. *The application of knowledge, skills, tools, and techniques to project activities to meet the project requirements.*

Project Management Office. *A management structure that standardizes the project-related governance processes and facilitates the sharing of resources, methodologies, tools, and techniques.*

Project Manager. *The person assigned by the performing organization to lead the team that is responsible for achieving the project objectives.*

Project Phase. *A collection of logically related project activities that culminates in the completion of one or more deliverables.*

Project Schedule. *An output of a schedule model that presents linked activities with planned dates, durations, milestones, and resources.*

Project Scope. *The work performed to deliver a product, service, or result with the specified features and functions.*

Project Scope Statement. *The description of the project scope, major deliverables, assumptions, and constraints.*

Quality Management Plan. *A component of the project or program management plan that describes how an organization's quality policies will be implemented.*

Re-Baselining. Project re-planning that results in a change that is outside the terms set forth in the award instrument for any of the following: 1) Total Project Cost (TPC); 2) overall project duration or end date; or 3) project scope, except for approved options in the scope contingency plan. Re-baselining actions require special review and approval by NSF beyond those of the typical change control approval process for re-planning actions.

Re-Planning. A normal project management process to modify or re-organize the Performance Measurement Baseline cost and/or schedule plans for future work without impacting total project cost, project end date, or overall scope objectives; or the implementation of approved de-scoping options. Formal change control processes are followed for all baseline changes. Retroactive changes to past performance should not be included in re-planning.

Requirement. *A condition or capability that is required to be present in a product, service, or result to satisfy a contract or other formally imposed specification.*

Resource Breakdown Structure. *A hierarchical representation of resources by category and type.*

Resource Calendar. *A calendar that identifies the working days and shifts upon which each specific resource is available.*

Resource Leveling. *A technique in which start and finish dates are adjusted based on resource constraints with the goal of balancing demand for resources with the available supply.*

Responsibility Assignment Matrix. *A grid that shows the project resources assigned to each work package.*

Review and Recommend. The act of carefully looking at or examining the quality or condition of something AND then suggesting that someone taken action or do something.

Risk. *An uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives.*

Risk Acceptance. *A risk response strategy whereby the project team decides to acknowledge the risk and not take any action unless the risk occurs.*

Risk Avoidance. *A risk response strategy whereby the project team acts to eliminate the threat or protect the project from its impact.*

Risk Breakdown Structure. *A hierarchical representation of risks that is organized according to risk categories.*

Risk Category. *A group of potential causes of risk.*

Risk Exposure. Quantitative impact of risk for a single event, quoted in currency or time, and typically estimated from probability of occurrence and a likely impact or consequence. Overall project risk exposure results from an accumulation of individual risk impacts for the work to be completed, typically determined by applying probabilistic analysis to the set of individual risks.

Risk Management Plan. *A component of the project, program, or portfolio management plan that describes how risk management activities will be structured and performed.*

Risk Mitigation. *A risk response strategy whereby the project team acts to reduce the probability of occurrence or impact of a risk.*

Risk Register. *A document in which the results of risk analysis and risk response planning are recorded.*

Risk Transference. *A risk response strategy whereby the project team shifts the impact of a threat to a third party, together with ownership of the response.*

Rolling Wave Planning. *An iterative planning technique in which the work to be accomplished in the near term is planned in detail, while the work in the future is planned at a higher level.*

Schedule Compression. *A technique used to shorten the schedule duration without reducing the project scope.*

Schedule Contingency. An amount added to a baseline schedule estimate to allow for identified delays, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional project duration. Typically estimated using statistical analysis or judgment based on past asset or project experience.

Schedule Management Plan. *A component of the project or program management plan that establishes the criteria and the activities for developing, monitoring, and controlling the schedule.*

Schedule Model. *A representation of the plan for executing the project's activities, including durations, dependencies, and other planning information, used to produce a project schedule along with other scheduling artifacts.*

Schedule Performance Index. *A measure of schedule efficiency expressed as the ratio of earned value to planned value.*

Schedule Variance. *A measure of schedule performance expressed as the difference between the earned value and the planned value.*

Scope Baseline. *The approved version of a scope statement, work breakdown structure (WBS) and its associated WBS dictionary, which can be changed only through formal change control procedures and is used as a basis for comparison.*

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

Scope Contingency Plan. A component document of the Project Execution Plan that describes how scope contingency is determined, monitored, and controlled over the project lifetime.

Scope Creep. *The uncontrolled expansion to product or project scope without adjustments to time, cost, and resources.*

Scope Management Plan. *A component of the project or program management plan that describes how the scope will be defined, developed, monitored, controlled, and validated.*

S-Curve Analysis. *An earned value management technique used to indicate performance trends by using a graph that displays cumulative costs over a specific time period.*

Secondary Risk. *A risk that arises as a direct result of implementing a risk response.*

Sponsor. *A person or group that provides resources and support for the project, program, or portfolio, and is accountable for enabling success.*

Staffing Management Plan. *A component of the human resource plan that describes when and how team members will be acquired and how long they will be needed.*

Stakeholder. *An individual, group, or organization that may affect, be affected by, or perceive itself to be affected by a decision, activity, or outcome of a project, program, or portfolio.*

Start-to-Finish. *A logical relationship in which a successor activity cannot finish until a predecessor activity has started.*

Start-to-Start. *A logical relationship in which a successor activity cannot start until a predecessor activity has started.*

Successor Activity. *A dependent activity that logically comes after another activity in a schedule.*

Summary Activity. *A group of related schedule activities aggregated and displayed as a single activity.*

Termination Stage. The stage in the facility life cycle encompasses divestment of the facility to control by another entity or decommissioning, including dismantling/demolition, starting after of the NSF Operations Stage ends and funding for termination begins.

Threat. *A risk that would have a negative effect on one or more project objectives.*

Three-Point Estimate. *A technique used to estimate cost or duration by applying an average or weighted average of optimistic, pessimistic, and most likely estimates when there is uncertainty with the individual activity estimates.*

To-Complete Performance Index. *A measure of the cost performance that is required to be achieved with the remaining resources in order to meet a specified management goal, expressed as the ratio of the cost to finish the outstanding work to the remaining budget.*

Total Float. *The amount of time that a schedule activity can be delayed or extended from its early start date without delaying the project finish date or violating a schedule constraint.*

Total Project Cost. The sum of the Performance Measurement Baseline budget and the budget contingency.

Total Project Duration. The sum of the Performance Measurement Baseline schedule duration and the schedule contingency.

Trigger Condition. *An event or situation that indicates that a risk is about to occur.*

Variance Analysis. *A technique for determining the cause and degree of difference between the baseline and actual performance.*

Variance at Completion. *A projection of the amount of budget deficit or surplus, expressed as the difference between the budget at completion and the estimate at completion.*

WBS Dictionary. *A document that provides detailed deliverable, activity, and scheduling information about each component in the work breakdown structure.*

What-If Scenario Analysis. *The process of evaluating scenarios in order to predict their effect on project objectives.*

Work Breakdown Structure. *A hierarchical decomposition of the total scope of work to be carried out by the project team to accomplish the project objectives and create the required deliverables.*

Work Package. *The work defined at the lowest level of the work breakdown structure for which cost and duration can be estimated and managed.*

Workaround. *A response to a threat that has occurred, for which a prior response had not been planned or was not effective.*

9 APPENDICES

Appendix A: 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 B: Memoranda Requesting NSB Approval of MREFC Project

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

In addition to the NSF Form 10 (for clearance) and the Assistant Director/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 the Total Project Cost (TPC) Estimate and estimated duration. 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 National Science Board (NSB). First, the Director should prepare a *Memorandum for NSB Action*.[1] 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 with contingency; TPC which includes the performance baseline and contingency; the

[1] See *Proposal and Award Manual* (PAM) VI.H.3.b.

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.

The Memorandum should also include a statement regarding plans for the end of the award period, consistent with the policies set forth in NSB-08-16, "NSB Statement on Competition, Recompetition and Renewal of NSF Awards" and the accompanying Resolution passed by the NSB at its meeting of February 7, 2008.