



# Contingency for MREFC Projects

Large Facilities Workshop

San Juan, Puerto Rico

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# Major Considerations for MREFC Contingency

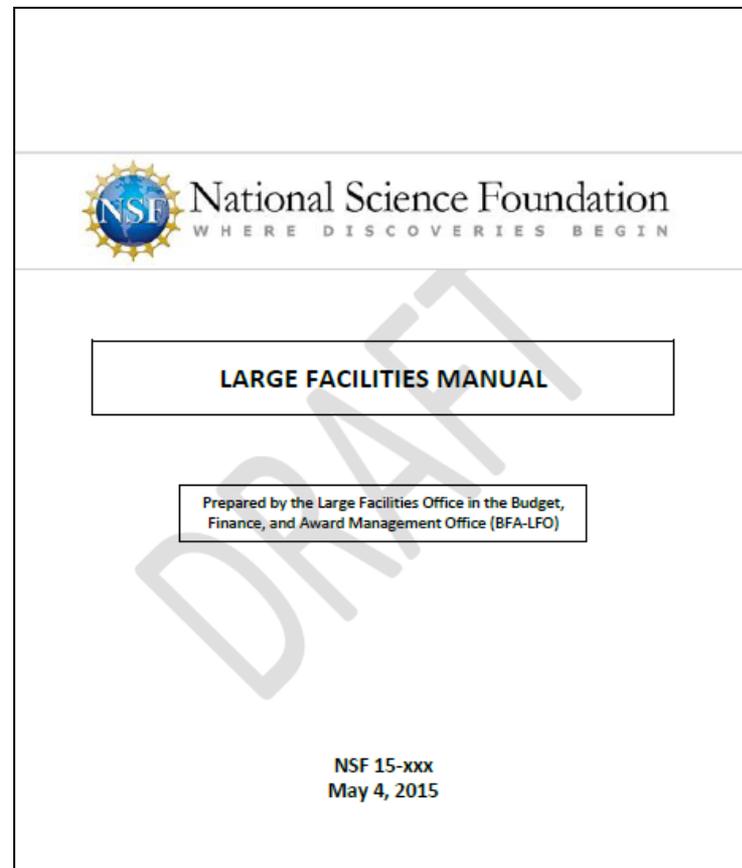
- Total Project Cost and duration derived from Preliminary Design Review (PDR) proposal
  - Cost, schedule, and contingency estimates must be comprehensive and mature at PDR
  - Timed for NSB determination of Total Project Cost (TPC) and duration, and subsequent submission to OMB budget planning process
- “No Cost Overrun” policy leads to requirement for Scope Contingency plan
  - Pre-determined options for re-scoping within approved TPC and project definitions
- Standards for contingency basis of estimate and methodology
  - GAO Cost Estimating and Assessment and Schedule Assessment Guides (some differences)
  - Probabilistic methods for risk exposure estimates (i.e. Monte Carlo)
- Formal contingency control, documentation, and status reports
  - Contingency Management Plan, including Change Control and approval levels
  - Monthly reporting standards for contingency status and use



# Large Facilities Manual

May 2015 revision of the LFM is the source for:

- Policies, requirements, and standards for contingency for MREFC construction
  - LFM Section 4.2.5 Budget Contingency Planning for the Construction Stage
- Guidelines for contingency estimation and management as part of Risk Management
  - LFM Section 5.2 Risk Management Guidelines



LFM can be found on the Large Facilities Office public website

<http://nsf.gov/bfa/lfo/index.jsp>



# Additional Sources for Guidance

- Government Accountability Office (GAO) Cost Estimating and Assessment Guide, 2009 (in revision)
- Government Accountability Office (GAO) Schedule Assessment Guide, 2013
- Guide to the Project Management Body of Knowledge, (PMBOK® Guide), Project Management Institute

Warning: Although principles and methodologies in the above guides are similar to those of NSF, there are significant differences in terminology for, and handling of, contingencies.

- See the Large Facilities Manual (LFM), References in Section 6 for additional references and to the Lexicon in Section 8 of the LFM for NSF terminology.



# NSF Policy Positions on Contingency

From [LFM Section 4.2.5.1](#)

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. (TPC = Baseline + contingency)
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.



# NSF Definition of Allowed Contingency

## From LFM Section 5.2.3.1:

**Contingency:** *“a planned amount of money or time which is added to a baseline estimate to address specific, identified risks.”*

Identified risks are often referred to as “known unknowns” in the literature. 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.”

**Management reserve:** *“a planned amount of money or time which is added to a baseline estimate to address unforeseeable events.”*

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.



# Contingency in Context: Component of Risk Management

- Processes and assignments needed to address and manage risks and uncertainties in the baseline plan
  - Evaluate the range of possible project outcomes w.r.t. goals and plans
  - Ensure that the project finishes up on budget, on time, in scope, and with promised performance
- Identification and assessments of Risks => threats and opportunities
  - **NSF Definition of Risk:** "... an uncertain event or condition that, if it occurs, has a positive or negative effect on at least one project objective.
- Implementation to control, mitigate, or accept threats and opportunities
  - Contingency used to mitigate in anticipation of or to recover from risks



# Risk Management Planning Products

Risk Management planning for large facility projects results in four products:

- Risk Management Plan (RMP)
- Risk Register
- Contingency Estimates
- Contingency Management Plan (CMP)



# Risk Management Plan Elements

Typical elements of a mature RMP from LFM Section 5.2.5.1. Many guides and sources available for producing an RMP.

Section	Description
<b>1. Introduction</b>	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.
<b>2. Definitions</b>	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.
<b>3. Risk Management Strategy and Approach</b>	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.
<b>4. Organization</b>	Describe the risk management organization of the Recipient and list the roles and responsibilities of each of the risk management participants.
<b>5. Resources Implications of the Plan</b>	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.
<b>6. Schedule Implications of the Plan</b>	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 stated along with the schedule stusing plan.
<b>7. Risk Management Process and Procedures</b>	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.
<b>8. Risk Planning</b>	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.

Section	Description
<b>9. Risk Identification</b>	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.
<b>10. Risk Register Analysis and Ranking</b>	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.
<b>11. Probabilistic Risk Analysis and Contingency</b>	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.
<b>12. Risk Handling</b>	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.
<b>13. Risk Monitoring</b>	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.
<b>14. Risk Management Information System, Documentation and Reports</b>	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.
<b>15. Risk Exposure and Contingency Management</b>	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.



# Risk Register

Defined Conditions for Impact Scales of a Risk on Major Project Objectives Examples for Negative Impacts Only					
Project Objective	Very Low	Low	Moderate	High	Very High
Cost	< \$5,000	\$5,000 - \$20,000	\$20,000 - \$50,000	\$50,000 - \$100,000	> \$100,000
Time	Insignificant Time increase	<1 week	1 - 2 weeks	2 - 4 weeks	>1 month
Scope	Scope Decreases are barely Noticeable	Minor Areas of Scope Affected	Major Areas of Scope Affected	Scope Reduction Unacceptable to Customer	Project End Item is Effectively Useless
Quality	Quality Degradation Barely Noticeable	Only Very Demanding Applications are Affected	Quality Reduction Requires Customer	Quality Reduction Unacceptable to Customer	Project End Item is Effectively Useless

Probability and Impact Matrix for an Objective: (e.g., Time, Cost, Scope, Quality)						
Probability %						
Very High (81 - 100)	5	5	10	15	20	26
High (61 - 80)	4	4	8	12	16	20
Mod (41 - 60)	3	3	6	9	12	15
Low (21 - 40)	2	2	4	6	8	10
Very Low (1 - 20)	1	1	2	3	4	5
		1	2	3	4	5
		Very Low	Low	Moderate	High	Very High
		Impact				

- Management tool for tracking and control of impacts from identified risks
- Ranked list of identified risks and assessments of impacts, with specified responsibilities and actions for mitigation
- May be qualitative or semi-quantitative in nature
- Provides input to contingency estimates on discrete risk events

Risk ID	Risk Description	Associated WBS	Pre-Mitigated Scores							Post-Mitigated Scores										
			Probability and Impacts				Resulting Risk Score			Risk Action			Probability and Impacts				Resulting Risk Score			
			Prob. Risk Occurs	On Sched.	On Cost	On Scope/Quality/Performance	Risk on Sched.	Risk on Cost	Risk on Scope/Quality/Performance	Risk Owner	Risk Mitigation Actions	Trigger or Watch date	Major Risk Flag	Prob. Risk Occurs	On Schedule	On Cost	On Scope/Quality/Performance	Risk on Sched.	Risk on Cost	Risk on Scope/Quality/Performance
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



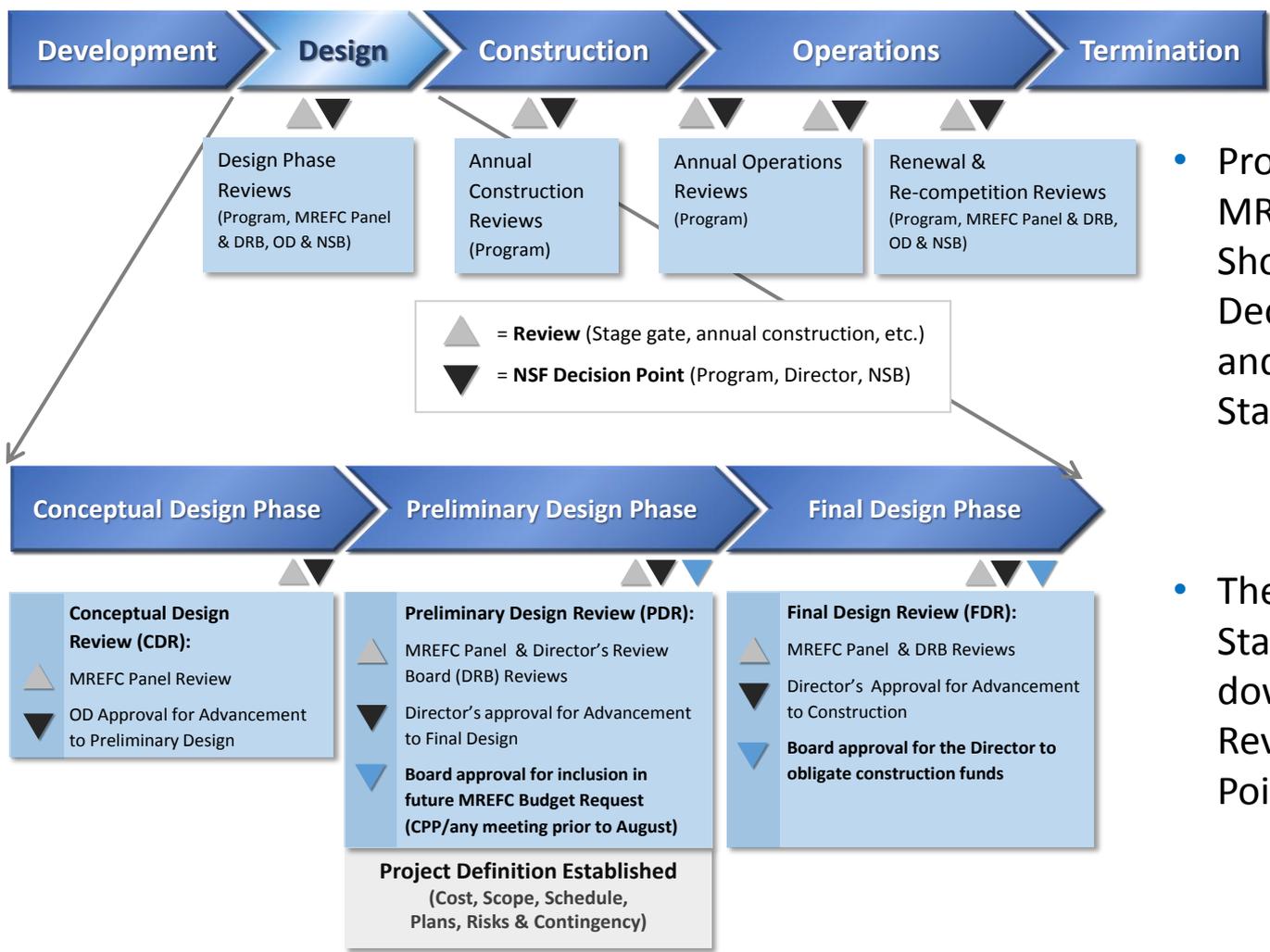
# Types of Contingency

- Budget and Schedule Contingencies
  - Amounts held separately from performance measurement baseline, used to mitigate impacts
  - Includes uncertainties in estimation as well as discrete risk events or circumstances listed in risk register
  - Result from probabilistic methods applied to cost and schedule estimates (i.e. Monte Carlo simulation using a resource loaded schedule)
- Scope Contingencies
  - De-scoping options equal to 10% of the baseline budget at PDR that can be employed to keep project within budget (included in baseline)
  - Up-scope options that could be implemented if budget permits (not in baseline)



# Project Timeline and Progression

(Taken from LFM Section 2, *Large Facility Life Cycle and the MREFC Process*)



- Progressive Steps in the MREFC Life Cycle, Showing Review and Decision Points for Exit and Entry into Each Stage.

- The highlighted Design Stage is further broken down into phases, with Review and Decision Points indicated.



# RMP, Initial Proposal

Risk Management planning and implementation begins with the initial proposal from the Development Stage and continues to evolve during the Design Phases:

- **Initial MREFC proposal**
  - Scientific need and significance
  - Description of infrastructure and performance
  - Initial cost estimate based on parametric analysis
  - Major risks and possible mitigation plans identified, usually heavily focused on technical issues
  - Qualitative ranking of risks and potential impacts



# RMP at Conceptual Design Review

- At Conceptual Design Review (CDR)
  - Polished statement of scientific need and definition of project
  - Cost and duration estimates are more accurate
  - Basis of estimate for cost and schedule and identification of risks are more refined, with advances in design and planning
  - Project Execution Plan outlined and components sketched in
  - Draft of RMP with initial processes and methodologies outlined
  - Risk Register established with qualitative or semi-quantitative risk assessment and ranking (Some identified risks already mitigated or retired during CD phase)
  - Preliminary estimate of expectation for risk exposure and contingency needs (may be algorithmic or probabilistic)



# Use of Algorithmic Contingency Estimates

- Algorithmic methods include summing individual risk estimates scored using probability weighted estimates or according to risk factor tables (aka Maxwell's or Sander's method) to obtain contingency estimates.
- Algorithmic methods** are acceptable only for the conceptual design estimate of contingency and for Risk Register ranking
- Probabilistic methods** are required in the determination of TPC at the PDR and later.

## Example of algorithmic risk factor method:

$$\text{Overall Contingency} = \sum (\text{Baseline item cost} \times \text{Contingency factor})$$

Where, for each line item:

$$\begin{aligned} \text{Contingency Factor} = & (\text{Technical factor}) * (\text{Technical risk multiplier}) \\ & + (\text{Cost factor}) * (\text{Cost risk multiplier}) \\ & + (\text{Schedule factor}) * (\text{Schedule risk multiplier}) \end{aligned}$$

Factor	Technical Uncertainty	Cost Uncertainty	Schedule Uncertainty
1	Existing design and off-the-shelf hardware	Off the shelf or catalog item	Not used
2	Minor modifications to an existing design	Vendor quote from established drawings	No schedule impact on any other item
3	Extensive modifications to an existing design	Vendor quote with some design sketches	Not used
4	New design within established product line	In-house estimate for item within current production line	Delays completion of non-critical path subsystem item
6	New design different from established product line. Existing technology	In-house estimate for item with minimal company experience but related to existing capabilities	Not used
8	New design. Requires some R&D development but does not advance the state-of-the-art	In-house estimate for item with minimal company experience and minimal in-house capability	Delays completion of critical path subsystem item
10	New design. Development of new technology which advances the state-of-the-art	Top down estimate from analogous programs	Not used
15	New design way beyond the current state-of-the-art	Engineering judgment	Not used

	Condition	Risk-Factor Multiplier
<b>Technical Risk</b>	Design or manufacturing concerns only	2%
	Design and manufacturing concerns	4%
<b>Cost Risk</b>	Material cost or labor rate concern	1%
	Material and labor rate concern	2%
<b>Schedule Risk</b>		1%



# RMP at Preliminary Design Review (PDR)

- **Baseline Definition and Plans are determined (auditable!)**
  - Product-oriented Work Breakdown Structure and Scope Definition
  - Cost book with Basis of Estimate for all baseline costs
  - Integrated Master Schedule (resource loaded is best practice)
  - Project Execution Plan draft complete for most components
- **RMP for risk identification, assessment, and management processes complete**
  - Processes and methodologies that will be used during development and construction
- **Risk Register and Contingency Estimates ready (auditable)**
  - Risk Register and mitigation plans updated
  - Probabilistic estimate of Total Project Cost and schedule (70% - 90% confidence level) based on identified uncertainties and Risk Register inputs, including correlations
  - Risk exposure/contingency amounts for cost and schedule
  - Scope Contingency Plan with time-phased options equal to 10% of baseline cost
  - Contingency Management Plan with change control and documentation

**Subsequent to PDR and approval, the NSB sets TPC and total duration**



# Match Level of Risk Management to Complexity of Project

- “Single Contract” projects (research vessels)
  - PM handles requirements, vendor oversight, and acceptance
  - Small number of procurements, with majority of costs in one vendor contract
  - Relatively small number of activities in schedule (<1,000)
  - Significant portion of risk management rests with vendor
- Medium Complexity projects (telescopes)
  - PM adds some fabrication plus integration and testing to above
  - Moderate number of procurements, with majority of costs in limited number of contracts
  - Moderate number of activities in schedule (few thousands)
  - Majority of risk management rests with project
- High Complexity projects (arrays, networks, multi-instrument observatories)
  - PM handles significant fabrication, procurement, integration, testing, acceptance
  - Large number of procurements
  - Large number of activities in schedule (several thousands)
  - Multiple partners and/or sites
  - Risk management rests with project



# RMP at FDR/Construction Start

- **Baseline Definition and Plans are updated and complete (auditable)**
  - Updated Cost book with Basis of Estimate for all baseline costs
  - Integrated Master Schedule (resource loaded is preferred)
  - Project Execution Plan complete
- **RMP complete**
  - Processes and methodologies that will be used during construction
- **Risk Register and Contingency Estimates ready (auditable)**
  - Risk Register and mitigation plans updated
  - Updated Probabilistic estimate of Total Project Cost and schedule (70% - 90% confidence level)
  - Risk exposure/contingency amounts for cost and schedule
  - Scope Contingency Plan updated
  - Contingency Management Plan complete

Although updated baseline and contingency estimates may vary from the values proposed at PDR, the sums remains within the approved TPC and duration. Scope contingency may also change as the project becomes more refined.

- **Funding allocated and Cooperative Agreement created based on review of project readiness and approval of baseline and contingencies**



# GAO on Risk-Adjusted Cost Estimation

Quote from GAO

“It is inaccurate to add up the most likely WBS elements to derive a program cost estimate, since their sum is not usually the most likely estimate for the total program, even if they are estimated without bias.... Simulation of program risks is a better way to estimate total program cost”



# Probabilistic Methods

- Many software programs exist for project risk estimation – most based on Monte Carlo methods\*
- Minimalistic programs generate total cost and schedule from cost spread sheets and high level schedules
- The most capable are based on a resource loaded baseline schedule, with inputs and correlations for risk and uncertainty details for activities

\*See LFM Section 5.2 for examples  
of commercial RM software

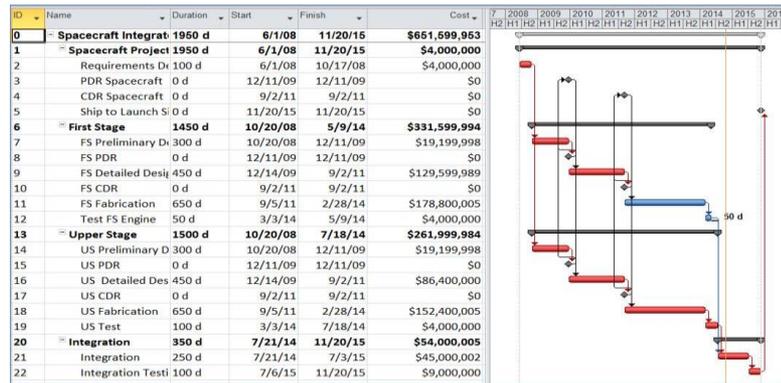
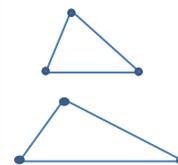
- @Risk
- Primavera Risk Analysis
- Crystal Ball
- Polaris
- JACS
- Full Monte
- Risky Project
- Etc.



# Inputs to Typical Risk Model

- Point estimates of baseline cost and schedule duration for each activity/item (the baseline)
- Uncertainty distributions and ranges for point estimates (inherent in predicting the future)
  - Example: triangular distribution with best, most likely, and worst case estimates
- Integrated schedule with logic links and critical path (resource loaded for Best Practice/complex projects)
- Risk Register of discrete events with estimates of probability of occurrence and range of impact on project variables/goals
- Correlations: between cost and schedule, other variables, and/or between activities

Estimate Uncertainty			
Item #1	Best Case	Most Likely	Worst Case
Cost	\$3,000	\$3,560	\$4,500
Duration	38 days	42 days	65 days



RISK REGISTER
<p><b>Maintaining Engineering Staff Through Commissioning (RiskID: SE-012)</b>                      Exposure Cost: \$ 347 K; Schedule 60 days (Probability: 50 - 75%)                      Description: IF the project cannot retain key engineering and technical staff through the commissioning phase THEN commissioning will be delayed or compromised.</p>
<p><b>Significant weather events delay commissioning effort (RiskID: SE-004)</b>                      Exposure Cost: \$ 306 K; Schedule 20 days (Probability: 10 - 25%)                      Description: IF there is a long period of poor weather in System Integration and Test or Commissioning THEN there will be a delay in system first light and/or operation readiness.</p>
<p><b>Wavefront Sensor/Focal Plane Assembly Calibration Convergence (RiskID: SE-008)</b>                      Exposure Cost: \$ 306 K; Schedule 20 days (Probability: 10 - 25%)                      Description: IF during Camera integration the calibration of the focal plane wavefront measurement to those obtained by the wavefront sensors does not converge efficiently THEN the overall system integration and verification will be delayed.</p>



# Monte Carlo S-Curve and Confidence Level

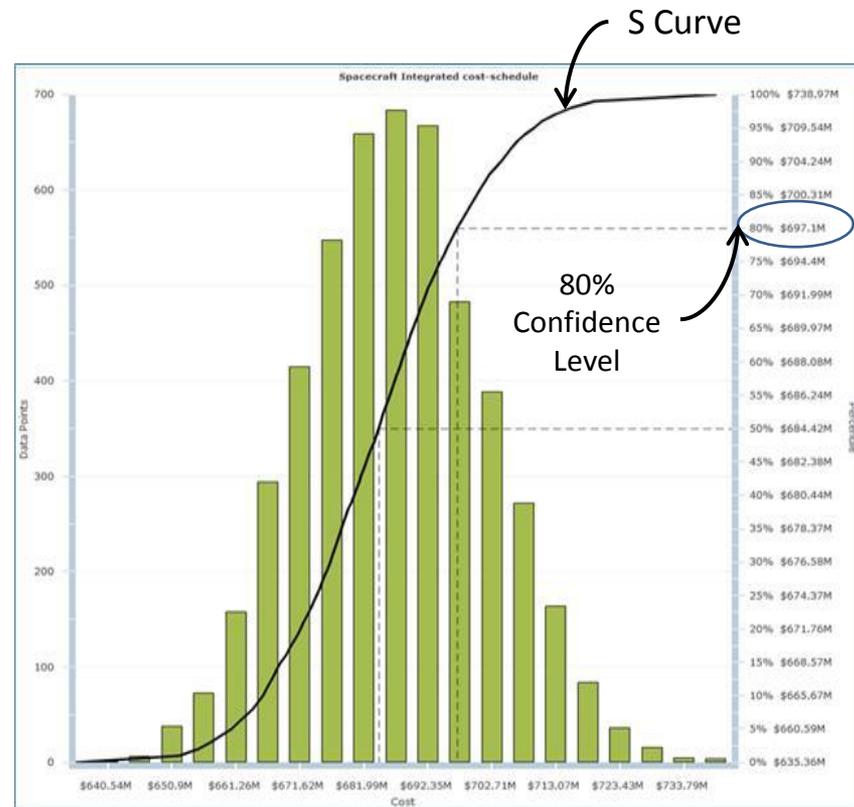
## Developing a Credible S Curve of Potential Program Costs\*

Steps are associated with developing a justifiable S curve:

1. Determine the program cost drivers and associated risks;
2. Develop probability distributions to model various types of uncertainty (for example, program, technical, external, organizational, program management including cost estimating and scheduling);
3. Account for correlation between cost elements to properly capture risk;
4. Perform the uncertainty analysis using a Monte Carlo simulation model;
5. Identify the probability level associated with the point estimate;
6. Recommend sufficient contingency reserves to achieve levels of confidence acceptable to the organization.

\*Taken from GAO Cost Estimating Guidelines

Sample distribution of total project cost from multiple iterations of a Monte Carlo simulation of project base costs, risks, and uncertainties (from LFM Section 5.2)

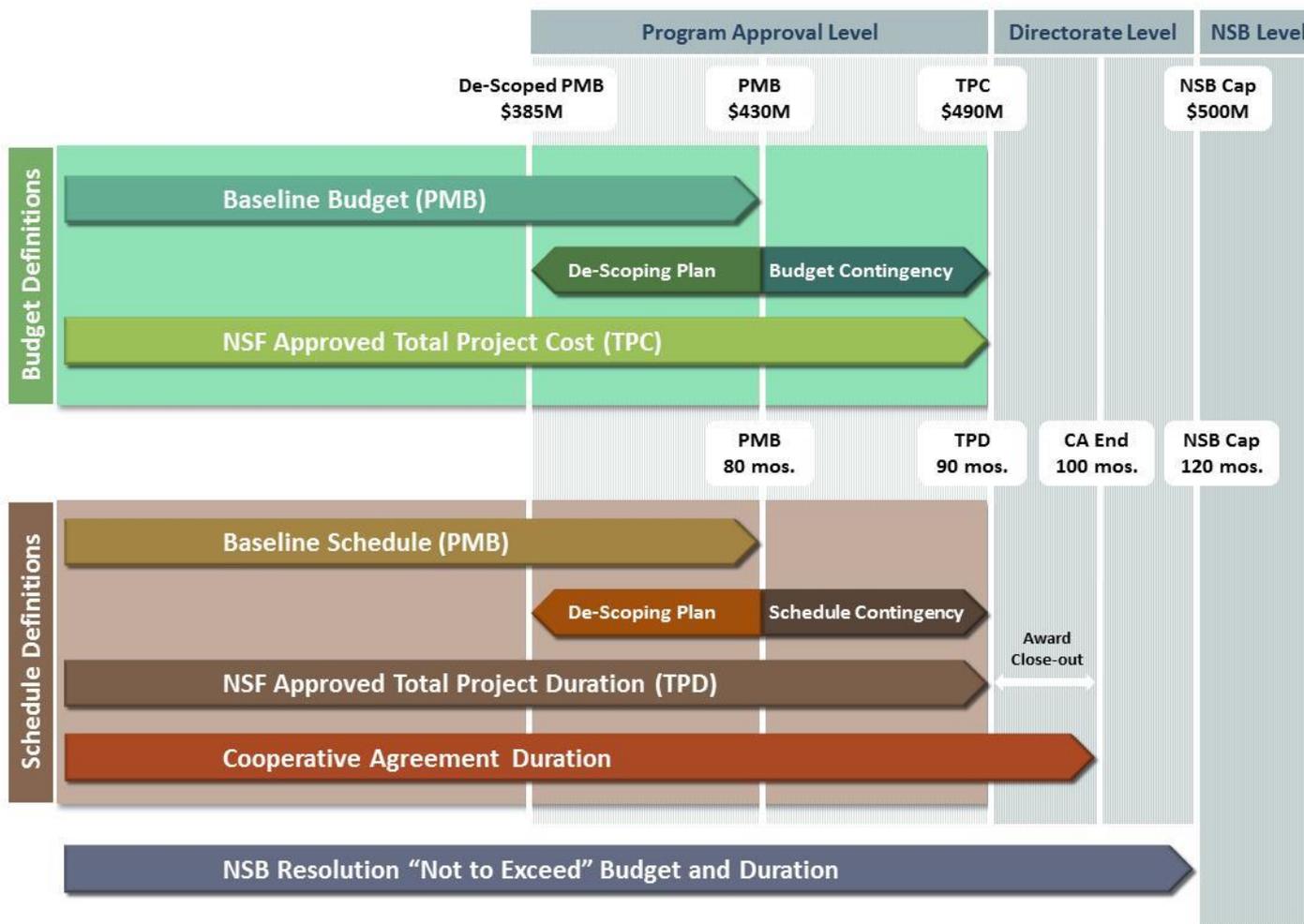


NSF requires confidence level for contingency estimates between 70 and 90 percent



# Terminology and Change Approval Levels

## MREFC Project Definitions and Change Approval Level (Post PDR)





# Contingency Management Plan (CMP)

## CMP is a sub-component of the Risk Management Plan (RMP)

- **RMP: timeline and processes for managing risks**
  - Periodic Updates to Risk Register, monitoring of risk status, execution of mitigation/response plans
- **CMP: periodic re-estimation of risk exposure**
  - Periodic updates to MC model and results
  - Periodic updates of need time profile for remaining contingencies
- **CMP: processes for maintaining contingency compatible with risk exposure and need profile**
  - Opportunity management in the RMP to replenish contingency
  - Scope Contingency management to bolster contingency as needed
- **CMP: processes and controls for adjustments to contingency amounts**
  - Change Control process and project Approval Levels
  - NSF Approval Levels per Cooperative Agreement
- **CMP: tracking and documentation**
  - Contingency adjustments documentation and status log
  - Liens List



# Liens and Unallocated Contingency

Use Liens List(s) to track existing and forecasted calls on contingency that are yet not in baseline

One method of defining terms in order to address potential components of a liens list:

- Contingency “Budgets” (Cost and Schedule)
  - Cost Contingency “Budget” = Total Project Cost - Budget at Complete
  - Schedule Contingency “Budget” = Total Duration – Baseline schedule duration
- Unallocated contingency = Contingency “Budget” – Liens
  - Available contingency for remaining risks
- Liens = Variances + Reserved Contingency
  - Variance at Complete = Actual variances to date plus forecasted variances
  - Pending Change Requests not yet in baseline
  - Contingency amounts on hold for selected watch-list risks with high potential for realization
  - Delayed scope from Scope Contingency plan waiting for decision at trigger point



# Contingency Use Documentation and Reporting

- Monthly reporting of contingency status, liens, and usage
- All change requests, with or without adjustments to contingency, require change documentation to be submitted to NSF
  - NSF standards for adequate description, basis of estimate, and justification for contingency use
- Use of contingency above thresholds set in the project Cooperative Agreement requires NSF pre-approval



# Reviews and Audits of Contingency

- External review panels charged to examine risk and contingency estimation methodology and assumptions, basis of estimate, and management
  - Design reviews (CDR, PDR, FDR)
  - Annual reviews for design and construction stages
- Audits (DCAA and others)
- Independent Cost Assessments by NSF Office of Budget, Finance, and Awards at PDR, FDR, and any significant re-planning that impacts contingency
- Business Systems Reviews



# Summary

- NSF methodologies and principles for risk-adjusted total project cost and schedule duration estimates follow standard guidelines
  - NSF treatment of contingency differs in a few ways from standard guides
    - Terminology
    - Allowability
    - Separation from baseline
- NSF policies allow for a range of acceptable, pre-approved outcomes for project success with respect to budget, schedule, and scope
- Emphasis is placed on proactive risk management, taking advantage of opportunities as well as managing threats
- Timeline for mature cost, schedule, scope, and contingency proposals is aggressive
  - Planning for contingency needs for construction starts early in the MREFC life cycle
  - TPC and duration set at PDR
- Risk management effort and resources can be significant and need to be included in planning for both design and construction stages
  - Formality of NSF requirements indicates need for dedicated, “expert” RM staff

“Proactive Risk Management: Formal, Early, Continuous”