



LARGE SYNOPTIC SURVEY TELESCOPE

Large Synoptic Survey Telescope (LSST) Risk & Opportunity Management Plan

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LPM-20

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Change Record

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The LSST Risk & Opportunity Management Plan

Background

The LSST Risk & Opportunity Management Plan describes the project's approach to identifying, assessing, responding to, and managing risks and opportunities associated with the technical, cost, and schedule aspects of the project. Risk of harm to personnel and equipment is the focus of the LSST Safety Policy (LPM-18) and the LSST Hazard Analysis Plan (LPM-49).

The LSST Risk & Opportunity Management Plan is one plan in a group of LSST Project plans that collectively define a comprehensive approach to managing risk, opportunity, and contingency, which are collectively known as approaches to making decisions under conditions of uncertainty.

A summary of the Cost Estimating Plan (LPM-81) and the Contingency Management Plan (LPM-61) are provided below to provide further context of the overall LSST approach to managing uncertainty. All three documents recognize and plan for interdependencies.

Cost Estimating Plan - The Cost Estimating Plan (CEP) defines the guidelines and methodology used to prepare and maintain the activity-based cost estimate and schedule for the LSST Project. This guidance is provided to ensure that the final product is complete, consistent, and well documented. This document is applicable to NSF and privately funded portions of the project, not DOE-funded portions, which are subject to DOE guidance.

The primary objective is to develop and maintain a comprehensive program plan for the LSST Project construction and commissioning effort. This includes the planned costs and schedule for engineering, analysis, procurement, fabrication, assembly, installation, and commissioning. This plan defines the process for estimating costs, schedules, and risks for each activity in the plan, including estimates of their uncertainty, and for the documentation of those estimates.

Contingency Management Plan - The LSST project plan includes contingency estimates for budget, schedule and scope. This document describes the management processes for the estimation and allocation of those contingency resources. This plan addresses the approach used to estimate the overall LSST technical scope (performance margins), the integrated project schedule contingency (schedule float), and the NSF MREFC budget contingency at the onset of the Construction Project as well as the methodology to manage the allocation (and approval) of these contingencies to the baseline plan. This plan also outlines the periodic review of the contingencies and the tools for comparing these to the remaining risk exposures as a measure of the overall Project progress and health. SLAC National Accelerator Laboratory has detailed plans for the use of DOE contingencies.



Acronyms and Definitions of Terms

- Glossary of Abbreviations ([Document-11921](#))
- Glossary of Definitions ([Document-14412](#))

Reference Documents

Camera Risk Management Plan (LCA-29)

Camera Risk Registry (LCA-30)

Change Control Process (LPM-19)

Contingency Management Plan (LPM-61)

Cost Estimating Plan (LPM-81)

Project Execution Plan (LPM-54)

Hazard Analysis Plan (LPM-49)

Safety Policy (LPM-18)

Scope Options (LPM-72)

Memorandum of Understanding between the National Science Foundation and the Department of Energy Concerning Cooperation on the Large Synoptic Survey Telescope (Document-13847)

Tools

LSST Risk & Opportunity Registry Tool: <http://ls.st/avr>

Definitions

Risk – The degree of exposure to an event that might happen to the detriment of a program, project, or other activity. It is described by a combination of the probability that the risk event will occur and the consequence of the extent of loss from the occurrence, or impact. Risk is an inherent part of all activities, whether the activity is simple and small, or large and complex.

Risk Categories

Technical Risk – The possibility that a technical requirement of the system may not be achieved in the system life cycle. Technical risk exists if the system may fail to achieve performance requirements; to meet operability, producibility, testability, or integration requirements; or to meet environmental protection requirements. A potential failure to meet any requirement that can be expressed in technical terms is a source of technical risk (INCOSE, pg. 220).

Cost Risk – The possibility that available budget will be exceeded. Cost risk exists if a) the project must devote more resources than planned to achieve technical requirements, b) the project

must add resources to support slipped schedules due to any reason, c) if changes must be made to the number of items to be produced, or d) if changes occur in the organization or national economy. Cost risk can be predicted at the total project level or for a system element. The collective effects of element-level cost risk can produce cost risk for the total project (INCOSE, pg. 220).

Schedule Risk – The possibility that the project will fail to meet scheduled milestones. Schedule risk exists if there is inadequate allowance for acquisition delays. Schedule risk exists if difficulty is experienced in achieving schedule technical accomplishments, such as the development of software. Schedule risk can be incurred at the total project level for milestones such as deployment of the first system element. The cascading effects of element-level schedule risks can produce schedule risk for the total project. (INCOSE, pg. 220).

Programmatic Risk – Produced by events that are beyond the control of the project manager. These events often are produced by decisions made by personnel at higher levels of authority, such as reductions in project priority, delays in receiving authorization to proceed with a project, reduced or delayed funding, changes in organization or national objectives, etc. Programmatic risk can be a source of risk in any of the other three risk categories. (INCOSE, pg. 220).

Risk Management – The art and science of planning, assessing, and handling future events to avoid unfavorable impacts on project cost, schedule, or performance to the extent possible. Risk management is a structured, formal, and disciplined activity focused on the necessary steps and planning actions to determine and control risks to an acceptable level. Risk Management is an event-based management approach to managing uncertainty.

Risk Handling Approaches

There are four basic approaches to handling/managing risks. Each is defined below.

- **Avoidance** – Avoid the risk through the change of requirements or redesign. (INCOSE, pg. 223)
- **Acceptance** – Accept the risk and the consequences of it becoming realized.
- **Mitigation** – Also known as control. Requires the expenditure of budget or other resources to reduce the likelihood and/or consequence. Mitigations are proposed activities that are not part of the project baseline. Once mitigation activities are approved, they are just baselined activities and no longer referred to as mitigations.
- **Transfer** – Transferring responsibility for the risk by agreement with another party that it is in their scope to mitigate and respond to impacts if the risk is realized. Purchasing insurance is an example of transferring risk.

Contingency – The project's overall reserves in excess of the documented baselines for budget, schedule, and technical scope. Contingency is defined as the total estimate uncertainty associated with cost, schedule and technical performance.

Contingency Management – The formal process that provides the project the ability and flexibility to solve unforeseen issues that may impact the project's budget, schedule, and technical performance.

The process incorporates activity-based uncertainties and high impact event-based uncertainties.

Issue – A risk that has been realized, e.g. the undesired outcome has materialized.

Event – A specific incident/item that occurs at unique points in time (specific time, distributed time period, or random) on the project. Events are defined in terms of something happening and are independent of activities. Events with negative consequences, when coupled with their probability of occurrence, impact to the project, and handling approach, are the basis for defined entries in the Risk Register.

Activity – A specific task or set of tasks that are required by the project, use up resources, and take time to complete (Project Management, pg. 338).

Opportunity – The degree of exposure to an event that might happen to the *benefit* of a program, project, or other activity. It is described by a combination of the probability that the opportunity event will occur and the consequence of the extent of *gain* from the occurrence, or impact. There are two levels of opportunities. At the macro level, a project itself is the manifestation of the pursuit of an opportunity. At the element level, tactical opportunities exist, whereby certain events, if realized, provide a cost or schedule savings to the project or increase technical performance.

Opportunity Management – The proactive art and science of planning, assessing, and handling future events to seek favorable impacts on project, cost, schedule, or performance to the extent possible. Opportunity management is a structured, formal, and disciplined activity focused on the necessary steps and planning actions to determine and exploit opportunities to the extent possible.

Opportunity Handling Approaches

There are two basic approaches to handling/managing opportunities. Each is defined below.

- **Acceptance** – Accept the opportunity as stated and do nothing about it for the time being.
- **Exploit** – Increase the likelihood of the opportunity occurring through the expenditure of budget or other resources. The expenditure of budget should be evaluated against the probability weighted exposure of the opportunity to ensure that the likely net payoff is a positive one.

Benefit – An opportunity that has been realized, e.g. the desired outcome has materialized.



The LSST Risk & Opportunity Management Plan

1 Introduction

1.1 Objective and Scope

The LSST Risk & Opportunity Management Plan recognizes the benefits of managing uncertainty on the project in a holistic and systematic manner. Whereas, traditionally, projects focused primarily on identifying and mitigating risks, LSST recognized as the project transitioned into the Construction and Commissioning phases, that the identification and potential exploitation of opportunities has the potential to possibly negate the effects of some risks, and on the whole, increase the probability that less contingency will be needed than if the focus was solely on risk management.

The objective of the LSST risk management effort is to identify, assess, and manage risks, which are defined as future events that can have a negative impact on the construction and commissioning of the LSST. Similarly, the objective of the LSST opportunity management effort is to identify, assess, and exploit opportunities, which are defined as future events that can have a positive impact on the construction and commissioning of the LSST.

1.1.1 Risk Management Process Overview

The risk management process is a continuous and proactive approach to keeping risk at an acceptable level through awareness, tracking, and response handling. There are three types of risk associated with the project: 1) Technical Risk, consisting of the risk of not meeting performance requirements or specifications; 2) Cost Risk, consisting of the risk that the available budget will be exceeded; and 3) Schedule Risk, consisting of the risk that the project will fail to meet scheduled milestones. A related category of Risk is called Programmatic Risk, which is risk produced by events that are beyond the control of the Project Manager. Programmatic Risk can be a source of risk in any of the other three risk categories. See Figure 1-1 for a contextual diagram showing the relationships between the various categories of risk.

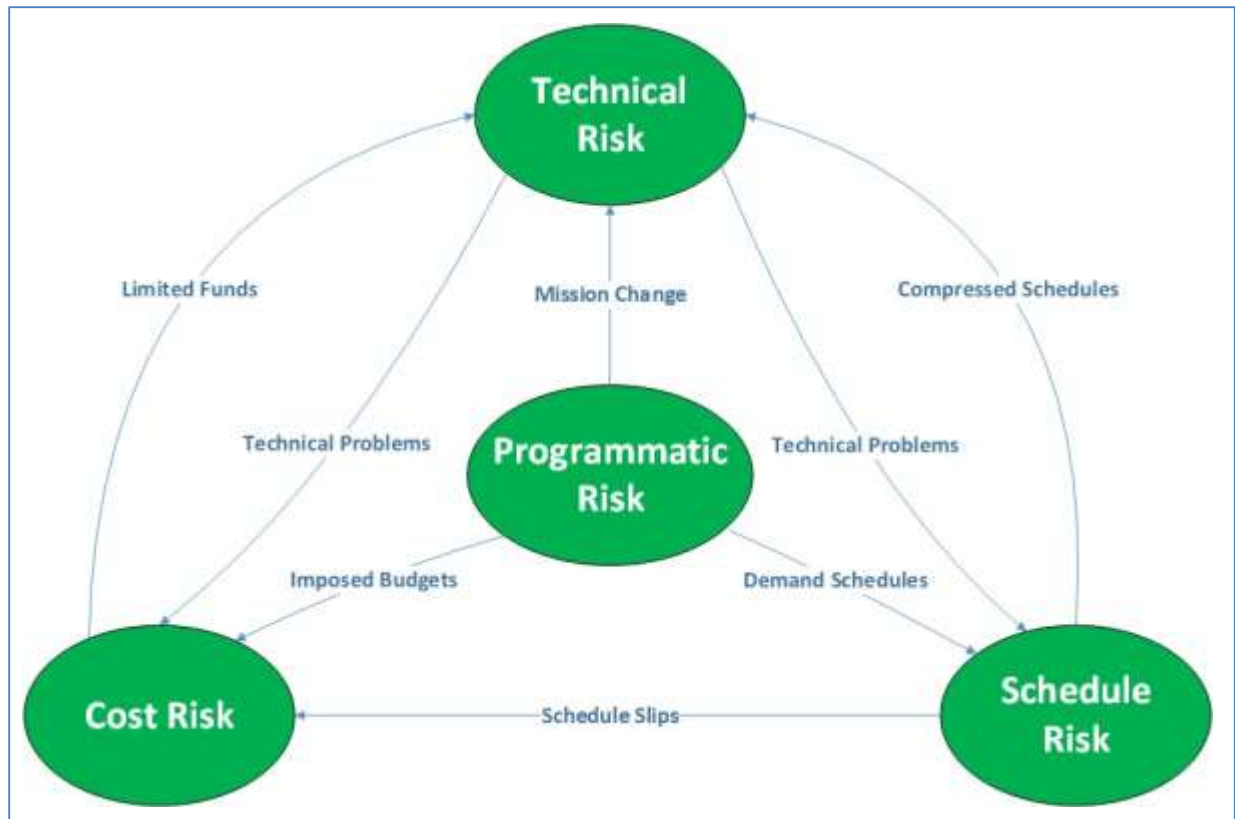


Figure 1-1: Relationships between Risk Categories (adopted from INCOSE SE Handbook, ver 3.2, pg. 220)

Additionally, there is the Risk of Harm, consisting of risk to personnel, equipment, and collected data. This document focuses on the technical, cost, and schedule risks. Risk of Harm is the focus of the LSST Safety Policy (LPM-18) and Hazard Analysis Plan (LPM-49). LSST recognizes and plans for interdependencies but approaches each risk class differently to allow an appropriate level of analysis and tracking. Hazards that have unresolved mitigations or continue to represent a risk to the project are referred to the Project Risk Register for high level tracking; they are also kept in the Hazard Register for detailed handling.

1.1.2 Opportunity Management Process Overview

The opportunity management process is a continuous and proactive approach to identifying and potentially exploiting opportunities through awareness, tracking, and response handling. Just as with risks, opportunities can be broken down into three types: 1) Technical Opportunity, consisting of the opportunity to increase technical performance or trade technical margin in one area for a deficiency in another; 3) Cost Opportunity, consisting of the opportunity that the available budget will not be needed in its entirety or an identified event may be cost positive and return funds to the project (e.g. favorable exchange rates); and 3) Schedule Opportunity, consisting of the opportunity that the event or major task may be completed early.

1.1.3 Key Aspects of the Risk & Opportunity Management Plan

The key aspects of this Risk & Opportunity Management Plan (RMP) are

- A standard methodology to identify and assess major risks and opportunities associated with WBS elements and project functions from design and development, through fabrication, and into integration, test and Commissioning;
- A continuous process to review and re-assess current project risks and opportunities on a monthly basis and address new risks and opportunities as they emerge;
- Common techniques for assignment of budget and schedule for the anticipated response in the event of a realized risk;
- An approach and tool to measure and compare to contingency levels, the remaining major risk exposure across the full project; and
- A single dynamic and interactive system to inform project management, to support communication across the project, to facilitate and encourage regular participation of project team members, and to produce standard reporting and tracking features.

The LSST Risk & Opportunity Management process is an event-centric approach. It is characterized by the identification of events that may occur in the future with resulting negative or positive consequences for the project. It is distinct from the activity-based estimates and uncertainty developed and managed in the LSST Project Management Control System (PMCS) scheduling software, Primavera P6. The project's overall not-to-exceed contingency budget is established through a Monte Carlo analysis that utilizes the activity-based uncertainty estimates established in P6 and a subset of the event-based risks & opportunities from the Risk & Opportunity Registry that exceed a specified Probability Weighted Cost Exposure. See LPM-81 and LPM-61 for further details.

1.2 Background

1.2.1 LSST Risk Management during the Design and Development Phase

The LSST Design and Development phase was guided by the process of risk identification, analysis and mitigation. The process included identifying key performance and cost drivers; identifying the critical paths through construction completion; reviewing proven designs, concepts, and lessons from other systems; performing "value-engineering" studies to optimize the designs; considering the fit of major subsystems to industry capabilities; engaging experienced, independent reviewers in the design progress; and finally, developing and executing mitigation efforts through prototype, testing, or design analysis. Several tasks designed to reduce technical and programmatic risks to the project have already been completed, some through the use of private funds. A few significant examples include site selection, selecting a monolithic primary-tertiary mirror and beginning construction of it, producing fully functional prototype sensors, executing data challenges and software releases for algorithm and hardware testing, and completing high fidelity image, operation and calibration simulations to demonstrate performance and support system analysis.

1.2.2 The Evolution of the Plan

As the project moves forward, it continues to use a formalized approach to identify and analyze risks, but the focus has shifted to tracking and planning for impacts. Additionally, the project has added

opportunity management into the overall scope of the process, and current work is focused on identifying opportunities that exist during construction and commissioning and documenting proposed handling approaches to increase their likelihood of occurrence.

This Risk & Opportunity Management Plan is defined for the period from the Final Design Review (FDR) through LSST construction, integration, and commissioning, ending with the successful completion of the Operations Readiness Review (ORR)¹.

For this period, the program plan and baseline budget are established and include defined activities to mitigate risks to an acceptable level. Opportunities are identified, and handling responses to increase the probability of occurrence are proposed. Proposed opportunity handling activities are reviewed by the Project Manager, where their implementation costs are weighed against the potential payoff if the opportunity is realized. Any opportunity handling activities approved by the Project Manager are added to the project baseline through a Change Request to update the PMCS.

A Total Project Cost (TPC) is established to cover the baseline plan and residual risk exposure to the successful completion of the project through Commissioning. The NSF has a no cost overrun policy, so all risks must be handled through avoidance, transfer, technical margin, budget contingency, schedule contingency, offsets against realized opportunities, or mitigation through scope reduction. LSST has a Contingency Management Plan (LPM-61) that describes the assessment and use of all contingency. To guide decision-making in the event a technical de-scope is required, the LSST maintains a list of Scope Options (LPM-72).

1.2.3 Agency Interactions

Federal funding of the LSST project is shared between the National Science Foundation (NSF) and the Department of Energy (DOE). The NSF is the lead agency and will provide the majority of the proposed funding. The DOE is funding the LSST camera. Although the end result is the same, the DOE risk management terminology and guidelines differ from those of the NSF. This document deals exclusively with risk management of the NSF-funded part of the project. The DOE risk management process is described in the companion documents Camera Risk Management Plan (LCA-29) and Camera Risk Registry (LCA-30). A Letter of Understanding between the NSF and DOE specifies each agency's role for unified project planning, execution and oversight. The LSST project keeps a copy of the letter in its document archive as Document-13847.

As described in the Project Execution Plan (LPM-54), responsibility and authority over the risk and opportunity management process and contingency allocation belongs to the LSST Project Manager in collaboration with the Change Control Board. NSF policy requires that the allocation of contingency funds receive NSF approval as defined in LPM-54 and the LSST Contingency Management Plan (LPM-61). All allocations of contingency funds must be reported monthly to the NSF.

¹The Risk Management Plan for the Design and Development Phase of the LSST project used a similar risk identification and analysis process but focused on mitigation strategies. To see the Risk Management Plan for the Design and Development Phase, please see the 7/11/2011 version of this document.

1.3 Risk & Opportunity Management Transition to Construction

In transitioning from the D&D phase to the construction phase, there have been a number of changes in the focus of the risk and opportunity management approach. The following paragraphs summarize the evolution of the LSST Risk assessment and tool development during the transition:

- The risk registry was moved from five Excel spreadsheets to a single, web-accessible MySQL database.
- Risk impacts are quantified by cost. Capital equipment, contracts, labor costs and schedule delays are all expressed in either base-year or then-year dollars. Risks that impact the critical path have appropriate costs associated with extending the project duration.
- The project no longer uses the terminology pre-mitigation and post-mitigation risk. When the project entered the construction phase, all D&D risk mitigation activities had been completed. All Activities established as risk mitigation in the construction phase are now baseline tasks; they are managed, statused, and reported like all other baseline activities.
- Risks are assigned trigger dates. Trigger dates define when the risk might be realized and indicates when contingency funds would be obligated for corrective action. Trigger dates can be captured as specified dates (e.g., milestone dates), random occurrence (e.g., critical staff leave the project), or distributed annually (e.g., risks that are continually evaluated for realization, such as software). Introduction of the trigger model is required to predict the expected contingency budget spend plan. A proposed management response is included with every identified risk to support the overall project management process and provide some guidance in how to respond to those risks that do occur.
- A Monte Carlo simulator tool has been added to evaluate risk occurrence and cost impact for a large number of possible occurrence scenarios. The objective is to provide a time-based cost exposure model for Project Management as one measure of project health.
- An independent and integrated view of cost and schedule risk is implemented in the Project Management Control System (PMCS) based on Primavera 6 and the Primavera Risk Management module. This module was added to support establishment of the initial contingency and can be exercised periodically to address residual risk exposure during the construction.
- Supplementing the LSST Risk Management Tool with the project-wide issue tracking tool, JIRA (one of a suite of Atlassian tools adopted by the LSST Project). The Risk & Opportunity Management Plan recognizes interdependencies, including the review of JIRA issues for their potential elevation to Risks or Opportunities, and tracking realized risk and opportunity responses.
- Adoption of the associated Atlassian wiki-tool, Confluence, which is used to document Monthly Risk & Opportunity Review Meeting Minutes, plan upcoming meetings, and generally act as a central location for anyone looking for further information regarding LSST's Risk & Opportunity Management activities.
- Inclusion of Opportunity Management into the process, resulting in the identification and

exploitation of potential beneficial events occurring in the future. Opportunity management follows the same rigorous approach outlined for risk management; however, because opportunity management was not part of the formal process during the D&D phase, the identified opportunity handling approaches are not baselined by default. Rather, as they are identified, they are reviewed by the Risk & Opportunity Review Board and Project Manager to determine if the Probability Weight Exposure of the realized opportunity is worth the associated handling activity implementation costs and redirection of project staff or resources.

2 Construction Risk & Opportunity Management

Construction phase risk management emphasizes a continuous review of the LSST risk landscape, including identification and review of risks, quantification of risks' impacts, assessment of probability of occurrences, assignment of occurrence dates, and identification of proposed management responses. Activities aimed at reducing the likelihood and/or consequence of risks identified prior to the start of construction continues to be important, but because all such currently identified activities are part of the LSST Baseline for construction, these activities are not referred to as mitigations but rather baseline activities. New risk handling approaches for new or existing risks can be identified throughout the Risk & Opportunity Management process, but they are only pursued following approved change requests to the plan that will implement the mitigations or other handling approaches as new resource loaded tasks.

Construction phase opportunity management emphasizes the identification, quantification, and development of proposed handling approaches of opportunities. Proposed opportunity handling approaches, generally intended to either increase the probability that the opportunity event will occur or increase the positive impact of the opportunity event, are reviewed by the Project Manager, and promising activities are added to the baseline through an approved change request.

This section describes the key aspects of the Risk & Opportunity Management process, including the tools used in administering the process and the process the Team follows in order to identify, track, and otherwise manage the Project Risks and Opportunities.

2.1 Risk & Opportunity Management Process

The LSST Risk & Opportunity Management Process functions at two levels: first, at the subsystem level to identify risks and opportunities at the lowest detailed level of work within the Project and second, at the project level to communicate the exposure to the LSST Risk & Opportunity Review Board and to review the assessment level for normalization across the project. This is an on-going process of comprehensively assessing project risks and opportunities, developing and assessing plans to manage those risks and opportunities, and tracking and communicating those risks and opportunities as they evolve over the life of the project. Since exposures, consequences, and handling strategies change over the life cycle of the project, the risk and opportunity management process is continuous and iterative.

Each subsystem reviews and updates its complete list of existing risks and opportunities and proposes new ones at least on a quarterly basis using the process defined in Section 3. Dashboard indicators in the Risk & Opportunity Registry identify entries as yellow if dormant after 60 days, and red if not reviewed for 90 calendar days. This enforces a continuous awareness within the teams and ensures that risk and opportunity information is suitably up-to-date to allow management to be responsive to the

dynamic internal and external environments.

The full Project has monthly risk and opportunity meetings that focus on one or two subsystems in detail. These monthly meetings also provide the forum to review any new emerging risks or opportunities that have been proposed in any subsystem, any risks or opportunities that have upcoming trigger dates, and trends in risk/opportunity exposure at both the project and subsystem levels. To ensure that the full project risk and opportunity management team is aware of any new risks and/or opportunities and has participated in the discussion, only the Project Manager may promote risks and opportunities from a "proposed" state to an "active" state.

2.2 Roles and Responsibilities

The LSST Project Manager has overall responsibility for managing and controlling project risks and opportunities. The Project Manager uses the tools and process to maintain an awareness of the project-wide risk/opportunity conditions, directs or manages efforts to mitigate risks and exploit opportunities, approves all new risk and opportunity entries, and is responsible for reporting to external stakeholders on risk and opportunity status at least monthly.

The LSST Risk & Opportunity Review Board is the group of project-wide staff charged with reviewing the Risk & Opportunity Registry, evaluating the risk and opportunity assessments, collaborating on risk and opportunity handling options, and developing implementation recommendations, which are forwarded to the Project Manager. The Project Risk & Opportunity Review Board consists of the Manager and Project Scientist in every subsystem (Data Management, Camera, Telescope and Site, Education and Public Outreach), the project Systems Engineering Manager and Systems Scientist, as well as the LSST Project Manager and LSST Project Scientist. The Risk & Opportunity Review Board expects involvement from the subsystem systems engineers or other key subsystem staff involved in the low-level risk process to participate in the monthly meetings that focus on their particular parts of the project.

The Risk & Opportunity Review Board Chair is responsible for the organization and leadership of the Risk & Opportunity Management Process. The Chair leads the monthly meetings, maintains the risk & opportunity registry tools, and summarizes and quantifies the project risk & opportunity conditions to support the subsystem managers and the full Risk & Opportunity Review Board. The Chair also produces the monthly reporting statistics and maintains the Risk & Opportunity Confluence page, the key collaboration tool for keeping the team organized and informed.

Subsystem Risk & Opportunity Teams are responsible for the detailed identification and assessment of risks and opportunities recognized to impact the subsystem deliverables and plans. The subsystem teams include the Subsystem Project Manager, the Subsystem Systems Engineer (or Systems Architect), the Subsystem Project Scientist and others as appropriate for that subsystem. These teams are assigned to maintain a continuous and methodical assessment of their low-level risks and opportunities through regular meetings at which they address each current risk and opportunity, consider potential changes in the conditions, elaborate on potential handling approaches or management responses, and recommend removal or addition of risks and opportunities.

2.3 Risk & Opportunity Management Tools

The LSST Project maintains several Risk and Opportunity Management Tools that collectively provide a comprehensive means of managing overall project uncertainty exposure and communicating this information to stakeholders. Each of these tools is described in detail in the following section.

Risk & Opportunity Registry: LSST maintains its risk and opportunity registry in a MySQL database available through a web interface for project-wide access. This is the repository of all risks and opportunities, including assessment and analysis data. Each risk and opportunity entry is assigned a unique risk identification tag. The web-based front end dashboard provides specific scripts for analysis and sorting tools that allow each subsystem to focus on its' entries. As a single database, full project comparisons and analysis can also be accomplished. New entries or updates are time-stamped and appended as new database rows so that no information is deleted. The database can be "rolled-back" to any selected date for reference and comparative analysis.

The Risk & Opportunity Registry home page is <http://ls.st/avr>. Risks or opportunities can be viewed for any selected set of the six basic project areas: the Project Office, Systems Engineering, and the four subsystems. The database includes the Camera Subsystem risks; however, these are imported from spreadsheets maintained by the Camera team following the SLAC/DOE Risk Management processes. This import happens at least every six (6) months but more frequently as project-wide analysis requires.

There are many query options available to support the analysis and management of the recorded risks and opportunities. Examples include keyword searches, report generation, and sorting by registry column headings.

Each risk and opportunity is labelled with the number of days since it was last reviewed in order to provide quality assurance on the three (3) month revisit requirement for risk evaluation. "Note" fields contain information on the bases of estimate for impact assessment, status updates, and proposed management response.

The Risk & Opportunity Registry tool provides real-time assessment of the Probability Weighted Exposure (PWE), which is defined as:

$$PWE = Probability\ of\ Occurrence * Cost\ Impact$$

PWE applies to both risks and opportunities; however, when an overall PWE is desired, the proper sign convention must be applied to the Cost Impact (negative for risks, positive for opportunities). The Cost Impact included both labor and non-labor costs.

The tool also includes Monte Carlo routines to develop a probabilistic assessment of the risk and/or opportunity exposure within subsystems or the project as a whole.

Risk Management Confluence Site: A Confluence space has been established to enable efficient and productive communication amongst members of the Risk & Opportunity Review Board and additional stakeholders. The site is the repository for the monthly meeting agendas and minutes and provides the communication work space for the Board to conduct the monthly meetings.

The Risk & Opportunity Management Confluence space is:

<https://confluence.lsstcorp.org/display/RM/LSST+Risk+Management+Home>

LSST Issue Tracker: LSST uses JIRA as its project-wide issue tracking system. It is a tool for consolidated management of issues to be studied and resolved that arise in the course of the project during the project's numerous and distributed meetings or from informal discussions. This is not strictly a Risk and Opportunity Management tool; however, the issue tracking tool provides a continuous set of topics to understand and analyze as potential risks or opportunities. In addition to managing issues, JIRA provides a history of previously discussed issues and their resolutions that can be referenced when future related issues arise.

There are two specific uses of JIRA with respect to the LSST Risk & Opportunity Management Plan:

- **Elevation of JIRA Issues to Risks:** JIRA is periodically reviewed for issue tickets that capture the essence of event-based risks that are not captured in the Risk Register. Additionally, issue tickets that are not being addressed in a timely manner, such as those that are significantly past due, may be presented to the Risk & Opportunity Review Board as possible items presenting schedule risk to the project.
- **Tracking the Project Responses to Realized Risks and Realized Opportunities:** For risks, as trigger dates come to pass, if the negative event occurs, the associated risk is realized and becomes an issue. For opportunities, as trigger dates come to pass, if the positive event occurs, the associated opportunity is realized and becomes a benefit. At this point, the Risk & Opportunity Registry is no longer the proper tool for statusing the items moving forward. The realized events are entered as new issue tickets in the JIRA "LSST Issue Tracker" (LIT) project with an issue type of "Realized Risk" or "Realized Opportunity", as appropriate. This issue ticket should cross reference the Risk & Opportunity Registry's unique identifier tag (and vice versa), and then the associated risk or opportunity category should be changed to "Realized" in the registry. The JIRA Issue ticket should then be used for capturing the project's response to the issue or benefit, such as the allocation of contingency and the ongoing impact of the issue if it is a realized risk, or the potential return of funds to contingency if it is a realized opportunity.

The LSST JIRA main page is <http://ls.st/0wm>.

3 Risk and Opportunity Identification and Assessment

Risks and opportunities are identified and assessed at the subsystem level of the Project. Each subsystem manager, working with his/her engineers, scientists, and product developers, conducts a continuous process of risk and opportunity review focused on the subsystem's program plan and deliverables. Risks and opportunities are also assessed at the Project level by Project Management, Project Systems Engineering, and the LSST Risk & Opportunity Review Board in order to address programmatic, shared, and common risks and opportunities as well as those that span long time horizons and those that span project phases.

There are six aspects to assessing the state of each risk and opportunity within a subsystem.

- 1) **Identification:** identifying elements of risk or opportunity in the subsystem or Project.
- 2) **Establishing time frame:** determining the likely time at which a risk or opportunity event would come to pass.

- 3) **Assessing probability:** estimating the probability that an undesirable (for risks) or desirable (for opportunities) event may occur.
- 4) **Assessing severity:** gauging the severity of the impact that such an event would have on the status of the project if the event were to occur.
- 5) **Developing risk/opportunity handling options:** For risks: developing plans to avoid, accept, mitigate, or transfer. For opportunities: developing plans to permit or promote.
- 6) **Developing a management response:** consider how the project may respond if the event should occur.

The following sections detail the process to be used in identifying and analyzing elements of an identified risk or opportunity.

Because of the similar but opposite nature of risks and opportunities, LSST has implemented a common approach to identifying and documenting both. This ensures a common format is maintained throughout the Risk & Opportunity Registry, which aids in developing user familiarity with the tool and allows a common database structure to be maintained. Where semantic differences exist between opportunities and risks in terms of assessing probabilities and severity, notes have been added to the entry form for clarification.

3.1 Risk and Opportunity Identification

Risk Identification is the process of determining which events, if they occur, will adversely affect the project, then documenting the characteristics of the events that may happen in order to delineate why the event is considered a risk. Similarly, Opportunity Identification is the process of determining which events, if they occur, will advantageously benefit the project, then documenting the characteristics of the events that may happen in order to delineate why the event is considered an opportunity.

Both risks and opportunities should be described with “If...then” statements in order to clearly identify the triggering event and the possible outcome.

Four methods may be used in identifying elements of risk, listed here in increasing order of involvement and complexity.

- First, project team assessments are performed by the technical and program leads for the subsystem, based on their experiences.
- Second, identification may require expert interviews or involvement by third-parties who have specific expertise or directly related experience.
- Third, lessons-learned from other projects may be used to identify events that resulted in impacts on past projects.
- Fourth, Failure Modes and Effects Analysis (FMEA) may be needed to formalize the cause-and-effect relationships of risks, if such a rigorous analysis is deemed necessary by the project team.

The first three methods may also be used in identifying elements of opportunity.

Once risks and opportunities have been identified, they are classified and documented with data as shown in Table 3-1 below. Drop-down menus are provided to ensure consistent data entry, and pop-up “Help” data is provided to remind the user of the specific terminology and definitions. The classification

data also includes references to specific parts of the WBS and even specific activities. A WBS identification is always required, even if the risk is broad and is therefore identified at a high WBS level. The Activity Code reference is not always possible, for example if the risk is situational and not associated with an activity or if many activities could be impacted.

Table 3-1: Part 1 of Entry form that captures the general information for a given risk or opportunity.

Part 1: General risk/opportunity information	
Risk/Opportunity ID:	Auto assigned in code
*Project system:	Project Management Office For a new risk or opportunity you must select a value, defaults to PMO
*Risk/Opportunity status:	Proposed new Risk Click for definitions
Subsystem:	
*WBS code(s):	Click here to open WBS on new tab or window
Activity code(s):	
*Risk/Opportunity title:	Enter risk/opportunity title
*Description:	
Model for contingency obligation date(s):	☐ Trigger date ☐ Random occurrence(s) ☐ Distributed occurrence
Trigger date OR End date for distributed obligation:	Month: Jan CALENDAR year: 2014 Date not used if occurrence is random Click for milestone schedule
If random occurrence:	0 Enter non-zero number of times it may randomly occur. Cost per event = (Total cost/number of possible occurrences) Random risk/opportunities may occur during: ☐ Construction only ☐ Commissioning only ☒ Both Construction and Commissioning
*Registered estimator:	Select Name
General Notebook 1:	Enter notebook comments

Risks and opportunities are categorized by a “Status” category or state. The same categories apply to both risks and opportunities, but their definitions are slightly different (see Table 3-2**Error! Reference source not found.** for definitions). These classifications are only changed after discussion at a monthly project-wide Risk & Opportunity Review meeting and upon approval by the Project Manager.

Table 3-2: Status Categories Defined

Status Category	Definition
Proposed	A potential new risk or opportunity event identified by one of the subsystems. As new risks or opportunities are identified, they are added to the register in this state. Risks or opportunities that were previously in the Subordinated state and have been updated with new information with the intent of returning to the Active state first transition through this state to receive approval by the Project Manager. Risks and opportunities in this state do not affect the statistics generated from the registry.
Active	Risks and opportunities that have been reviewed by the Risk & Opportunity Review Board and approved by the LSST Project Manager for inclusion in the active set of risks and opportunities. Active risks and opportunities have identified probabilities of occurrence, impacts, handling approaches, proposed management responses, trigger

	dates that are in the future, and are statused at a minimum of every 3 months. Statistics generated from the Risk & Opportunity Registry are generally based on the entries in the Active state.
Subordinated	Risks or opportunities that overlap or are identified as being included in another Active risk or opportunity entry. So as to not double count, the entry is subordinated and removed from the active set. This state can also be used as a holding area for “what-if” risks or opportunities.
Deprecated	Risks or opportunities that are removed from consideration because they are no longer applicable as assigned to this state. This state is used instead of deleting an entry.
Retired	For Risks: There are two subclasses to risks that have been retired: • The trigger date has passed and the risk event did not materialize. • The risk was successfully mitigated such that the probability of occurrence was reduced to zero (or sufficiently close to zero) or its impact was reduced such that the consequences have been deemed inconsequential. For Opportunities: There are two subclasses to opportunities that have been retired: • The trigger date has passed and the opportunity event did not materialize. • The probability of occurrence is undesirably low or the impact has been reduced such that the consequences have been deemed no longer beneficial.
Realized	For Risks: Risks where the negative event has occurred. The realized risk is subsequently referred to as an Issue. Realized risks are tracked in JIRA with their own issue ticket, identified with a “Realized Risk” Issue Type, to track the actual management response and project impacts. For Opportunities: Opportunities where the positive event has occurred. The realized risk is subsequently referred to as a Benefit. Realized opportunities are traced in JIRA with their own issue ticket, identified with a “Realized Opportunity” Issue Type, to track the actual management response and project benefits.

The states are related to each other based on the state machine shown in Figure 3-1. Opportunities follow a similar state machine.

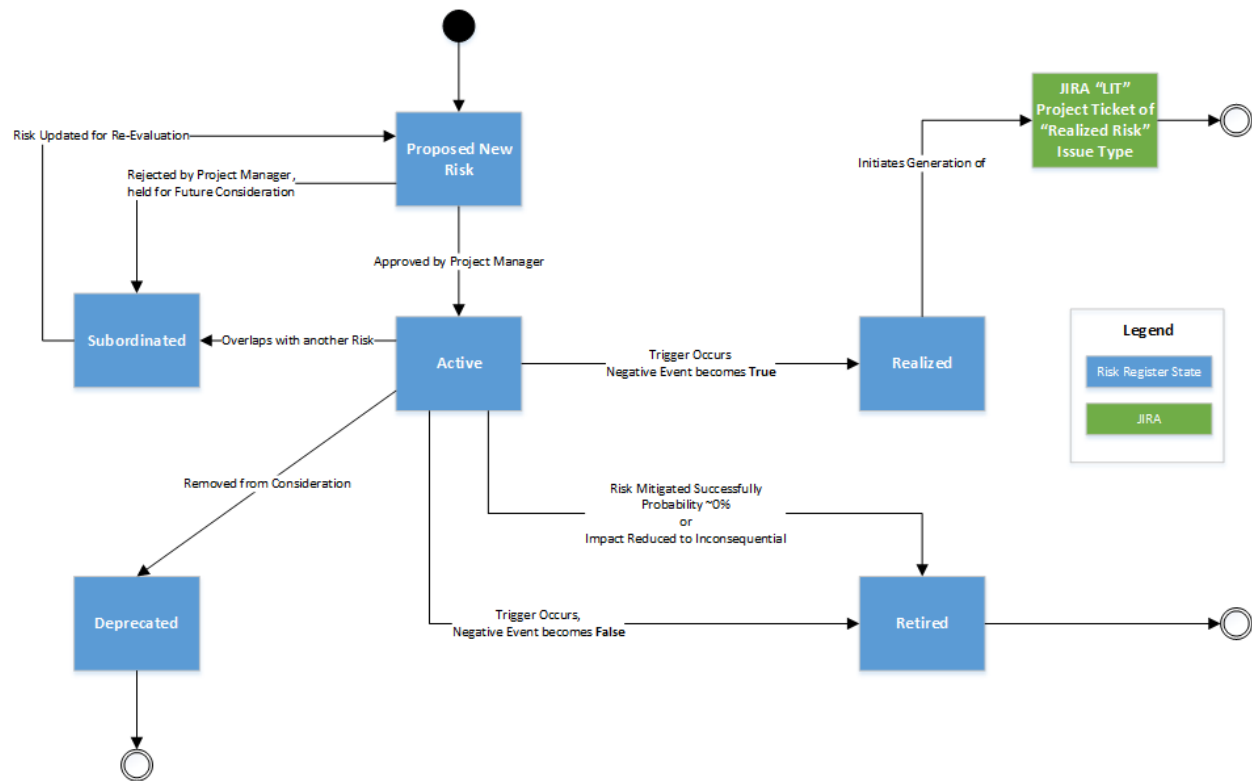


Figure 3-1: Risk State Machine

Assigning a trigger date is an important part of risk/opportunity identification. This provides a method for time-based planning and provides the necessary data for the Monte Carlo analysis described in Section 4.1. There are three models available for the trigger date:

- **Specific trigger date:** A specific calendar date is available when the LSST Project Manager will know if contingency funds must either be obligated to respond to a risk or the risk can be retired. This would occur, for example, on a project milestone date when a component must be delivered or a contract cost finalized. Similarly, a specific trigger date applies to an opportunity when the LSST Project Manager will know if the beneficial event will occur and if cost or schedule can be returned to the Project Management Office or the opportunity can be retired.
- **Random occurrence:** Certain risks or opportunities are known to potentially occur but their date(s) are random. For example, critical staff may depart the project or weather may delay construction. In this case, the model requires an estimate of the number of random occurrences and the cost of each. Each Monte Carlo simulation selects different random dates of occurrence.
- **Distributed occurrence:** Identical risks or opportunities are sometimes distributed throughout periods in the project. For example, software packages are evaluated for performance on an annual basis. In this case, the model distributes the possible contingency obligation profile over the specified time span.

3.2 Risk and Opportunity Assessment - Analysis

Once a risk or opportunity has been identified, it is then analyzed. This analysis is captured in Part 2 of the entry form, shown in Table 3-3.

Table 3-3: Part 2 of Entry form that captures risk/opportunity analysis.

Part 2: Current evaluation of risk/opportunity exposure (prior evaluations with dates are stored)	
Current probability of occurrence (%) Expected range: 0 - 5% If Risk: Technical Margin: If this risk occurs, is there at least a partial remedy possible using technical performance margins? Technical margins are available in: (1) Image quality (FWHM) (2) Image depth/Sensitivity (5σ SNR) (3) Photometric repeatability/Calibration precision (4) Astrometric repeatability – Systematic floor for bright objects (5) Integrated astrometry If Opportunity: Leave blank.	☐ No ☐ Yes
If Risk: Non-labor cost: Current expense cost required (without using technical margin) if risk occurs (Thousands-\$) If Opportunity: Non-labor cost recovery/financial benefit: Current cost recovery or financial benefit incurred if opportunity occurs (Thousands-\$)	Expected K\$: 0
If Risk: Labor cost: Cost of months of labor overtime and/or cost of project schedule slip (without using technical margin) if risk occurs. If Opportunity: Leave blank. Enter all opportunity in terms of non-labor cost recovery/economic benefits if opportunity occurs.	Hover here to read note about schedule risk Can schedule be recovered with overtime or adding staff without slipping total project schedule? ☒ Yes ☐ No Expected (months): 0 How many full-time staff equivalents (#FTE's) are required for overtime or added staff: 0 FYI: Computed expected labor risk cost: 0 K\$(monthly)
New notebook entries on current risk/opportunity exposure Previous entries are stored	Enter notebook comments

Risk and opportunity analysis considers two characteristics for establishing the magnitude of the identified entry and subsequently prioritizing them. These are:

- Probability:** the likelihood of an event actually occurring. Table 3-4 indicates the six (6) levels available in the assessment. These rankings apply equally to risks and opportunities, however with risks the desire is to drive the probability to as close to 0% as reasonably possible and with opportunities the desire is to drive the probability to as close to 100% as reasonably possible. This assessment is made in consideration of the current state of the project and all activities that are baselined and affect the risk or opportunity's probability.
- Impact:** the severity of the result with respect to cost, schedule and technical performance, if the event were to occur. The impact is often captured through rating levels, and this was the methodology LSST used during the Design and Development Phase. In construction, with greater details available and an approved baseline, impact costs are more specific, and full quantification of technical impact is resolved at the Systems Engineering level where routine assessment of performance margin and predicted system performance takes place. The impact is captured in terms of non-labor and labor costs. For risks, these costs would be draws against contingency (negative net values). For opportunities, these costs would be returns to the PMO (positive net values).

Table 3-4: Ranking of occurrence probabilities used for risk impact assessment.

#	Likelihood of Occurrence	Approximate Probability	Description of Probability
1	Rare	<1%	Likelihood of occurrence is not credible
2	Unlikely	1-5%	Not reasonably expected to occur
3	Possible	5-10%	Possible but difficult to assess the chance of occurrence
4	Moderate	10-25%	Moderate chance of occurrence can be assessed
5	Likely	25-50%	Very likely that the event will occur
6	Almost Certain	50-75%	Near-certainty that the event will come to pass

Both of these characteristics are further developed through entering the data in Table 3-3. The LSST Contingency Management Plan (LPM-61) outlines the three (3) types of contingency available to the project to respond to realized risks: technical margin or scope options, schedule float, and cost contingency. The risk analysis section gathers the data to support management assessment on the exposure from the risk and quantifies impact costs by non-labor, labor, and standing-army labor if the risk occurrence is expected to drive the critical path of the project. The schedule impacts are translated into dollars in the tool, with the assumption that the cost to maintain the standing-army is \$1,800K/month.

3.3 Risk & Opportunity Assessment – Handling

The next step in the assessment process is to determine the options available to handle the risk or opportunity. There are four general types of risk handling action that can be taken, listed here in order of decreasing preference of action:

1. Take preventative action to **avoid** the risk through change of requirements or redesign.
2. **Accept** the risk as stated and do nothing about it for the time being.
3. **Mitigate** the risk through the expenditure of budget or other resources to reduce the likelihood and/or consequence.
4. **Transfer** or **share** the risk by moving responsibility in whole or part elsewhere.

There are two general types of opportunity handling actions that can be taken:

- **Permit (accept)** the opportunity as stated and do nothing about it for the time being.
- **Exploit** the opportunity through the expenditure of budget or other resources to increase the likelihood. The expenditure of budget should be evaluated against the PWE of the opportunity to ensure that the likely net payoff is a positive one.

Early in the project lifecycle many risks likely have mitigation strategies that include preventative action in the form of analysis, prototyping activities, and other Design and Development efforts. However, these options become increasingly unavailable as the project progresses. As new risks are identified in the continuous review process, any identified mitigation requiring the application of cost or schedule to activities or specification changes are promoted to the Change Control Board for consideration (***note that any proposed risk handling activities documented in the registry should be explicitly noted as***

“PROPOSED”). The cost/benefit trade and impact analysis for the proposed mitigation is conducted there. The resulting actions and updated project baseline is then reflected in the Risk and Opportunity Registry.

Because the introduction of Opportunity Management to the LSST Project did not occur until the start of Construction, there were no previously baselined opportunity handling activities. As opportunities are identified and documented, any handling activities requiring the application of cost or schedule to activities are promoted to the Change Control Board for consideration (***note that any proposed opportunity handling activities documented in the registry should be explicitly noted as “PROPOSED”***). The cost/benefit trade and impact analysis for the proposed activity is conducted there. The resulting actions and updated project baseline is then reflected in the Risk and Opportunity Registry.

Each time an existing risk or opportunity is assessed, the relative success of the baselined activities associated with the risk/opportunity handling approach(es) are evaluated, and the probability of occurrence can be adjusted lower or higher. Additionally, the trigger date(s) can be reassessed based on the latest schedule. The timing of handling actions is important, so they need to include the time at which the activity must be completed to stay on schedule with the overall handling response plan.

There are also “Programmatic Risks”, the type of risks that cannot be targeted since the event is out of the control of the project (e.g., natural disaster or loss of funding). Programmatic risks must be accepted; however, they are still important to capture, as it is useful to determine the Management Response prior to their potential occurrence. Additionally, it is important to include these Programmatic Risks in the risk exposure calculations.

Table 3-5 shows Part 3 of the entry form, used to document the risk/opportunity handling activities in or to document that nothing can be done.

Table 3-5: Part 3 of Entry form that captures risk/opportunity handling actions.

Part 3: Risk/Opportunity Handling - actions and status	
Handling Action 1	
Handling title:	Enter Risk/Opportunity Handling Event title
Handling description: Risk Handling actions are intended to decrease the probability of occurrence or impact. Opportunity Handling actions are intended to increase the probability of occurrence or impact.	Enter Risk/Opportunity Handling Event description
Anticipated completion date:	Month: Jan Year: 2012
Notebook of current handling status: Previous entries are stored	Enter notebook comments
Handling Action 2	
Handling title:	
Handling description: Risk Handling actions are intended to decrease the probability of occurrence or impact. Opportunity Handling actions are intended to increase the probability of occurrence or impact.	
Anticipated completion date:	Month: Jan Year: 2012
Notebook of current handling status: Previous entries are stored	

3.4 Management Response

The final step in risk identification and assessment is to indicate the potential management response

should the risk or opportunity be realized. This provides an opportunity to capture such possibilities within the context of the analysis and gives managers an initial consideration if the item is realized. Table Table 3-6 shows Part 4 of the entry form.

Table 3-6: Part 4 of Entry form that captures the proposed management response.

Part 4: Proposed Management Response	
Notebook for Proposed Management Response: Previous entries are stored.	Details of proposed management response (activities, budget & schedule of response): Enter proposed management response:

3.5 Commit Change Note

While not part of the main body of the risk or opportunity documentation, the last part of the entry form requires the user to summarize the changes made during the update to the entry or to note if this is a new entry. These notes are used to as input to the LSST Monthly Report to the NSF, whereby significant changes/updates to the Risk and Opportunity Registry are summarized. Note that the “commit changes” button is locked out/unavailable until a comment has been entered in this field. Table Table 3-7 shows this portion of the entry form.

Table 3-7: Part 5 of the Entry form that captures the commit change note.

Part 5: Commit Change Note	
Last change comment:	
Summarize changes made since last update:	

4 Risk and Opportunity Analysis and Reporting

4.1 Monte Carlo Cost Exposure

It is extremely unlikely that a project will encounter all of the risks and opportunities identified. Therefore, the overall Project exposure to risks and opportunities is determined through a Monte Carlo statistical model. The LSST risk and opportunity tool includes a routine to simulate a specified number of project execution scenarios; a typical number is 5,000 scenario instances. The process predicts the distribution of contingency expenditure for event-based risks and opportunities at the end of the project

and the distribution of the contingency expenditure as a function of time if the response to each realized risk/opportunity follows the assessed costs documented with the risk/opportunity.

Figures 4-1 and 4-2 are typical Monte Carlo results generated for the project. The results of this example are shown in 2013 base-year USD. Figure 4-1 shows the distribution of event-based contingency expenditure at the end of the project based on the known risks. At the end of the project, the total expenditure of contingency for these risks would be \$47M in 2013 USD or less with 80% confidence. Figure 4-2 shows how the \$47M would be allocated during the project with the modelled risks.

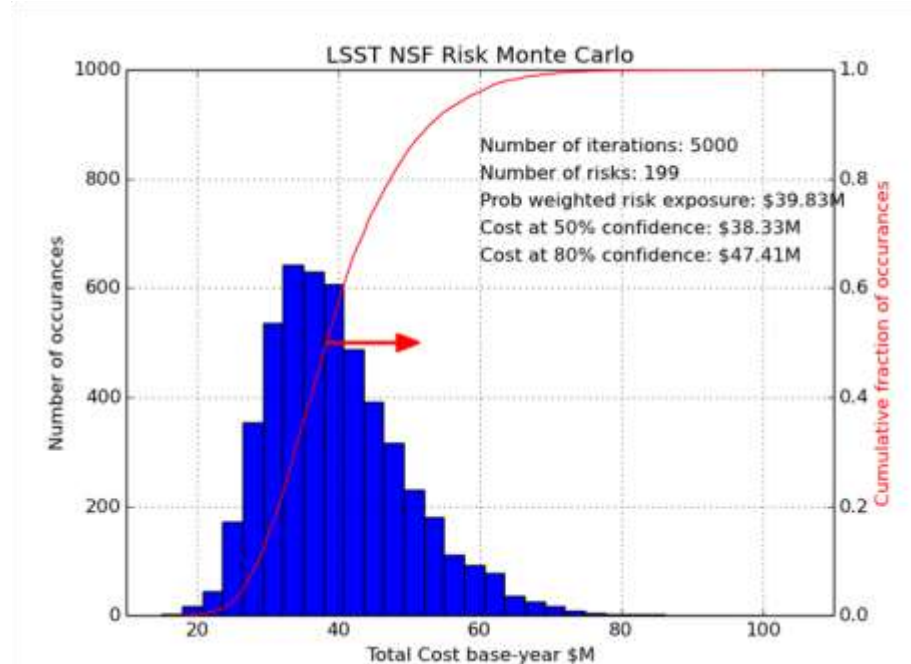


Figure 4-1: Distribution of costs associated with the known NSF project risks for 5,000 Monte Carlo simulations of the project. 80% of the simulations require an allocation of \$47M USD or less.

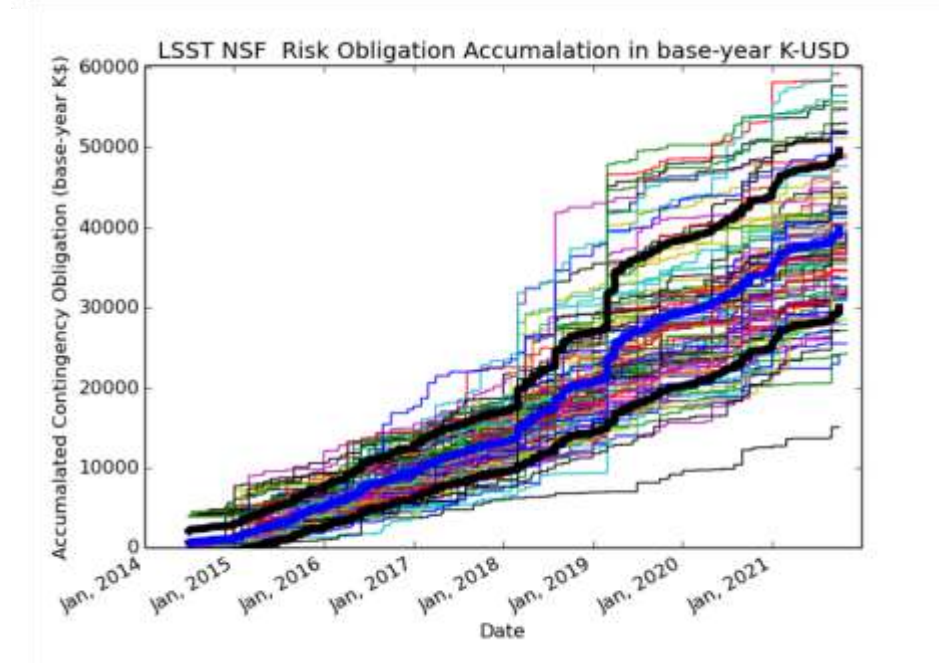


Figure 4-2: The risk register exposure costs for the NSF-funded project calculated using Monte Carlo modelling. The upper bold line is the so-called 80% confidence line. The center bold line is the 50% confidence line. The lighter lines are realized exposure cost curves for single executions of the Project. The model was run 5,000 times; for clarity every 50th simulation run is plotted.

4.2 Risk & Opportunity Tracking

The trends in the assessment of each risk and opportunity are tracked using the monthly Risk & Opportunity Review Meeting to update assessment status and report on entries showing significant trend changes – whether positive or negative. The database is sorted to provide the top 10 risks as measured by the Probability Weighted Exposure. In addition, the nearest 10 risks are listed as determined by the trigger dates. Both of these sorts serve as "Watch" lists to support detailed review by the Review Board each month. Historical trend graphs for Probability Weighted Exposure for each subsystem and relative cost weighting of each subsystem are shown in order to determine trends and address them as necessary. As opportunities are identified, similar trend graphs and tables will be generated.

The results of the Monte Carlo analysis on the cost exposure are also plotted routinely to review the trend of realized risks and the forecast for how the risks could materialize. This is similar to a "Lien List" and plots of potential draw-downs on project Contingency for event-based risks.

4.3 Risk & Opportunity Reporting and Communication

The Risk & Opportunity Registry is always available online through the website defined in Section 2. This keeps the register available as a daily tool to the engineering and management team in the Project. On a monthly basis, the risk and opportunity meeting facilitates detailed discussions of each subsystem on a rotating basis as well as any changes in the Project that may represent changes in risk/opportunity portfolio. The top-10 lists mentioned in section 4.3 are also developed monthly to support the meeting and serve as the primary input into the formal monthly reporting by the Project.

Risk and opportunity analysis reporting is also a key component of formal internal and external reviews. This provides one measure of the health of the project and provides expert review committees with a better understanding of how project risks and opportunities are being managed at both the subsystem and Project levels.

Finally, the Project Monthly Report will include a section to address the status of the Project's Risk & Opportunity Management activities. The reporting will include the Probability Weighted Exposure for each subsystem and indicate the changes since the previous reporting period.

5 Relationship between the Risk & Opportunity Management and Contingency Management Processes

The Risk & Opportunity Management Process is a continuous and proactive approach to keeping risk at an acceptable level through awareness, tracking, and handling while also identifying and exploiting opportunities. The two central elements to the risk and opportunity management process are the regular risk/opportunity review board meetings to actively address changing situations in the project that impact risk and opportunity and the Risk & Opportunity Registry to document and track identified risks. The Risk & Opportunity Management Process is a key tool for communication of concerns from the science and engineering staff to other project personnel and managers.

Contingencies exist in the Project as a key method to handle risks or to respond to realized risks. The Project has contingencies in the form of technical scope, budget, and schedule. The process to

determine an acceptable amount and proportion of each, and the methodology for applying these contingencies is the subject of the Contingency Management Plan (LPM-61). The methodology described to address cost and schedule contingency relies on both a resource loaded schedule and the risk register. These are combined in the Primavera Risk Module to allow simulations of cost and schedule performance to be run based on described uncertainties along with the application of risks that are realized when, where, and with their associated probabilities.

Cost uncertainties on the resource loaded activities can be used in the PMCS to estimate necessary contingency. Monte Carlo simulations on the risk and opportunity registry can determine cost impacts if the risks and opportunities in the register are realized. The Primavera Risk Module combines all the uncertainties to provide a comprehensive and integrated view of the Project cost and schedule exposures and the amount of contingency that should be available to respond to project activities that have uncertain outcomes.

6 References

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Meredith, Jack R.; Mantel, Samuel J.; Project Management – A Managerial Approach. Hoboken, NJ: 2009. Print.