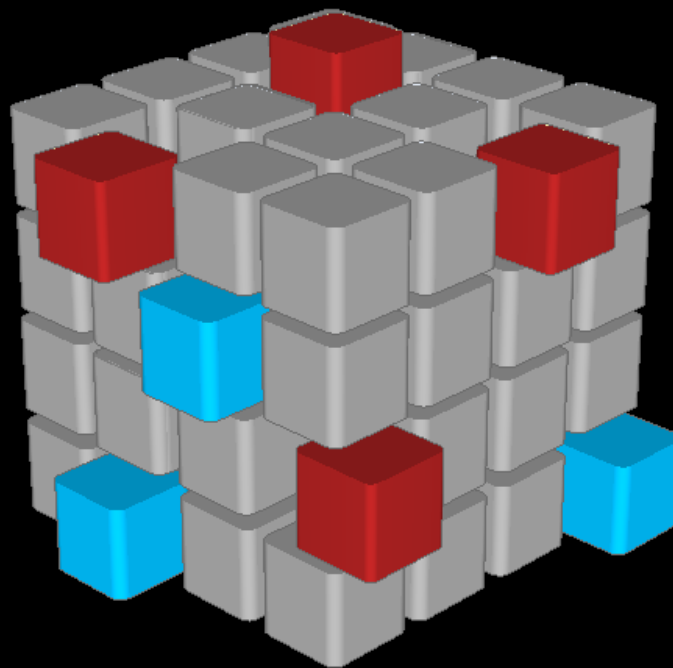


NASA/SP-2014-615

November 2016

Organizational **Risk** and **Opportunity** Management

Concepts and Processes for NASA's Consideration





Organizational Risk and Opportunity Management

Concepts and Processes for NASA's Consideration

National Aeronautics and Space Administration
NASA Headquarters
Washington, D.C. 20546

November 2016

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ACKNOWLEDGMENTS

The authors express their gratitude to the NASA Office of Safety and Mission assurance (OSMA) for their support and encouragement in developing this document. The development effort was conducted in stages, and was supported by briefings, reviews, and discussions with many risk management practitioners and stakeholders within the Agency. An enterprise risk and opportunity management workshop held at NASA Headquarters on October 30, 2014, brought together numerous stakeholders to discuss their diverse concerns and expectations and was especially helpful. An extensive review of the draft document by members of the Agency Risk Management Working Group and the NASA System Safety Steering Group (S3G) was also very helpful. The authors owe special thanks to Julie Pollitt (a retired NASA employee who worked for the Strategic Investments Division of the Office of Chief Financial Officer (OCFO)), Jessica Southwell (then chief of the Strategic Planning and Performance Management Branch of the OCFO, currently Chief Performance and Risk Management Officer at U.S. Department of Labor,) and Peter Rutledge (a retired NASA employee, currently Director of Risk Management Operations at Quality Assurance & Risk Management Services, Inc) for their support and advocacy for employing risk management at NASA.

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Preface

In order to appreciate this report as the latest development in the evolution of risk management (RM) at NASA, it is important for the reader to have some knowledge of the milestones that preceded it. Formal RM first began on an agency-wide basis in 1995 when the Office of Safety and Mission Assurance (OSMA) introduced it in the form of Continuous Risk Management (CRM), developed in the early 1990s for the Department of Defense by the Software Engineering Institute (SEI). (SEI is a Federally Funded Research and Development Center and part of Carnegie-Mellon University). It was at this time that OSMA became the NASA office of prime responsibility (OPR) for RM. In 2002, as the OPR for RM, OSMA published NASA Procedures and Guidelines (NPG) 8000.4, Risk Management Procedures and Guidelines, the first Agency directive on RM. The NPG continued to rely on CRM as the paradigm for NASA's RM process. At that time CRM focused mainly on NASA's *programs and projects* and on the identification and management of *individual risks*. In 2008, OSMA revised NPG 8000.4 and published it as NASA Procedural Requirements (NPR) 8000.4A, Agency Risk Management Procedural Requirements. NPR 8000.4A continued to use CRM but added an Analysis-of-Alternatives (AoA) type front-end to the process, calling it Risk-Informed Decision Making (RIDM). This revision of the NPR continued to address RM for programs and projects but added consideration of *institutional risk*. And while it still dealt with individual risks, it also recognized the overriding importance of *aggregate or cumulative risk*. The NPR was supplemented in 2011 by OSMA's publication of NASA/SP-2011-3422, NASA Risk Management Handbook, focusing on programs and projects. In 2016, OSMA published NASA Interim Directive (NID) 8000-108, an expedited partial update of NPR 8000.4A in response to a recommendation of the Aerospace Safety Advisory Board calling for improved accountability in risk acceptance decision making.

To sum up the evolution of RM since 1995 at NASA, it began with CRM and a focus on individual risks to programs and projects and has slowly expanded to include institutional risk, the concept of aggregate risk, and improved risk decision making. RM is now ready for the next logical steps in its evolution: 1) to consider "opportunity," as well as risk, and 2) to apply "risk and opportunity management" both horizontally across the agency or "agency-wide," as well as vertically to all levels of the agency from its lowest levels up to the executive level. It is the purpose of this report to provide material on "organizational risk and opportunity management" to begin a wider discussion of the future of RM where we envision a broader and more unified approach.

Incorporation of risk and opportunity management into an organization's operations requires integration of RM with the organization's strategic mission. According to the 2014 Strategic Plan, NASA's overriding mission is to "drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth." This mission is at once lofty, challenging, and creative. But in addition to lofty goals, the planning and implementation of strategies for achieving NASA's mission involves practical, hard choices about how to formulate a meaningful and achievable set of objectives, develop a relevant and effective portfolio of programs and projects, allocate human and physical assets among the programs and projects, evaluate whether the goals and objectives are being met, formulate controls, make adjustments when needed, and still meet externally imposed constraints. A principal intent of organizational risk management is to support these strategic planning and plan implementation activities.

As mentioned above, NASA has published several documents on the subject of risk management, including procedural requirements and general guidance. Since these requirements and guidelines apply to all activities at NASA, they extend beyond programs and projects to NASA's mission as a whole, including the strategic performance functions of the agency and the performance planning functions of the various centers and directorates within the agency.

This concepts and processes report is offered to stimulate thought about how to put organizational risk management into effect both at the executive level of NASA and at organizational levels that are responsible for the technical work (i.e., NASA centers). While directed especially toward NASA, the report is relevant as well for other agencies of the Government and nonprofit research institutions whose mission involves the development of science and technology in the national interest. For this reason, the development of principles and approaches often takes a broader viewpoint before focusing in on their applicability to NASA.

Attainment of a formal Organizational Risk and Opportunity Management (OROM) approach within the agency is a goal that will require some time to realize. Implementation plans will be developed with the broad participation of agency personnel and will be thoughtfully applied to assure a gradual but steady evolution of OROM from today's baseline to the optimum configuration. An earlier draft of this document was presented at the October 2014 enterprise risk and opportunity management workshop organized by the Office of Safety and Mission Assurance. The workshop was a catalyst for bringing key stakeholders together and airing diverse concerns and expectations regarding the management of organizational risks and opportunities at NASA. As a result, the 2014 version of this report has undergone considerable revision. The report has been reorganized and expanded to include the following topics:

- How various management units within the agency can separately apply OROM;
- The challenges of conducting OROM across extended partnerships;
- How OROM complies with agency, mission directorate, and center roles and responsibilities as outlined in the NASA Project Management Handbook;
- How the roll-up of risks and opportunities proceeds from center and mission directorate levels to executive level;
- How OROM can account for factors that produce unknown and underappreciated (UU) risks and include them in the roll-up process;
- How risk and opportunity drivers can be derived from the rationale developed during the roll-up process;
- How risk mitigations, opportunity actions, and controls can be derived from the risk and opportunity drivers, paying special attention to key assumptions that need to be protected;
- How OROM templates can be developed and used for strategic planning and for agency-wide organizational performance evaluation;
- How OROM can be used to inform risk acceptance decisions in harmony with competing objectives;
- The OROM organizational structure for organizations that involve multiple partners;

- How OROM can help inform acquisition, allocation, and retirement of resources across a center's extended organization;
- How OROM may interface with other strategic and agency-wide assessment activities at NASA such as the Technical Capability Assessment Team (TCAT), Capability Leadership Model (CLM), Baseline Performance Review (BPR), and strategic reviews.

Finally, it is important to note that:

- This concept paper does not describe an approach that has been adopted by NASA. Rather, it provides ideas for possible consideration in the Agency's implementation of an evolved risk management framework.
- Because this document was drafted over a period of time from within the Office of Safety and Mission Assurance, some of our assumptions on management processes might not be fully consistent with current practice.

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November 2016

1. Introduction

Organizational risk and opportunity management (OROM) concerns the means by which organizations apply risk and opportunity considerations in developing their strategic goals and objectives, in implementing them through a portfolio of programs, projects, institutional assets, and activities, and in managing them through controls. The use of the word “organizational” in the risk management context is consistent with the following definition provided in [1]: “Organizational risk management is risk management at the strategic level.” The overall purpose of OROM is to help reach an optimal balance between minimizing the potential for loss (risk) while maximizing the potential for gain (opportunity).¹

OROM is sometimes thought of as being identical to institutional risk management (IRM) but is in fact larger than it. IRM is the part of OROM that, according to NASA NPR 8000.4A [2], concerns “risks to infrastructure, information technology, resources, personnel, assets, processes, occupational safety, environmental management, or security.” Additionally, according to [2], institutional risks “affect capabilities and resources necessary for mission success, including institutional flexibility to respond to changing mission needs and compliance with external requirements (e.g., Environmental Protection Agency or Occupational Safety and Health Administration regulations).” OROM concerns itself with institutional risks, portfolio risks, program/project risks, operational risks, and various other types of risk and opportunity that are commonly categorized in the risk management literature.

The focus of this report is on the development of a framework and overall approach that serves the interests of nonprofit and Government organizations like NASA that focus on developing and/or applying new technology (henceforth referred to as “organizations like NASA”). These interests tend to place emphasis on performing services and achieving scientific and technical gains more than on achieving financial investment goals, which is the province of commercial enterprises. In addition, the objectives of organizations like NASA extend to institutional development and maintenance, financial health, legal and reputational protection, education and partnerships, and mandated milestone achievements.

This report discusses the philosophical underpinnings of OROM for organizations like NASA, the integration of OROM with existing management processes, and the nature of the activities that are performed to implement OROM within this context. The proposed framework includes a set of core principles that would be essential to any successful OROM approach, along with some features that are currently under development and are continuing to evolve. The report is intended to foster discussion of OROM at NASA in order to reach a consensus on the optimum approach for the agency.

Sections 2 and 3 are intended mainly for high-level managers and their administrative staffs who wish to understand the organizational aspects of OROM and the broad concepts of how it could be applied at organizations like NASA. Section 2 is presented in the form of a primer on OROM,

¹ The purpose of OROM is similar to that of enterprise risk management (ERM), but the term “enterprise” is sometimes construed as emphasizing financial objectives, whereas the focus in this report is on achieving scientific and technical objectives as well as financial objectives.

answering fundamental questions about how OROM works at a high level, how OROM is particularly relevant to pioneering technical organizations like NASA, how it works in tandem with existing management structures, how it facilitates interactions with external agencies, and how it can be applied both across the organization as a whole and within individual management units of the organization. Section 3 discusses how OROM coordinates with the major management functions within most technically oriented organizations, how it helps to shape and corroborate the information that flows within, between, and out of these management functions, and how it may be practiced in technological organizations like NASA that interact with many partners, both domestic and international.

Sections 4 and 5 are directed more toward technical managers and practitioners who wish to gain an understanding of some of the more important technical aspects and the fine points of implementing OROM at organizations like NASA. Section 4 provides guidance on the activities that are conducted within an OROM analysis for organizations like NASA, including advice on how risk tolerances and opportunity appetites can be established, how risk and opportunity scenarios can be formulated and categorized, how indicators of the potential importance of risks and opportunities can be identified, tracked, and evaluated, how the overall degree of achievement for each objective can be inferred from the indicators, how the potential for unknown and/or underappreciated (UU) risks can be evaluated, and how responses to risks and opportunities and control options can be identified and evaluated. Section 5 provides helpful templates for conducting OROM within organizations like NASA, and using an example of interest to NASA, shows how the templates may be populated and exploited for purposes of evaluating overall performance and planning strategy.

Section 6 focuses on how OROM may be applied at a regional or center level, such as at NASA's centers. Sections 6.1 and 6.2 speak about the managerial aspects of OROM at the center level, emphasizing the various roles that each center plays in executing its programmatic and institutional responsibilities, the nature of the strategic objectives that require centers to manage multiple partnerships, the ways in which a center can use an OROM approach to facilitate its management responsibilities, and the organizational aspects of OROM that permit effective communication between centers and their various partnering organizations. Section 6.3 discusses the technical activities that may be conducted within an OROM analysis for centers, emphasizing the types of risks and opportunities and associated indicators that pertain to its core competencies and the development, allocation, and retirement of its resources and assets. Section 6.3 also provides additional templates which, together with those in Section 5, can be of significant use for planning its strategies and evaluating its overall performance.

Section 7 provides a brief discussion of how OROM in general and the templates in particular can potentially interact with important strategic initiatives and other agency-wide activities currently practiced within NASA, including the Technical Capability Assessment Team (TCAT) process, the Capability Leadership Model (CLM) process, and the Baseline Performance Review (BPR) process.

Finally, Section 8 deals with the application of OROM results to assist decision makers in making risk acceptance decisions at key decision points when there are competing objectives at the top level of the organization with correspondingly different levels of risk tolerance. It uses an example applicable to a sister Federal agency (the Department of Defense) to illustrate the processes

involved, and discusses how these processes can be applied to NASA programs such as the Commercial Crew Transportation (CCT) program.

2. A Primer on OROM for NASA and Pioneering Technical Organizations like NASA

2.1 OROM Scope and Objectives

2.1.1 What is OROM?

Organizational risk and opportunity management (OROM) is a means by which organizations account for risks and opportunities in identifying and implementing their strategic goals, objectives, and priorities, subject to imposed constraints, through a process of strategic planning, execution, and performance evaluation.

- According to [3], the principal concerns of organizational risk management are as follows: *Aligning risk tolerance, opportunity appetite² and strategy* – Management considers the entity’s risk tolerance and opportunity appetite in evaluating strategic alternatives, setting related objectives, and developing mechanisms to manage related risks.
- *Enhancing risk response decisions* – Organizational risk management provides the rigor to identify and select among alternative risk responses – risk avoidance, reduction, sharing, and acceptance.
- *Reducing operational surprises and losses* – Entities gain enhanced capability to identify potential incidents and establish responses, reducing surprises and associated costs or losses.
- *Identifying and managing multiple and cross-organizational risks* – Every organization faces a myriad of risks affecting different parts of the organization, and organizational risk management facilitates effective response to the interrelated impacts, and integrated responses to multiple risks.
- *Seizing opportunities* – By considering a full range of potential incidents, management is positioned to identify and proactively realize opportunities.
- *Improving deployment of capital* – Obtaining robust risk and opportunity information allows management to effectively assess overall capital needs and enhance capital allocation.

The overall objectives of OROM are to facilitate the successful development of the strategic plan, to promote an overall best approach for implementing the plan, and to evaluate performance with respect to the plan. The means for doing this is to seek an optimal balance between minimizing the potential for loss (risk) while maximizing the potential for gain (opportunity) with respect to the organization’s overall mission. OROM is an integration of risk and opportunity management over all programs, projects, initiatives, and activities in the organization’s portfolio. Achievement of an *optimal* balance implies the involvement of the decision maker(s) in setting maximum tolerable levels for risk, minimum desirable levels for opportunity, and the tradeoffs between them.

2.1.2 Why is OROM important to organizations like NASA?

² In [3], the term “risk appetite” has the same meaning as the term “risk tolerance and opportunity appetite” in this document. Contrarily, the term “risk tolerance” in [3] has a different meaning and connotation.

Organizations that perform pioneering technical work in the public interest must continually assess whether their strategic objectives continue to be achievable as conditions evolve, whether the balance between the risks and the opportunities has changed with time so as to require a recalibration of the strategic plan or a reassessment of how it is being implemented, and whether the funding agencies have introduced new requirements or constraints that need to be addressed.

For example, NASA, in response to new directions advocated by the executive branch of the US Government, announced its intentions in 2013 to embark on new space exploration missions that necessitated a change in philosophy from strict risk minimization to a balanced combination of risk control and opportunity exploitation. This direction was enunciated in the following statements made by the NASA Administrator in a letter addressed to all NASA employees dated April 19, 2013³.

“...throughout our history NASA’s explorer spirit has led us deeper into the unknown where we continue to learn as much from our failures as our successes. One of the things that impress me most about our workforce is the willingness of so many to dream big, think outside the box, and take risks. ... We have to be willing to do daring things. Put another way, **risk intolerance is a guarantee of failure to accomplish anything of significance** [emphasis is the Administrator’s].

“... As long as we ensure that our people are protected we can manage and tolerate failures as part of the price of progress. ... As we prepare to undertake the many challenges offered in the President’s 2014 budget for our agency, I ask you to continue to think about how we can identify and seize opportunities to make progress quickly and affordably, identify and manage risks, learn fast and adapt our plans to take the next steps. While we do this, we must constantly balance our risks and rewards and always, always put the lives and safety of our people first.”

This change in philosophy indicates a need to expand the approach to organizational risk management from one that is centered on reducing risks to one that includes recognizing, cultivating, and exploiting opportunities. OROM is a rational, structured approach to reaching an optimal balance between minimizing the potential for loss (risk) while maximizing the potential for gain (opportunity).

2.1.3 How does OROM for organizations like NASA differ from OROM for commercial organizations?

The last ten to fifteen years has seen a steadily expanding development of processes and standards for conducting OROM within commercial organizations [3, 4]. While these developments have undoubtedly provided impetus for the acceptance and practice of OROM, they have tended to emphasize monetary risks and opportunities as would be paramount for profit-making companies. OROM to this point has been used less widely for non-profit Government agencies and research institutions. For OROM to be effective at organizations like NASA, it must focus on the multidimensional objectives and constraints that NASA is required to satisfy, including:

- Achievement of scientific and technical gains in the public interest, over both short-term and long-term horizons

³ The full letter is reprinted in Appendix A.

- Exploration of new frontiers and knowledge development
- Partnerships with other nations, commercial organizations, and academia
- Public education and outreach
- Objectives common to both commercial and nonprofit organizations, including institutional development and maintenance, legal and reputational protection, and financial health
- Specific annual outcomes mandated by the Government including Congress and the White House
- Outcomes specified by oversight bodies such as independent advisory groups and inspectors general
- Satisfaction of Government requirements and policies

In addition, these objectives must be met within financial, schedule, and political constraints that are subject to periodic change due to changing Administrations and changing public priorities.

Thus, the OROM framework for organizations like NASA may utilize ideas from previous frameworks developed for private enterprises and from standardized quality management systems such as the SAE Standard AS9100 [5], where applicable, but also must include the capability of addressing strategic objectives that are fundamental to the mission of the organization and should build upon its culture and history of performance management and risk management. Furthermore, it should adhere to the basic principles in its directives, requirements, and standards, which for NASA includes NPR 8000.4A and the NASA Risk Management Handbook. These documents address roles and responsibilities pertaining to risk management and, for NASA, the functions to be addressed by risk-informed decision-making (RIDM) and continuous risk management (CRM).

2.1.4 To what extent does OROM work within the existing management structure of an organization like NASA?

For any well-established organization, the OROM approach is framed and structured to synchronize with and facilitate the philosophy and management processes that already exist within that organization. OROM does not fundamentally alter the existing management approach for setting strategic direction, goals, architectures, requirements, and policies; establishing metrics, setting mission and budget priorities, or approving major new initiatives, although it may result in adjustments to some of the processes. Rather, it generally supports the existing approach for overseeing and approving risk plans and mitigation strategies, reviewing progress, overseeing controls, identifying deficiencies, and reviewing corrective actions.

Over the years, NASA has evolved a set of processes for establishing agency-level strategic objectives and desired outcomes while developing its core institutional and technical capabilities and tailoring its programmatic initiatives to support these objectives. In facilitating these processes and helping make them more effective, the OROM framework for NASA should support decisions made within the strategic management, mission support management, and program management functions of the agency. Simultaneously, it should support existing high-level reviews and decision forums conducted within NASA, such as meetings of the management councils, acquisition planning and procurement meetings, and performance review meetings.

The OROM process facilitates management activities by providing some of the key data and insights needed to make informed decisions. These processes are guided by information obtained

from both external and internal sources. The needed information includes knowledge and understanding of the constraints that are imposed by Government and other sources, as well as recognition of the problems that occur during the execution of the strategic plan, the opportunities that present themselves, the risks from potential adverse events that have not yet occurred, and the leading indicators that portend emerging problems, opportunities, and risks. (Note: leading indicators are traceable measures that are quantifiable, correlatable with the likelihood of success of one or more of the agency's objectives, and actionable.⁴)

2.1.5 How does OROM facilitate negotiations between an organization like NASA and the entities that govern it?

Although strategic planning is performed within the organization that is responsible for executing the strategic plan, external stakeholders often mandate many of the strategic objectives that the executing organization must achieve. OROM has a role to play in informing external stakeholders and funding entities about the achievability of various strategic objective alternatives so that these stakeholders can make informed decisions about which objectives to mandate. OROM does this by determining the overall risk of not being able to meet each strategic objective, taking into account all the individual risks and opportunities that accompany the objective. While stakeholders like Congress and the White House may have different views from an organization like NASA about what constitutes gain and what level of opportunity is significant, a majority can agree on whether the risk of not being able to achieve an objective is intolerably high so long as the case is laid out plainly and accurately. The justification of the case is the role that OROM plays. When an organization like NASA determines through OROM analysis that the aggregate risk of not being able to achieve an objective is steep and there are few opportunities for reducing it, it makes these findings known to all stakeholders to help discourage them from mandating unachievable objectives and from having unrealistic expectations.

2.1.6 Can various management units within the organization separately apply OROM?

OROM can be applied to autonomous, self-contained organizations such as agencies, institutions, and companies, or it can be applied separately to management units within an organization so long as the objectives of each management unit are consistent with the objectives of the organization as a whole, and the cross-cutting risks and opportunities are handled consistently. For example, NASA's management structure can be considered to consist of its administration and supporting offices providing its executive management, a set of mission directorates providing its programmatic management, and a set of centers and independent facilities providing its institutional and technical management as well as program/project support. Each of the mission directorates, centers, and independent facilities has its own top objectives and lower-level performance objectives, each with its own set of risks, opportunities, and associated indicators. Therefore, the OROM framework can be applied to each unit separately. However, the OROM processes applied for management units will not be successful unless there are both formal and informal communication channels to ensure that the top objectives of each mission directorate, center, and independent facility support the strategic objectives developed at the executive level,

⁴ Leading indicators will be discussed in considerable detail in Sections 4.4, 4.5, 5.4, 5.5, and 6.3.

and that the technical performance objectives of the centers and independent facilities support the program/project performance objectives of the mission directorates. Such communication channels must also ensure that risks, opportunities, and associated indicators that cut across management units are identified and accounted for by all affected parties in a consistent manner.

2.1.7 In what areas does OROM facilitate strategic planning, implementation, and evaluation of performance for organizations like NASA?

Following are examples of the planning, implementation, and evaluation processes that benefit from an OROM approach:⁵

- Developing the organization's strategic plans and performance management plans by selecting options that maximize the likelihood of successfully advancing the organization's fundamental mission. In the case of Federal agencies like NASA, OROM provides traceable and documented evidence for justifying the selections of objectives in a manner that is consistent with the constraints placed by the Government.
- Developing a portfolio of programs, projects, research initiatives, institutional assets, and other activities and resources by selecting alternatives that maximize the likelihood of successfully achieving the strategic objectives. OROM uses a risk-and-opportunity-informed decision making process to help the decision makers within the organization select the most viable portfolio.
- Promoting creative technologies and new processes and/or leveraging legacy systems for advancing the organization's mission in a manner that promotes a more optimal tradeoff between risk and opportunity while working within the reality of a limited and sometimes shrinking budget.
- Allocating the organization's facilities, infrastructure, and human resources in a manner that promotes a more optimal balance between the probability of success and the cost of implementation. In concert with the organization's ongoing technology capabilities assessment processes, OROM identifies organization-wide risks and opportunities that pertain to staffing requirements, the qualifications of the staff, test facility requirements, information technology needs, and other program/project support needs, thereby providing focus for institutional and mission support functions and initiatives.
- Tracking and controlling risks, opportunities, and leading indicators so as to facilitate evaluation of performance relative to the strategic and performance management plans. OROM provides traceable and documented evidence of how well the programs, projects, and other portfolio items are being implemented and the degree to which that implementation is satisfying the strategic and nearer-term objectives.
- Updating and amending the strategic and performance management plans at selected (usually different) intervals to reflect status changes and the emergence of new risks and opportunities.

⁵ Further elaboration on these points will be provided throughout the report.

- Complying with Federal and other regulations on risk and controls.
- Informing baseline performance reviews (BPRs) and periodic reviews of progress on objectives. OROM interacts with BPR and objectives-based reviews by helping to identify risk and opportunity indicators that each program needs to track and controls that each program needs to manage; by informing these reviews about how the indicators and controls cross programmatic boundaries; by helping to provide a logical basis for self-assessing performance relative to the strategic plan; and by helping to generate results that are required by external entities, including self-assessment results and rankings.
- Enabling an agile response to pervasive new conditions, either positive or negative, that demand immediate action. By treating risks and opportunities that cut across programs, projects, entities, and organizational units in a consistent and integrated fashion, OROM helps ensure that the means are in place to develop timely responses to newly developing cross-cutting issues that require an integrated response.
- Facilitating risk acceptance decisions at key decision points. Results obtained from OROM include an aggregation of risk and opportunity information from lower to higher levels, allowing decision makers to obtain insight into the overall level of concern or confidence attributable to the organization's chances of satisfying each of its top objectives.

The benefits that derive from using an OROM approach are particularly significant for complex missions that involve difficult choices between alternative pathways. Since NASA's mission and the programs that support it are by their nature complex (e.g., the proposed flexible path to Mars), the agency should benefit significantly by implementing an integrated OROM approach into its current management practices.

2.2 OROM Definitions and Technical Attributes

2.2.1 What is meant by “risk” and “opportunity” within the context of OROM?

Within the context of OROM, we define *risk* and *opportunity* as follows:

- *Risk* is the possibility of future performance shortfalls with respect to achieving explicitly established and stated objectives at all organizational levels, including the agency's strategic objectives.
- *Opportunity* is the possibility of future performance improvements with respect to achieving the explicitly established objectives and accomplishing the mission of the agency.

Risks and opportunities are always possible occurrences that may take place in the future. Once a risk is realized it becomes a problem and is no longer a risk. Once an opportunity is realized it becomes a gain and is no longer an opportunity.

Although the realization of a risk is viewed as negative and the realization of an opportunity is viewed as positive, risk and opportunity are two sides of the same coin. We speak of “the risk of missing an opportunity” to emphasize that missing an opportunity is a form of risk. In the same way, we speak of “the opportunity of mitigating a risk” to emphasize the fact that mitigating a risk is a form of seizing an opportunity. Both risk and opportunity require an action to achieve the best

possible outcome (i.e., mitigate a risk or seize an opportunity). The actions must occur within an acceptable timeframe to be effective.

That said, the fundamental difference between a risk and an opportunity is that the action is intrinsic to the definition of an opportunity but extrinsic to the definition of a risk. The potential negative outcomes that are the basis for identifying a risk exist as concerns prior to any intervention, whereas the potential benefits of an opportunity that are the basis for identifying a circumstance as an opportunity, only exist in the context of some action(s) that could be taken to realize those benefits.

In the present context, opportunity has two dimensions. The first applies to the potential to reduce the risk of not meeting one or more already-stated strategic goals or desired outcomes. For example, an emerging opportunity for an organization that has begun execution on a project to share a research and development task with a partner organization that has specialized expertise in that area, might result in a reduction of the risk of the originating organization failing in that task. The event that leads to the possibility of a partnership (e.g., the partnering organization expressing a willingness to participate) is an opportunity because it offers the promise of leading to a positive outcome. (In contrast, a risk leads to the possibility of a negative, or unwanted, outcome.)

The second dimension applies to an opening for changing strategic objectives or desired outcomes to align them better with the agency's vision and mission. For example, the emergence of a new technology might open up possibilities for the originating organization to achieve strategic benefits that were not previously considered possible. The latter type of opportunity pertains to promoting accomplishment of the agency's mission through strategic re-planning, rather than reducing the risk of not meeting its existing strategic objectives.⁶

Risks and opportunities may both have a timeframe associated with them, a "window of opportunity," after which response to the risk or seizure of the opportunity is no longer possible. This is one reason that an organization must be agile.

Significant gains in advancement or progress may involve proactively searching for opportunities, such as putting resources into basic or applied research, with the expectation that on the whole these efforts will bear fruit and speed the rate of progress toward long-term goals. In the words of Francis Bacon in 1612 [6]: "A wise man will make more opportunities than he finds."

2.2.2 How do we differentiate between risks and opportunities during strategic planning versus during plan implementation and performance evaluation?

OROM is concerned with agency-wide risks and opportunities during strategic planning, during development of the agency's portfolio of programs, projects, initiatives, and other activities, and during evaluation of performance. Strategic planning often occurs when the functions to be performed have been conceived but the specifics of the system design, and even the system architecture, have not yet been decided upon. In that case, the identification of risks and opportunities derives from historical experience, tempered with expert judgment, gained from

⁶ In Webster's online dictionary, "opportunity" is defined as: (1) a favorable juncture of circumstances, and (2) a good chance for advancement or progress. The two-dimensional definition in this paper is related to Webster's definitions, in the sense that an opportunity to reduce risk may emanate from "a favorable juncture of circumstances" and an opportunity to expand the strategic objectives may constitute "a good chance for advancement or progress." The relationship is, of course, not exact.

missions that have preceded the present one but are in some ways similar to it. (For example, the identification of risks for a low-earth-orbit mission using some future, as-yet undefined system may, for preliminary purposes, be considered to be informed by the risks that were identified for the Space Shuttle. These are risks that may or may not remain applicable as the system design matures, but that the organization needs to be aware of in making strategic decisions.)

Obviously, the state of definition of risks and opportunities for future missions without a specific system design will be less mature than for missions that have well-defined system designs. Correspondingly, the state of risk and opportunity definition during strategic planning will generally be less mature than during implementation and performance evaluation.

2.2.3 How does OROM achieve an optimal balance between risk and opportunity?

The concept of balancing risk against opportunity is illustrated schematically in Figure 2-1. As shown in the figure, the balance is a reflection of the decision maker's sense of the risk relative to his/her sense of the opportunity. In this context, "sense of the risk" is equivalent to one's tolerance for the risk as presently perceived, and "sense of the opportunity" is equivalent to one's appetite for the opportunity as presently perceived. Factors such as the availability of resources or assets, together with other fixed constraints, enter into the decision maker's sense of risk or opportunity.

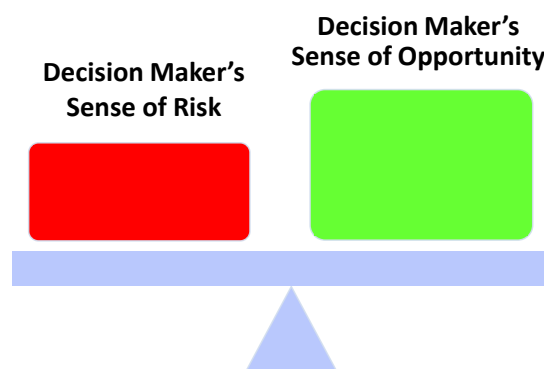


Figure 2-1. Decision making is a balance between risk and opportunity.

The balance between tolerating risks and seizing opportunities for organizations like NASA is informed by the NASA Administrator's comments cited earlier, which imply that the organization must manage risks and opportunities in a graded manner across its portfolio of activities. As shown in Figure 2-2, the organization has stricter standards (low tolerance for risk) relative to preserving its core capabilities and human lives and safety, while at the same time having more lenient standards (tolerating higher risk) relative to accepting the possibility of losing hardware in the pursuit of pioneering or capability-expanding activities that create new opportunities to more effectively advance the organization's mission. This considered grading of risk tolerance during strategic planning and during execution of the plan sets the ground-rules for *strategic risk taking* that is essential for progress and success over the long term. It creates areas where the organization learns rapidly, in part through constructive failures and setbacks, as well as promoting areas where

the gains made through high-risk activities are consolidated and institutionalized into a more capable agency.⁷



Figure 2-2. Risk tolerance relative to diverse goals and objectives.

There is a well-known tendency for such balances to be made based on psychological factors that are not always in the interest of making the optimum decision. A variety of treatises on risk aversion point out that when people are confronted with two choices where the balance between opportunity for success and risk of loss is neutral or even moderately favorable to the opportunity, they will tend to choose the path with lower risk. This aversion is related to the so-called Ellsberg paradox [7], which concerns people's choice between situations that exhibit different levels of certainty (they have "ambiguity aversion"). Use of OROM in a structured approach helps to counter risk aversion and ambiguity aversion by ensuring that strategic decisions are made more objectively.

The decision to pursue an opportunity in one area invariably involves exposure to risk in another area. For example, a major revision to a design may provide an opportunity to increase technical performance but simultaneously introduce risks to cost and schedule. OROM provides an structured means for determining the break-even point between the opportunity and the risk. It does this by examining the degree to which the opportunity meets or exceeds the decision maker's minimum expectation for an opportunity to be worthwhile, and comparing it to the degree to which the concomitant risk meets or exceeds the decision maker's tolerance for risk. In other words, OROM assesses the likelihood and magnitude of benefit and the likelihood and magnitude of loss relative to each of the agency's strategic objectives, and the decision maker's stated risk tolerance and opportunity appetite determine whether or not the former justifies the latter.

In the case of NASA, this point is strongly supported by the Aerospace Safety Advisory Panel (ASAP), who in their 2013 Annual Report stated: "We fundamentally believe that NASA should be plain-speaking and transparent with regard to risk acceptance and that risk and reward must be pursued in harmony and balance." Ultimately, the decision maker has the responsibility to define risk tolerance levels rather than simply accept a risk-averse stance.

⁷ The subjects of risk tolerance, opportunity appetite, and the break-even point between them will be discussed further in Sections 4.3, 5.5, and 8.4.

2.2.4 What is meant by the terms “risk scenario,” “opportunity scenario,” “cumulative risk,” and “cumulative opportunity”?

The OROM process identifies specific concerns that are perceived as presenting a risk to the ability to achieve one or more strategic objectives. Each concern implies a scenario of events that must happen in order for the risk to “come true.” Collectively, these individual scenarios comprise the cumulative, or aggregate, risk of not being able to achieve the objective.

It is common practice to use the term “risk” to denote both the individual concern, or scenario, and the cumulative likelihood of not meeting the objective. The differentiation between the two is provided by the context, but sometimes, this dual usage leads to confusion when the context is not clear. In such cases, we refer to the specific concerns as being “risk scenarios” and the effect on the strategic objective as being “cumulative risk” or “aggregate risk.” For example, the possibility of staffing shortages in a crucial technical area due to higher than expected retirements is a risk scenario, and the likelihood of not being able to launch a mission that is critical to a strategic objective or goal as a result of this and other risk scenarios is a cumulative risk.

Likewise, the OROM process identifies specific scenarios that, if they should occur, would lead to an opportunity to either increase the likelihood of achieving a strategic objective or open the possibility of defining a new objective that coincides with the agency’s mission. Therefore, we sometimes use the term “opportunity scenario” to differentiate the individual context for opportunity from the cumulative context. For example, the possibility of a breakthrough in the development of a new technology, opening the possibility of taking a positive action to reap the benefit, is an opportunity scenario. The prospect of translating that development, along with other opportunistic developments and directed actions, into higher performance for a strategically critical mission is a cumulative opportunity.⁸

2.2.5 How does OROM incorporate RIDM and CRM within the organization as a whole and within different management units?

OROM is operationalized within an organization through the introduction of risk- and opportunity-informed decision making and continuous risk and opportunity management into the organization’s management processes. In both the program/project domain and the institutional/technical domain, they are denoted as risk-informed decision making (RIDM) and continuous risk management (CRM). For NASA, definitions and guidance for RIDM and CRM may be found in NPR 8000.4A [2] and in the NASA Risk Management (RM) Handbook [8]. As shown in Figure 2-3, they are executed at each of the management levels of the organization.

⁸ The concept of cumulative risks and cumulative opportunities will be discussed in considerably more detail in Sections 4.5 and 5.5.

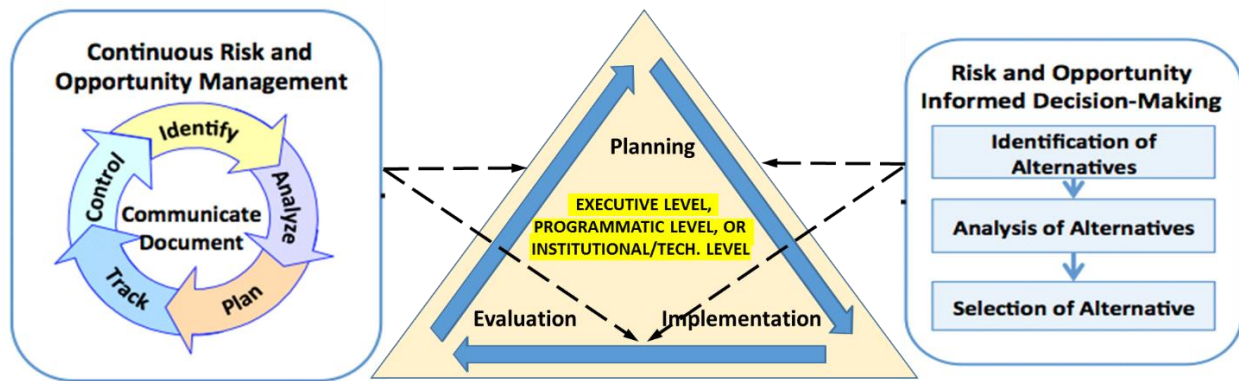


Figure 2-3. The elements of RIDM and CRM applied to the agency's management activities at various levels.

For the organization as a whole, risk- and opportunity-informed decision making is applicable to strategic planning activities and the selection of the agency's portfolio of programs, projects, etc. It is similar to its counterpart for programs/projects, RIDM, but it is expanded to make opportunity a major component of the decision making process. It is used first to help executive management select from among various alternative sets of long-term strategic objectives and nearer-term programmatic objectives in formulating a strategic plan, subject to external constraints, that supports the agency's mission. It is then used to help executive management select from among various alternative portfolios of programs, projects, institutional initiatives, and other major initiatives, and/or between different overall implementation approaches, to support the achievement of the strategic objectives. Like the RIDM process that it is derived from, it is composed of the following three steps: 1) identification of alternatives, 2) analysis of alternatives, and 3) the selection of an alternative.

Continuous risk and opportunity management, for the agency as a whole, is applicable to implementation of the portfolio approved at the executive level and to evaluation of the agency's performance relative to the strategic objectives. The process of managing risks and opportunities on a continuing basis is similar to the CRM process exercised for programs/projects as described in the NASA RM Handbook, except again for the expansion to make opportunity a major component in the management process. Like its CRM counterpart, it consists of the following five basic actions: 1) identify, 2) analyze, 3) plan, 4) track, and 5) control. This five-step process is supported by robust communication and documentation.

In incorporating RIDM and CRM into OROM for different management units, the areas of emphasis tend to differ according to the responsibilities assigned to each unit. At the executive level, emphasis is on strategic objectives and meeting the overall goals of the agency. For management units within the programmatic level (e.g., NASA mission directorates), the emphasis shifts to programmatic objectives and meeting project milestones within established schedules and costs. For management units within the institutional/technical level (e.g., NASA centers), there is an increased emphasis on the development and maintenance of the workforce, facilities, and support systems. While the areas of emphasis may differ, however, the general approach for incorporating RIDM and CRM into OROM is basically the same whether applied at the executive level, the programmatic level, or the institutional/technical level.

2.2.6 Is the analysis in OROM principally qualitative or quantitative?

OROM uses a mixture of qualitative and quantitative methods. On the one hand, quantitative models are used for assessing and predicting specific outcomes that are amenable to quantitative analysis (e.g., matters of budget and schedule). On the other hand, there is a greater reliance on qualitative methods for OROM than there is for program/project risk management. That is because OROM involves assessments of strategic goals and objectives that are largely subjective in their interpretation and for which there are no easily formed quantitative models (e.g., increase human knowledge of the solar system; promote the development of groundbreaking new technology; etc.). To assess the status or potential for achieving such goals and objectives, OROM relies on risk and opportunity leading indicators⁹, which serve as surrogates for the identified risks and opportunities. Although the leading indicators are in themselves quantifiable, their relationship to the actual risks and opportunities is qualitative, and hence the OROM analysis itself is more qualitative than quantitative.

2.2.7 Can OROM account for unknown and underappreciated (UU) risks?

Unknown and underappreciated (UU) risks are risk scenarios that either have not been identified and are therefore unknown at the time of analysis, or have been correctly identified but for which the likelihood of occurrence and/or potential severity of harm or loss are underestimated. By definition, it is not possible to identify unknown scenarios before they are revealed, or to be aware that a known scenario is underappreciated before it is better understood. It is possible, however, to be aware of various types of indicators that can be correlated with the likelihood of unknown and underappreciated risks, based on experiences that have been reported in the literature. These indicators tend to be associated with organizational shortcomings, questionable managerial practices, and certain design approaches. As will be discussed shortly, OROM analyses are able to include these indicators in the assessment of whether UU risks are likely to be a large contributor to the overall risk of not achieving the organization's objectives.

Recent work reported in Volume 2 of the NASA System Safety Handbook [9] and in the Journal of Reliability Engineering and System Safety [10] has demonstrated that for complex systems that are breaking new ground, the probability of loss from UU risks early in a program or during the initial stages of operation can be several times greater than the probability of loss from known risks. This has been found to be true not only for safety risks but also for technical, cost, and schedule risks, and not only for space systems but also for other systems such as commercial nuclear and military. The presence of UU risks can therefore significantly affect the ability of an organization to achieve its strategic objectives.

An understanding of the potential magnitude of UU risks in each area of concern, and the factors that are causing them to be of concern, is important for at least the following two reasons:

⁹ We use the term "risk leading indicator" to refer to a possible future development that is indicated by a present condition which is evolving with time. We include the word "leading" to emphasize that these indicators may be changing with time, and that one needs to track not only their present values but also their trends to infer potential future values.

- It helps inform external stakeholders about the achievability of various strategic objectives and portfolio alternatives so that these stakeholders can make informed decisions about how to allocate funding.
- It helps identify ways for mitigating the design-related, organizational and programmatic causes of UU risks, thereby increasing the potential for achieving the agreed-upon strategic objectives.

It has *not* been common practice for UU risks to be considered as a part of an OROM analysis, but the approach recommended in this report goes beyond present practice by considering the organizational, programmatic, and design factors that can lead to UU risks. These factors, obtained largely from [9] and [10], are treated as leading indicators of UU risk, and are included in the roll-up of leading indicators that is performed to estimate the aggregate risk of not being able to meet each strategic objective. The treatment of UU risks is itself qualitative, in keeping with the epistemic nature of UU risks and the overall qualitative nature of OROM. The potential effects of UU risks are included both in the strategic planning, RIDM-based aspect of OROM, and in the performance evaluation, CRM-based aspect of OROM. The treatment of UU risks within the OROM framework will be discussed further in Sections 4.4.4, 5.4.3, and 5.6.5.

3. Coordination of OROM with Management Activities

Although the need for OROM in nonprofit technical organizations may be driven by a need to provide innovative technical solutions to complex problems, it is also desirable, and often necessary, to implement OROM within the current management framework of the organization.

3.1 The Executive, Programmatic, and Institutional/Technical Management Functions and their Interfaces

While the detailed organizational and management structure of individual organizations differs, most share common top-level organizational entities, management processes, and management activities. Generally, as illustrated in Figure 3-1, an organization like NASA may be described as being comprised of three management levels: 1) an executive level that sets and manages the direction and strategy for the organization, 2) a programmatic level that develops and manages the programs and projects that support the strategic plan, and 3) an institutional/technical level that develops and manages the institutional and technical resources that support the programs and projects. Decision making involves robust communication within and among all levels.

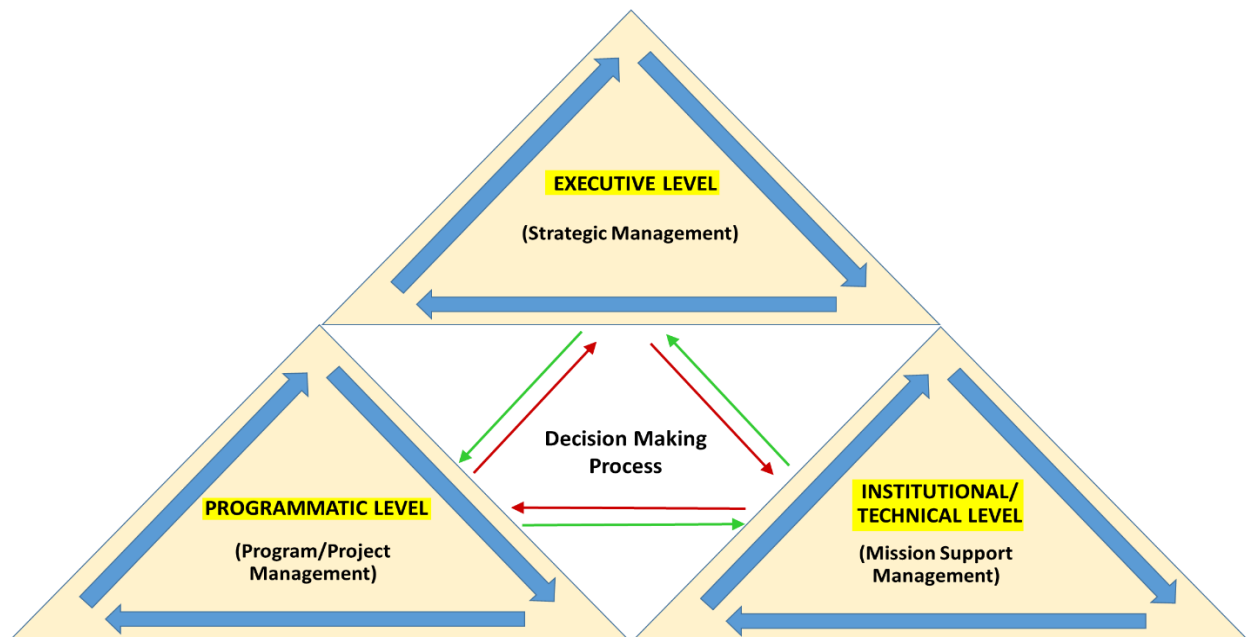


Figure 3-1. The three levels of management within an organization like NASA.

Each of these organizational levels performs a similar set of management activities, as shown in Figure 3-2. These activities include planning, plan implementation, and performance evaluation. At the executive level, management sets the overall strategic objectives, goals, and desired outcomes for the organization; develops a plan for implementation, including the definition of major programs and projects and specification of institutional support requirements; evaluates performance in terms of the degree to which its strategic objectives are being realized; and makes major course correction or course resetting decisions when conditions warrant. At the programmatic level, program/project management provides the same goal setting and execution oversight with respect to the programs and projects that the executive level initiates. At the institutional/technical level, management does the same for the institutional and technical

capabilities of the organization, including the sufficiency of the workforce, availability of facilities, and integrity of procurement and quality control practices. The transfer of information between the organizational levels is bidirectional, with the results of the planning activities being communicated in general from executive to programmatic to institutional/technical level, and the results of the evaluation activities being communicated in general from institutional/technical to programmatic to executive level (although the direction of communication may vary according to the nature of the organization).



Figure 3-2. The principal activities and transfer of information within and between levels of management.

3.2 OROM-Relevant Management Activities within Each Level

At the executive level, the processes of strategic planning, strategic plan implementation, and strategic performance evaluation are guided by information obtained from both external and internal sources, as shown in Figure 3-3. The information to be gleaned from external sources includes:

- Mission priorities, programs/projects, schedules, and budgets that are mandated by external stakeholders and funding authorities, such as Congress and the President in the case of Federal agencies such as NASA
- Supply constraints such as the availability of suppliers, parts, and materials
- Marketplace constraints such as inflation rates and competition from other agencies, both domestic and foreign
- Political constraints, such as the prospects for changes in the Administration or the makeup of Congress, or restrictions on certain foreign entities
- Legal constraints, such as new enactments with new requirements or threats of litigation

- The emergence of new technology that may open opportunities for undertaking new objectives or achieving faster progress toward current objectives, or conversely pose new threats (e.g., cyber security)

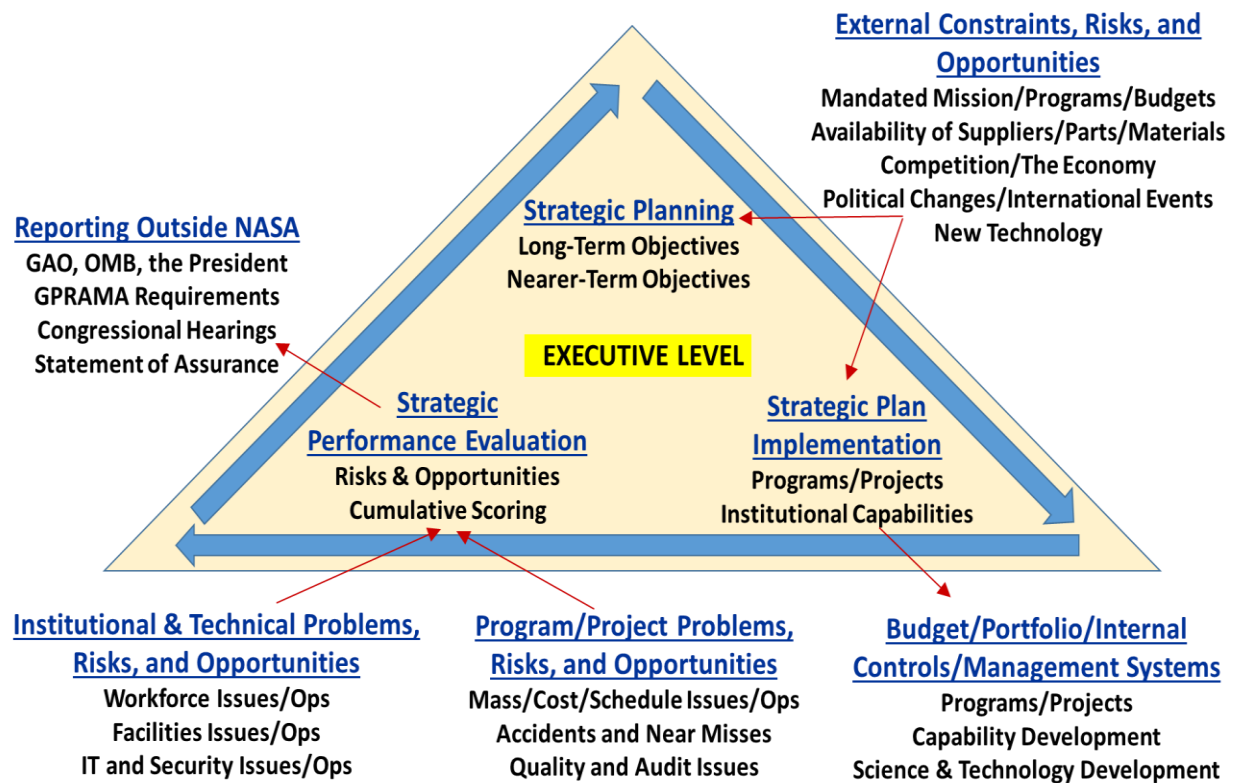


Figure 3-3. Activities within the executive level at NASA and transfer of information from/to external and internal sources.

In addition, information is transferred from the executive level to agencies external to or independent from the NASA management structure, such as the GAO, the OMB, Inspectors General, and Congress in the form of presentations and reports.

Information to be received from internal sources (programmatic and institutional/technical levels) includes:

- The status of risks and opportunities for programs/projects, including safety concerns, technical performance concerns, cost concerns, and schedule concerns
- The status of risks and opportunities at the institutional/technical level, including workforce concerns, concerns with facilities and equipment, IT concerns, and security concerns
- Identification and evaluation of risks and opportunities that cut across programs, projects, and institutional/technical entities
- The status of concerns within the programmatic and institutional/technical levels that have evolved from risks to problems, and the status of corrective actions

Correspondingly, information is transferred from the executive level to the programmatic and institutional/technical levels via the strategic plan, and associated back-up material, including in particular, the specifications for the agency's portfolio of programs, projects, institutional initiatives, research and development initiatives, resource expectations, schedules and budgets, etc.

The activities and transfer of information at the programmatic or mission directorate level parallel the activities and transfer of information at the executive level, but with the following differences as shown in Figure 3-4:

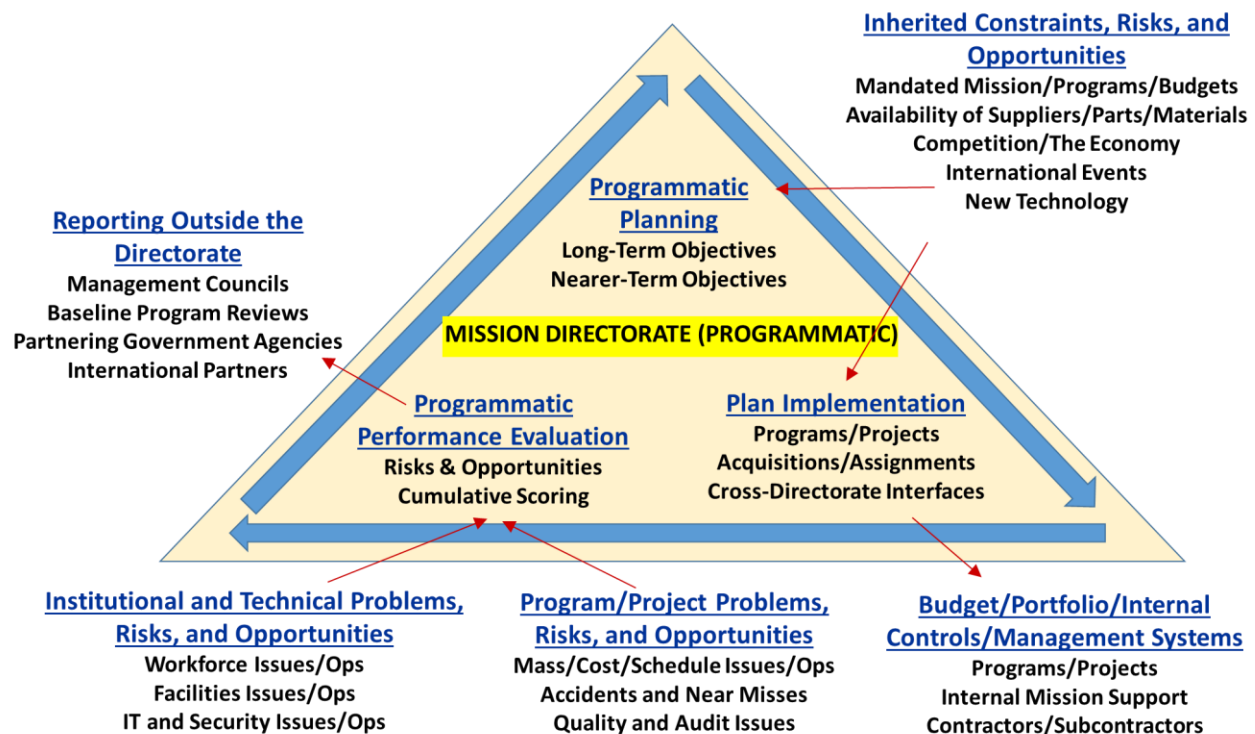


Figure 3-4. Activities within a mission directorate (programmatic level) at NASA and transfer of information from/to external and internal sources.

- The top objectives are programmatic and, for the most part, are received from the executive level as part of its strategic planning and plan implementation activities.
- The results from the programmatic planning, implementation, and performance evaluation activities are presented to the various governing councils within NASA.
- The results from the programmatic performance evaluation also provide input to NASA's Baseline Performance Reviews (BPRs).
- Implementation of the programmatic planning activity includes feedback to and from other mission directorates, particularly regarding concerns that cut across mission directorates.

By and large, the mission directorates operate as individual organizations, so from a practical point of view, the principles of OROM apply to them as well as to the executive level.

The same is true for the centers, as shown in Figure 3-5. The activities and transfer of information at the center level parallel the activities at the mission directorate level, except that the top

objectives concern institutional and technical capability development as well as support of the programs/projects. These top objectives require the centers to concentrate, in their planning processes, on how to achieve an efficacious balance between services provided directly by them versus services acquired from other entities such as commercial companies, universities, and other agencies.

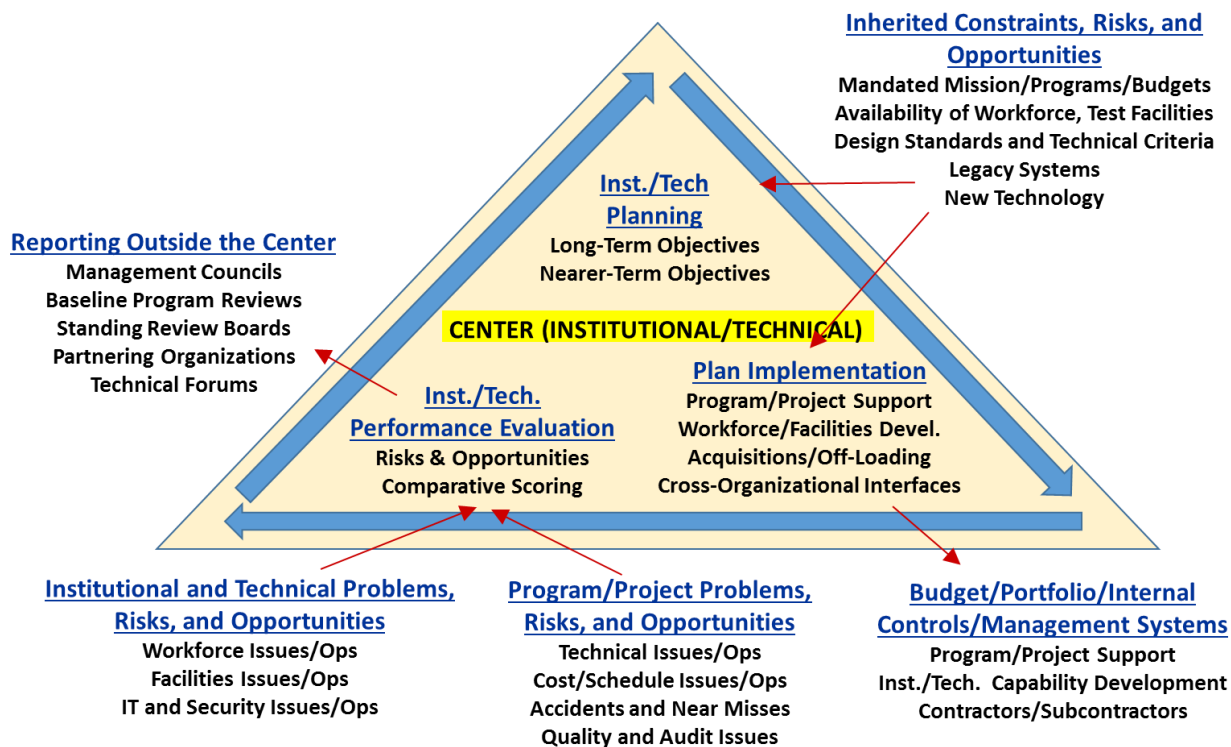


Figure 3-5. Activities within a center (institutional/technical level) at NASA and transfer of information from/to external and internal sources.

3.3 Coordination of OROM with Management Activities

3.3.1 Organizational Planning and Plan Implementation

The manner in which OROM assists management at all three levels in developing a responsive and achievable plan is illustrated in Figure 3-6. Following is a brief summary of the activities depicted in this figure:

Management activities that provide input to the OROM process

- Understand and comply with external constraints such as mandated missions and programs, mandated budgets, the availability of suppliers and parts or materials, and legal realities.
- Identify alternative objectives hierarchies that comply with the external constraints and have the potential for achieving the organization's mission in all timeframes.

OROM activities that provide input to the management activity of selecting among alternative objectives and preparing the organizational plan

- Characterize and understand all relevant historical experience pertaining to failures, successes, precursors, anomalies, unexpected benefits, and lessons learned.
- Identify risks and opportunities for each alternative set of objectives based on the historical record and expert judgment.
- From past experience and current risk/opportunity leading indicators, assess the state of risks/opportunities as they pertain to the likelihood of achieving each objective.
- Risk-inform the selection and application of internal controls.

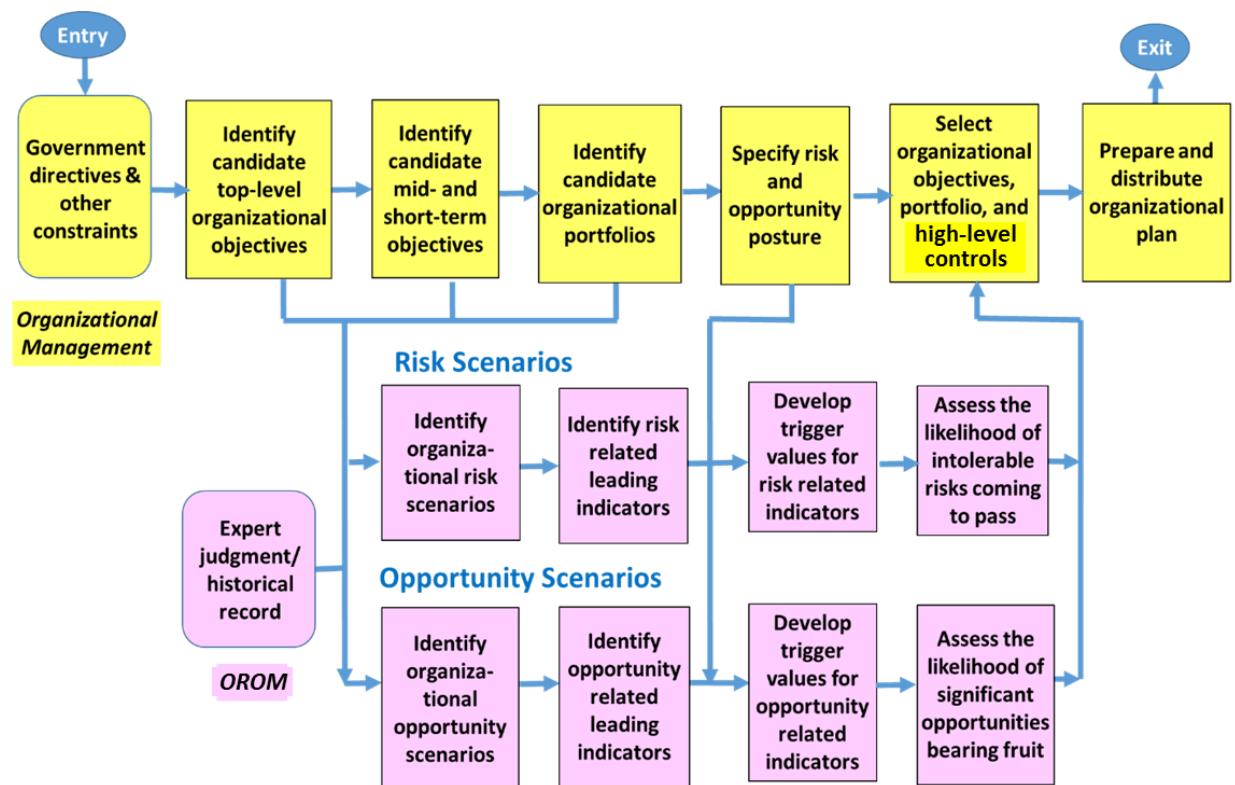


Figure 3-6. Interfaces between OROM activities and management activities in the development of an organizational plan

3.3.2 Evaluation of Organizational Performance and Re-Planning

The evaluation of performance at the various management levels also involves close coordination between management activities and OROM activities. From an OROM perspective, the activities that support performance evaluation are similar to the activities that support organizational planning in the sense that both involve the identification and evaluation of risks and opportunities. As discussed in Section 2.2.2, the key difference is in the level of maturity that exists in the definition of risks and opportunities.

The manner in which OROM assists management in evaluating organizational performance is illustrated in Figure 3-7. Following is a brief summary of the activities depicted in that figure:

Management activities that provide input to the OROM process

- Track progress on individual programs, projects, institutional initiatives, and other activities in the portfolio with respect to meeting the mid- and short-term objectives in the organizational objectives hierarchy.
- Conduct a baseline performance review (BPR) at periodic intervals to assess overall adherence to the performance plan and to identify and evaluate cross-cutting issues.

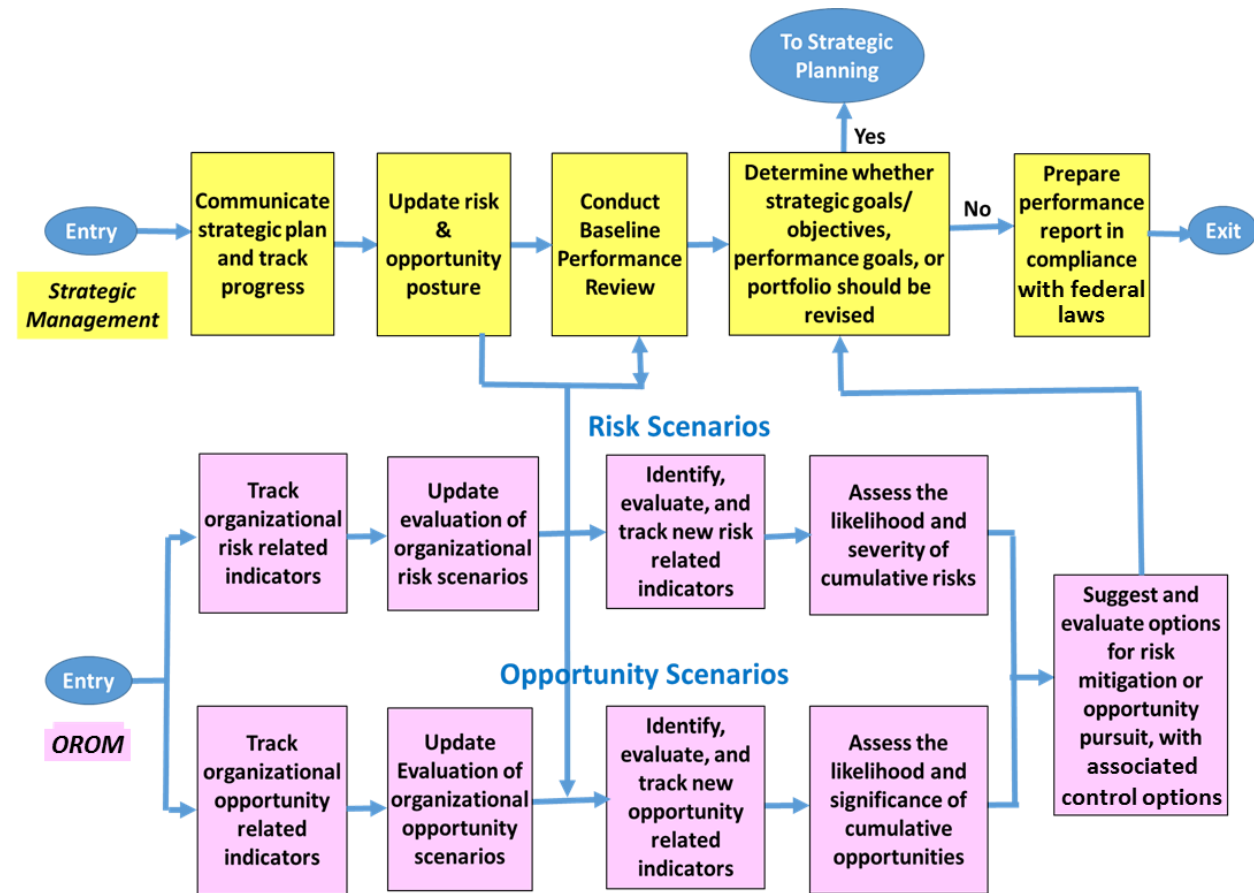


Figure 3-7. Interfaces between OROM activities and management activities in the evaluation of performance relative to the organizational plan

OROM activities that provide input to the management activity of conducting the baseline performance reviews

- Track leading indicators that pertain to organizational risks and opportunities. (Note that risks and opportunities that enter at executive level generally emanate from external sources such as political, economic, or regulatory changes, whereas risks and opportunities that enter at lower management units and propagate upward generally emanate from internal sources such as the depletion of reserves and margins in any of the mission execution domains: safety, technical performance, schedule, and cost.)
- From the current values of the leading indicators, assess the significance of the risks and opportunities at each level in the organizational objectives hierarchy.

OROM activities that provide input to the management activity of evaluating organizational performance

- Identify and track internal performance measures and internal/external leading indicators of risks and opportunities that pertain to the mid- and short-term organizational objectives.
- From the current values of the performance measures and leading indicators and their observed trends, assess the state of risks and opportunities as they pertain to the likelihood of achieving the top organizational objectives.
- When risks are of concern, or when opportunities are attractive, perform an analysis to suggest options that may be pursued to mitigate risks or pursue opportunities and identify associated controls.

With these inputs in hand, management has a solid basis for determining whether the organization's objectives are being achieved and whether there are imposing reasons (either positive or negative) for amending or changing some of the objectives and/or portfolio elements. The organization also is in a better position to prepare performance reports and presentations of the type required by the external stakeholders and funding agencies.

3.4 Communication across Extended Partnerships

3.4.1 Nature of the Strategic Objectives that Require Extended Partnerships

Large not-for-profit organizations like NASA tend to have a diversity of strategic objectives that go beyond technical and scientific accomplishments related to the prime mission to geopolitical, macroeconomic, and societal objectives that require extensive collaboration. Following are several strategic objectives (S.O.'s) from NASA's strategic plan that fall into this category [emphasis added to highlight the point]:

- [S.O. 1.1] Expand human presence into the solar system and to the surface of Mars to advance exploration, science, innovation, benefits to humanity, and *international collaboration*
- [S.O. 1.2] Conduct research on the International Space Station (ISS) to enable future space exploration, *facilitate a commercial space economy*, and advance the fundamental biological and physical sciences for the benefit of humanity

- [S.O. 1.3] Facilitate and utilize U.S. *commercial capabilities* to deliver cargo and crew to space
- [S.O. 1.7] Transform NASA missions and advance the Nation's capabilities by maturing *crosscutting and innovative technologies*
- [S.O. 2.4] Advance the Nation's STEM education and workforce pipeline by working *collaboratively with other agencies* to engage students, teachers, and faculty in NASA's missions and unique assets

These objectives require NASA to work collaboratively with other US agencies, foreign agencies, commercial entities, and educational entities. Most of the collaboration takes place within projects, programs, and special activities (such as new technology development) that are designed to satisfy the strategic objectives of the managing organization.

3.4.2 The Challenges of Conducting OROM across Extended Partnerships

Implementing an effective OROM process within an organization that depends on extended partnerships can be challenging. For example, according to a deputy director of the US Department of Defense's National Geospatial-Intelligence Agency [11], writing about the practice of risk management across extended partnerships: "Culture resistance to change and unwillingness to share information viewed as negative prevail. There is additional complexity convincing people to adopt a process that is part of the bigger organization and sharing information regarding their ability to achieve program objectives."

In general, the following attitudinal and operational perspectives are needed to accomplish a satisfactory implementation of OROM when extended partnerships are involved [11, 12]:

- Managers within each of the partners need to be convinced that making risk known to all participants in the extended partnership will be positively recognized and at times rewarded with an allocation of risk mitigation funds.
- Partners whose components or systems are being integrated with those of other partners need to be convinced that it is to their benefit to collaboratively and cooperatively manage risks evolving from the integrated relationships.
- When joining entities managed by distinctly different organizations to create an extended partnership, diverse leaderships, objectives, motivations, and other cultural views (and ways of doing risk management) need to be melded in accordance with proprietary, ITAR, and other considerations.

According to various sources, the single most important factor for achieving buy-in across an extended partnership is for senior leaders of each partnering organization, especially at the top level, to repeatedly voice their support and enforce accountability for an integrated risk and opportunity management process across the partnership. More discussion on this subject will occur in Section 6.2 within the context of the extended partnerships that are managed within NASA centers.

4. Overview of the OROM Process and Analysis Approach

This section discusses some of the main processes and analysis activities that are involved in conducting OROM in coordination with organizational planning, plan implementation, and organizational evaluation of performance. The topics include the basic principles for deriving organizational objectives hierarchies; developing risk and opportunity information for each objective; understanding risk tolerance and opportunity appetite; composing organizational risk and opportunity scenario statements; identifying corresponding risk and opportunity leading indicators, including leading indicators for UU risks; correlating strategic success likelihoods with leading indicator values; rating the likelihood of success for the various goals and objectives; identifying risk and opportunity drivers; and identifying/evaluating various options for mitigating risk, availing opportunity, and setting up internal controls.

4.1 Organizational Objectives Hierarchies

4.1.1 Objectives Hierarchies for Each Management Unit

Although the particulars of the management structures of organizations like NASA tend to vary from one organization to another, the process of developing objectives hierarchies for each management unit tends to be uniform. It consists of identifying the unit's top objectives, which tend to be mandated by the entities that the management unit supports, and for each top objective, devising a set of underlying performance objectives whose success leads to the success of the top objective. The top objectives generally have a longer-term focus, and the supporting performance objectives a shorter-term focus. We can therefore illustrate the process of devising objectives hierarchies assuming a management structure similar to NASA's and contend that the process applies equally well to organizations that have a different management structure.

Strategic planning at the executive level generally produces a set of strategic objectives, and under the strategic objectives a set of top programmatic objectives and a set of top institutional and technical objectives (see Figure 4-1). The strategic objectives typically cover a 10-year timeframe or greater. [Example: Expand human presence into the solar system and to the surface of Mars.] The top programmatic objectives typically cover a 5 to 10 year timeframe, although these boundaries are flexible. [Example: Develop the Space Launch System (SLS), the Orion

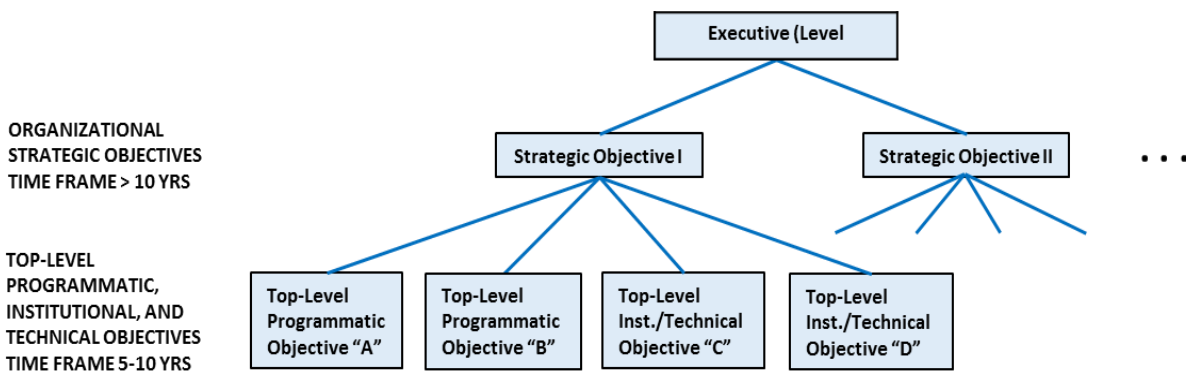


Figure 4-1. Types of objectives developed at the executive level

Multi-Purpose Crew Vehicle (MPCV), and the Exploration Ground Systems (EGS).] Similarly, the top institutional and technical objectives typically cover a 5 to 10 year timeframe and support the top programmatic objectives. [Example: Maintain a qualified workforce and necessary facilities to support the SLS, MPCV, and EGS programs, and develop the needed technology base for human survival on Mars.]

The managerial units at the programmatic level at NASA consist of a set of mission directorates. Each mission directorate is responsible for one or more of the top programmatic objectives that flow down from the executive level. Underneath each top programmatic objective is a set of nearer-term objectives, which for convenience are divided into different timeframes (see Figure 4-2). At NASA, these nearer-term objectives are referred to as performance goals, which have a 1 to 5 year timeframe, and annual performance goals, which have a 1-year or less timeframe. Those with especially high priority are referred to as Agency Priority Goals (APGs). In this report we refer to the NASA performance goals and annual performance goals as mid-term objectives and short-term objectives, respectively, to keep the nomenclature more-or-less generically applicable not only to NASA but also to organizations like NASA.

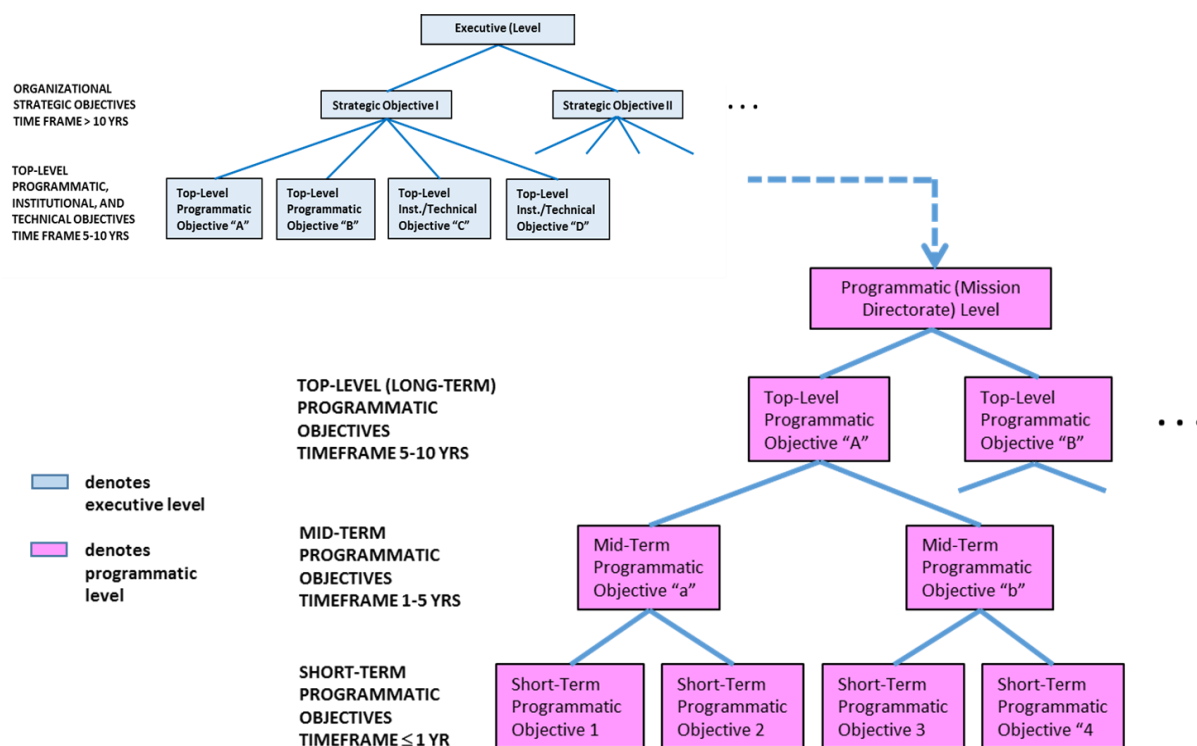


Figure 4-2. Types of objectives developed at the programmatic level

The managerial units at the institutional/technical level at NASA consist of a set of centers. Each center generally serves two purposes: (1) developing and maintaining the institutional and technical capabilities needed to satisfy those strategic objectives that pertain to infrastructure and technical capability, and (2) taking technical (often including technical management)

responsibility for ensuring that the programmatic objectives are successfully satisfied.¹⁰ Similar to the objective breakdown for the mission directorates, the objectives for the centers start from top objectives passed down from the executive level and continue down to mid-term and short-term objectives (i.e., performance goals and annual performance goals in NASA’s terminology). This breakdown is shown in Figure 4-3.

4.1.2 Objectives Hierarchy for the Agency as a Whole

Once the objectives hierarchies have been determined for each management unit of the agency, it should be possible to combine them into a single agency-wide objectives hierarchy that consists of an amalgam of the various management unit hierarchies. A conceptualization of such a composite agency-wide objectives hierarchy is shown in Figure 4-4. The red arrows between units in this figure are intended to be representative of the interfaces that would exist between different management units and their respective objectives. It is these interfaces that dictate how the status of objectives within the various management units affects the status of the strategic objectives at the top of the organization.

The interfaces shown by red arrows in Figure 4-4 are in reality a simplification of the complex interactions that tend to exist between the various management units and their objectives. These interactions are better displayed by other means such as tables and templates. The use of templates to account for inter-unit interactions in the roll-up of risks and opportunities to strategic level will later be demonstrated in Section 5.

4.2 Populating the Organizational Objectives Hierarchies with Risk and Opportunity Information

A principal product that OROM provides to support both organizational planning and organizational performance evaluation is an assessment, including a ranking, or rating, of each objective in the objectives hierarchy in terms of its “cumulative risk” and “cumulative opportunity.” The cumulative risk, or aggregate risk, for an objective is basically the likelihood of not being able to achieve the objective based on following the current plan. The cumulative opportunity for an objective is the likelihood that it will be possible to improve the plan based on future developments so as to be able to achieve the objective. Refer to Section 2.2.4 for a definition of these terms.

This ranking evolves as a result of completing the processes that were outlined in Sections 3.3.1 and 3.3.2 and depicted in Figures 3-6 and 3-7. The processes involve the following steps, the results of which are illustrated in Figure 4-5:

- Identifying the individual risks and opportunities that affect each objective
- Identifying associated leading indicators that can be used to gauge the significance of the risk/opportunity and trend its status over time

¹⁰ The centers also serve in an additional role as Technical Authority, but this role does not entail an associated decomposition of objectives and is therefore not included in the discussion that follows.

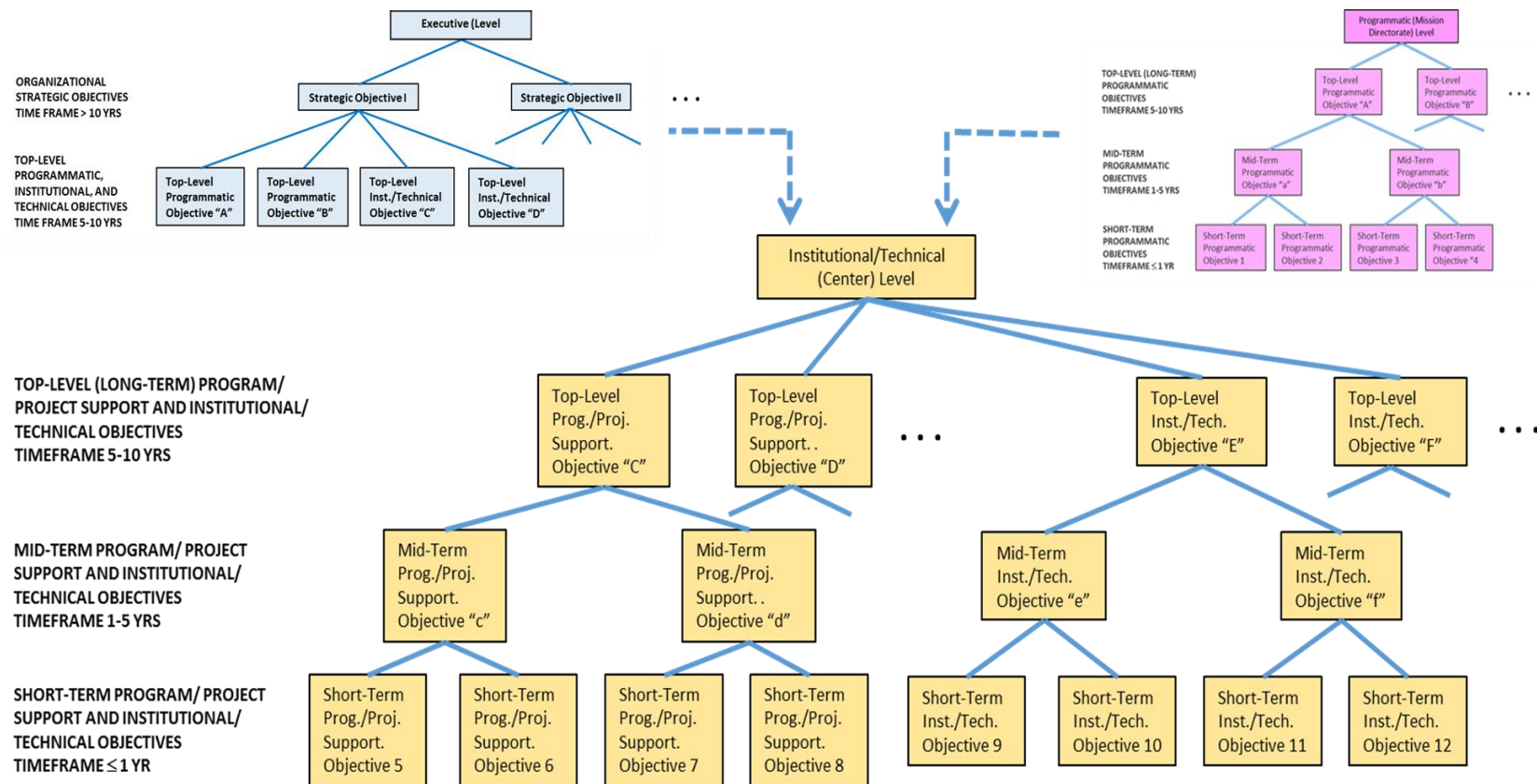


Figure 4-3. Types of objectives developed at the institutional/technical level

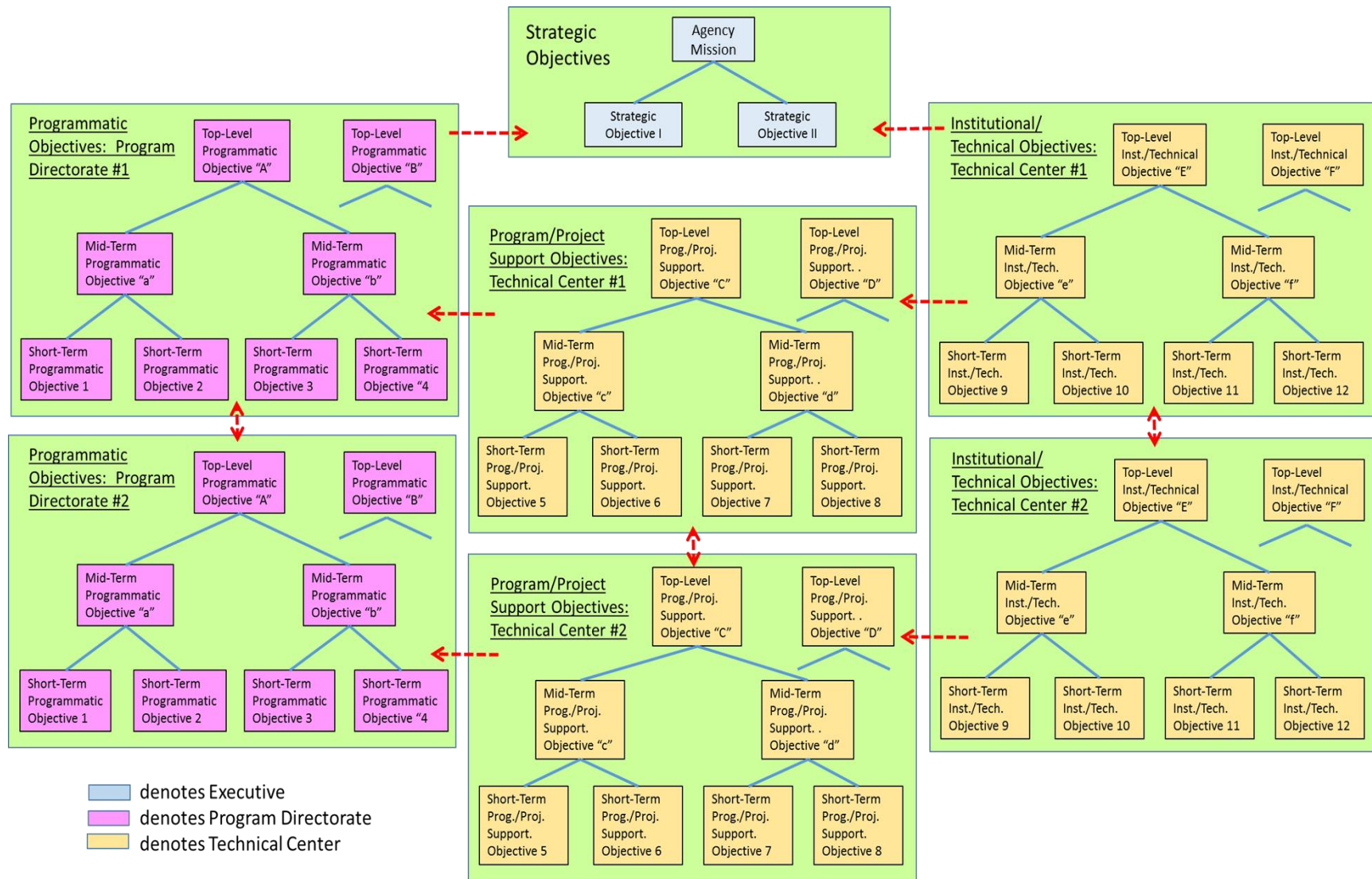


Figure 4-4. Conceptualization of an agency-wide objectives hierarchy

- Establishing trigger values for the leading indicators based on the risk tolerances and opportunity appetites that the stakeholders (which may include both external funding authorities and internal decision makers) have relative to the affected objective(s)
- Determining the current status of each leading indicator, accounting for both the current values of the indicators and their current trends

Two other steps are depicted in Figure 4-5, the intricacies of which may not be immediately obvious to the reader:

- Rolling-up the statuses of the risk and opportunity leading indicators for each objective to infer aggregated risk and opportunity status rankings (or ratings) for the objective
- Rolling-up the risk and opportunity status rankings for the all objectives in the hierarchy to infer risk and opportunity status rankings that include influences from other objectives.

The processes involved in performing these roll-up steps will become more apparent as the explanation of the processes unfolds in later sections.

As called out in Figure 4-5, the same steps are performed with the same form of results being obtained whether the processes are applied during organizational planning or during organizational performance evaluation. During organizational planning, details of architecture and design are generally not yet available, and so the risks and opportunities are based on historical experience. During organizational performance evaluation, the architectures and designs are in a mature enough state to base the risks and opportunities on actual architectures and designs.

In Figure 4-5, the information provided for the individual opportunities may be seen to include not only opportunity scenarios but also introduced risk scenarios. Introduced risks are a by-product of opportunities in the sense that the fulfillment of an opportunity requires an action that is not currently in the plan and that may introduce one or more associated risks. For example, availing an opportunity created by the emergence of a new technology may introduce risks associated with first-of-a-kind uncertainties and development costs. The nature of introduced risks will be explored more fully in Sections 5.4 and 5.5.

4.3 Establishing Risk Tolerances and Opportunity Appetites

As discussed in Section 2.2.3 and depicted conceptually in Figure 2-2, a preliminary step needed before establishing trigger values for leading indicators or rolling up individual risks and opportunities to cumulative values is to establish the risk and opportunity posture for the stakeholders. The risk and opportunity posture is specified through an elicitation of their risk tolerance and opportunity appetite for each objective on the objectives hierarchy.

Risk tolerances and opportunity appetites for the top organizational objectives generally evolve from a roll-up of the tolerances and appetites specified by the stakeholders at the lower levels, taking into account other considerations such as the timeframe for response.

4.3.1 Risk and Opportunity Parity Statements

The risk tolerances and opportunity appetites elicited from the stakeholders may be expressed in the form of risk and opportunity parity statements. These statements define boundaries between tolerable and intolerable risks, and between significant and insignificant opportunities. Each risk

and opportunity parity statement reflects a common level of pain or gain from the stakeholders' perspective. This enables comparisons between risk and opportunity to be meaningful because:

- The amount of risk perceived by the stakeholders (i.e., their level of pain) is the same for each parity statement.
- The amount of opportunity perceived by the stakeholders (i.e., their level of gain) is the same for each opportunity parity statement.
- For each pairing of risk and opportunity parity statements, the amount of risk (pain) is balanced by the amount of opportunity (gain).

Risk tolerance and opportunity appetite statements that are elicited from the stakeholders can take various forms. For example, they may involve probabilities of failure or success in satisfying a particular objective, or they may involve changes in the achievable values of key performance parameters that affect a particular objective. To illustrate this point, consider the following hypothetical risk and opportunity parity statements:

Examples of Risk and Opportunity Parity Statements

[Example Risk Tolerance Statement 1]: A risk scenario is considered to reach the risk tolerance boundary if the likelihood of failure to land humans on Mars by 2035 increases from its targeted value of 10% to 20%.

[Example Risk Tolerance Statement 2]: A risk scenario is considered to reach the risk tolerance boundary if the targeted date of 2035 for landing humans on Mars increases to 2045.

[Example Risk Tolerance Statement 3]: A risk scenario is considered to reach the risk tolerance boundary if the total cost of landing humans on Mars by 2035 increases by 10%.

[Example Opportunity Appetite Statement 1]: An opportunity scenario is considered to reach the opportunity appetite boundary if the total cost of landing humans on Mars by 2035 decreases by 20%.

[Example Opportunity Appetite Statement 2]: An opportunity scenario is considered to reach the opportunity appetite boundary if the launch system for landing humans on Mars will also be capable of being used for exploratory missions to the moons of Jupiter and Saturn.

The implication of parity suggests that these five statements involve equal pain or gain. For example, the stakeholders are willing to accept a doubling of the mission failure probability or a slippage of 10 years in the landing date in exchange for being able to use the launch system as well for exploratory missions to Jupiter's and Saturn's moons.

In summary, strategic decisions between disparate choices can be made if the baselines for risk and opportunity, as defined by the boundaries, are commensurate in terms pain and gain.

4.3.2 Response Boundaries and Watch Boundaries

To provide greater flexibility to the stakeholders, two separate risk tolerance and opportunity appetite boundaries (i.e., two levels of pain and gain) are elicited to differentiate risks and opportunities that need to be responded to from those that need only to be watched. The two

boundaries are illustrated in Figure 4-6, where they are referred to as “response boundaries” and “watch boundaries”:

- Exceedance of a *response boundary* suggests that an action is imminently needed; e.g., mitigation of the risk or exploitation of the opportunity. A risk that exceeds the risk response boundary is “intolerable,” and an opportunity that exceeds the opportunity response boundary is “significant.”
- Exceedance of a *watch boundary* without exceeding a *response boundary* suggests that an action should be considered but is not imminently needed. Risks and opportunities that exceed the watch boundary but do not exceed the response boundary are referred to as “marginal.”²³ While marginal risks/opportunities fall below the threshold of needing a response, they should be trended and reported at formal reviews.
- A risk that does not exceed the risk watch boundary is “tolerable,” and an opportunity that does not exceed the opportunity watch boundary is “insignificant.”

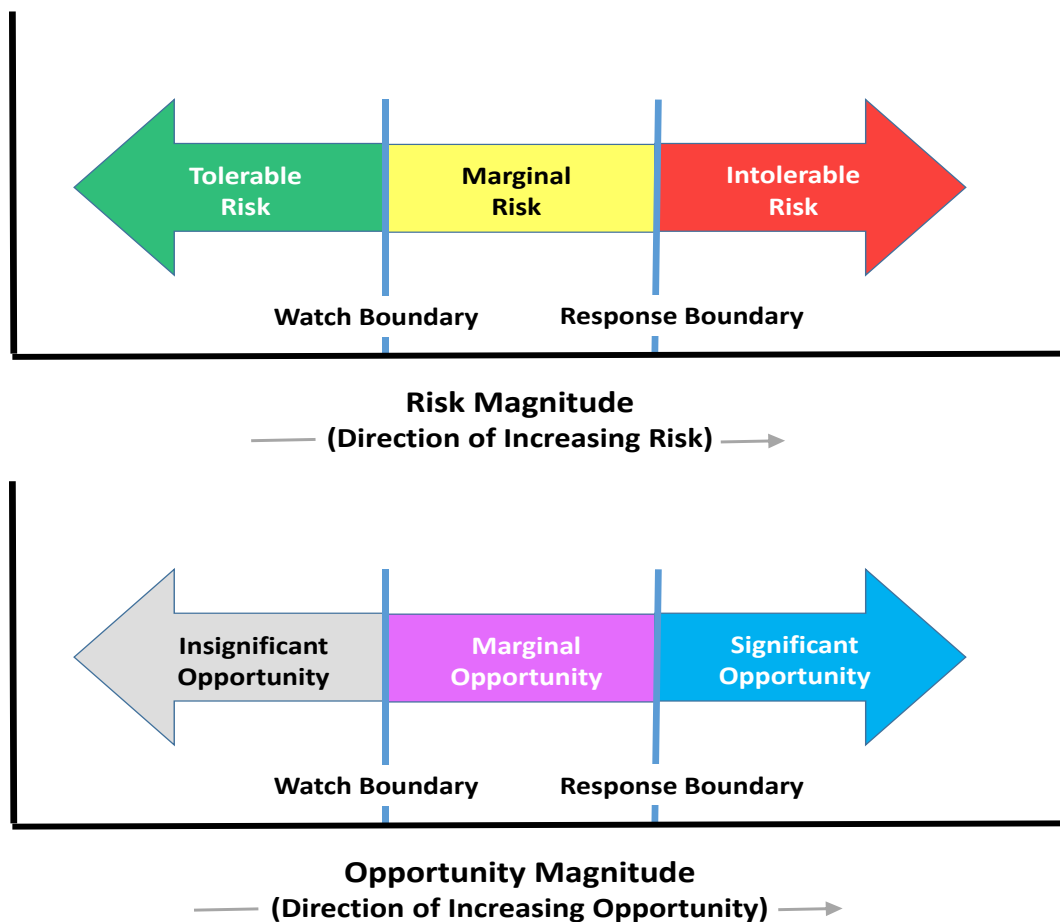


Figure 4-6. Risk and opportunity response and watch boundaries

²³ The term “watch” is used advisedly in this context. In practice, tolerable risks may be accepted but continue to be watched to ensure they remain tolerable.

4.4 Identifying Risk and Opportunity Scenarios and Leading Indicators

Once the stakeholders' risk and opportunity posture has been established by eliciting risk tolerance and opportunity appetite boundaries, the OROM analysis team proceeds to develop a set of risk and opportunity scenarios and associated leading indicators for each entity in the objectives hierarchy. Note that some risks and opportunities and their associated leading indicators may appear under more than one objective.

At lower levels of the objectives hierarchy, risk and opportunity scenarios and leading indicators tend to be specified by direct assignment using historical experience, expert judgment, and "What If" analysis. At higher levels, scenarios and indicators that are identified by the OROM analysis team may also be augmented by additional scenarios and indicators that are obtained by roll-up from lower levels. This process recognizes the fact that the success of strategic goals and objectives may be affected not only by scenarios and leading indicators that enter at that level, but also by scenarios and leading indicators that enter at the levels of mid-term and short-term objectives and propagate upward.

An example of an opportunity scenario that is specified directly at a higher level and a risk scenario that is rolled-up from lower levels is provided in the yellow box below.

Example of an Opportunity Scenario that is Specified Directly at a Higher Level and a Risk Scenario that is Rolled-up from Lower Levels

Opportunity for 10-Year Strategic Objective a: There is a possibility that new technology in the area of electric propulsion may become available within a ten-year time frame, making it possible to gain a far greater knowledge of the outer solar system over the next decade.

Risk for 5-Year Performance Goal X: If milestone slippages that have occurred during the past year in Program X are not corrected, there is a possibility that System X will not be ready for launch in five years.

Risk for 5-Year Performance Goal Y: If milestone slippages that have occurred during the past year in Program Y are not corrected, there is a possibility that System Y will not be ready for launch in five years.

Roll-Up Risk for 10-Year Strategic Objective a: If Systems X and Y are not successfully launched in five years, there is a possibility that exploration of the outer solar system will be severely impaired over the next decade.

4.4.1 Risk and Opportunity Taxonomies

A taxonomy is a tree structure of classifications that begins with a single, all-encompassing classification at the root of the tree, and partitions this classification into a number of sub-classifications at the nodes below the root. This process is repeated iteratively at each node, proceeding from the general to the specific until a desired level of category specificity is reached.

Taxonomies can be used to group organizational risk and opportunity scenarios into categories that reflect, first, the types of goals and objectives that they affect, and second, the types of events

that could create risk and opportunity for each goal or objective. Risk and opportunity taxonomies provide the following benefits:

- They assist in the identification of risk and opportunity scenarios that otherwise might be missed (e.g., by facilitating the brainstorming process), and in the identification and understanding of the cross-cutting nature of some of these scenarios.
- They help identify leading indicators that can be used to rank the likelihood (at least qualitatively) that a postulated event that either threatens or benefits a goal or objective will occur.
- They facilitate the process of identifying planning alternatives and control options to effectively mitigate the risks or exploit the opportunities.
- They assist in properly allocating resources among the entities or organizational units of the agency (e.g., to mitigate a risk or exploit an opportunity).

Figure 4-7 illustrates an example three-level organizational risk and opportunity taxonomy that is applicable to nonprofit technical organizations like NASA. For each categorical unit in the bottom level of the taxonomy, it also provides an example individual risk (R) or opportunity (O) scenario summary description. In addition to categories that derive from NASA's mission and manner of conducting business, NASA and other Government agencies are responsible for meeting outcomes and milestones that are directly mandated by the Government, e.g., through Congressional amendments signed into law by the President.

As noted in Figure 4-7, each bottom-level sub-category can be further decomposed into one or more goals or objectives that apply to that categorical unit. For example, new technology pursuits pertaining to mission performance are comprised of different individual technology pursuits, each of which represents a goal or objective of the organization. Thus, the taxonomy in Figure 4-7 may be construed as having an unseen bottom level corresponding to the goals and objectives that are affected.

4.4.2 Risk and Opportunity Scenario Statements

According to the NASA RM Handbook [8], risk scenario statements should contain three to four elements, as follows:

1. A condition or set of conditions encapsulating the current key fact-based situation or environment that is causing concern, doubt, anxiety, or uneasiness
2. A departure event or set of departure events describing a possible change from the baseline plan
3. (Optional) An organizational entity or set of entities representing the primary resources that are affected by the risk scenario. (Note: the resources most affected by the risk scenario may be at the top level or at a lower level in the organization.)
4. A consequence or set of consequences describing the foreseeable, credible negative impacts on the organization's ability to meet its expected performance

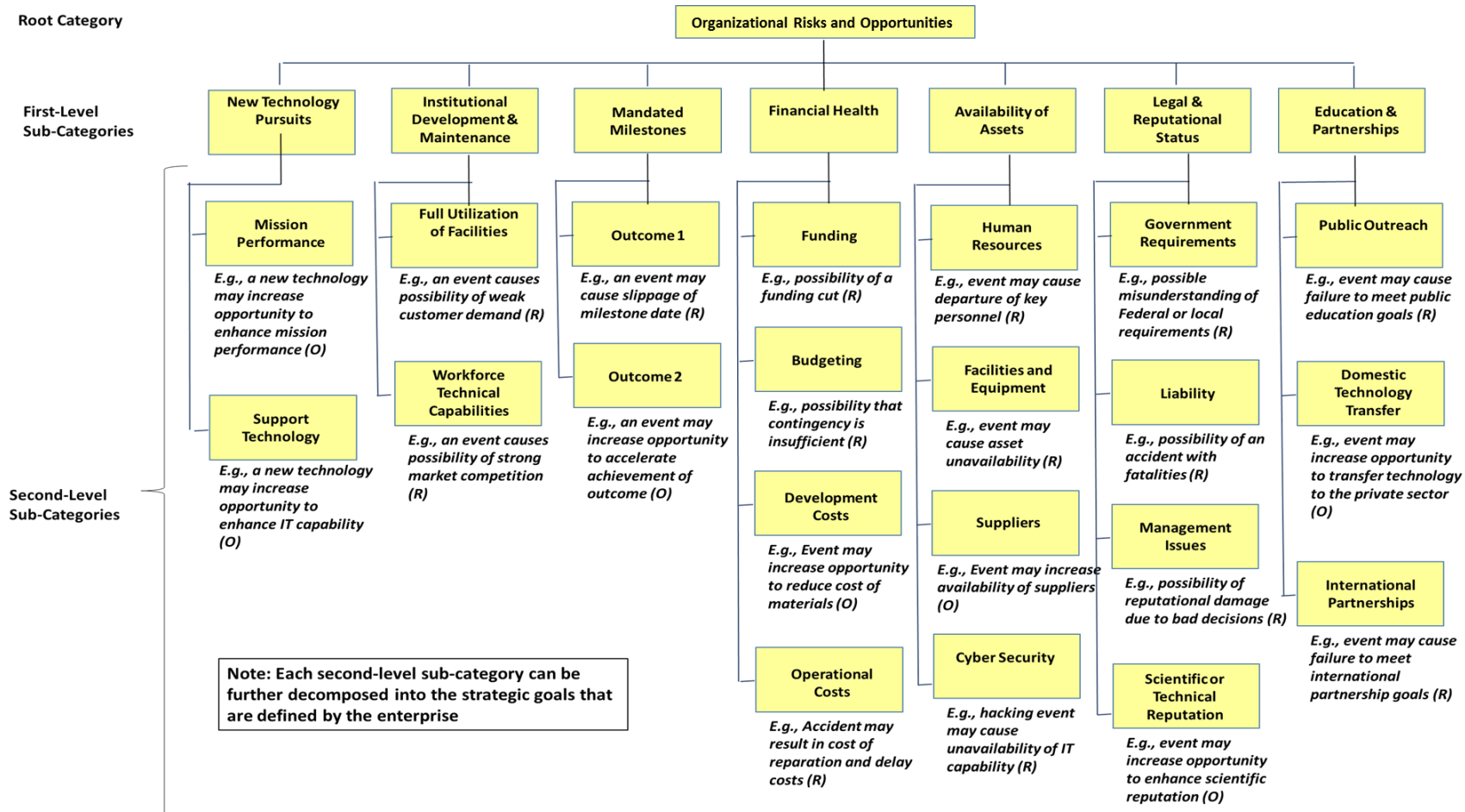


Figure 4-7. Example taxonomy for organizational risks and opportunities

To facilitate strategic planning, it is useful to add the following element to the four cited in the RM Handbook:

5. The objective(s) in the organizational objectives hierarchy affected by the risk scenario

The examples in the yellow box below provide organizational risk scenarios that conform to this format:

Examples of Risk Scenario Statements

1. Category: Mandated performance goals:

Given that [*condition*] the schedule for System X is much more stringent than was the schedule for the development of the Space Shuttle, there is a possibility that [*departure from plan*] the uncrewed test launch will be delayed by as much as 6 months resulting in [*entity*] the System X program [*consequence*] being unable to reach launch capability prior to closure of the launch window, adversely affecting [*mid-term objective*] fielding of System X by 2020.

2. Category: Financial:

Given that [*condition*] economic indicators suggest the possibility of a recession, there is a possibility that [*departure from plan*] funding to NASA will be cut by Congress resulting in [*entity*] the budgeting organization [*consequence*] having insufficient financial resources to work with, adversely affecting [*strategic objective*] human exploration of the solar system.

3. Category: Availability of assets / loss of assets:

Given that [*condition*] the workforce is aging, there is a possibility that [*departure from plan*] there will be a larger number of retirements next year than anticipated resulting in [*entity*] the hiring and technical organizations [*consequence*] being unable to meet their staffing goals, adversely affecting [*strategic objective*] maintenance of a qualified workforce.

4. Category: Legal and reputational:

Given that [*condition*] an audit of ethics training has indicated shortcomings in the contents and attendance of the training, there is a possibility that [*departure from plan*] there will be a serious ethical infraction resulting in [*entity*] the agency [*consequence*] losing public confidence, adversely affecting [*long-term objective*] the long-term viability of the agency.

Opportunity scenario statements should contain analogous information:

1. A condition or set of conditions encapsulating the current key fact-based situation or environment that is promoting the possibility of an opportunity
2. An enabling event or potential advance, or a set of enabling events or potential advances, that could happen to promote the possibility to a reality
3. (Optional) An organizational entity or set of entities representing the primary resources that are affected by the opportunity scenario
4. An action that must be taken to realize the opportunity
5. A benefit or set of benefits describing the foreseeable, credible possible impacts on the organization's ability to perform its mission
6. The objective(s) in the organizational objectives hierarchy affected by the opportunity scenario

As discussed in Section 2.2.1, the inclusion of an action, which is not needed for the definition of a risk scenario, is intrinsic to the definition of an opportunity scenario. Example opportunity scenario statements following this format are presented in the yellow box below.

Examples of Opportunity Scenario Statements

1. Category: New technology development and application:

Given that [*condition*] new technology in the area of electric propulsion shows promise, there is a possibility that [*enabling event or potential advance*] the technology will become available for use within 5 years so that if [*entity*] the propulsion organization [*action*] implements the new technology for Mission X, it may be able to [*benefit*] achieve its thrust requirements with a 50% weight savings, thereby contributing to [*strategic objective*] development and realization of creative new technologies and more distant exploration of the solar system.

2. Category: Education and partnerships:

Given that [*condition*] enrollment in NASA's public education STEM programs has been higher than expected, there is a possibility that [*enabling event or potential advance*] enrollment will double in the next two years, so that if [*entity*] the public education organization [*action*] correspondingly doubles the number of STEM courses offered, it may be able to [*benefit*] meet the Administration's STEM requirements sooner than expected, thereby contributing to [*strategic objective*] the advancement of the Nation's STEM education.

The RM Handbook [11] also provides guidance about narrative descriptions that should accompany risk scenario statements. That guidance is applicable as well to OROM.

4.4.3 Risk and Opportunity Leading Indicators

Risk and opportunity leading indicators are used to infer the likelihood that each objective in the organizational objectives hierarchy will be successfully achieved within the assigned timeframe. During the organizational planning process, they are used to help decide from among various candidate objectives on the basis of their projected likelihood of success. During the performance evaluation process, they are used to assess how the likelihoods of success based on current conditions stand with respect to the initial projections.

Most organizations monitor numerous key *performance* indicators (KPIs) that shed insights about risk events that have already affected the organization [13]. Leading indicators, on the other hand, help to monitor potential future shifts in risk conditions or new emerging risks so that management can more proactively identify potential impacts on the organization's portfolio of risks.

It should be noted, however, that indicators of past performance (i.e., lagging indicators) can also be indicators of possible future performance. For example, the occurrence of missed milestones in the past may indicate a potential for missed milestones in the future. Therefore, the set of leading indicators normally includes past performance as well as present conditions that are not related to past performance.

Risk and opportunity leading indicators should possess the following characteristics:

- **Quantifiability:** There should be one or more quantifiable measures by which to assess the status of the leading indicator.

- **Correlatability:** There should be a direct correlation between the value of a leading indicator and the likelihood of success of one or more of the objectives in the organizational objective hierarchy.
- **Actionability:** In the event that the value of a leading indicator leads to concern about a risk or optimism about an opportunity, there should be means for reducing the risk or exploiting the opportunity. It is not necessary for all leading indicators to be actionable (as some are caused by external forces that are beyond the control of the organization). Rather, it is only necessary that for each nontrivial risk or opportunity, there are some leading indicators that can be controlled to help contain the risk or grow the opportunity,

Risk and opportunity leading indicators may have different levels of complexity. For example, a simple indicator might be a ratio that management tracks to infer the status of an evolving risk or opportunity. A more elaborate indicator might involve the aggregation of several individual indicators into a multi-dimensional score about emerging events that may lead to new risks or opportunities. In addition, leading indicators might emerge from internal sources (such as missed project milestones) or from external sources (such as the state of the national economy).

Leading indicators may also be grouped according to the type of risk or opportunity to which they relate. Table 4-1 provides examples showing how various leading indicators may be grouped into categories of risk and opportunity.

4.4.4 Leading Indicators of Unknown and Underappreciated (UU) Risks

As mentioned in Section 2.2.7, the factors that contribute to UU risks can be considered to be leading indicators, and they, too, should be included in the roll-up of risks and opportunities from lower to higher levels in the objectives hierarchy. Based on work reported in [9] and [10], the following design, organizational, and programmatic factors are among the principal leading indicators of UU risks:

- Amount of complexity, particularly involving the interfaces between different elements of the system. Technical systems more prone to UU failure are complex, tightly coupled systems that make the chain of events leading to a disaster incomprehensible to operators.
- Amount of scaling beyond the domain of knowledge. UU risks may occur either from incrementally scaling up a design to achieve higher performance or incrementally scaling down a design to save on cost or time, without providing adequate validation.
- Use of fundamentally new technology or fundamentally new application of an existing technology. The use of new technology in place of heritage technology may lead to an increase in UU risks when other factors within this list are not well handled.
- Degree to which organizational priorities are focused toward safety and reliability. UU risks occur more frequently when top management is not committed to safety as an organizational goal, when there is no or little margin in the availability of qualified personnel, and when organizational learning is not sufficiently valued.
- Degree to which the management style is hierarchical. Two-way flows of information are essential in technological systems to maximize the sharing of information among all personnel regardless of position in the organizational hierarchy.

Table 4-1. Typical risk and opportunity scenario types and associated leading indicators

Category	Example Risks	Example Opportunities	Example Internal (INT) and External (EXT) Leading Indicators
New technology development and application	Degradation of mission performance or of institutional capability or cost increases due to unknowns	Enhancement of mission performance or of institutional capability or cost reductions because of technology improvements	INT: Initiation of and results from internal state-of-the-art assessments
			INT: Technology Readiness Level (TRL) rate of progress
			INT: Number of patents applied for
			EXT: Technology trends in areas pertinent to NASA missions (propulsion, diagnostics, materials, Information Technology, etc.)
Mandated performance goals	Failure to meet mandated or targeted milestone dates	Exceedance of expectations in meeting mandated or targeted milestone dates	INT: Schedule compared to other programs / projects *
			INT: Number of missed intermediate milestones & slippage amount *
			INT: Unresolved action items & uncorrected problems *
			EXT: Changes in prioritization of agency outcomes
Financial	Funding cut	Funding increase	EXT: Economic indicators
			EXT: Congressional makeup
			EXT: Changes in national priorities
	Insufficient contingency	More-than-sufficient contingency	INT: Contingency relative to other programs/projects *
			INT: Rate of spending compared to other programs/projects *
			INT: Unresolved assignment of roles and responsibilities
	Increased cost of materials / purchased services	Decreased cost of materials / purchased services	EXT: Price trends
			EXT: Threats of foreign conflicts or political changes (e.g., affecting rare material costs)
			EXT: Supplier financial problems
	Increased cost of operations	Decreased cost of operations	INT: Monthly cost reports *
			INT: Low scores on self-assessments and audits *
	Milestone slippage costs	Milestone acceleration savings	INT: Earned value reports *
			EXT: Government shutdown
	Accident costs		INT: Precursors, anomalies, mishap reports *
Availability of assets / loss of assets	Loss of key personnel	Gain of Key Personnel	INT: Age of workforce
			INT: Workplace morale (e.g., from surveys)
			EXT: Changes in competitive labor market
			EXT: Demographic changes
	Loss or unavailability of facilities or equipment	Increased availability of facilities or equipment	INT: Number of unplanned maintenance actions *
			INT: Age of equipment
			EXT: Terrorism trends
			EXT: Changes in OSHA regulations

* Asterisked leading indicators are measured at program/project level or center level and are aggregated to obtain leading indicators that apply to the agency as a whole.

Table 4-1 (Continued)

Category	Example Risk Event	Example Opportunity Event	Example Internal (INT) and External (EXT) Leading Indicators
Availability of assets / loss of assets (cont.)	Loss or unavailability of suppliers	Increased availability of suppliers	EXT: Market factors (demand versus supply)
			EXT: Supplier financial or legal problems
	Loss or unavailability of IT capability	Increased availability of IT assets	INT: Number of unaddressed vulnerabilities
			EXT: Hacking trends
			EXT: New viruses
Legal and reputational	Failure to meet Federal or local requirements	Exceedance of Federal or local requirements	INT: Quality of ethics program
			INT: Quality of record keeping (e.g., for OSHA requirements) *
			EXT: New regulations
	Increase in financial liability given an accident	Decrease in financial liability given an accident	INT: Increased use of hazardous or toxic materials *
			INT: Accident precursors (ground and flight operations)*
			EXT: Trends in Court decisions regarding liability
	Reputational damage due to mgmt. failures	Reputational enhancement due to mgmt. successes	INT: Findings of independent reviews (e.g., CAIB and ASAP reports)
			INT: Seeking and resolution of internal dissenting opinions *
	Degradation of scientific reputation	Enhancement or maintenance of scientific reputation	INT: Number of technical papers published
			INT: Number of patents granted
			EXT: Number of citations in technical papers
			EXT: Number of nominations or awards received
Education and partnerships	Failure to meet public educ. goals	Exceedance of public educ. goals	INT: Missed or made milestones
			INT: Low or high enrollment in educational programs
	Failure to meet technology transfer goals	Exceedance of technology transfer goals	INT: Missed or made milestones
			INT: Number of technology transfer agreements
			EXT: Lack or surplus of interest or progress from potential commercial partners
			EXT: Trends regarding the sharing of sensitive information and materials
	Failure to meet international partnership goals	Exceedance of international partnership goals	INT: Missed or made milestones that NASA is responsible for*
			EXT: Lack or surplus of interest or progress from potential international partners
			EXT: New regulations regarding sensitive information
			EXT: Competition from a foreign country

* Asterisked leading indicators are measured at program/project level or center level and are aggregated to obtain leading indicators that apply to the agency as a whole.

- Degree of oversight when responsibilities are distributed among various entities. Interfaces between different elements of the system provided by different suppliers require stringent oversight by the managing agency.
- Amount of pressure to meet schedule and budget constraints. In particular, time pressure beyond the level of comfort is a fundamental reason for high human error rates.
- Likelihood of major or game-changing external events that affect the agency's direction, such as changes in the Administration or geopolitical upheavals. Such events impact the stability of long-term strategic planning and of constraints such as ITAR, etc.

References [9] and [10] provide useful guidelines on how various combinations of the above leading indicators affect the relative magnitude of UU risks compared to the magnitude of known risks.

4.5 Specifying Leading Indicator Trigger Values and Evaluating Cumulative Risks and Opportunities

Leading indicator trigger values are used to signal when a risk is reaching a risk tolerance boundary or when an opportunity is reaching an opportunity appetite boundary. Reaching the trigger values for risk leading indicators implies that the likelihood of not being able to satisfy an objective in the organizational objectives hierarchy is becoming a concern. Reaching the trigger values for opportunity leading indicators implies either that there is a potential for significantly increasing the likelihood of being able to satisfy an objective, or that there is an emerging opportunity to achieve new goals and objectives that were formerly considered unreachable or inconceivable.

Leading indicator trigger values are specified for each risk and opportunity scenario for each objective in the organizational objectives hierarchy. Once specified, it is possible to compare the actual values of the leading indicators to their trigger values to provide a measure of the overall risk and opportunity for each objective in the hierarchy.

4.5.1 Leading Indicator Trigger Values

Similar to the way that risk tolerance and opportunity appetite were characterized by two boundaries, a response boundary and a watch boundary, it is useful to define two triggers for risk and opportunity leading indicators, a response trigger and a watch trigger. The values of the leading indicator triggers are elicited by the OROM analysis team from appropriate technical authorities and subject matter experts.

Leading indicator triggers may be positively or negatively correlated with risk or opportunity, depending on whether the leading indicator is defined in the positive or negative sense. For example, remaining cost reserve is defined in the opposite direction from expenditure to date. As cost expenditure increases, the risk of overrun increases (a positive correlation), but as remaining cost reserve increases, the risk of overrun decreases (a negative correlation). This opposite duality is captured by the mirror-image effects of positive and negative correlations shown in Figure 4-8.

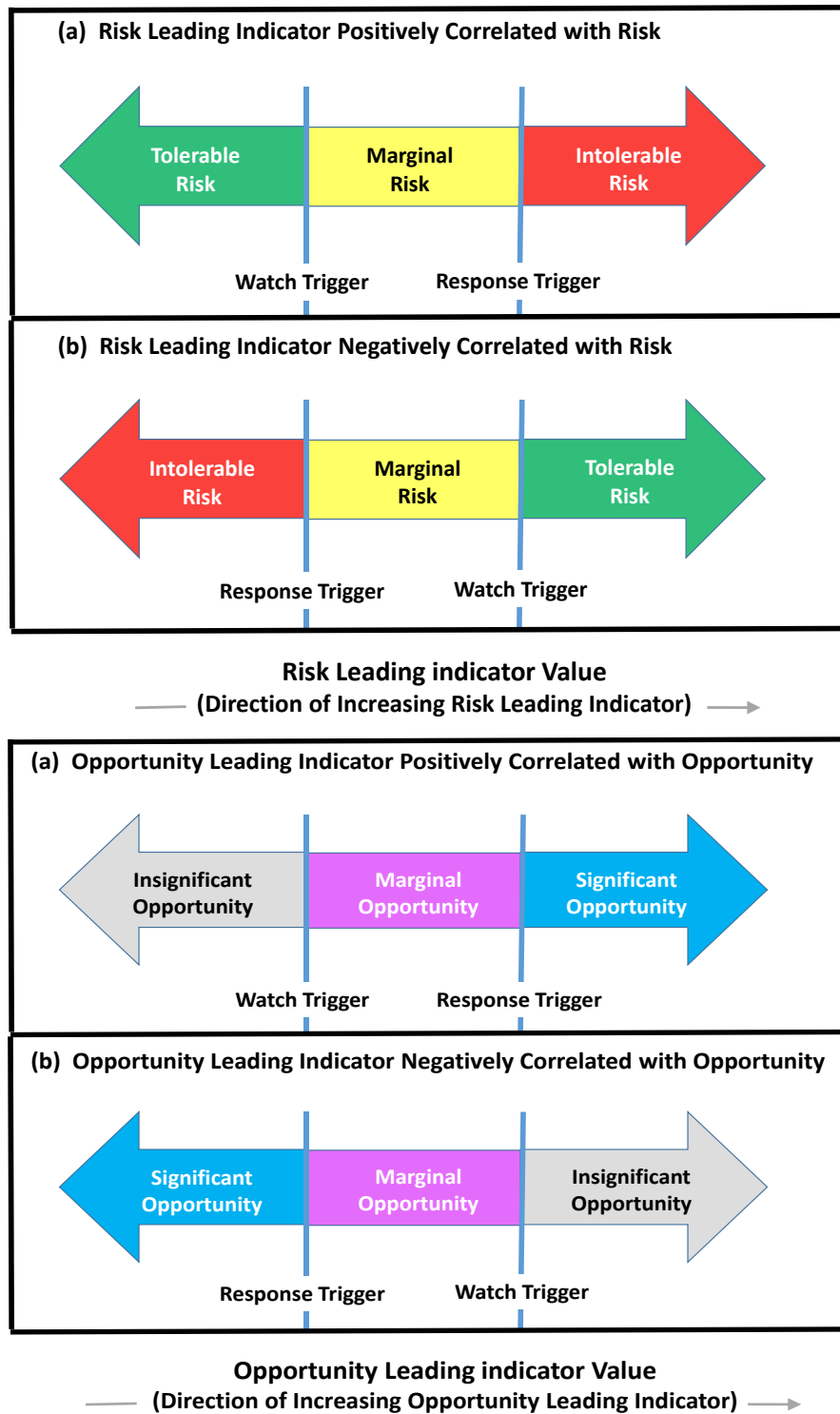


Figure 4-8. Risk and opportunity leading indicator triggers.

Leading indicator triggers are intended to be quantitative surrogates for the often qualitative risk tolerance and opportunity appetite boundaries. Their accuracy as surrogates depends upon the skill of the technical authorities, subject matter experts, and OROM analysis team in defining leading indicators and specifying their trigger values.

4.5.2 Cumulative Risks and Opportunities

The cumulative risk and cumulative opportunity for each objective in the organizational objectives hierarchy is derived from the current status of the associated leading indicators relative to their trigger values, where “current status” refers to both the current value and the current trend. The term “cumulative” in this context refers to the accumulation of the various leading indicators that apply to the objective being evaluated.

Figure 4-5, presented earlier, conceptually illustrates the general process for determining the cumulative risks and opportunities for a set of objectives in an organizational objectives hierarchy. A more detailed illustration of the roll-up process will be provided in Sections 5.6.2 and 5.6.3 in connection with a particular example.

4.6 Identifying and Evaluating Risk Mitigation, Opportunity Exploitation, and Control Options

If a cumulative risk is intolerable (or marginal) and/or a cumulative opportunity is significant (or marginal), it may become desirable to consider means for mitigating the risk and/or exploiting the opportunity, along with the associated setting of controls. This section discusses processes for identifying and evaluating such options.

4.6.1 Deducing Risk and Opportunity Drivers

Risk drivers are defined in the NASA RM Handbook [8] as: “those elements found within the aggregate performance risk models that contribute most to the performance risks because of uncertainties in their characterization. ... When varied over their range of uncertainty, [they] cause the performance risk to change from tolerable to intolerable (or marginal).”

In the context of OROM, a risk driver can be thought of as a significant source of risk contributing to the overall, cumulative risk of not satisfying a top organizational objective. A risk driver can be a departure event in a risk scenario statement, an underlying cause of a departure event, a leading indicator, a particular assumption used in evaluating the significance of an individual risk, an assumption made in evaluating a cumulative risk, an essential internal control, or any combination of such elements that cause the cumulative risk to change its color from green (tolerable) to yellow (marginal) or red (intolerable) or from yellow to red. For example, the following elements in the analysis of risk and implementation of controls are potential risk drivers:

- Congress may cut funding for the Space Program next year (a departure event).
- Human error may cause a catastrophic accident to occur during a mission (an underlying cause of the departure event “catastrophic accident”).
- The schedule reserve for a key task in a key program is uncomfortably low and trending lower (a leading indicator of the risk of not completing the key task on time).

- If needed, personnel can be diverted from Task A to Task B (an assumption used to evaluate the significance of the risk of not completing Task B on time).
- All pertinent information needed to evaluate the organization's strategic performance is being transmitted in an unbiased fashion to the technical authorities (an assumption used to justify assurance that the organization is meeting its strategic objectives).
- There is a process and document trail to ensure that all significant risks and opportunities are elevated to responsible individuals with management authority to act upon them (an internal control).

If no one element individually is sufficient to change the color of the cumulative risk, a combination of them may constitute a risk driver.

Risk drivers focus risk management attention on those potentially controllable situations that present the greatest opportunity for risk reduction. Often, risk drivers affect more than one individual risk and cut across more than one organizational unit.

Similarly, opportunity drivers are generally departure events in an opportunity scenario statement or leading indicators of opportunity. For example, the following elements in the analysis of opportunity are potential opportunity drivers:

- Congress may increase funding for the Space Program next year (a departure event).
- The schedule reserve for a key task in a key program is higher than expected and trending higher (a leading indicator of an opportunity to reduce program cost by reallocating personnel so as to finish the program ahead of schedule).

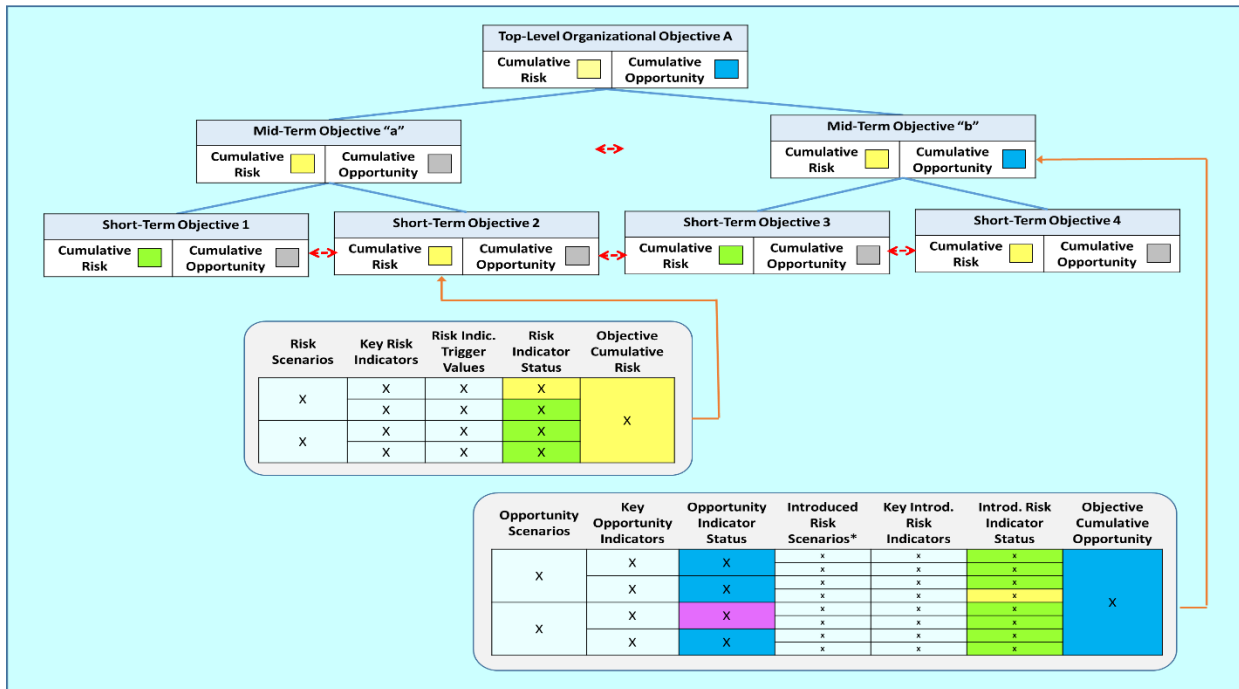
Risk and opportunity drivers can be identified by applying the risk and opportunity roll-up process (illustrated schematically in Figure 4-5) to determine whether the color of the cumulative risks and opportunities for the top organizational objectives change as various sources of risk and opportunity are eliminated. For example, Figure 4-9 shows schematically how the removal of Risk Driver 1 propagates up through the objectives hierarchy to change the ranking of the cumulative risk for the top objective from marginal to tolerable, and how the removal of Opportunity Driver 1 changes the ranking of the cumulative opportunity for the top objective from significant to marginal.

4.6.2 Deducing Risk and Opportunity Scenario Drivers

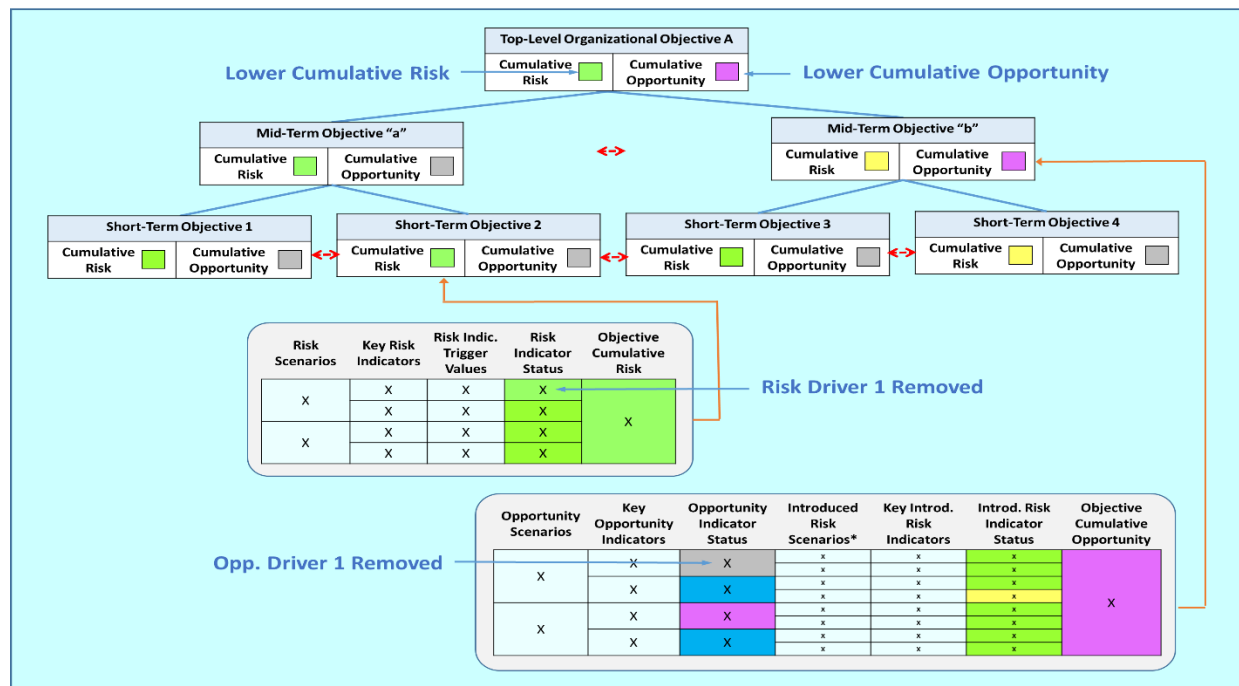
Organizations like NASA are typically required to identify their top risk scenarios, report on the likelihood of their occurrence and severity of their impact, and explain how they are being responded to.

Risk and opportunity scenario drivers are a higher-order representation of risk and opportunity drivers. The elements that constitute risk and opportunity drivers (i.e., key departure events, underlying causes, assumptions, existing controls, etc.) are embedded within risk and opportunity scenarios, either as part of the conditions, departure events, and consequences that comprise a risk or opportunity scenario statement or as part of the narrative that accompanies one. Therefore, just as a risk or opportunity driver is defined in Section 4.6.1 as an element or set of elements that cause the cumulative risk or opportunity for a top objective to change color,

Hypothetical Risk Rollup Results with All Risk and Opportunity Drivers Included



Hypothetical Risk Rollup Results with One Risk Driver and One Opportunity Driver Removed



Risk Concern: ☐ TBD ☒ Tolerable ☐ Marginal ☐ Intolerable
Opportunity Interest: ☐ TBD ☒ Significant ☐ Marginal ☐ Insignificant

Figure 4-9. Hypothetical results showing how the elimination of a risk driver affects cumulative risk and the elimination of an opportunity driver affects cumulative opportunity.

a risk or opportunity scenario driver can be defined as a scenario or set of scenarios that leads to the same result.

Also, just as risk or opportunity drivers can be identified by applying the risk or opportunity roll-up process while selectively eliminating one or more sources of risk or opportunity until the color of a top objective changes, risk or opportunity scenario drivers can be identified in the same way by selectively eliminating one or more risk or opportunity scenarios. Figure 4-10 shows how the removal of Risk Scenario Driver 1 and Opportunity Scenario Driver 1 might propagate up through the objectives hierarchy to change the ranking of the cumulative risk and opportunity.

4.6.3 Identifying Options for Risk Response, Opportunity Action, and Internal Control

When there is a need to reduce the cumulative risk or a desire to take advantage of the cumulative opportunity for one or more top objectives, there are several types of options to be considered:

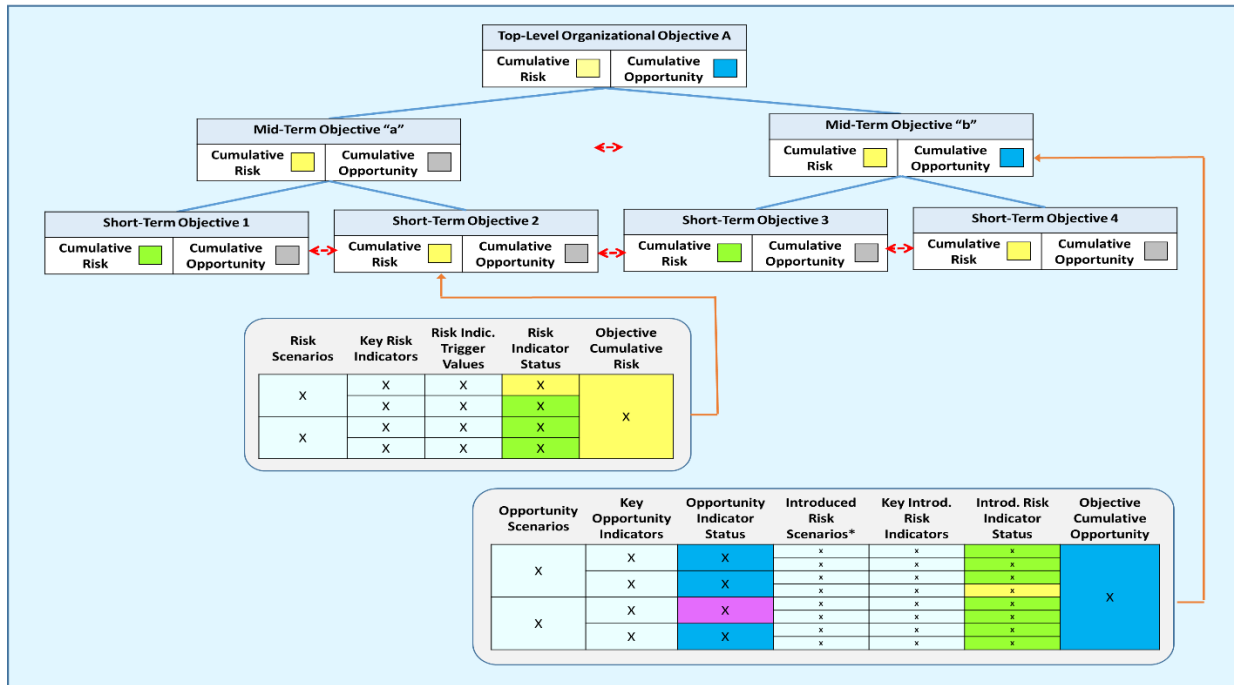
- Responses to mitigate the cumulative risk
- Actions to seize the cumulative opportunity
- Institution of controls to provide effective management oversight and protect operative assumptions

The formulation of risk responses and opportunity actions can take many forms, including changes in the design of a system that is in development, retrofits to existing systems, changes in manufacturing processes, changes in operating procedures, changes in management, formation of partnerships, proactive actions to inform and influence governing agencies, improved public relations, and cost sharing arrangements, to name a few. What these various formulations have in common is that they are based on certain assumptions, and their effectiveness depends upon the accuracy of those assumptions. For example, design changes to a system are based on assumptions about the environments that the system will be exposed to, and whether or not those environments will stay within the parameters that are called out in the design specifications. One of the main functions of internal controls, therefore, pertains to the protection of the accuracy of the assumptions.

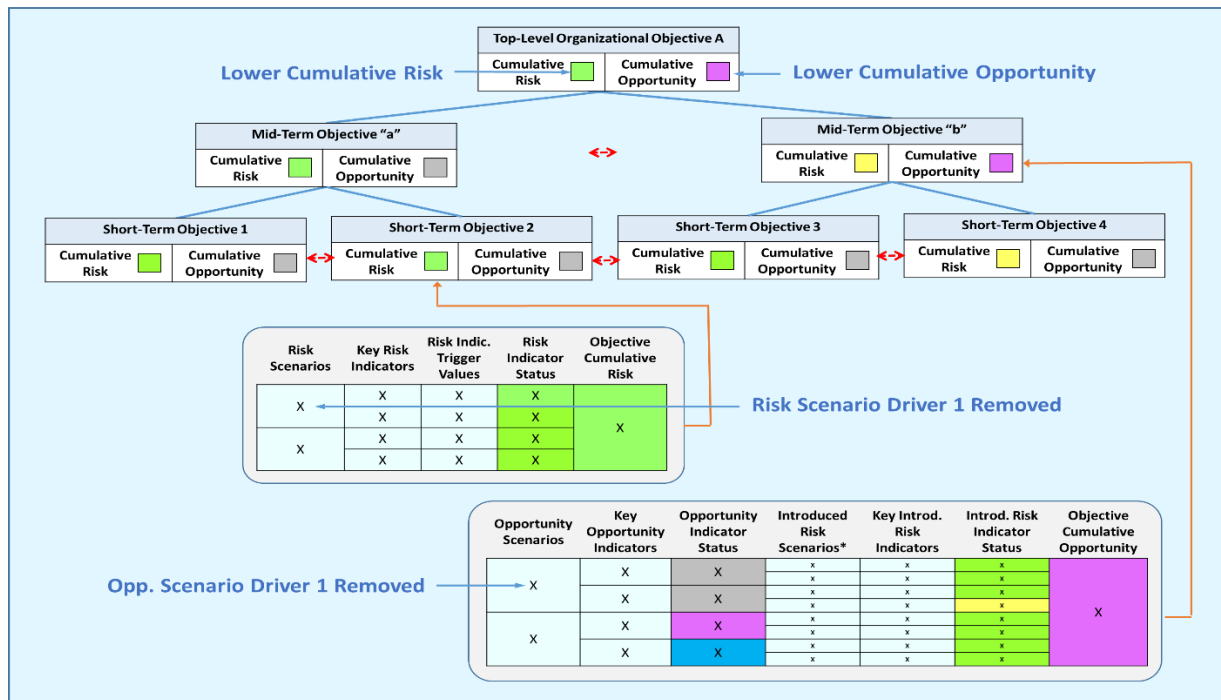
The use of controls to protect operative assumptions is emphasized by Leveson within the domain of safety performance in [14]. The types of assumptions of interest to Leveson include the following:

- Assumptions about the system hazards and the paths to (causes of) hazards
- Assumptions about the effectiveness of the controls, that is, the shaping and hedging actions, used to reduce or manage hazards
- Assumptions about how the system will be operated and the environment (context) in which it will operate, for example, assumptions that the controls will be operating as assumed by the designers
- Assumptions about the development environment and processes

Hypothetical Risk Rollup Results with All Risk and Opportunity Scenario Drivers Included



Hypothetical Risk Rollup Results with One Risk Scenario Driver and One Opportunity Scenario Driver Removed



Risk Concern: ☐ TBD ☒ Tolerable ☐ Marginal ☐ Intolerable
Opportunity Interest: ☐ TBD ☒ Significant ☐ Marginal ☐ Insignificant

Figure 4-10. Hypothetical results showing how the elimination of a risk scenario driver and an opportunity scenario driver affect cumulative risk and opportunity.

- Assumptions about the organizational and societal control structure during operations, i.e., that it is working as designed, the design was adequate to ensure the system requirements are enforced, and the system controllers are fulfilling their responsibilities and operating as designed
- Assumptions about vulnerability or severity in risk assessment that may change over time and thus require a redesign of the risk management and leading indicators system itself

These types of assumptions, with minor modification, apply not only to the safety domain considered by Leveson but as well to virtually all other risk domains (technical, cost, schedule, institutional, acquisition, financial viability, liability, etc.) at all levels of the organization (executive, program directorate, technical directorate, etc.). Controls should ensure:

- Either that such assumptions remain valid over time in all risk and opportunity domains for all organizational levels
- Or, if the conditions should change, that the operative assumptions are changed accordingly and the new assumptions are monitored and controlled

The identification of risk mitigation responses, opportunity exploitation actions, and control options is directed at finding viable ways to act upon the risk and opportunity drivers and/or scenario drivers discussed in the preceding subsection. The purpose is to reduce risks or act upon opportunities when the cumulative risks and opportunities demand that such influence be exercised. There is, however, an obvious limitation on the ability of an agency or business to influence risk and opportunity drivers, in that not all drivers are actionable. When a driver is not actionable, the fallback is to identify other risk and opportunity drivers that are actionable and that can exert an influence on the cumulative risk or opportunity. For example, it is not within the province of a government agency to influence whom the voters choose to elect to Federal office, but it is within their province to track public sentiment and develop contingency plans.

The identification of meaningful responses, actions, and control options will be discussed further in Section 5.7.2.

4.6.4 Evaluating Options for Risk Response, Opportunity Action, and Internal Control

Options for risk response, opportunity action, and internal control can be evaluated by assessing how the cumulative risks and opportunities for the top organizational objectives would change as a result of incorporating the responses, actions, and controls into the organizational structure and its operation. The process for performing this assessment includes the need to consider not only the positive effects that such options might have on some parts of a system or operation but also the possible unintended negative effects on other parts of the system or operation.

The process for performing this evaluation follows the framework that was developed in Sections 4.4 and 4.5. Risk and opportunity scenarios are redeveloped taking into account the proposed response, action, and control option. In the case of opportunity actions, new risk scenarios introduced by the proposed actions and associated controls are included in the accounting. The existing leading indicators are modified and new ones added to reflect the content of the redeveloped risk and opportunity scenarios. Leading indicator trigger values are specified

consistent with the modified leading indicators. Finally, the cumulative risks and opportunities are reevaluated based on a roll-up of the new risk and opportunity information.

Figure 4-11 presents a flow chart depicting the development of a risk response, opportunity action, and control plan as an iterative process. The plan is initially proposed if the evaluation of the cumulative risks and opportunities of the various objectives indicates that one or more risks is intolerable or marginal and/or one or more opportunities is significant or marginal. The iteration of the plan continues until there is an optimal or near-optimal balance between the cumulative risks, the cumulative opportunities, and the cost of implementing the plan. Optimality is considered to be reached when the following conditions all apply:

- The cumulative risks and opportunities for the top objectives are in balance (a condition which evolves from using the risk and opportunity drivers to guide the development of the plan at each iteration).
- The cumulative risks cannot be reduced further without violating cost constraints imposed on the organization.
- The cumulative opportunities cannot be availed further without violating the cost constraints.
- The cost of implementing the plan cannot be reduced further without negatively changing the status of one or more of the cumulative risks.

The evaluation of proposed responses, actions, and control options will be discussed further in Section 5.7.2.

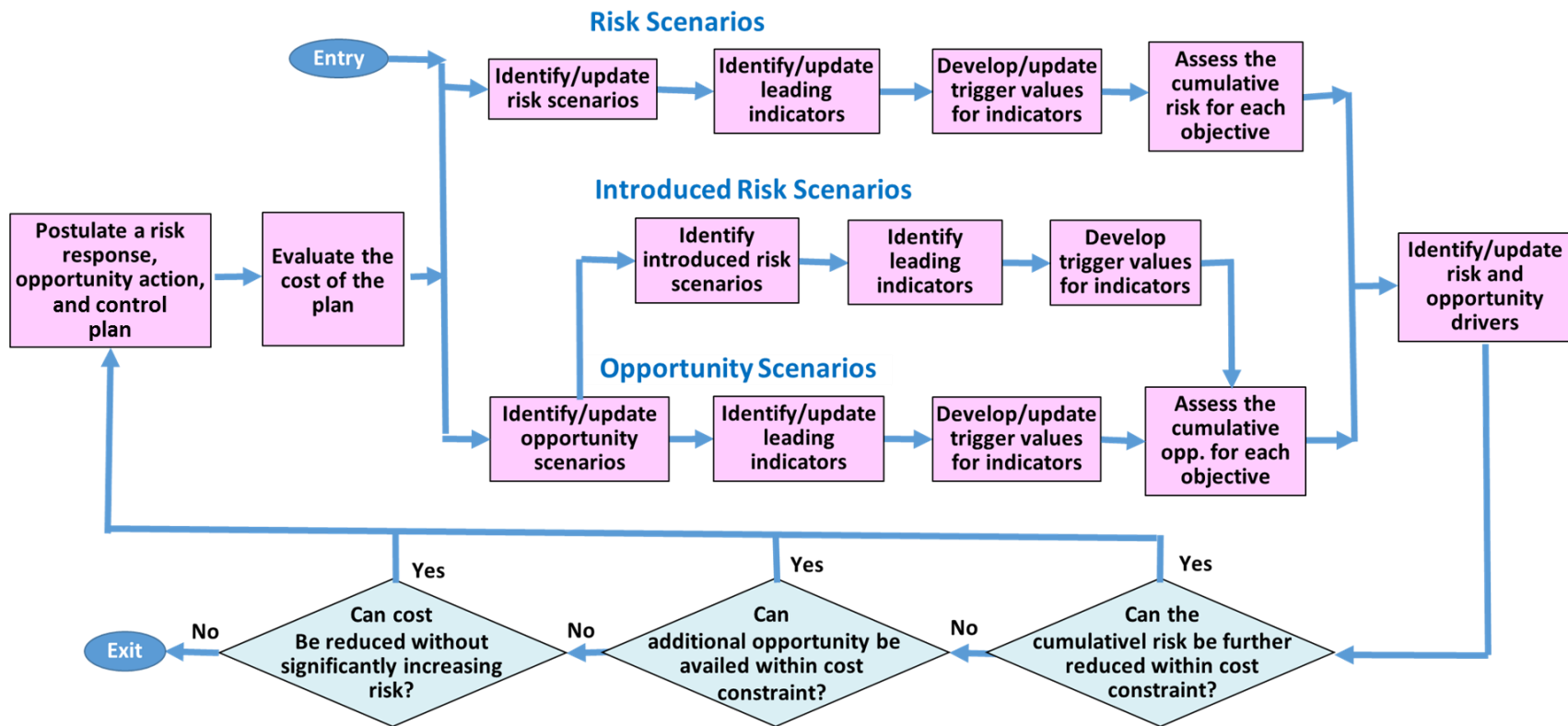


Figure 4-11. Iterative process for identifying and evaluating a risk response, opportunity action, and control plan that balances cumulative risk, cumulative opportunity, and cost

5. Development and Utilization of OROM Templates for Performance Evaluation and Strategic Planning

5.1 Overview

As discussed earlier (e.g., Section 2.1.3), the literature contains a significant amount of guidance on the organizational aspects of risk and opportunity management and the fundamental framework to be used. However, it provides very few details on how to conduct the analyses that are needed in order to reap the benefits. Section 5 attempts to fill that gap by describing and demonstrating how comprehensive OROM analyses can be conducted using templates. In Sections 5.1 through 5.8, the templates will be introduced by pursuing an example that examines OROM's role in evaluating organizational performance for its ongoing programs, projects, activities, and initiatives, and in identifying and evaluating actions and controls to reduce risk and/or seize opportunity. In Section 5.9, the example will be modified to show how the same templates with different inputs can be applied to examine OROM's role in organizational planning, where the organization is interested in examining its likelihood of success in meeting its top objectives for various candidate sets of programs, projects, etc., that are in the conceptual stage.

The use of templates is a practical, efficient, and broad-based approach for implementing the framework for OROM that is discussed in Sections 3 and 4. To illustrate how templates can be applied effectively, a real-world example relevant to NASA will be pursued. The example will treat OROM from various vantage points: first by considering OROM implementation from the perspective of each of the major management levels in the organization (i.e., the executive level, the programmatic or mission directorate level, and the institutional/technical or center level), and then from the perspective of the organization as a whole (i.e., integrated across the major management units).

The templates developed for this example pertain principally to organizations like NASA that conduct risky technical or scientific ventures and whose interest is mainly in achieving technical gain and knowledge advancement rather than financial gain for its stakeholders. Following are the types of results that will be generated by the templates used in this example:

High-Level Results (Suitable as a Synopsis for Management)

- A hierarchical list of objectives to be satisfied across the organization and the way that they interface with various levels of the organization (executive; programmatic; institutional/technical)
- A substantiated ranking (or rating) of the level of risk of not being able to achieve each objective
- A substantiated ranking of the level of opportunity available for improving the ability to achieve each objective
- A list of risk and opportunity drivers for each objective, leading to suggestions for responses such as risk mitigations, opportunity actions, and control options

Low-Level Results (Suitable for Explaining the Details behind the High-Level Results)

- Identification of the complex interfaces between objectives, and the rationale for how the likelihood of success for each objective affects the likelihood of success for other objectives
- A list of the significant individual risk and opportunity scenarios for each objective, and the rationale for why these scenarios are considered significant
- A list of the key risk and opportunity indicators and the rationale for how these indicators relate to the likelihood of success of each objective
- Specification of trigger values for each indicator, and the rationale for why these particular values signal the need for increased watchfulness or for a direct response
- A roll-up of the significant individual risks and opportunities from the bottom level of the objectives hierarchy (near-term objectives) to the top level (long-term or strategic objectives), along with the rationale for choices made during the roll-up
- Sensitivity results showing how the cumulative risk and opportunity for each objective are affected by various combinations of risk and opportunity scenarios and their constituent parts
- Matrix-like risk and opportunity driver charts showing the time criticality for initiating response

5.2 Example: The NASA Next Generation Space Telescope as of 2014

The example application involves the development, deployment, and operation of a large-scale space telescope, based on the the James Webb Space Telescope (JWST), formerly known as the Next Generation Space Telescope. Note that throughout this example we will keep the more generic term “Next Generation Space Telescope” in place of the more specific designation JWST, to indicate the pedagogical nature of the example, focusing the reader’s attention on the structure and form of the templates and how they may be used to facilitate strategic planning and performance evaluation in a general sense. To lend authenticity and promote recognition of the kinds of risks and opportunities that have to be dealt with, however, actual data pertinent to both the JWST and the Hubble Space Telescope (HST) are used throughout the example. The data for the JWST project reflects its status as of the end of 2014.

Timely development and launching of the telescope is an Agency Priority Goal (APG): “By October 2018, NASA will launch the James Webb Space Telescope, the premier space-based observatory. To enable this launch date, NASA will complete the James Webb Space Telescope primary mirror backplane and backplane support structures and deliver them to the Goddard Space Flight Center for integration with the mirror segments by September 30, 2015.”

The principal source of information is Report GAO-15-100 on the JWST project issued by the US Government Accountability Office in December 2014 to Congressional committees [15]. Among other things, the report addresses the degree to which technical challenges are impacting the JWST project’s ability to stay on schedule and budget, and the extent to which budget and cost estimates reflect current information about project risks. The following bits of information obtained from

this and other sources are mentioned here not to criticize the project or its management but rather to provide a basis for analyzing risks and opportunities in this example using published information¹²:

Information Pertinent to JWST Schedule and Cost

- JWST is one of the most complex projects in NASA's history (GAO [15]).
- In addition to the design, the scale of JWST's integration and test effort is more complex than most NASA projects (GAO [15]).
- The cryocooler subsystem is particularly complex and challenging because of the relatively great distance between the cooling components and the need to overcome multiple sources of unwanted heat (GAO [15]).
- The cryocooler subcontractor has experienced prior schedule delays and continued performance challenges (SpaceNews website "Manufacturing Issues Plague JWST," November 2014 [16]).
- The cryocooler element deferred seven earlier milestones until fiscal year 2015 as a result of manufacturing and development delays (GAO [15]).
- The schedule reserve for development of the cryocooler subsystem diminished in 2014 from 5 months to 0 months (GAO [15]).
- The schedule reserve for the development of other subsystems has also diminished in the past year, but not as much as that for the cryocooler subsystem (GAO [15]).
- The project entered fiscal year 2015 with approximately 40 percent of its cost reserves already committed, leaving fewer dollars available to mitigate other threats to the project schedule (GAO [15]).
- The White House and Congress have sparred about cancelling existing operating programs (e.g., SOFIA, Spitzer) to help fund JWST, although no cancellations have yet occurred (NationalGeographic.com, "NASA Facing New Space Science Cuts," May 2014 [17]).

Information Pertinent to JWST Technical Requirements, Performance, and Design

- Successful attainment of high resolution data requires a highly controlled environment, including minimum vibration, minimum stray light, particularly in the mid-infrared range, and minimum departures from a cold and stable temperature environment (GAO [15]; also NASA webpage "Explore JWST" [18])
- Although the subcontractor has built test cryogenic compressor units that perform to NASA's specifications when connected to the spacecraft platform by bolts, they have not yet been able to get a brazed unit to perform to specification, and brazing is a design

¹² In addition to the sources cited in the bulleted list below, the Jet Propulsion Laboratory published "James Webb Space Telescope Independent Comprehensive Review Panel Final Report," JPL D-67250, in October 2010. The report provides additional information on root causes of schedule and cost slippages, particularly those associated with the roles of NASA Headquarters and Goddard Space Flight Center in the 2010 timeframe. The problems associated with establishing realistic budgets were particularly emphasized. NASA management responded to the recommendations in the report in "NASA's Detailed Response to the James Webb Space Telescope Independent Comprehensive Review Panel Report," presently available on the web under that title.

requirement for NASA systems (SpaceNews website “Manufacturing Issues Plague JWST,” November 2014).

- The cold head assembly for the cryocooler has not been vacuum-tested in its flight-ready configuration to verify leak-tight operation with replacement valves that were recently installed in the assembly (SpaceNews [16]).
- The JWST is considered unserviceable, since it will be located far from Earth at the second LaGrange point approximately 1 million miles from Earth (NASA [18]).
- Although nominally unserviceable, the JWST is designed to have a grapple fixture for docking, implying that the option to conduct service missions has not been completely relinquished (NASA [18]).

In addition to information pertaining to the JWST project, historical experience obtained from the operation of the HST in low Earth orbit is relevant to this example because of the similarity of the missions. Of particular interest are the following bits of information obtained from various sources:

Relevant Information Pertaining to HST

- The HST has undergone several successful servicing missions enabled by its proximity to Earth, but initially there was uncertainty as to whether a successful servicing mission could be accomplished (HubbleSite.org webpage “Team Hubble: Servicing Missions” [19]).
- Several serious operational difficulties for the Hubble required servicing missions to perform retrofits and/or corrective actions, including the famous mirror fabrication error which greatly degraded the quality of the image (SpaceflightNow.com, “The history of Hubble: a grand space telescope,” 2009 [20]).
- Other operational difficulties that required a servicing mission included replacement of solar panels to correct a jitter problem caused by excessive flexing due to orbital cycling of solar input, and replacement of several gyros that were adversely affected by the launch environment (SpaceflightNow.com, [20]).
- New opportunities were also availed through servicing missions, including incorporation of new, more sensitive instruments and addition of the Advanced Camera for Surveys, which was used to explore dark energy and other cosmological findings revealed by the HST (NASA webpage “Hubble Space Telescope Servicing Mission 4” [21]).

5.3 Example Objectives Hierarchies

We first specify objectives separately for each organizational management unit and then integrate them together into a single objectives hierarchy that spans the organization. The management units for this example are grouped into the following three NASA organizational levels: executive (E), mission directorate or programmatic (P), and center (C).

5.3.1 Objectives Hierarchies for Different Management Levels

Executive-level objectives are the strategic objectives of the organization, derived in this case from the NASA Strategic Plan, and are considered to have a timeframe of more than 10 years. Two strategic objectives are considered in this example, as shown in Figure 5-1:

Executive-Level Objectives: Strategic Focus

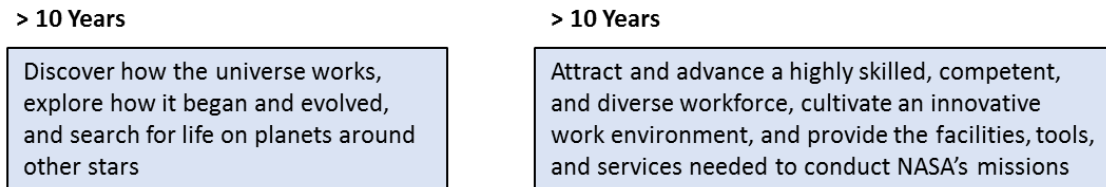


Figure 5-1. Executive-level objectives for the example.

Programmatic-level objectives are concerned with design, development, fabrication, fielding, and operation of systems that support the various strategic objectives that relate to NASA's mission. Four programmatic-level objectives are included in this example, as shown in Figure 5-2, differentiated according to the timeframes over which they apply.

Programmatic-Level Objectives: Program/Project Management Focus

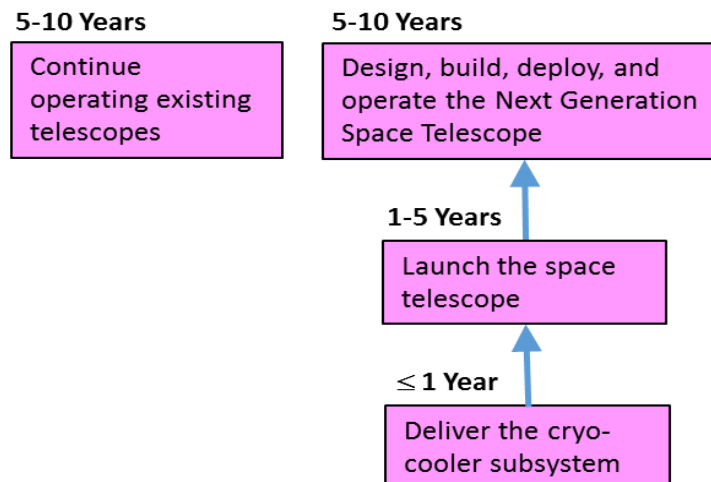


Figure 5-2. Programmatic-level objectives for the example.

Center-level objectives fall into two different categories: program/project support and development of the institutional capability. Two of each category are considered in this example, as shown in Figure 5-3. Like programmatic-level objectives, they are differentiated according to the timeframes over which they apply.

5.3.2 Integrated Objectives Hierarchy for the Organization as a Whole

Figure 5-4 illustrates for the example how the objectives hierarchies at executive, programmatic, and center levels are integrated into a single objectives hierarchy that maintains the relationships between objectives within each level and introduces the principle interfaces that exist across levels. In general, the programmatic-level objectives support one or more executive-level objectives, whereas the center-level objectives may support both the programmatic-level objectives and one or more executive-level objectives. For example, the objective numbered C (5-10) #6 and entitled “Maintain a sufficient cadre of highly capable analysts,” directly supports both objective P (5-10) #4 entitled “Design, build, deploy, and operate the Next Generation Space Telescope,” and objective E (>10) #2 entitled “Attract and advance a highly skilled workforce, cultivate an innovative work environment, and provide the facilities, tools, and services needed to conduct NASA’s missions.”

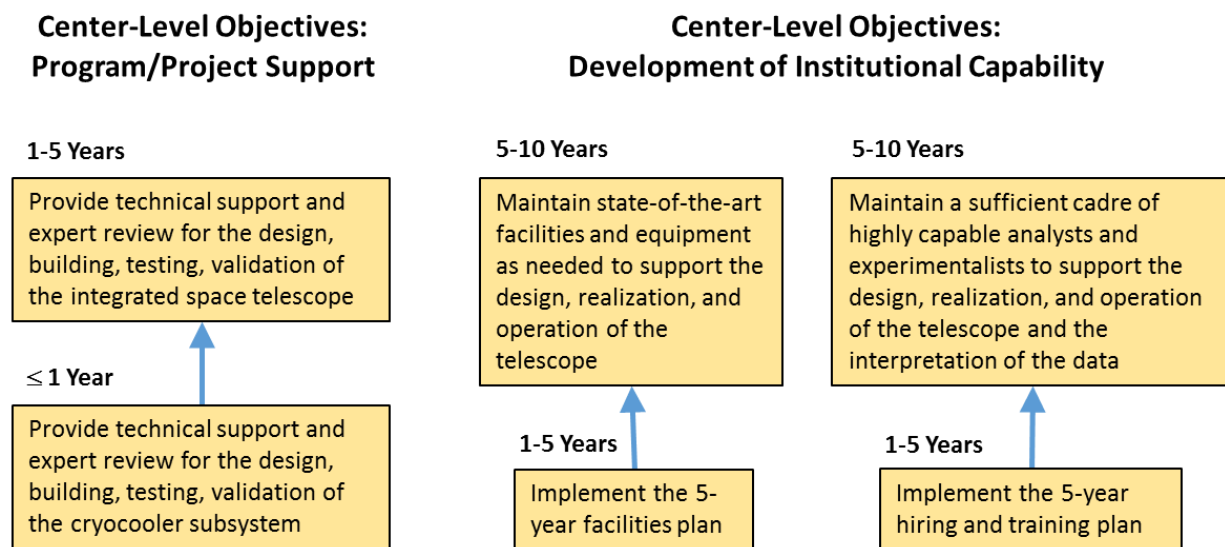


Figure 5-3. Center-level objectives for the example.

In Section 5.6.1, some additional cross-organizational interfaces between the objectives in Figure 5-4 will be identified and included in the development of the example.

5.4 Risks, Opportunities, and Leading Indicators

In the example, as in the methodology development presented earlier (e.g., Section 2.2.4), we speak of two levels of risk and opportunity: (1) individual and (2) cumulative or aggregate. Individual risks and opportunities are introduced by means of scenario statements. Each objective in the hierarchy may have several risk and opportunity scenarios associated with it. Each objective also has cumulative risk and opportunity, which represents the roll-up of:

1. The individual risk and opportunity scenarios that feed into it;
2. The cumulative risks and opportunities of the interfacing objectives that feed into it (i.e., its daughter objectives).

In preparation for demonstrating each step that is needed to complete the space telescope example, it is important to keep an eye on the principal outcomes that are sought. These include:

- Identification, evaluation, and ranking of individual known risks
- Identification, evaluation, and ranking of individual known opportunities
- Evaluation and ranking of cumulative known risks
- Evaluation and ranking of cumulative known opportunities
- Evaluation and ranking of cumulative UU risks
- Identification of risk and opportunity drivers and suggestions for responses, including actions and control options

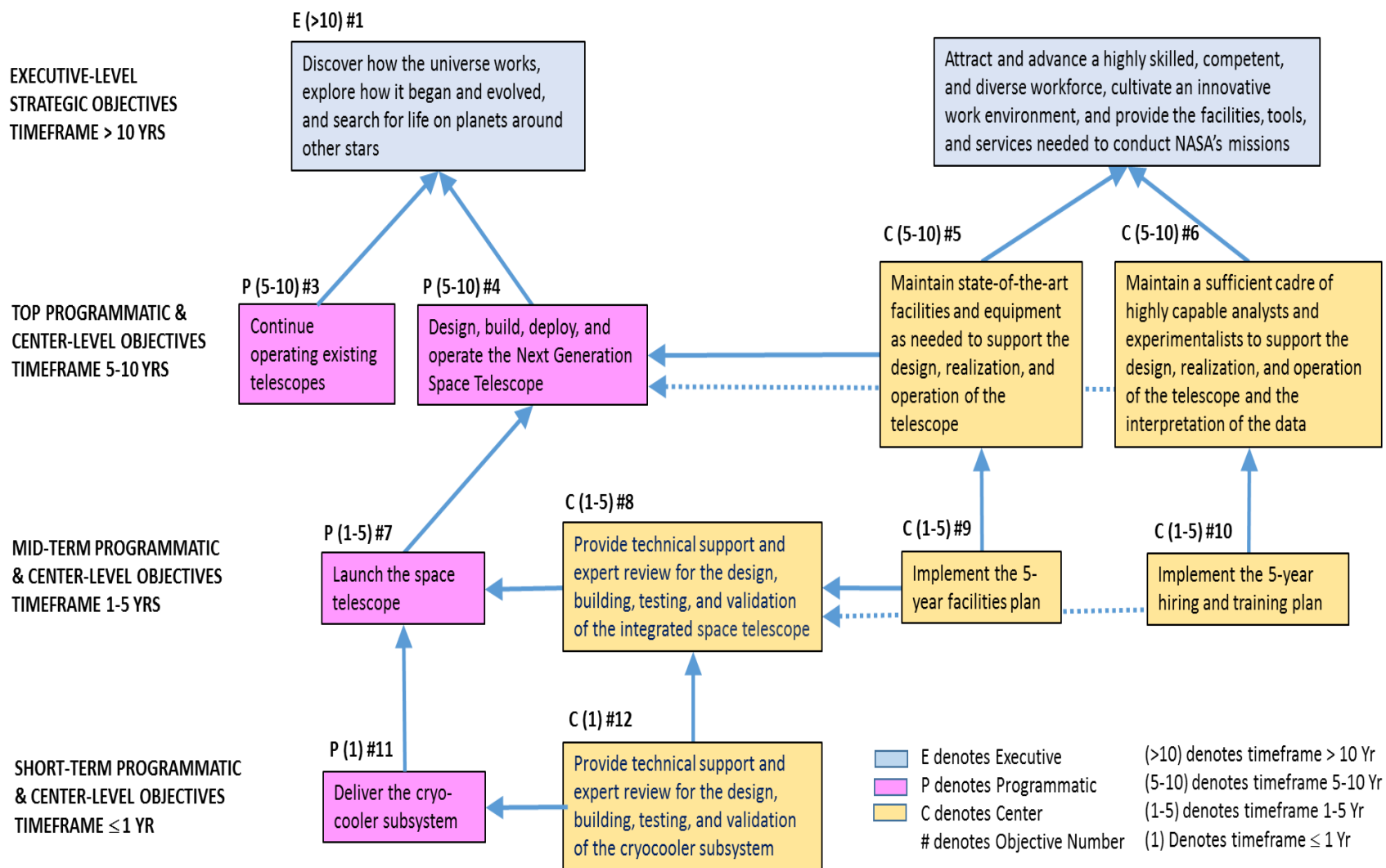










Figure 5-4. Integrated objectives hierarchy showing primary interfaces between objectives.

For conceptual purposes, a high-level schematic of the form of the anticipated results for cumulative risks and opportunities is shown in Table 5-1. The pursuit of the example in the following sections leads to results such as these.

Table 5-1. A view of the form of the outcome for cumulative risks and opportunities

Objective Index	Objective Description	Risk to Objective Level of Concern	Opportunity Level of Interest	Drivers	Suggested Responses & Control Options	UU Risk to Objective Level of Concern	UU Drivers	Suggested Responses & Control Options
C (1) #12	Provide tech. support & expert review for design, building, testing, validation of the cryocooler subsystem	TBD	TBD	TBD	TBD	TBD	TBD	TBD
P (1) #11	Deliver the cryocooler subsystem	TBD	TBD	TBD	TBD	TBD	TBD	TBD
C (1-5) #10	Implement the 5-year hiring and training plan	TBD	TBD	TBD	TBD	TBD	TBD	TBD
C (1-5) #9	Implement the 5-year facilities plan	TBD	TBD	TBD	TBD	TBD	TBD	TBD
C (1-5) #8	Provide technical support and expert review for the design, building, testing, validation of the integrated space telescope	TBD	TBD	TBD	TBD	TBD	TBD	TBD
P (1-5) #7	Launch the space telescope	TBD	TBD	TBD	TBD	TBD	TBD	TBD
C (5-10) #6	Maintain a sufficient cadre of highly capable analysts and experimentalists to support design, realization, and operation of telescope and interpretation of data	TBD	TBD	TBD	TBD	TBD	TBD	TBD
C (5-10) #5	Maintain state-of-the-art facilities and equipment to support design, realization, and operation of the telescope	TBD	TBD	TBD	TBD	TBD	TBD	TBD
P (5-10) #4	Design, build, deploy, and operate the Next Generation Space Telescope	TBD	TBD	TBD	TBD	TBD	TBD	TBD
P (5-10) #3	Continue operating existing telescopes	TBD	TBD	TBD	TBD	TBD	TBD	TBD
E (>10) #2	Attract/advance a highly skilled workforce, cultivate an innovative work environment, and provide the facilities, tools, and services needed to conduct NASA's missions	TBD	TBD	TBD	TBD	TBD	TBD	TBD
E (>10) #1	Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Risk and Opportunity Coloration

 Tolerable Risk	 Intolerable Risk	 Significant Opportunity	 Insignificant Opportunity
 Marginal Risk	 Undetermined Risk	 Marginal Opportunity	 Undetermined Opportunity

5.4.1 Known Individual Risks and Opportunities

Based on the information pertinent to JWST and HST presented in Section 5.2, a total of eight individual risks and one individual opportunity are postulated for this example. Three of the individual risks are assigned to strategic objective E(>10) #1, as shown below in Figure 5-5, and two of those are also assigned to objective E(>10) #2 because they directly affect both objectives. Also shown are suggested leading indicators that apply to each risk.

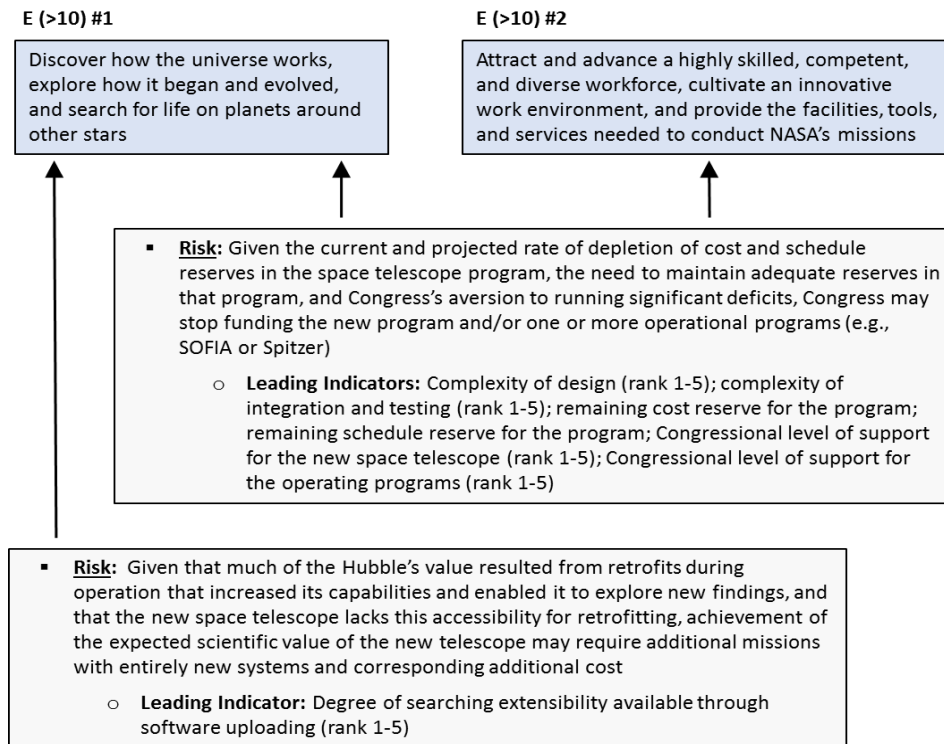


Figure 5-5. Individual risks and associated leading indicators for executive-level objectives.

In Figure 5-6, another three risks, with associated leading indicators, are assigned respectively to programmatic objectives at the top level, the mid-term level, and the short-term level, and in Figure 5-7, two risks, with associated leading indicators, are assigned to mid-term mission support objectives C (1-5) #9 and C (1-5) #10 in the institutional category. Finally, in Figure 5-8, a single opportunity, with associated leading indicators, is identified for strategic objective E (>10) #1, along with three introduced risks, with their own associated leading indicators, that would be of concern if the opportunity were acted upon.

5.4.2 Cross-Cutting Risks and Opportunities

Risk and opportunity scenarios identified during the practice of OROM may be cross-cutting in several ways:

- Organizationally cross-cutting scenarios affect multiple organizational units within an organization. All the risks and opportunities in Figures 5-5 through 5-8 are cross-cutting in this sense.

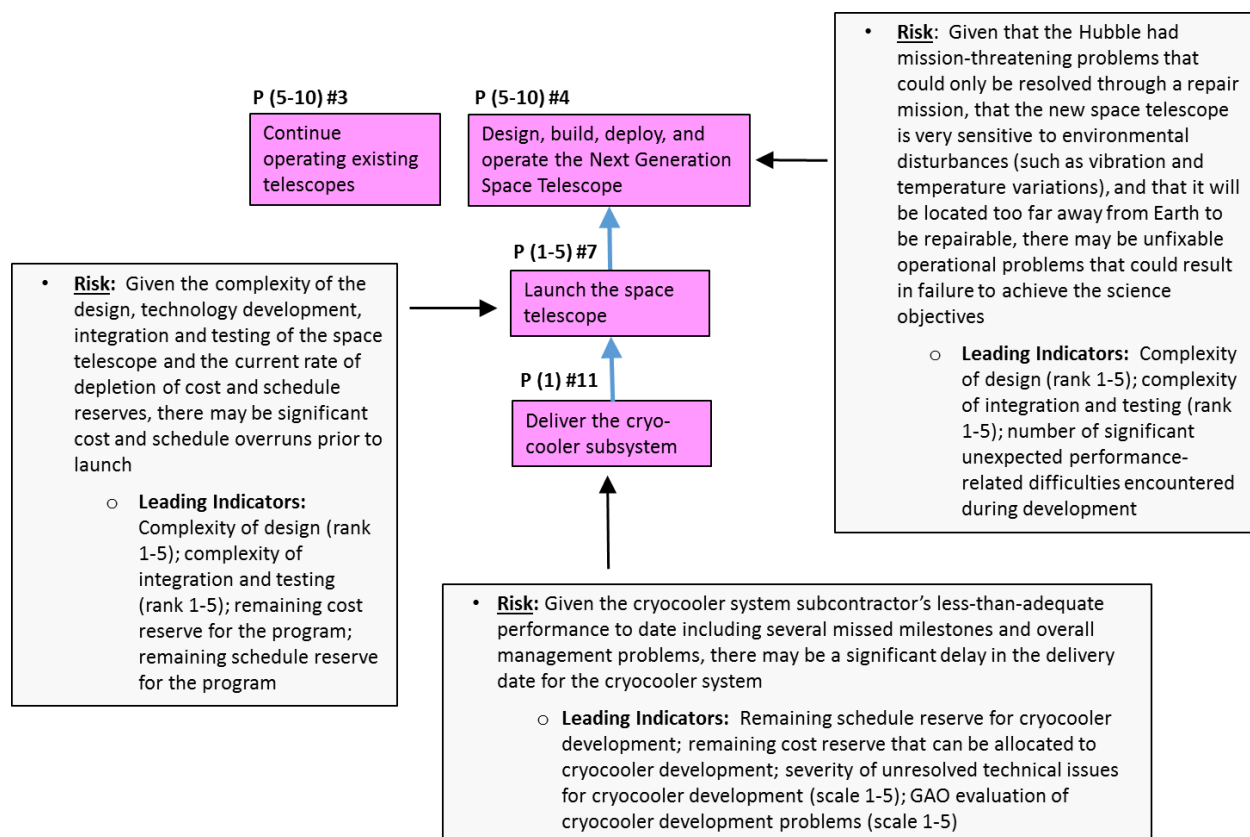


Figure 5-6. Individual risks and associated leading indicators for program-level objectives.

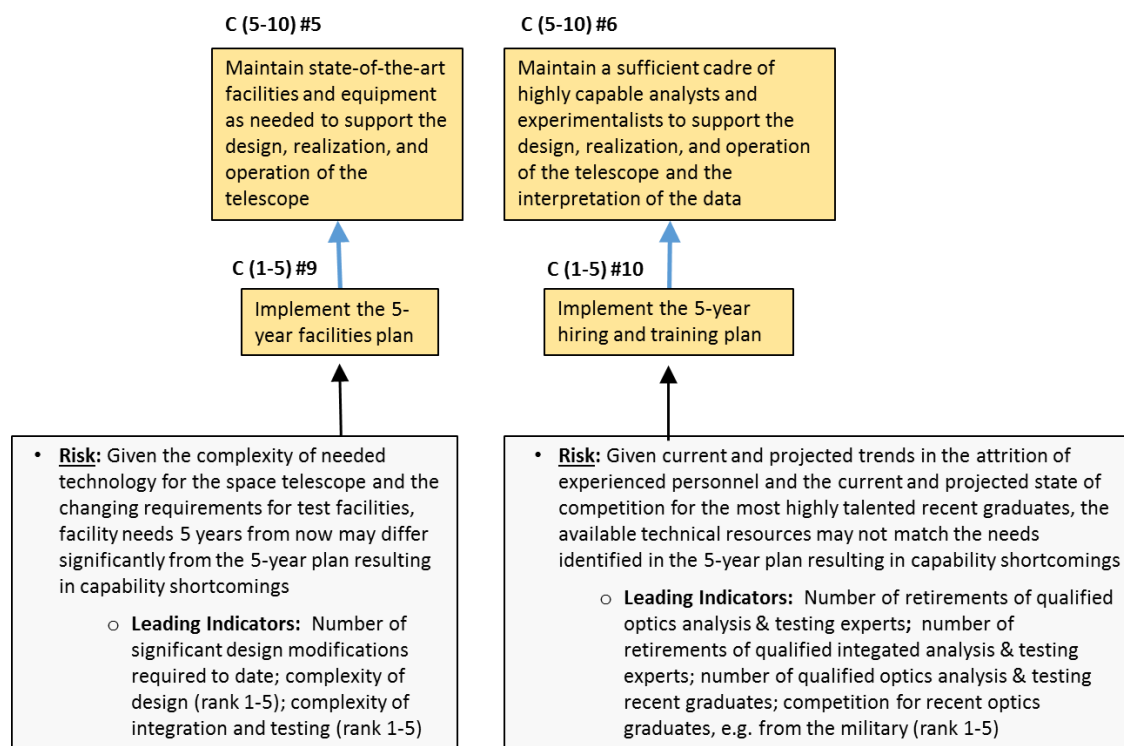


Figure 5-7. Individual risks and associated leading indicators for center-level objectives.

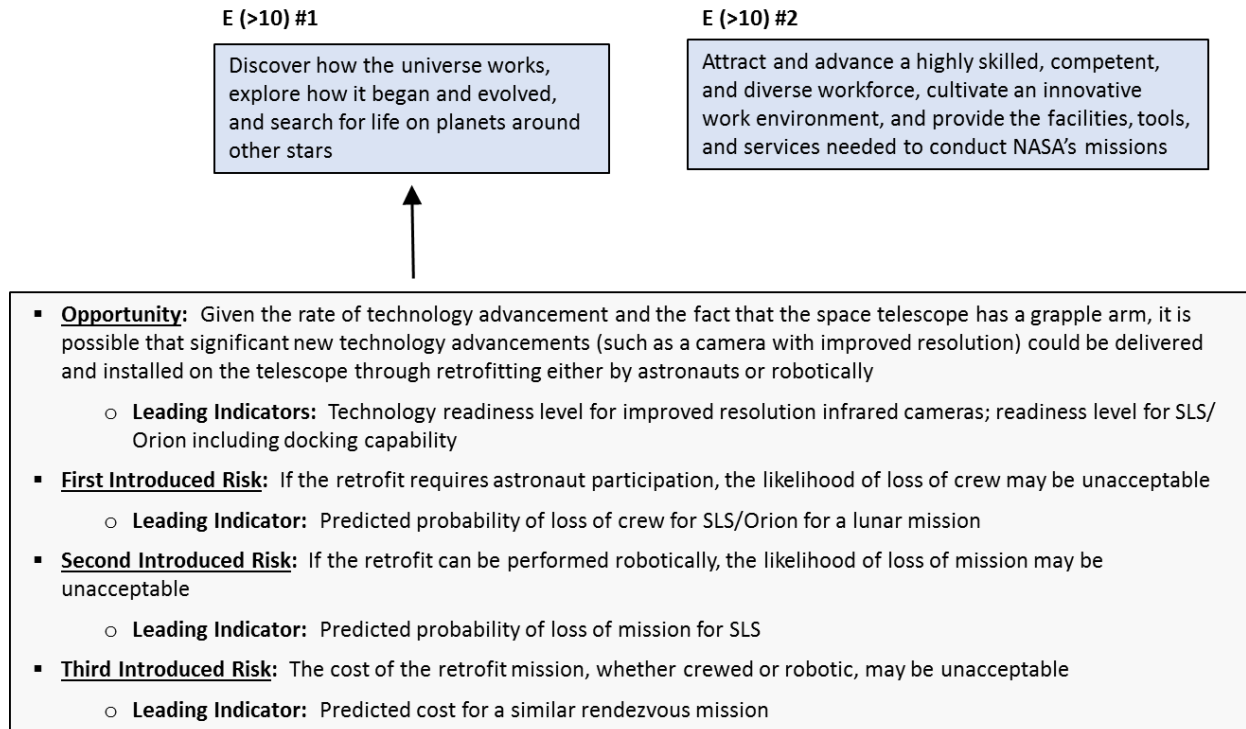


Figure 5-8. Individual opportunities, introduced risks, and associated leading indicators for executive-level objectives.

- Programmatically cross-cutting scenarios affect multiple programs and/or projects within the organization. One of the two risks in Figure 5-5 (the one placed higher in the chart) and both risks in Figure 5-7 are programmatically cross-cutting.
- Strategically cross-cutting scenarios directly affect multiple high-level objectives in the objectives hierarchy. The risk in Figure 5-5 identified in the previous bullet as being programmatically cross-cutting is also strategically cross-cutting.
- Pan-agency cross-cutting scenarios affect more than one agency. Such risks occur when agencies are involved in a cooperative effort.

Furthermore, it may be observed in Figures 5-5 through 5-8 that certain leading indicators may affect multiple risk scenarios and/or multiple objectives. For example, the indicator “complexity of design” affects a risk scenario and two objectives in Figure 5-5, as well as two risks and two objectives in Figure 5-6. This may be thought of as a “cross-cutting” leading indicator.

The OROM methodology is designed to promote consideration of cross-cutting risks, opportunities, and leading indicators by allowing for them to be entered into the accounting wherever is appropriate. Multiple listings of the same scenario or indicator under different entities, programs, or objectives are not a problem so long as they are treated consistently each time they are encountered. The use of taxonomies, as described in Section 4.4.1, can facilitate the identification of cross-cutting risk and opportunity scenarios and cross-cutting leading indicators.

5.4.3 Unknown and Underappreciated Risks

The process of identifying risk and opportunity scenarios is, of course, aimed at known risks and opportunities. In addition to known scenarios, however, the potential for unknown and/or underappreciated (UU) risk scenarios must be considered when determining the overall likelihood of success or failure (i.e., the cumulative risk of not being able to satisfy the top objectives of the organization).

It may be noted that several of the leading indicators listed in Figure 5-5 through 5-7 pertain either directly or indirectly to sources of UU risk. For example, “complexity of design” and “complexity of integration and testing” are direct exemplars of the first UU factor cited in Section 4.4.4: “amount of complexity, particularly involving the interfaces between different elements of the system.” In addition, the following leading indicator cited in Figure 5-6: “severity of unresolved technical issues for cryocooler development,” is an indirect exemplar of the third UU factor in Section 4.4.4: “use of fundamentally new technology or fundamentally new application of an existing technology.” If the assessment in this example had been performed prior to 2010, the sixth UU factor in Section 4.4.4 might also have been cited as a leading indicator of future risks based on commentary provided in [15] and [16] about former management deficiencies pertaining to cryocooler development: “degree of oversight when responsibilities are distributed among various entities.”

Beside these indicators, there are also other leading indicators (see Section 4.4.4) that tend to be correlated with the occurrence of UU challenges. Two of the most important are:

- Pressures to meet extremely tight schedules and/or budgets, particularly in combination with a complex set of tasks
- Deficiencies of management such as failure to maintain adequate oversight of distributed suppliers and failure to respect and promote open communication

In addition to the ranking of cumulative known risks and opportunities for each objective, therefore, the principal outcome of the example will also include a ranking of the cumulative level of concern for UU risks based on the leading indicators that pertain to UU risks, along with a list of the key attributes of the UU indicators that drive that cumulative ranking. A demonstration of the roll-up process leading to this type of result will be presented in Section 5.6.5.

5.5 Example Templates for Risk and Opportunity Identification and Evaluation

Sections 5.5, 5.6, and 5.7 present a series of templates intended to demonstrate how the information presented in the preceding sections can be used first to evaluate the aggregate risk and aggregate opportunity associated with each objective in the integrated hierarchy of objectives, and then to identify and evaluate options for risk mitigation, opportunity action, and internal control. The principal purpose of the templates is to ensure that all relevant information is brought to bear in a fashion that is rational, comprehensive, and transparent.

5.5.1 Risk and Opportunity Identification Template

Table 5-2 presents the Risk and Opportunity Identification Template, which collects the information about known risks and opportunities presented in Section 5.4. It does this by

Table 5-2. Risk and Opportunity Identification Template

Blue typeface denotes repeated instances of risks, opportunities, or leading indicators

Obj. No.	Objective Description	Scen. Type	Scen. No.	Scenario Statement	Leading Indicator Number	Leading Indicator Description
P (1) #11	Deliver the cryocooler subsystem	Risk	1	Given the cryocooler system subcontractor's less-than-adequate performance to date including several missed milestones and overall management problems, there may be a significant delay in the delivery date for the cryocooler system	1	Remaining schedule reserve for cryocooler development
					2	Remaining cost reserve for the program that can be allocated to cryo. devel.
					3	Severity of unresolved technical issues for cryo development (scale 1-5)
					4	GAO evaluation of cryocooler development problems (scale 1-5)
C (1-5) #10	Implement the 5-year hiring and training plan	Risk	2	Given current and projected trends in the attrition of experienced personnel and the current and projected state of competition for the most highly talented recent graduates, the available technical resources may not match the needs identified in the 5-year plan resulting in capability shortcomings	5	Number of retirements of qualified optics analysis & testing experts
					6	Number of retirements of qualified integrated analysis & testing experts
					7	Number of qualified optics analysis & testing recent graduates
					8	Competition for recent optics graduates, e.g. from the military (rank 1-5)
C (1-5) #9	Implement the 5-year facilities plan	Risk	3	Given the complexity of needed technology for the space telescope and the changing requirements for test facilities, facility needs 5 years from now may differ significantly from the 5-year plan resulting in capability shortcomings	9	Number of significant design modifications required to date
					10	Complexity of design (rank 1-5)
					11	Complexity of integration and testing (rank 1-5)
P (1-5) #7	Launch the space telescope	Risk	4	Given the complexity of the design, technology development, integration and testing of the space telescope and the current rate of depletion of cost and schedule reserves, there may be significant cost and schedule overruns prior to launch	10	Complexity of design (rank 1-5)
					11	Complexity of integration and testing (rank 1-5)
					12	Remaining cost reserve for the program
					13	Remaining schedule reserve for the program
P (5-10) #4	Design, build, deploy, and operate the Next Generation Space Telescope	Risk	5	Given that the Hubble had mission-threatening problems that could only be resolved through a repair mission, that the new space telescope is very sensitive to environmental disturbances, and that it will be located too far away from Earth to be repairable, there may be unfixable operational problems that could result in failure to achieve the science objectives	10	Complexity of design (rank 1-5)
					11	Complexity of integration and testing (rank 1-5)
					14	Number of significant unexpected performance-related difficulties encountered during development
E (>10) #2	Attract a highly skilled work-force, cultivate an innovative work environment, and provide needed facilities, tools, & services	Risk	6	Given the current and projected rate of depletion of cost and schedule reserves in the space telescope program, the need to maintain adequate reserves in that program, and Congress's aversion to running significant deficits, Congress may stop funding the new program and/or one or more operational programs (e.g., SOFIA or Spitzer)	12	Cost reserve for the program
					13	Schedule reserve for the program
					15	Congressional level of support for the new space telescope (rank 1-5)
					16	Congressional level of support for the operating programs (rank 1-5)
E (>10) #1	Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars	Risk	6	Same as above	10-13, 15,16	Same as above
		Risk	7	Given that much of the Hubble's value resulted from retrofits during operation that increased its capabilities and enabled it to explore new findings, and that the new space telescope lacks this accessibility for retrofitting, achievement of the expected scientific value of the new telescope may require additional missions with entirely new systems and corresponding additional cost	17	Degree of searching extensibility available through software uploading (rank 1-5)
E (>10) #1	Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars	Opp.	8	Given the rate of tech. advancement and the fact that the space telescope has a grapple arm, it is possible that significant new technology advancements (such as a camera with improved resolution) could be delivered and installed on the telescope through retrofitting either by astronauts or robotically	18	Technology readiness level for improved resolution infrared cameras
					19	Readiness level for SLS/Orion including docking capability
		Intr. Risk	9	If the retrofit requires astronaut participation, the likelihood of loss of crew may be unacceptable	20	Predicted P(LOC) for SLS/Orion for a lunar mission
		Intr. Risk	10	If the retrofit can be performed robotically, the likelihood of loss of mission may be unacceptable	21	Predicted P(LOM) for SLS
		Intr. Risk	11	The cost of the retrofit mission, whether crewed or robotic, may be unacceptable	22	Predicted cost for a rendezvous mission

tabulating the identified individual risk, opportunity, and introduced risk scenarios, the leading indicators for each scenario, and the objective to which each scenario is assigned.

5.5.2 Leading Indicator Evaluation Template

Table 5-3 presents the Leading Indicator Evaluation Template, which is used to assign watch and response trigger values to each leading indicator, record the current value of the indicator, and provide an indication of the trend. As explained earlier, leading indicator trigger values are used to signal when a risk is reaching a risk tolerance boundary or when an opportunity is reaching an opportunity appetite boundary. Reaching the trigger values for risk leading indicators implies that the likelihood of not being able to satisfy an element of the strategic objectives hierarchy is becoming a concern. Reaching the trigger values for opportunity leading indicators implies either that there is a potential for significantly increasing the likelihood of being able to satisfy an element of the strategic objectives hierarchy, or that there is an emerging opportunity to achieve new goals and objectives that were formerly considered unreachable or inconceivable. Exceedance of a *watch trigger* suggests that an action should be considered but is not imminently needed. Exceedance of a *response trigger* suggests that an action may be imminently needed; e.g., mitigation of the risk or exploitation of the opportunity.

The level of concern for a given leading indicator is determined by where the current value of the leading indicator and/or a projected future value lie with respect to the watch and response trigger values. In Table 5-3, the projected future value one year from the present (referred to earlier as the “trend”) is shown as a range to account for uncertainty. For conceptual purposes, it may be helpful for some people to think of the uncertainty range as being more-or-less a 90% confidence interval for the future value of the leading indicator. However, if confidence levels are used in this context, they should be thought of as qualitative degrees of belief and not statistical quantities.

Table 5-4 illustrates how the Leading Indicator Evaluation Template might be completed for short-term programmatic objective P (1) #11, entitled “Deliver the cryocooler subsystem.” The entries are based principally on information about the JWST that was previously itemized in Section 5.2, i.e., publicly available material. The use of this information is summarized in the columns labeled “Rationale.” In short, the template records the following information:

- The 100% reduction during the past year in the schedule margin for development of the cryocooler (leading indicator 1) has caused concern about the cryocooler delivery date and the schedule of the program as a whole.
- The 40% reduction during the past year in the cost margin for the program as a whole (leading indicator 2) has caused concern about the amount of resources that can be reallocated to the cryocooler.
- The fact that several significant technical issues have not yet been completely resolved (leading indicator 3) has caused further concern.
- A somewhat negative progress report written by the GAO (leading indicator 4) about management problems concerning the cryocooler development has again caused concern.

Table 5-3. Leading Indicator Evaluation Template

Blue typeface denotes repeated instances of leading indicators

Obj No.	Leading Indicator Number	Leading Indicator Description	Risk, Opp., or Intr. Risk	Scen. No.	Lead. Ind. Watch Value	Rationale or Source	Lead. Ind. Resp. Value	Rationale or Source	Lead. Ind. Current Value	Rationale or Source	Lead. Ind. 1-Yr. Projected Value	Rationale or Source	Leading Indicator Level of Concern
P (1) #11	1	Remaining schedule reserve for cryocooler development	Risk	1	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	2	Remaining cost reserve that can be allocated to cryo devel.	Risk	1	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	3	Severity of unresolved technical issues for cryo devel.	Risk	1	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	4	GAO evaluation of cryocooler development problems	Risk	1	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
C (1-5) #10	5	No. of retirements of qualif. optics anal. & testing experts	Risk	2	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	6	No. of retirements of qualif. integr. anal. & testing experts	Risk	2	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	7	No. of qualified optics analysis & testing recent graduates	Risk	2	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	8	Competition for recent optics grads, e.g. from the military	Risk	2	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
C (1-5) #9	9	No. of significant design modifications required to date	Risk	3	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	10	Complexity of design (rank 1-5)	Risk	3	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	11	Complexity of integration and testing (rank 1-5)	Risk	3	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
P (1-5) #7	10	Complexity of design (rank 1-5)	Risk	4	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	11	Complexity of integration and testing (rank 1-5)	Risk	4	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	12	Remaining cost reserve for the program	Risk	4	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	13	Remaining schedule reserve for the program	Risk	4	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
P (5-10) #4	10	Complexity of design (rank 1-5)	Risk	5	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	11	Complexity of integration and testing (rank 1-5)	Risk	5	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	14	No. significant unexpected perf. difficulties during devel.	Risk	5	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
E (>10) #2	12	Cost reserve for the program	Risk	6	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	13	Schedule reserve for the program	Risk	6	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	15	Congressional level of support for the new space telescope	Risk	6	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	16	Congressional level of support for the operational progs.	Risk	6	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
E (>10) #1	10	Complexity of design (rank 1-5)	Risk	6	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	11	Complexity of integration and testing (rank 1-5)	Risk	6	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	12	Cost reserve for the program	Risk	6	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	13	Schedule reserve for the program	Risk	6	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	15	Congressional level of support for the new space telescope	Risk	6	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	16	Congressional level of support for the operational progs.	Risk	6	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	17	Degree of searching extensibility avail. thru S/W uploading	Risk	7	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
E (>10) #1	18	Tech. readiness level for improved resolution IR cameras	Opp.	8	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	19	Readiness level for SLS/ Orion including docking capability	Opp.	8	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	20	Predicted P(LOC) for SLS/ Orion lunar mission	Intr. R.	9	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	21	Predicted P(LOM) for SLS	Intr. R.	10	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD
	22	Predicted cost for a rendezvous mission	Intr. R.	11	XX	XX	XX	XX	XX	XX	XX to XX	XX	TBD

Table 5-4. Example entries for Leading Indicator Evaluation Template for Objective P(1) #11: Deliver the cryocooler subsystem

Objec. No.	Leading Indicator Number	Leading Indicator Description	Risk, Opp., or Ind. Risk	Scen. No.	Lead. Ind. Watch Value	Rationale or Source	Lead. Ind. Resp. Value	Rationale or Source	Lead. Ind. Current Value	Rationale or Source	Lead Ind. 1-Yr. Projected Value	Rationale or Source	Leading Indicator Level of Concern
P (1) #11	1	Remaining schedule reserve for cryocooler development	Risk	1	50% of plan	Historically correlated with moderate likelihood of overrun	10% of plan	Historically correlated with high likelihood of overrun	0% of plan	As reported by GAO	0% to 30% of plan	The schedule reserve for cryo development diminished from 5 months to 0 months in the past year, but there is enough schedule reserve in other tasks to divert manpower to the cryocooler development task so as to regain its positive reserve	Significant
	2	Remaining cost reserve for the program that can be allocated to cryocooler development	Risk	1	50% of plan	Historically correlated with moderate likelihood of overrun	10% of plan	Historically correlated with high likelihood of overrun	10% of plan	As reported by GAO, 60% of last year's program cost reserve remains. Assuming that 50% of the initial cost reserve has to be available for other contingencies, there is a remaining reserve of 10% that can be allocated to cryo devel.	30% to 50% of plan	More cost reserves will become available in 2016, according to the GAO. Also, JPL's analysis of subcontractor performance trends projects that cryocooler development will not be delayed by more than 7 months, making it likely that integrated testing will begin on time (February 2016).	Marginal
	3	Severity of unresolved technical issues for cryocooler development (scale 1-5)	Risk	1	2	Any nontrivial unresolved technical issue requires watching	3	Technical issues of moderate severity require a response	3	Unresolved issues include (1) failure of compressor to perform to specification when brazed to spacecraft; (2) validation of replacement valves in cold-head assembly during vacuum testing; (3) cryocooler generated vibration possibly exceeding permissible levels	1 to 3	Resolution of these technical issues has to be verified by as-flown testing of prototype assemblies, which will occur during 2015. Successful results are expected but, as with any test, success is not guaranteed beforehand.	Marginal
	4	GAO evaluation of cryocooler development problems (scale 1-5, 1=very low confidence, 5=very high confidence)	Risk	1	4	When confidence is high but not very high, watchfulness is needed	2	When confidence is low, a response is needed	3	GAO report: "During the past year, delays have occurred on every element and major subsystem schedule—especially with the cryocooler—leaving all at risk of negatively impacting the overall project schedule reserve if further delays occur."	3 to 5	JPL's analysis of subcontractor performance trends, cited above, suggests that GAO's concerns may be resolved within the next year.	Marginal

- A trend analysis by JPL implying that the schedule margin will not be further degraded (1-year projected value for leading indicator 1) has alleviated some concern, particularly since the analysis indicates that the schedule for integrating the cryocooler with the spacecraft and beginning the integrated testing should remain intact.
- The warning signs discussed by the GAO, however, suggest there is a large amount of uncertainty in JPL's estimate, leading to additional concern.

5.6 Example Templates for Risk and Opportunity Roll-Up

5.6.1 Objectives Interface and Influence Template

While the principal interfaces between the objectives were displayed in Figure 5-4, a number of secondary interfaces could also be postulated. For this example, three secondary interfaces between the top level of the programmatic and mission support objectives and the executive level strategic objectives are also considered, as shown in Figure 5-9:

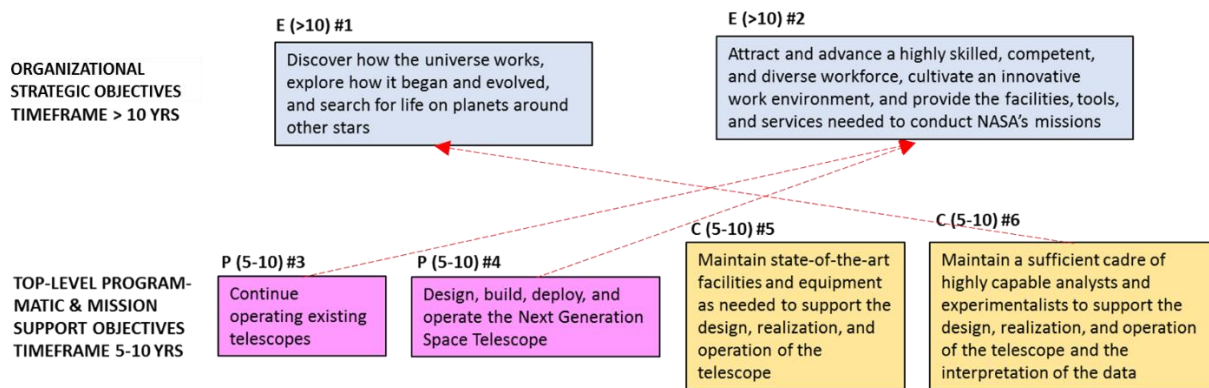


Figure 5-9. Secondary objective interfaces for the example

Two of the secondary objectives account for the fact that the success of the exploratory programs and projects (objectives P (5-10) #3 and P (5-10) #4) influence the success of attracting a highly skilled workforce and providing the needed facilities (objective E (>10) #2) by defining the technical qualifications that are needed within the workforce, by providing an incentive for qualified technical people to work at NASA, and by providing the driving function for the facilities to be developed. The third recognizes the fact that maintaining a sufficient cadre of highly capable analysts (objective C (5-10) #6) is necessary in order to successfully interpret the data obtained from the telescopes during their operation and to set the direction for additional observations.

The objectives interface and influence template encodes this sort of information in tabular form, as shown in Table 5-5.

Table 5-5. Objectives Interface and Influence Template.

Red typeface denotes secondary interfaces

Obj. No.	Objective Description	Num. Infl. Objs.	Influencing Obj. No.	Influencing Objective Description	Basis for Influence
C (1) #12	Provide technical support and expert review for the design, building, testing, and validation of the cryocooler subsystem	0			
P (1) #11	Deliver the cryocooler system	1	C (1) #12	Provide technical support and expert review for the design, building, testing, and validation of the cryocooler subsystem	Necessary milestone before delivery
C (1-5) #10	Implement the 5-year hiring and training plan	0			
C (1-5) #9	Implement the 5-year facilities plan	0			
C (1-5) #8	Provide technical support and expert review for the design, building, testing, validation of the integrated space telescope	3	C (1) #12	Provide technical support and expert review for the design, building, testing, and validation of the cryocooler subsystem	Necessary milestone before integration
			C (1-5) #10	Implement the 5-year hiring and training plan	Necessary capability to achieve objective
			C (1-5) #9	Implement the 5-year facilities plan	Necessary capability to achieve objective
P (1-5) #7	Launch the space telescope	2	P (1) #11	Deliver the cryo system	Necessary milestone before launch readiness
			C (1-5) #8	Provide technical support and expert review for the design, building, testing, validation of the integrated space telescope	Necessary milestone before launch readiness
C (5-10) #6	Maintain a sufficient cadre of highly capable analysts and experimentalists to support the design, realization, and operation of the telescope and the interpretation of the data	1	C (1-5) #10	Implement the 5-year hiring and training plan	Necessary capability to achieve objective
C (5-10) #5	Maintain state-of-the-art facilities and equipment as needed to support the design, realization, and operation of the telescope	1	C (1-5) #9	Implement the 5-year facilities plan	Necessary capability to achieve objective
P (5-10) #4	Design, build, deploy, and operate the Next Generation Space Telescope	3	P (1-5) #7	Launch the space telescope	Necessary milestone before operation
			C (5-10) #6	Maintain a sufficient cadre of highly capable analysts and experimentalists to support the design, realization, and operation of the telescope and the interpretation of the data	Supports telescope design, development, deployment, and operation
			C (5-10) 5	Maintain state-of-the-art facilities and equipment as needed to support the design, realization, and operation of the telescope	Supports telescope design, development, deployment, and operation
P (5-10) #3	Continue operating existing telescopes	0			
E (>10) #2	Attract and advance a highly skilled, competent, and diverse workforce, cultivate an innovative work environment, and provide the facilities, tools, and services needed to conduct NASA's missions	4	C (5-10) #6	Maintain a sufficient cadre of highly capable analysts and experimentalists to support the design, realization, and operation of the telescope and the interpretation of the data	Supports maintenance of technical capabilities
			C (5-10) #5	Maintain state-of-the-art facilities and equipment as needed to support the design, realization, and operation of the telescope	Supports maintenance of technical capabilities
			P (5-10) #4	Design, build, deploy, and operate the Next Generation Space Telescope	Program success promotes public interest & supports NASA's mission
			P (5-10) #3	Continue operating existing telescopes	Program success promotes public interest
E (>10) #1	Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars	3	C (5-10) #6	Maintain a sufficient cadre of highly capable analysts and experimentalists to support the design, realization, and operation of the telescope and the interpretation of the data	Necessary capability to ensure optimal science gain
			P (5-10) 4	Design, build, deploy, and operate the next space telescope	Program success promotes discovery of universe
			P (5-10) 3	Continue operating existing telescopes	Program success promotes discovery of universe

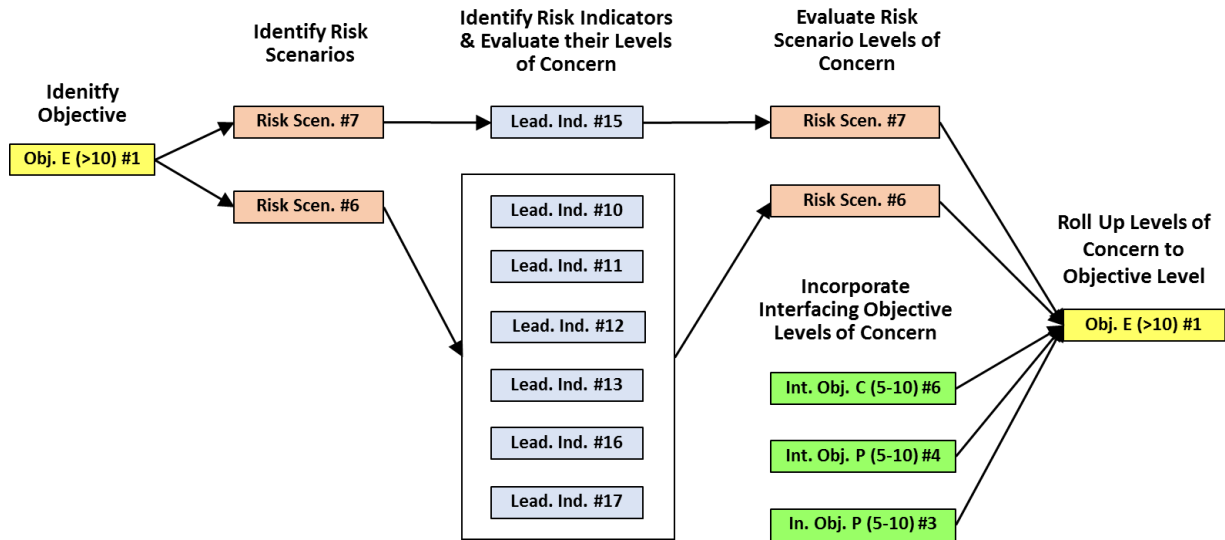


Figure 5-10. Schematic of roll-up method alternative 1 for Objective E (>10) #1

5.6.2 Known Risk Roll-Up Template

The aggregate risk of not successfully meeting an objective can be evaluated by rolling up the individual risk scenarios in either of two alternative ways. The first alternative is illustrated in Figure 5-10, with reference to one of the top objectives in Figure 5-4, and consists of the following steps:

- Identify the objective of interest from the objectives hierarchy (Figure 5-4)
- Identify the risk scenarios associated with the objective from the Risk and Opportunity Identification Template (Table 5-2)
- Identify the risk leading indicators associated with each risk scenario from the Risk and Opportunity Identification Template (Table 5-2), and evaluate the leading indicator levels of concern using the Leading Indicator Evaluation Template (Table 5-3)
- Roll up the leading indicator levels of concern for each risk scenario to obtain a corresponding level of concern for each risk scenario using a transparent and documented roll-up rationale
- Roll up the levels of concern for the risk scenarios, obtained from the previous bullet, with the levels of concern obtained for the interfacing objectives, using the Objectives Interface and Influence Template (Table 5-5) to identify the interfacing objectives. (The order of the roll-up is such that the levels of concern for the interfacing objectives will have been determined prior to the present roll-up.)

The rolled-up level of concern at the end of the process is defined as the aggregate, or cumulative, risk of not meeting the objective, and the transparent and documented rationale for the roll-up process defines the justification for the aggregate risk.

The second alternative for rolling up levels of concern to obtain the aggregate risk of an objective is illustrated in Figure 5-11. The difference between it and the first alternative is that it cuts out

one of the steps. Specifically, the aggregate risk of the objective is determined by rolling up the levels of concern for the leading indicators directly (together with the levels of concern for the interfacing objectives), without first performing a roll-up from the leading indicators to the risk scenarios. The rationale is that the leading indicators are *de facto* surrogates for the risk scenarios, and so it is as reasonable to infer the aggregate risk of not meeting an objective from the levels of concern associated with the leading indicators as it is to infer the aggregate risk from the levels of concern of the risk scenarios. Thereafter, it is possible to determine levels of concern for each risk scenario by performing an after-the-fact roll-up from leading indicators to individual risk scenarios in order to assess the importance of each risk scenario.

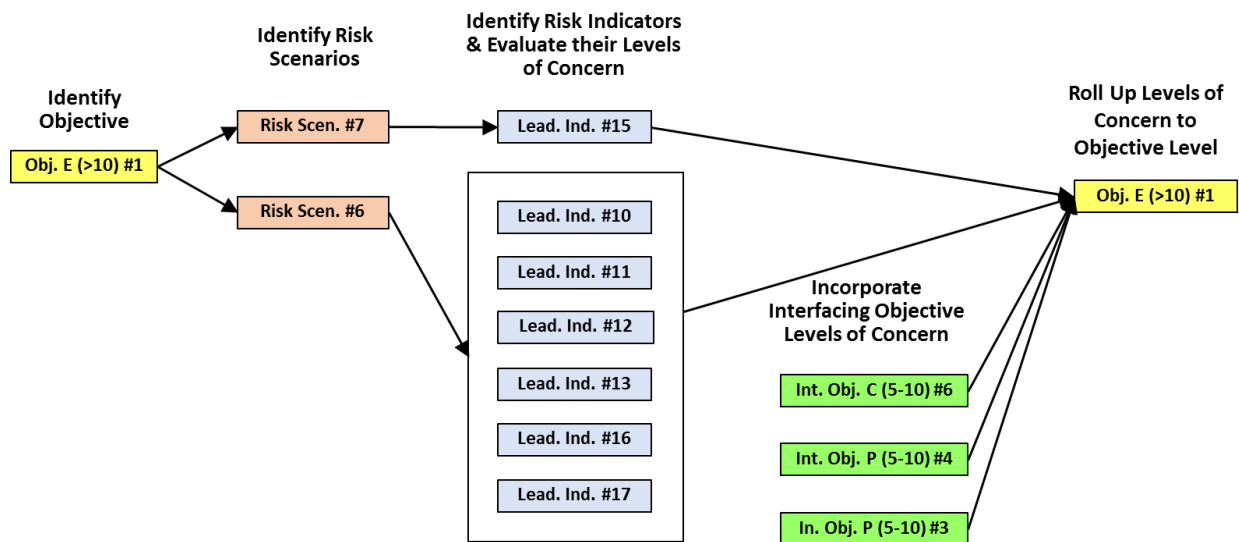


Figure 5-11. Schematic of roll-up method alternative 2 for Objective E (>10) #1

Using the second alternative, the aggregate risk of not being successful in delivering the cryocooler subsystem in a timely manner (Objective P (1) #11) is reflective of a roll-up of the levels of concern for Leading Indicators 1 through 4 and the aggregate risk of not being able to provide the needed technical support for this task (Objective C (1) #12), as shown in Figure 5-12.

The associated roll-up is performed on the Known Risk Roll-Up Template, Table 5-6. A similar template for opportunity roll-up will be discussed in the next subsection.

For each objective, starting from the bottom and working up to the top, the Known Risk Roll-Up Template lists all the risk indicators and interfacing objectives that feed into it. As mentioned, these inputs are obtained from prior templates. The following paragraphs discuss the additional information that is contained in the template, starting from the 6th column.

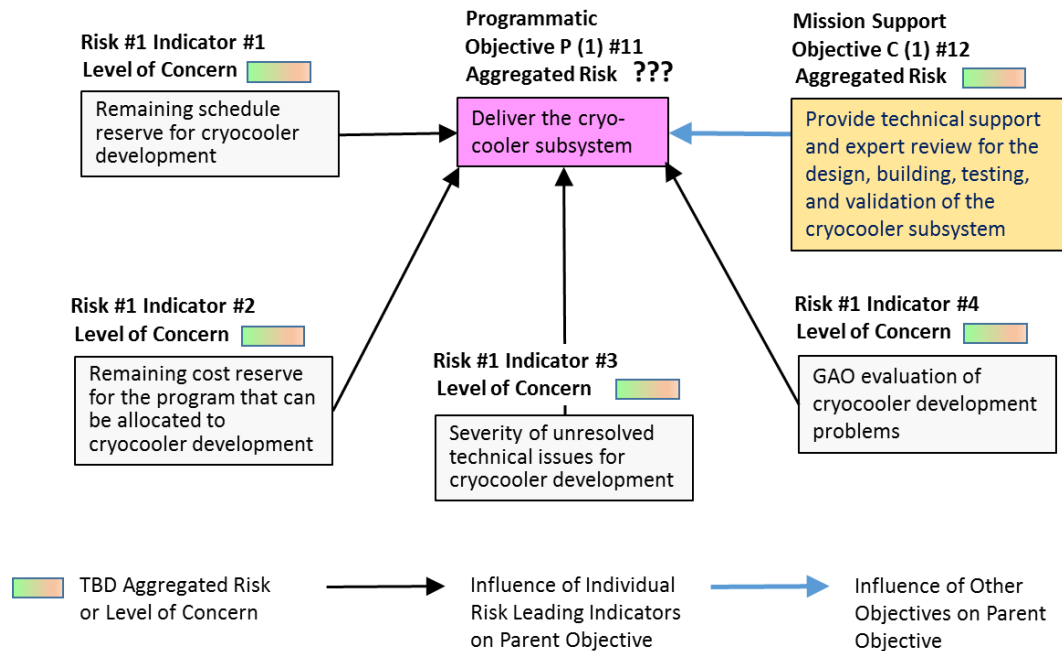


Figure 5-12. Schematic of risk roll-up for Objective P (1) #11 in the example.

Composite Indicator

The column labeled “Composite Indicator” provides a means for accounting for the fact that the trigger values for some of the indicators may be dependent on the values of other indicators. Such co-dependencies may be important. (For example, trigger values for cost and schedule margins will normally depend on the amount of work remaining to be accomplished, as indicated by the number and complexity of unresolved issues.) For simplicity, we initially assume that we do not need to specify co-dependencies between indicators to execute the example, but we will return to the subject in Section 5.6.4.

Leading Indicator Level of Concern / Influencing Objective Level of Risk

As mentioned, the roll-up process accounts for two types of risk input: (1) the level of concern for the leading indicators that are associated with the objective, and (2) the aggregate risk for the interfacing objectives that feed into it. The level of concern for leading indicators has already been recorded in the Leading Indicator Evaluation Template (Table 5-3) and is transcribed from that template into the Known Risk Roll-Up Template. The aggregate risk for influencing objectives, on the other hand, is obtained from the portion of the roll-up process that has already been performed and entered earlier into the Known Risk Roll-Up Template. For example, the aggregate risk for Objective C(1) #12, which feeds into Objective P(1) #11, has been entered higher up in Table 5-6.

Table 5-6. Known Risk Roll-Up Template

Blue typeface denotes repeated instances of leading indicators

Red typeface denotes secondary interfaces

Objec. No.	Objective Description	Type of Scen.	Lead. Ind. No. or Influencing Objec. No.	Description of Leading Indicator or Influencing Objective	Composite Indicator	Lead. Ind. Concern or Objec. Aggr. Risk	Aggregate Risk of Objective	Rollup Rationale
C (1) #12	Provide tech. support & expert review for design, building, testing, and validation of the cryocooler subsystem	None	None	None	None	None	None	No risks entered
P (1) #11	Deliver the cryocooler subsystem	Risk	1	Remaining schedule reserve for cryocooler development	None	TBD	TBD	TBD
			2	Remaining cost reserve for the program allocatable to cryo devel.	None	TBD		
			3	Severity of unresolved tech issues for cryo devel. (scale 1-5)	None	TBD		
			4	GAO evaluation of cryocooler development problems (scale 1-5)	None	TBD		
			C (1) #12	Provide tech support & expert review for design, ... of cryo subsys.	None	None		
C (1-5) #10	Implement the 5-year hiring and training plan	Risk	5	No. of retirements of qualified optics analysis & testing experts	None	TBD	TBD	TBD
			6	No. of retirements of qualified integrated analysis & testing experts	None	TBD		
			7	No. of qualified optics analysis & testing recent graduates	None	TBD		
			8	Competition for recent optics graduates, e.g., from the military	None	TBD		
C (1-5) #9	Implement the 5-year facilities plan	Risk	9	Number of significant design modifications required to date	None	TBD	TBD	TBD
			10	Complexity of design	None	TBD		
			11	Complexity of integration and testing	None	TBD		
C (1-5) #8	Provide technical support and expert review for the design, building, testing, and validation of the integrated space telescope	Risk	C (1) #12	Provide tech support & expert review for design, ... of cryo subsys	None	None	TBD	TBD
			C (1-5) #10	Implement the 5-year hiring and training plan	None	TBD		
			C (1-5) #9	Implement the 5-year facilities plan	None	TBD		
P (1-5) #7	Launch the space telescope	Risk	10	Complexity of design (rank 1-5)	None	TBD	TBD	TBD
			11	Complexity of integration and testing (rank 1-5)	None	TBD		
			12	Cost reserve for the program	None	TBD		
			13	Schedule reserve for the program	None	TBD		
			P (1) #11	Deliver the cryo system	None	TBD		
			C (1-5) #8	Provide tech. support & expert review for design, ... of integr scope	None	TBD		
C (5-10) #6	Maintain a sufficient cadre ... to support ... operation of telescope and interpretation of data	Risk	C (1-5) #10	Implement the 5-year hiring and training plan	None	TBD	TBD	TBD
C (5-10) #5	Maintain state-of-the-art facilities and equipment ... to support the design, realization, and operation of the telescope	Risk	C (1-5) #9	Implement the 5-year facilities plan	None	TBD	TBD	TBD
P (5-10) #4	Design, build, deploy, and operate the Next Generation Space Telescope	Risk	10	Complexity of design (rank 1-5)	None	TBD	TBD	TBD
			11	Complexity of integration and testing (rank 1-5)	None	TBD		
			14	No. of significant unexpected performance-related difficulties encountered during development	None	TBD		
			P (1-5) #7	Launch the space telescope	None	TBD		
			C (5-10) #6	Maintain a sufficient cadre ... to support ... operation of telescope and interpretation of data	None	TBD		
			C (5-10) #5	Maintain state-of-the-art facilities & equipment to support design, realization, operation of the telescope	None	TBD		
P (5-10) #3	Continue operating existing telescopes	Risk	None	None	None	TBD	TBD	TBD
E (>10) #2	Attract a highly skilled workforce, cultivate an innovative work environment, and provide needed facilities, tools, and services	Risk	12	Cost reserve for the program	None	TBD	TBD	TBD
			13	Schedule reserve for the program	None	TBD		
			15	Congressional level of support for new space telescope (rank 1-5)	None	TBD		
			16	Congressional level of support for existing programs (rank 1-5)	None	TBD		
			17	Degree of searching extensibility available through S/W uploading	None	TBD		
			C (5-10) #6	Maintain a sufficient cadre ... to support ... operation of telescope and interpretation of data	None	TBD		
			C (5-10) #5	Maintain state-of-the-art facilities & equipment to support design, realization, & operation of the telescope	None	TBD		
			P (5-10) #4	Design, build, deploy, and operate the next generation telescope	None	TBD		
			P (5-10) #3	Continue operating existing telescopes	None	TBD		
E (>10) #1	Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars	Risk	10	Complexity of design (rank 1-5)	None	TBD	TBD	TBD
			11	Complexity of integration and testing (rank 1-5)	None	TBD		
			12	Cost reserve for the program	None	TBD		
			13	Schedule reserve for the program	None	TBD		
			15	Congressional level of support for new space telescope (rank 1-5)	None	TBD		
			16	Congressional level of support for existing programs (rank 1-5)	None	TBD		
			C (5-10) #6	Maintain a sufficient cadre ... to support ... operation of telescope and interpretation of data	None	TBD		
			P (5-10) #4	Design, build, deploy, and operate the next generation telescope	None	TBD		
			P (5-10) #3	Continue operating existing telescopes	None	TBD		

Table 5-7. Example entries for Known Risk Roll-Up Template for Objective P(1) #11: Deliver the cryocooler subsystem

Objec. No.	Objective Description	Type of Scen.	Lead. Ind. No. or Infl. Obj. No.	Description of Leading Indicator or Influencing Objective	Composite Indicator	Lead. Ind. Concern or Objec. Aggr. Risk	Aggregate Risk of Objective	Rollup Rationale
C (1) #12	Provide tech. support & expert review for design, building, testing, and validation of the cryo subsystem	None	None	None	None	Concern	Risk	No risks entered
P (1) #11	Deliver the cryocooler subsystem	Risk	1	Remaining schedule reserve for cryocooler development	None	Concern	Risk	Although the remaining schedule reserve for the cryocooler development is red (surpassing the response trigger), the overall risk of not meeting the objective of delivering the cryocooler subsystem is yellow (marginal) because: 1. According to the current track and control plan, the cryocooler development schedule can be accelerated if needed by diverting additional budget & manpower to this task from other tasks whose reserves are not at risk (note that the divertible remaining cost reserve from other tasks is yellow, not red) 2. JPL's analysis of subcontractor performance trends projects that development will not be delayed by more than 7 months, making it likely that integrated testing will begin on time (February 2016)
			2	Remaining cost reserve for the program that can be allocated to cryocooler development	None	Concern		
			3	Severity of unresolved technical issues for cryocooler development (scale 1-5)	None	Concern		
			4	GAO evaluation of cryocooler development problems (scale 1-5, 1=very low confidence, 5=very high confidence)	None	Concern		
			C (1) #12	Provide technical support & expert review for design, building, testing, and validation of cryocooler subsystem	None	Concern		

Aggregate Risk of Objective and Roll-Up Rationale

The roll-up of levels of concern for leading indicators and aggregate risks for influencing objectives is conducted according to the rationale provided in the last column of the Risk Roll-Up Template. The process is objective but not quantitative. It is most easily demonstrated by considering the roll-up rationale that might be employed for Objective P(1) #11: Deliver the cryocooler subsystem. Table 5-7 provides this demonstration. As before with the example for the Leading Indicator Evaluation Template (Table 5-4), the rationale is based on publicly available information about the JWST that was previously itemized in Section 5.2. In short, the template records the following information:

- The cryocooler development schedule can be accelerated by diverting additional budget and manpower to this task from other tasks whose reserves are not at risk.
- JPL's analysis of subcontractor performance trends projects that development will not be delayed by more than seven months to November 2015, making it likely that integrated testing will begin on time during February 2016.
- Therefore, the overall risk of not meeting the objective of delivering the cryocooler subsystem is marginal, even though the year's schedule reserve for cryocooler development has been depleted.

For comparison, Table 5-8 illustrates how Table 5-7 would be reconstructed to reflect the alternative 1 roll-up method, which includes an intermediate roll-up of leading indicators to risk scenario level in accordance with the schematic representation in Figure 5-10.

5.6.3 Opportunity Roll-Up Template

The Opportunity Roll-Up Template, Table 5-9, is comparable to the Known Risk Roll-Up Template, Table 5-6, with the exception that the opportunity scenarios generally have accompanying introduced risks. For the example being considered, the opportunity scenario (as entered into the Risk and Opportunity Identification Template, Table 5-2) is that it may be possible for significant new technology advancements (such as a camera with improved resolution) to be delivered and installed on the telescope through retrofitting either by astronauts or robotically, since the JWST spacecraft is designed with a grapple fixture. This could be the case even though the JWST is described by NASA as unserviceable, given that the incentive for trying such a rendezvous mission is strong enough to justify the risks. In this case, the introduced risks are that the likelihood of loss of crew (LOC) or loss of mission (LOM), depending on whether the mission is crewed or robotic, may be unacceptably high, and/or that the cost of the retrofit mission may likewise be too high. The leading indicators for the opportunity are the technology readiness level for improved resolution infrared cameras and the readiness level for the Space Launch System (SLS), including Orion if the mission is crewed. The leading indicator for the introduced risk pertaining to the probability of LOC or LOM is the most current predictive estimate of P(LOC) or P(LOM) obtained from a probabilistic risk assessment (PRA) for an analogous SLS/Orion mission involving lunar orbit. The leading indicator for the introduced risk pertaining to cost is likewise the most current cost estimate for the analogous mission.

Table 5-8. Example entries for Known Risk Roll-Up Template for Objective P(1) #11 including an intermediate roll-up to risk scenario level

Objec. No.	Objective Descrip.	Type of Scen.	Risk No. or Influencing Objec. No.	Risk or Influencing Objec. Descrip.	Lead. Ind. No.	Description of Leading Indicator	Composite Indicator	Leading Indicator Level of Concern	Rollup to Risk Scen. Level of Concern	Rationale for Rollup to Risk Scenario Level	Aggregated Risk of Objective	Rationale for Rollup to Objective Level
C (1) #12	Provide tech. support & expert review for design, building, testing, and validation of the cryo subsystem								Tolerable	No risks entered	Tolerable	No rollup at the lowest level
P (1) #11	Deliver the cryocooler subsystem	Risk	1	There may be a significant delay in the delivery date for the cryocooler system	1	Remaining schedule reserve for cryocooler development	None	Intolerable	Marginal	Although the remaining schedule reserve for the cryo. development is red, the overall risk of not meeting the objective of delivering the cryo. subsystem is yellow (marginal) because: 1. The cryo. development schedule can be accelerated by diverting additional budget & manpower to this task from other tasks 2. JPL's analysis of subcontractor performance trends projects that development will not be delayed by more than 7 months	Marginal	There are no compensating factors in rolling up Risk 1 with the risk of not meeting Objective C (1) #12.
					2	Remaining cost reserve for the program that can be allocated to cryocooler development	None	Marginal				
					3	Severity of unresolved technical issues for cryocooler development (scale 1-5)	None	Marginal				
					4	GAO evaluation of cryocooler development problems (scale 1-5, 1=very low confidence, 5=very high confidence)	None	Marginal				
		Risk	C (1) #12	Org. may fail to provide adequate technical support & expert review for design, building, testing, and validation of cryo subsystem					Tolerable	Carried down from Objective C (1) #12		

Since the only opportunity scenario for this example is introduced at the top level of the objectives hierarchy (i.e., at Objective E(>10) #1), there are no roll-ups for opportunity from lower-level objectives to higher-level objectives. Rather, the roll-up in this example concerns only the relevant leading indicators for opportunity and introduced risk at the level of Objective E(>10) #1 (which is entered at the bottom of Table 5-9). Before performing this roll-up, the significance of the opportunity leading indicators and the tolerability of the introduced risk leading indicators are transferred from the Leading Indicator Evaluation Template (Table 5-3) to the column labeled “Leading Indicator Significance” in Table 5-9. The roll-up for the aggregate opportunity in the next-to-last column of Table 5-9 is based on the perceived balance between the opportunity and the introduced risks as informed by the values of the respective leading indicators. The rationale for the perception of balance is recorded in the last column of Table 5-9.

An example opportunity roll-up is shown in Table 5-10. In this example, the likelihood of being able to conduct a service mission to install a significantly improved IR camera is considered high based on anticipated technology developments, and so the opportunity leading indicators are colored blue (significant opportunity). Less happily, the present-day cost of a rendezvous mission is considered intolerable by today’s standards, and hence the leading indicator for the introduced

risk associated with cost is red (intolerable). However, the cost may be perceived to be more tolerable once the system is operational because of the following rationale:

- Public enthusiasm for the program will likely increase substantially, as it did for Hubble, once the telescope is operational and its scientific value is fully appreciated.
- Issues about the feasibility of performing a rendezvous will likely abate once the SLS/Orion system becomes operational and is shown to be reliable and safe.
- The economic recovery will likely increase the willingness of the country to spend more on space.

Since it is considered likely that the perceived cost of the rendezvous will become more tolerable over time, the aggregate opportunity considering leading indicators for both opportunity and introduced risks is ranked as marginal rather than insignificant.

Table 5-9. Opportunity Roll-Up Template

Objec. No.	Objective Description	Type of Scen.	Lead. Ind. No. or Influencing Objec. No.	Description of Leading Indicator or Influencing Objective	Composite Indicator	Lead. Ind. Significance or Objec. Aggr. Opp.	Aggregate Opp. of Objective	Roll-Up Rationale
C (1) #12	Provide tech. support & expert review for design, building, testing, and validation of the cryo subsystem	None	None	None	None	None	None	No opps. entered
P (1) #11	Deliver the cryocooler subsystem	None	None	None	None	None	None	No opps. entered
C (1-5) #10	Implement the 5-year hiring and training plan	None	None	None	None	None	None	No opps. entered
C (1-5) #9	Implement the 5-year facilities plan	None	None	None	None	None	None	No opps. entered
C (1-5) #8	Provide tech. support & expert review for the design, building, testing, and validation of the integrated space telescope	None	None	None	None	None	None	No opps. entered
P (1-5) #7	Launch the space telescope	None	None	None	None	None	None	No opps. entered
C (5-10) #6	Maintain a sufficient cadre ... to support ... operation of telescope and interpretation of data	None	None	None	None	None	None	No opps. entered
C (5-10) #5	Maintain state-of-the-art facilities and equipment to support design, realization, operation of the telescope	None	None	None	None	None	None	No opps. entered
P (5-10) #3	Continue operating existing telescopes	None	None	None	None	None	None	No opps. entered
E (>10) #2	Attract/advance a highly skilled, competent, & diverse workforce, cultivate an innovative work environment, & provide the facilities, tools, & services needed to conduct NASA's missions	None	None	None	None	None	None	No opps. entered
E (>10) #1	Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars	Oppor.	18	Tech. readiness level for improved resolution IR cameras	None	TBD	TBD	TBD
			19	Readiness level for SLS/ Orion including docking capability	None	TBD		
		Intr. Risk	20	Predicted P(LOC) for SLS/ Orion	None	TBD		
			21	Predicted P(LOM) for SLS	None	TBD		
			22	Predicted cost for a rendezvous mission	None	TBD		

Table 5-10. Example entries for Opportunity Roll-Up for Objective E(>10) #1: Discover how the universe works, explore how it began/evolved, search for life on planets around other stars

Objec. No.	Objective Description	Type of Scen.	Lead. Ind. No. or Influencing Objec. No.	Description of Leading Indicator or Influencing Objective	Composite Indicator	Lead. Ind. Significance or Objec. Aggr. Opp.	Aggregate Opp. of Objective	Rollup Rationale
E (>10) #1	Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars	Oppor.	18	Tech. readiness level for improved resolution IR cameras	None	Significant	Marginal	Although the estimated cost of a rendezvous is intolerable based on current funding for the program, it may become more tolerable once the system is operational because: 1. Public enthusiasm for the program will likely increase substantially, as it did for Hubble, once the telescope is operational and its scientific value is fully appreciated 2. Issues about the feasibility of performing a rendezvous will likely abate once the SLS/Orion system becomes operational and is shown to be reliable and safe 3. The economic recovery will likely increase the willingness of the country to spend more on space
			19	Readiness level for SLS/ Orion including docking capability	None	Significant		
		Intr. Risk	20	Predicted P(LOC) for SLS/ Orion	None	Marginal		
			21	Predicted P(LOM) for SLS	None	Tolerable		
			22	Predicted cost for a rendezvous mission	None	Intolerable		

5.6.4 Composite Indicator Identification and Evaluation Template

In the examples shown so far, all of the leading indicators have been considered to be stand-alone indicators, even though the templates have included the possibility for introducing composite indicators. Considering them to be independent in setting trigger values is acceptable as long as the rationale for aggregating them accounts for the more complex relationships that may exist between them. Thus, ameliorating factors were introduced in the rationale column in Table 5-7 to justify an aggregated risk that was yellow (marginal) rather than red (intolerable), and in Table 5-10 to justify an aggregated opportunity that was purple (marginal) rather than gray (insignificant), even though one of the indicators in each case was red.

Using a composite indicator recognizes the fact that the trigger values of some of the indicators may depend upon the values of other indicators. For example, in the Leading Indicator Evaluation Template in Table 5-4, leading indicators 1, 2, and 3 have just such a codependency that would justify the use of a composite indicator. That is, the amount of schedule margin needed for cryocooler development (Indicator 1) depends on both the amount of cost margin from other tasks that can be diverted to the cryocooler development task (Indicator 2) and the severity of the technical issues that remain to be resolved (Indicator 3). Note that a composite indicator does not necessarily collapse all the individual indicators for a risk or opportunity scenario. For example, Leading Indicator 4, which concerns GAO's evaluation of the cryocooler development progress, remains as a separate indicator for the risk of not delivering the cryocooler subsystem when required.

The yellow box below provides an example of how one might define a composite indicator to recognize the dependencies between leading indicators 1, 2, and 3.

Example Representation of a Composite Indicator

To define a composite indicator, the individual indicators comprising it must first be defined in precise quantitative terms. Suppose, for example, that leading indicators 1 through 3 are defined exactly as follows:

- Ind(1) = the fraction of the original planned schedule margin for the cryocooler development task that remains unused; has a possible value of 0 to 1
- Ind(2) = the fraction that remains unused of the original planned cost margin allocable to the cryocooler development task from the program as a whole; has a possible value of 0 to 1
- Ind(3) = the severity ranking of all unresolved technical issues for cryocooler development; has possible values of 1, 2, 3, 4, and 5.

Suppose Composite Indicator A is introduced at this point and is defined as follows:

$$CInd(A) = -4 \times Ind(1) - 4 \times Ind(2) + Ind(3) + 7; \text{ has a possible value of 0 (best case) to 12 (worst case)}$$

This example composite indicator has the feature that a change in any one of the three indicators from its worst value to its best value has the same numerical effect on CInd(A) as a change in any other of the three indicators from its worst value to its best value. For example, changing Ind(1) from 1 to 0 causes CInd(A) to change by a total of 4 in the positive direction, as does changing Ind(2) from 1 to 0 or changing Ind(3) from 1 to 5. As a further illustration, the compound indicator has a value of 6 for any of the following conditions:

- Schedule margin = 0% of plan, cost margin = 50% of plan; technical issue ranking = 1
- Schedule margin = 25% of plan, cost margin = 25% of plan; technical issue ranking = 1
- Schedule margin = 0% of plan, cost margin = 100% of plan; technical issue ranking = 3
- Schedule margin = 50% of plan, cost margin = 50% of plan; technical issue ranking = 3
- Schedule margin = 50% of plan, cost margin = 100% of plan; technical issue ranking = 5
- Schedule margin = 75% of plan, cost margin = 75% of plan; technical issue ranking = 5

In other words, all of these combinations produce the same level of concern.

The Composite Indicator Identification and Evaluation Template for this example is shown in Table 5-11. The third column in that table indicates that the following combination is a “watch peg point”:

- Schedule margin = 50% of plan, cost margin = 50% of plan; technical issue ranking = 2

and the fourth column indicates that the following combination is a “response peg point”:

- Schedule margin = 10% of plan, cost margin = 10% of plan; technical issue ranking = 3

These peg points set the watch and response triggers for the composite index as follows:

- Composite indicator watch trigger = $-4 \times (0.5) - 4 \times (0.5) + 2 + 7 = 5.0$
- Composite indicator response trigger = $-4 \times (0.1) - 4 \times (0.1) + 3 + 7 = 9.2$

These values appear in the 10th and 11th columns of Table 5-11.

Table 5-12 illustrates how the Known Risk Roll-Up Template example in Table 5-7 would change as a result of using this composite indicator. Note that the roll-up result remains the same but there is no longer a red (intolerable) risk indicator feeding into it.

Table 5-11. Composite Indicator Identification and Evaluation Template

Comp. Ind. No.	Lead. Ind. No.	Description of Leading Indicator or Composite Function of Leading Indicators	Watch Peg Point	Resp. Peg Point	Current Value	1-Yr. Projected Value	Composite Function	Rationale for Composite Function	Comp. Ind. Watch Trigger	Comp. Ind. Resp. Trigger	Comp. Ind. Current Value	Comp. Ind. 1-Yr. Projected Value	Comp. Leading Indicator Concern
A	1	Remaining schedule reserve for cryo devel (fraction of plan)	0.5	0.1	0.0	0.3 best to 0.0 worst	$\text{CompInd(A)} := -4 \times \text{Ind(1)} - 4 \times \text{Ind(2)} + \text{Ind(3)} + 7$	Historically informed correlation between time to complete a task of similar magnitude and complexity, funding required, and severity of unresolved technical issues pertaining to the task (source: XX)	5.0	9.2	9.6	4.8 best to 8.8 worst	Marginal
	2	Remaining cost reserve for the program that can be allocated to cryo devel (fraction of plan)	0.5	0.1	0.1	0.5 best to 0.3 worst							
	3	Severity of significant unresolved technical issues pertaining to cryo devel (scale 1 to 5)	2	3	3	1 best to 3 worst							

Table 5-12. Example entries for Risk Roll-Up Template for Objective P(1) #11 using a composite indicator

Objec. No.	Objective Description	Type of Scen.	Lead. Ind. No. or Infl. Obj. No.	Description of Leading Indicator or Influencing Objective	Composite Indicator	Lead. Ind. Concern or Objec. Aggr. Risk	Aggregate Risk of Objective	Roll-Up Rationale
C (1) #12	Provide tech. support & expert review for design, building, testing, and validation of the cryo subsystem	None	None	None	None	Concern	Risk	No risks entered
P (1) #11	Deliver the cryocooler subsystem	Risk	1	Remaining schedule reserve for cryocooler development	$\text{CompInd(A)} := -4 \times \text{Ind(1)} - 4 \times \text{Ind(2)} + \text{Ind(3)} + 7$	Concern	Risk	<p>Although the remaning schedule reserve for the cryocooler development has been depleted, the overall risk of not meeting the objective of delivering the cryocooler subsystem is yellow (marginal) because:</p> <ol style="list-style-type: none"> The cryocooler development schedule can be accelerated by diverting additional budget & manpower to this task from other tasks whose reserves are not at risk (note that the divertible remaining cost reserve from other tasks is yellow, not red) JPL's analysis of subcontractor performance trends projects that development will not be delayed by more than 7 months, making it likely that integrated testing will begin on time (February 2016)
			2	Remaining cost reserve for the program that can be allocated to cryocooler development				
			3	Severity of unresolved technical issues for cryocooler development (scale 1-5)				
			4	GAO evaluation of cryocooler development problems (scale 1-5, 1=very low confidence, 5=very high confidence)	None	Concern		
			C (1) #12	Provide technical support & expert review for design, building, testing, and validation of cryocooler subsystem	None	Concern		

5.6.5 UU Risk Roll-Up Template

In addition to the leading indicators for known risks provided in the Risk and Opportunity Identification Template, Table 5-2, and the Leading Indicator Evaluation Template, Table 5-3, there is an additional set of leading indicators that correlate with the relative importance of UU risks. Some of the more important ones were identified in Sections 4.4.4 and 5.4.3.

Just as the known risks were rolled up via the Known Risk Roll-Up Template, Table 5-6, to obtain insight into how known risks are affecting the likelihood of being able to satisfy the top objectives of the organization, it is possible to roll up the leading indicators for UU risks via a UU Risk Roll-Up Template to obtain insight into how UU risk indicators are affecting the likelihood of successful objectives achievement. For this example, we postulate the following two UU leading indicators to be the most significant sources of UU risk:

- Schedule/budget pressure
- Quality of oversight and communication

Both indicators are measured on a scale of 1 to 5 for each objective, with the lower end indicating lowest concern and the upper end indicating highest concern. The steps in the roll-up are identical to Section 5.6.2. The example template is shown in Table 5-13.

5.7 Example Templates for the Identification of Risk and Opportunity Drivers, Responses, and Control Options

5.7.1 Risk and Opportunity Driver Identification Template

As discussed in Sections 4.6.1, a risk driver causes the cumulative risk for one or more top organizational objectives to change color from green to yellow or red or from yellow to red. Risk factors might include any combination of departure events, underlying causes of departure events, leading indicators, unprotected key assumptions, deficiencies in controls, or other factors that affect the risk of meeting the objectives. Similarly, an opportunity driver can be any combination of opportunity factors/elements that collectively cause the cumulative opportunity for one or more top organizational objectives to change color. Risk or opportunity drivers, as defined above, constitute a detailed resolution of the principal factors that contribute to the cumulative risk or opportunity. They, therefore, are suitable for identifying the constituents of risk mitigations, opportunity actions, and control options.

As discussed in Section 4.6.2, a risk or opportunity *scenario* driver is any combination of risk or opportunity *scenarios* that causes the cumulative risk or opportunity of one or more top objectives to change color. Risk and opportunity scenario drivers provide a higher-level view of the concerns that need to be addressed, and are, therefore, suitable for summary presentations.

The Risk and Opportunity Driver Identification Templates facilitate the process of identifying both drivers (henceforth called “constituent drivers” for clarity) and scenario drivers. Table 5-14 illustrates the process schematically for the Next Generation Space Telescope example. A table similar to Table 5-14 is prepared for each strategic/top objective of the organization.

In Table 5-14, two risk scenarios are identified as candidate risk scenario drivers for the objective “Discover how the universe works” The first is “Failure to deliver the cryocooler subsystem on time,” a scenario that most directly affects the lower-level objective of delivering the cryocooler subsystem but also propagates up through the Known Risk Roll-Up Template to the top objective. The second is “Unavailability of expert technical staff for review.” This second risk scenario was not included in the earlier development of risks for this example, but is added here to make a point.

As shown in Table 5-14, neither of the risk scenarios causes the color of the cumulative risk for the top objective to change from yellow to green, but the combination of the two scenarios does.

Table 5-13. UU Risk Roll-Up Template

Blue typeface denotes repeated instances of leading indicators

Red typeface denotes secondary interfaces

Objec. No.	Objective Description	Type of Scen.	Lead. Ind. No. or Influencing Objec. No.	Description of Leading Indicator or Influencing Objective	Composite Indicator	Lead. Ind. UU Concern or Objec. Aggr. UU Risk	Aggregate UU Risk of Objective	Roll-Up Rationale
C (1) #12	Provide tech. support & expert review for design, building, testing, and validation of the cryocooler subsystem	UU Risk	UU1	Schedule/budget pressure (scale 1-5)	None	TBD	TBD	TBD
			UU2	Quality of oversight and communication (scale 1-5)	None	TBD		
P (1) #11	Deliver the cryocooler subsystem	UU Risk	UU1	Schedule/budget pressure (scale 1-5)	None	TBD	TBD	TBD
			UU2	Quality of oversight and communication (scale 1-5)	None	TBD		
			C (1) #12	Provide tech support & expert review for design, ... of cryo subsys.	None	TBD		
C (1-5) #10	Implement the 5-year hiring and training plan	UU Risk	UU1	Schedule/budget pressure (scale 1-5)	None	TBD	TBD	TBD
			UU2	Quality of oversight and communication (scale 1-5)	None	TBD		
C (1-5) #9	Implement the 5-year facilities plan	UU Risk	UU1	Schedule/budget pressure (scale 1-5)	None	TBD	TBD	TBD
			UU2	Quality of oversight and communication (scale 1-5)	None	TBD		
C (1-5) #8	Provide technical support and expert review for the design, building, testing, and validation of the integrated space telescope	UU Risk	UU1	Schedule/budget pressure (scale 1-5)	None	TBD	TBD	TBD
			UU2	Quality of oversight and communication (scale 1-5)	None	TBD		
			C (1) #12	Provide tech support & expert review for design, ... of cryo subsys	None	TBD		
			C (1-5) #10	Implement the 5-year hiring and training plan	None	TBD		
			C (1-5) #9	Implement the 5-year facilities plan	None	TBD		
P (1-5) #7	Launch the space telescope	UU Risk	UU1	Schedule/budget pressure (scale 1-5)	None	TBD	TBD	TBD
			UU2	Quality of oversight and communication (scale 1-5)	None	TBD		
			P (1) #11	Deliver the cryo system	None	TBD		
			C (1-5) #8	Provide tech. support & expert review for design, ... of integr scope	None	TBD		
C (5-10) #6	Maintain a sufficient cadre ... to support ... operation of telescope and interpretation of data	UU Risk	UU1	Schedule/budget pressure (scale 1-5)	None	TBD	TBD	TBD
			UU2	Quality of oversight and communication (scale 1-5)	None	TBD		
			C (1-5) #10	Implement the 5-year hiring and training plan	None	TBD		
C (5-10) #5	Maintain state-of-the-art facilities and equipment ... to support the design, realization, and operation of the telescope	UU Risk	UU1	Schedule/budget pressure (scale 1-5)	None	TBD	TBD	TBD
			UU2	Quality of oversight and communication (scale 1-5)	None	TBD		
			C (1-5) #9	Implement the 5-year facilities plan	None	TBD		
P (5-10) #4	Design, build, deploy, and operate the Next Generation Space Telescope	UU Risk	UU1	Schedule/budget pressure (scale 1-5)	None	TBD	TBD	TBD
			UU2	Quality of oversight and communication (scale 1-5)	None	TBD		
			P (1-5) #7	Launch the space telescope	None	TBD		
			C (5-10) #6	Maintain a sufficient cadre ... to support ... operation of telescope and interpretation of data	None	TBD		
			C (5-10) #5	Maintain state-of-the-art facilities & equipment to support design, realization, operation of the telescope	None	TBD		
P (5-10) #3	Continue operating existing telescopes	UU Risk	UU1	Schedule/budget pressure (scale 1-5)	None	TBD	TBD	TBD
			UU2	Quality of oversight and communication (scale 1-5)	None	TBD		
E (>10) #2	Attract a highly skilled work-force, cultivate an innovative work environment, and provide needed facilities, tools, and services	UU Risk	UU1	Schedule/budget pressure (scale 1-5)	None	TBD	TBD	TBD
			UU2	Quality of oversight and communication (scale 1-5)	None	TBD		
			C (5-10) #6	Maintain a sufficient cadre ... to support ... operation of telescope and interpretation of data	None	TBD		
			C (5-10) #5	Maintain state-of-the-art facilities & equipment to support design, realization, & operation of the telescope	None	TBD		
			P (5-10) #4	Design, build, deploy, and operate the next generation telescope	None	TBD		
			P (5-10) #3	Continue operating existing telescopes	None	TBD		
E (>10) #1	Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars	UU Risk	UU1	Schedule/budget pressure (scale 1-5)	None	TBD	TBD	TBD
			UU2	Quality of oversight and communication (scale 1-5)	None	TBD		
			C (5-10) #6	Maintain a sufficient cadre ... to support ... operation of telescope and interpretation of data	None	TBD		
			P (5-10) #4	Design, build, deploy, and operate the next generation telescope	None	TBD		
			P (5-10) #3	Continue operating existing telescopes	None	TBD		

Table 5-14. Example Risk and Opportunity Driver Identification Template

Objec. Index	Objective Description	Objective Cumulative Level of Concern or Interest	Candidate Scenario Driver Number	Scenario Number(s)	Candidate Scenario Driver Description	Objec. Level of Concern or Interest if Candidate Driver is Removed	Qualify as Driver?	Time-frame to Complete Response	Driver Constituent Number	Driver Constituent Description	Time-frame to Begin Response
E (>1) #1	Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars	Marginal Concern (Risk)	1	1	Failure to complete the cryocooler subsystem on time	Remains Marginal Concern	No				
			2	2	Unavailability of expert technical staff for review	Remains Marginal Concern	No				
			3	1 and 2	Failure to deliver the cryocooler subsystem on time and unavailability of expert technical staff for review	Changes to Tolerable Concern	Yes				
		Significant Interest (Opp.)	4	3	Commitment to develop new IR camera and demonstrate ability to conduct retrofit mission	Becomes Insignificant Interest	Yes	6 Months	1	Cryo delivery schedule reserve	Now
									2	Subcontractor mgmt. issues	Now
									3	Compressor performance for brazed unit	Now
									4	Thermal vac. testing of cold head assy	Now
									5	Cross-project competition for qualified review personnel	Now
								5 Years	6	TRL for IR camera	1 Year
									7	Readiness of SLS/Orion docking capability	2 Years
									8	Predicted P(LOC) for SLS/Orion	2 Years
									9	Predicted cost for rendezvous mission	2 Years
									10	Congress may cancel or defer other SLS/Orion missions	Now

Therefore, the risk scenario driver consists of the combination of the scenarios. The associated risk driver constituents, or principal factors that contribute to the cumulative risk, are shown in the next-to-last column of Table 5-14. They are the factors that are noted in the Known or UU Risk Roll-Up Template as being of particular concern, such that all of them have to be addressed in order for the cumulative risk to be reduced to a tolerable state.

It may be noted that although there are no UU risks included in this example for identifying risk drivers, there is no reason why they should not be included if the UU Roll-Up Template shows that they are a large source of concern.

The lower part of Table 5-14 concerns the identification of opportunity drivers. In this example there is only one opportunity scenario, and it is a driver because the deletion of the scenario causes the color of the cumulative opportunity for the top objective to change from blue (significant) to gray (insignificant). The associated opportunity driver constituents, shown in the next-to-last column, are the factors that are noted in the Opportunity Roll-Up Template as being of particular concern.

Also indicated in the Risk and Opportunity Driver Identification Template is the spare time available to initiate a response to mitigate the risk drivers or an action to avail the opportunity drivers without exceeding the available timeframe to complete the response. The combination of the identified driver scenarios, the driver identified constituents, and the timeframe available to begin a response for each constituent can be illustrated in a matrix format, as shown in Figures 5-13 and 5-14. This form of display is particularly useful for high-level presentations.

5.7.2 Risk Mitigation, Opportunity Action, and Control Option Identification Templates

As discussed in Section 4.6.3, the identification of risk mitigations, opportunity actions, and control options is directed at finding viable ways to act upon the risk and opportunity drivers that are identified after the risk and opportunity roll-up processes. This identification is performed on the Risk Mitigation and Control Option Identification Template, demonstrated in Table 5-15 for the Next Generation Space Telescope example, and on the Opportunity Action and Control Option Identification Template, demonstrated in Table 5-16 for the same example. The former starts from the risk drivers and the latter from the opportunity drivers that were identified in the Risk and Opportunity Driver Identification Template, Table 5-14.

For each risk or opportunity driver, there is one or more proposed mitigations or actions intended to respond to the driver, and for each mitigation or action, there is one or more control options intended to provide assurance of success. The control option is labeled “Assumption” if the intent is to protect an assumption made in defining the mitigation or action, and “Deficiency” if the intent is to address a shortcoming in the present controls. These proposed mitigations, actions, and controls are purely hypothetical and intended for illustration purposes only.

5.7.3 High-Level Display Template

The High-Level Display Template, shown in Table 5-17, displays results obtained from the preceding templates in a condensed form. It also includes suggested responses and controls that

		Objective E(>10) #1 Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars		Objective E(>10) #2 Attract a highly skilled work-force, cultivate an innovative work environment, and provide needed facilities, tools, and services	
		Risk Scenario Driver	Opportunity Scenario Driver	Risk Scenario Driver	Opportunity Scenario Driver
Time Criticality for Initiation of Response or Activity	1 (≤ 1 Yr)	3a. Possible failure to deliver the cryocooler subsystem on time 3b. Possible unavailability of tech. experts for review of next-gen telescope project	4. Possibility of a retrofit mission to install improved IR camera on next-gen telescope		
	2 (1 – 3 Yr)				
	3 (> 3 Yr)				

Figure 5-13. Matrix-like illustration of risk and opportunity scenario drivers and their timeframe criticalities

		Objective E(>10) #1 Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars		Objective E(>10) #2 Attract a highly skilled work-force, cultivate an innovative work environment, and provide needed facilities, tools, and services	
		Risk Driver Constituents	Opportunity Driver Constituents	Risk Driver Constituents	Opportunity Driver Constituents
Time Criticality for Initiation of Response or Activity	1 (≤ 1 Yr)	1. Cryo delivery sched. reserve 2. Subcontractor mgmt. issues 3. Compressor performance for brazed unit 4. Thermal vac. testing of cold head assy. 5. Cross-project competition for qualified review personnel	6. Technical Readiness Level for new IR camera 10. Congress may cancel or defer other SLS/Orion missions to pay for retrofit mission		
	2 (1 – 3 Yr)		7. Readiness of SLS/Orion docking capability 8. Predicted P(LOC) for SLS/Orion 9. Predicted cost for rendezvous mission		
	3 (> 3 Yr)				

Figure 5-14. Matrix-like illustration of risk and opportunity constituent drivers and their timeframe criticalities

Table 5-15. Example entries for Risk Mitigation and Control Option Template for Objective E (>10) #1: Discover how the universe works

...

Top Objec. Index	Top Objec. Descrip.	Risk to Objective (Level of Concern)	Risk to Objec. if Driver Removed	Driver / Constituent No.	Driver Constituent Type	Driver Constituent Description	Proposed Mitigations	Rationale for Proposed Mitigations	Control Option No.	Type of Control	Deficiency Needing Control or Assumption Needing Watchfulness	Proposed Control Option
E (>10) #1	Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars	Marginal	Tolerable	3 / 1	Risk	Cryo delivery schedule reserve	Borrow personnel from Task X	Task X has a larger schedule reserve than needed	1	Assumption	Personnel that can be transferred from Task X to cryo task are available and have applicable skills	Monitoring of Task X schedule and cost reserve assigned with responsibility to report status
									2	Assumption	Appropriate person has authority to move personnel between tasks	Responsibility to shift personnel assigned to a manager who has authority over both tasks
							If necessary, approve overtime		3	Assumption	Appropriate person has authority to approve overtime	Process for elevating overtime decision to the proper level
				3 / 2	Risk	Subcontractor management issues	Strengthen subcontractor management team	GAO evaluation	4	Deficiency	Acquirer's expectations not met	Process for acquirer to review qualifications and concur with subcontr. management choices
									5	Deficiency	Provider not motivated to provide best management team	Penalites for underperformance
							Increase oversight of subcontractor	GAO evaluation	6	Deficiency	Spotty and irregular communications	Regularly scheduled meetings and progress reports
									7	Deficiency	Action items not properly tracked and resolved	Process for assigning action items and monitoring progress
				3 / 3	Risk	Compressor performance for brazed unit	Add tests with modified brazing of compressor to platform	Brazing is a design reqt., and present brazing has not yet performed to spec.	8	Assumption	Needed test facility is available for the amount of time required	Process for elevating facility allocation decision to the proper level
				3 / 4	Risk	Thermal vac. testing of cold head assy	Add thermal vac. testing of cold head assy. using replacement valves	Replacement valves have not yet been tested	9	Assumption	Needed test facility is available for the amount of time required	Process for elevating facility allocation decision to the proper level
				3 / 5	Risk	Cross-project competition for qualified review personnel	Establish project review priority	Project with highest impact on top objective should have highest review priority	10	Assumption	Appropriate person has authority to assign qualified review personnel to highest priority task	Responsibility to assign personnel assigned to a manager who has authority over competing projects

Table 5-16. Example entries for Opportunity Action and Control Option Template for Objective E (>10) #1: Discover how the universe works ...

Top Objec. Index	Top Objec. Descrip.	Opportunity (Level of Interest)	Opportunity if Driver Removed	Driver / Constituent No.	Driver Constituent Type	Driver Constituent Description	Proposed Actions	Rationale for Proposed Actions	Control Option No.	Type of Control	Deficiency Needing Control or Assumption Needing Watchfulness	Proposed Control Option
E (>10) #1	Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars	Significant	Insignificant	4 / 6	Opp.	Technical Readiness Level for new IR camera	Increase priority of new IR camera R&D	Scientific value as described below	1	Assumption	TRL progress is being tracked and reported	Protocol for tracking and reporting on IR camera TRL progress
				4 / 7	Opp.	Readiness to launch a crewed mission to retrofit the space telescope with a new high-resolution IR camera	Increase priority of SLS/Orion usage for a space telescope retrofit mission	Camera replacement will greatly improve the mission's scientific value such as increasing the likelihood of understanding dark matter and energy	2	Assumption	Early success of space telescope will increase public support for improving its capability when new technology becomes available	Extremely high quality control and qualification testing to ensure that the telescope has no flaws at the time of launch that would degrade its scientific value
									3	Assumption	The economic recovery will increase the willingness of the country to spend more on space	Provisions to factor trends in economic conditions and public sentiment into planning for upgrades to the space telescope
				4 / 8	Intr. Risk	P(LOC) during retrofit mission exceeding P(LOC) threshold	None	None	4	Assumption	A rigorous probabilistic risk assessment of the retrofit mission will be performed	Provisions to ensure that adequate funding will be available to perform a rigorous PRA
									5	Assumption	P(LOC) reserve for unknown and under-appreciated (UU) risks will be sufficient to avoid significant P(LOC) underestimation	Protocol for ensuring that P(LOC) reserves are consistent with prior experience pertaining to UU risks
				4 / 9	Intr. Risk	Cost of retrofit mission	None	None	6	Assumption	Cost reserve for UU risks will be sufficient to avoid significant cost underestimation	Protocol for ensuring that cost reserves are consistent with prior experience pertaining to UU risks
				4 / 10	Intr. Risk	Increased priority on space telescope retrofit could result in other SLS/Orion applications being cancelled/ deferred	None	None	7	Assumption	Congress and the public are aware of the benefits of all the SLS/Orion planned projects	Provisions for educating Congress and the public about the benefits of all the SLS/Orion planned projects

Table 5-17. High-Level Display Template

Objective Index	Objective Description	Risk to Objective (Level of Concern)	Opportunity (Level of Interest)	Drivers	Suggested Responses and Control Options	UU Risk to Objective Level of Concern	UU Drivers	Suggested Responses and Control Options
C (1) #12	Provide tech. support & expert review for devel. of the cryo. subsystem	Tolerable	Insignificant	None	None	TBD	TBD	TBD
P (1) #11	Deliver the cryocooler subsystem	Marginal	Insignificant	<ul style="list-style-type: none"> • Cryocooler schedule reserve • Subcontractor management issues • Compressor performance for brazed unit • Thermal vac. testing of cold head assy. 	<ul style="list-style-type: none"> • Redistri-bution of resources • Increased project oversight • Brazing mod. testing XX • Cold head assy vac. testing XX 	TBD	TBD	TBD
C (1-5) #10	Implement the 5-year hiring and training plan	TBD	Insignificant	TBD	TBD	TBD	TBD	TBD
C (1-5) #9	Implement the 5-year facilities plan	TBD	Insignificant	TBD	TBD	TBD	TBD	TBD
C (1-5) #8	Provide technical support and expert review for the design, building, testing, and validation of the integrated space telescope	TBD	Insignificant	TBD	TBD	TBD	TBD	TBD
P (1-5) #7	Launch the space telescope	TBD	Insignificant	TBD	TBD	TBD	TBD	TBD
C (5-10) #6	Maintain a sufficient cadre of highly capable analysts and experimentalists to support design, realization, and operation of telescope and interpretation of data	TBD	Insignificant	TBD	TBD	TBD	TBD	TBD
C (5-10) #5	Maintain state-of-the-art facilities and equipment to support design, realization, and operation of the telescope	TBD	Insignificant	TBD	TBD	TBD	TBD	TBD
P (5-10) #4	Design, build, deploy, and operate the Next Generation Space Telescope	TBD	Insignificant	TBD	TBD	TBD	TBD	TBD
P (5-10) #3	Continue operating existing telescopes	TBD	Insignificant	TBD	TBD	TBD	TBD	TBD
E (>10) #2	Attract/advance a highly skilled workforce, cultivate an innovative work environment, and provide the facilities, tools, and services needed to conduct NASA's missions	TBD	Insignificant	TBD	TBD	TBD	TBD	TBD
E (>10) #1	Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars	TBD	Marginal	<ul style="list-style-type: none"> • Public enthusiasm after results obtained • Economic conditions • P(LOC) • Others TBD for risk to objective 	<ul style="list-style-type: none"> • Explore cost savings options • Others TBD for risk to objective 	TBD	TBD	TBD

address the risk and opportunity drivers. The entries that are completed in Table 5-17 correspond to those presented in Tables 5-7 and 5-10 and in Tables 5-15 and 5-16.

5.8 Upward Propagation of Templates for Full-Scope OROM Applications

5.8.1 Scope of the Problem

The example in the preceding sections was of limited scope, involving only twelve objectives of which two were strategic objectives with timeframes greater than 10 years, four were top programmatic and mission support objectives with timeframes of 5-10 years, four were mid-term performance objectives with timeframes of 1-5 years, and two were short-term performance objectives with timeframes of less than or equal to 1 year. Comparatively, this represents a very small sampling of all the objectives that NASA has listed in its 2014 Strategic Plan and its 2015 Performance and Management Plan, including fifteen strategic objectives and hundreds of

medium-term and short-term performance objectives. For an undertaking of this size, the volume of information to be collected, encoded, and integrated is challenging, to say the least.

5.8.2 Propagation of Templates

The development and population of templates for a full-scope OROM effort involves collaborative participation of all the organizational units in the larger organization from the bottom to the top. Each unit should have its own objectives hierarchy, individual risks, individual opportunities, and leading indicators. Each should complete the templates described in this report in a consistent manner, as shown in Figure 5-15, and pass the completed templates on to the next level of authority in the organization. Each higher level in the organization should utilize the templates provided by the organizations subordinate to it to create its own set of templates. Cross-organizational communication (vertically and horizontally) should freely occur during this process so that the templates produced by any one organizational unit are complete and consistent with those produced by other interfacing organizational units.

Obviously, this process requires that all organizational units use the same format in preparing their templates. Using the same format ensures that the information gleaned from the analysis can be passed readily up the chain of authority. It does not mean, however, that the information provided in the templates should be constrained to only risks and opportunities that are already recognized by others. Rather, each organizational unit should be creative in determining the risks and opportunities that influence the likelihood of success in meeting its objectives.

After receiving templates from its subordinate organizational units, the organizational unit at the next level up should determine whether the completed templates it receives are consistent in terms of assumptions made, the interpretation of input information, recognition of important interfaces, and overall conclusions. If there are inconsistencies or misunderstandings in these areas, then the higher-level unit has the obligation of determining why that is the case and how to resolve them.

The highest level of analysis in the OROM analysis scheme is the agency-wide level, as illustrated in Figure 5-15. The templates at agency-wide level represent a compilation of the templates from all the organizational units in the agency. Any differences between organizational units in terms of assumptions, interfaces, interpretations, and conclusions should be resolved at the agency-wide level. Once completed, the agency-wide level templates are passed back down the organizational chain of authority so that the individual organizational units can review them and provide their assent or dissent.

5.8.3 Development of an Integrated OROM Database

The templates prepared by the various units become part of an integrated database. Databases of risks, opportunities, and leading indicators that exist at each unit in the organization are integrated upward first to program directorate, center, and executive levels, and then into an agency-wide integrated database. At the executive level, the integrated database should typically include the information in the risk and opportunity templates, the owner for each risk and opportunity, the organizational entities that are involved, corresponding working groups and management boards, change plans, change history, and status. The development of an agency-wide database helps to ensure that cross-cutting risks and opportunities are correctly identified, consistently analyzed, and treated in an integrated manner. It also helps to facilitate the process of rolling up individual risk

and opportunity scenarios from lower levels to an aggregate view of the agency's overall likelihood of success in meeting its strategic objectives.

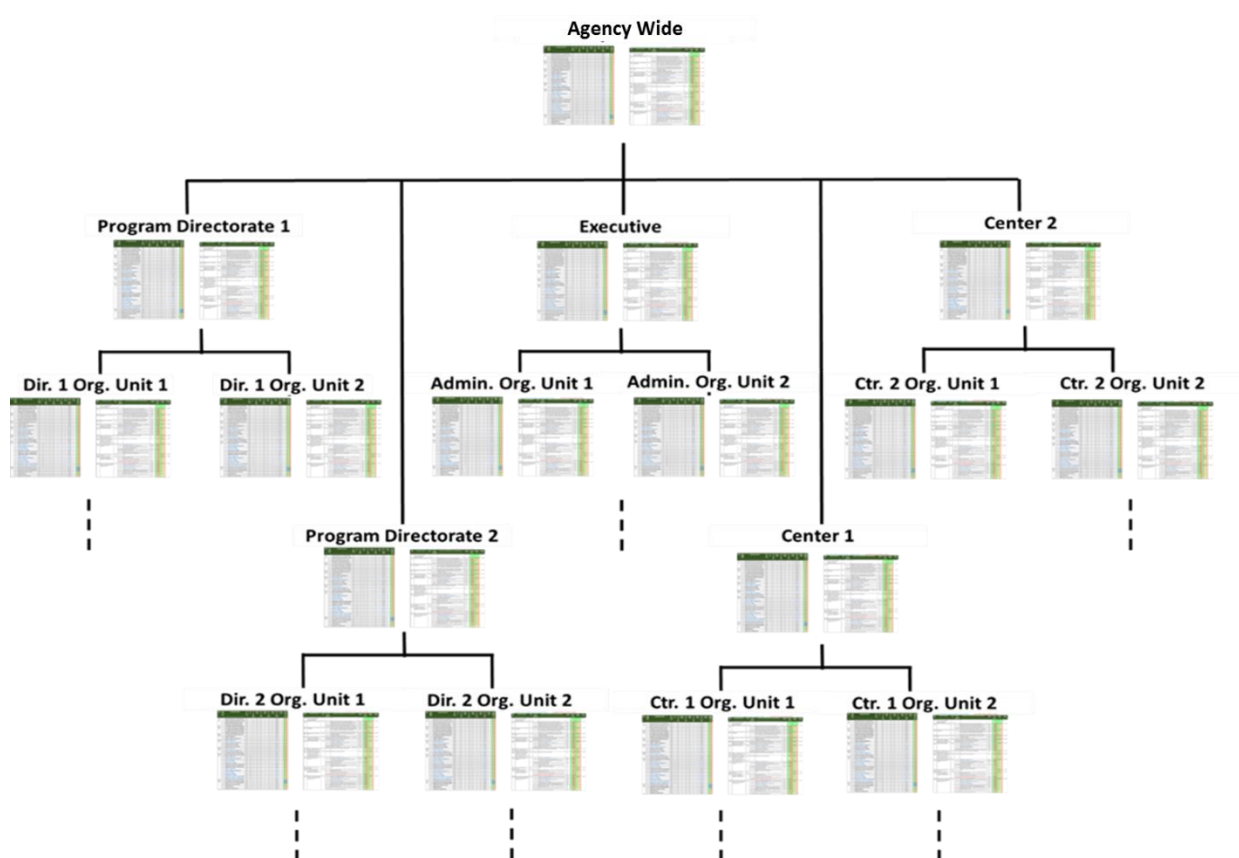


Figure 5-15. Schematic showing the upward propagation of templates for full-scope OROM applications

Section 6.2.4 will discuss the challenges of creating and managing a database that integrates risk and opportunity information vertically and horizontally across an extended organization consisting of both internal organizational entities and external partners. It will also discuss some best practices for doing so.

5.9 Application of the Templates to Organizational Planning and the Selection from among Alternative Candidate Portfolios

The templates developed in the preceding subsections can be applied, with some modification to the inputs, to examine OROM's role in organizational strategic and performance planning. In this application, the organization is interested in examining its likelihood of success in meeting its top objectives for various candidate sets of programs, projects, activities, and initiatives that are in the conceptual stage. There may be no detailed designs and likewise no direct experience in the development, fabrication, testing, deployment, and operation of the systems that would eventually unfold.

The form of the templates for organizational planning can be the same as the form of the templates for the evaluation of organizational performance, but the entries into the templates would need to be different in the following ways:

- Any risks, opportunities, leading indicators, and associated trigger values would have to be inferred from historical experience with related systems and from the judgment of those who are expert in the missions to be pursued and the challenges they bring, rather than from real-time experience with the actual systems to be used.
- Short-term objectives (e.g., those with timeframes of a year or less) in most cases would not be applicable since they tend to relate to milestones that emanate from a well-defined design.

Consider, for example, what would be included in the entries to the templates if the JWST project was in a conceptual stage and had not yet been initiated. The JWST challenges highlighted in the GAO report and other sources mentioned in Section 5.2 would not yet have been identified. The principal information for identifying risks and opportunities for a Next Generation Space Telescope would be from the experience gained for the HST system, which would already have been launched and operating. The risks in Table 5-2 associated with development and delivery of the cryocooler subsystem would probably not appear in the Risk and Opportunity Identification Template, because the design of the next-generation telescope would probably not yet be known in enough detail to identify that the cryocooler subsystem had to be completely unlike previous cryocooler subsystems. The potential status of leading indicators associated with shortages in cost and schedule reserves would have to be inferred without any direct information from the JWST project, but rather from HST experience and from the anticipated overall complexity of the next-generation mission.

In accordance with these observations, Table 5-18 shows how the entries in the Risk and Opportunity Roll-Up Template might appear if the next-generation telescope was being considered for inclusion in the agency's portfolio but was not yet past the concept stage. Those entries associated with the short-term (1-year) objectives relating to the cryocooler subsystem are no longer present, and the ones associated with cost and schedule reserves for the system as a whole are based on inference from the HST project (see yellow highlights in Table 5-18).

The other templates presented in Tables 5-2 through 5-17 would similarly be modified.

Table 5-18. Example Risk Roll-Up Template for the Next Generation Space Telescope as applied to alternative selection during organizational planning

Blue typeface denotes repeated instances of leading indicators

Red typeface denotes secondary interfaces

Objec. No.	Objective Description	Type of Scen.	Lead. Ind. No. or Influencing Objec. No.	Description of Leading Indicator or Influencing Objective	Composite Indicator	Lead. Ind. Concern or Objec. Aggr. Risk	Aggregate Risk of Objective	Roll-Up Rationale
C (1-5) #10	Implement the 5-year hiring and training plan	Risk	5	No. of retirements of qualified optics analysis & testing experts	None	TBD	TBD	TBD
			6	No. of retirements of qualified integrated analysis & testing experts	None	TBD		
			7	No. of qualified optics analysis & testing recent graduates	None	TBD		
			8	Competition for recent optics graduates, e.g. from the military	None	TBD		
C (1-5) #9	Implement the 5-year facilities plan	Risk	9	Number of significant design modifications experienced for HST	None	TBD	TBD	TBD
			10	Complexity of design	None	TBD		
			11	Complexity of integration and testing	None	TBD		
C (1-5) #8	Provide technical support and expert review for the design, building, testing, and validation of the integrated space telescope	Risk	C (1) #12	Provide tech support & expert review for design, ... of cryo subsys	None	None	TBD	TBD
			C (1-5) #10	Implement the 5-year hiring and training plan	None	TBD		
			C (1-5) #9	Implement the 5-year facilities plan	None	TBD		
P (1-5) #7	Launch the space telescope	Risk	10	Complexity of design (rank 1-5)	None	TBD	TBD	TBD
			11	Complexity of integration and testing (rank 1-5)	None	TBD		
			12	Cost reserve needed for HST	None	TBD		
			13	Schedule reserve needed for HST	None	TBD		
			P (1) #11	Deliver the cryo system	None	TBD		
C (5-10) #6	Maintain a sufficient cadre ... to support ... operation of telescope and interpretation of data	Risk	C (1-5) #10	Implement the 5-year hiring and training plan	None	TBD	TBD	TBD
C (5-10) #5	Maintain state-of-the-art facilities and equipment ... to support the design, realization, and operation of the telescope	Risk	C (1-5) #9	Implement the 5-year facilities plan	None	TBD	TBD	TBD
P (5-10) #4	Design, build, deploy, and operate the Next Generation Space Telescope	Risk	11	Complexity of integration and testing (rank 1-5)	None	TBD	TBD	TBD
			14	No. of significant unexpected performance-related difficulties encountered during development of HST	None	TBD		
			P (1-5) #7	Launch the space telescope	None	TBD		
			C (5-10) #6	Maintain a sufficient cadre ... to support ... operation of telescope and interpretation of data	None	TBD		
			C (5-10) #5	Maintain state-of-the-art facilities & equipment to support design, realization, operation of the telescope	None	TBD		
P (5-10) #3	Continue operating existing telescopes	Risk	None	None	None	TBD	TBD	TBD
E (>10) #2	Attract a highly skilled work-force, cultivate an innovative work environment, and provide needed facilities, tools, and services	Risk	12	Cost reserve needed for HST	None	TBD	TBD	TBD
			13	Schedule reserve needed for HST	None	TBD		
			15	Congressional level of support for new space telescope (rank 1-5)	None	TBD		
			16	Congressional level of support for existing programs (rank 1-5)	None	TBD		
			17	Degree of searching extensibility available through S/W uploading	None	TBD		
			C (5-10) #6	Maintain a sufficient cadre ... to support ... operation of telescope and interpretation of data	None	TBD		
			C (5-10) #5	Maintain state-of-the-art facilities & equipment to support design, realization, & operation of the telescope	None	TBD		
			P (5-10) #4	Design, build, deploy, and operate the next generation telescope	None	TBD		
E (>10) #1	Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars	Risk	P (5-10) #3	Continue operating existing telescopes	None	TBD	TBD	TBD
			10	Complexity of design (rank 1-5)	None	TBD		
			11	Complexity of integration and testing (rank 1-5)	None	TBD		
			12	Cost reserve needed for HST	None	TBD		
			13	Schedule reserve needed for HST	None	TBD		
			15	Congressional level of support for new space telescope (rank 1-5)	None	TBD		
			16	Congressional level of support for existing programs (rank 1-5)	None	TBD		
			C (5-10) #6	Maintain a sufficient cadre ... to support ... operation of telescope and interpretation of data	None	TBD		
			P (5-10) #4	Design, build, deploy, and operate the next generation telescope	None	TBD		
			P (5-10) #3	Continue operating existing telescopes	None	TBD		

6. Management and Implementation of OROM at the Institutional/Technical Level (NASA Centers)

6.1 OROM from a Center's Perspective

As discussed previously in Section 2.1.6, OROM can be applied separately to management units within an organization so long as the objectives of each management unit are consistent with the objectives of the organization as a whole, and the cross-cutting risks and opportunities are handled consistently. Since a center's top objectives are derived from the agency's strategic objectives, the top objectives of the center are consonant with those of the agency in all areas where the center's roles align with the agency's responsibilities.

To support the agency's strategic objectives, NASA's centers have multiple roles. They support programs and projects that are assigned to them by the mission directorates, as contributors to programs and projects as requested when another center has management responsibilities, as preservers of core competencies required to support programs and projects, and as preservers of other core competencies mandated by the executive level. In supporting programs and projects, they also act as integrators and arbitrators of an extended organization that includes other centers, prime contractors, other commercial suppliers, university partners, and international partners. Furthermore, as was illustrated in Figure 3-5, implementing a center's plan includes developing and managing the workforce, maintaining needed facilities and retiring unneeded ones, acquiring services and material, and off-loading responsibilities when appropriate to the partnering agencies and companies. Section 6 focuses on these areas in developing guidance for the conduct of OROM at the institutional/ technical level, viz. NASA centers.

The particular objectives of OROM at the center level vary as the roles of the center vary. For example, when the center is exercising its support role for programs and projects, the principal objective of OROM is to integrate the risks and opportunities discovered by the multiple organizations contributing to the program or project, ensuring that they are handled consistently across the program/project and across the center, that cross cutting risks and opportunities are accounted for, that the contribution of individual risk and opportunity scenarios are aggregated appropriately from lower levels to higher levels, and that responses such as mitigation of risks, exploitation of opportunities, and enactment of internal controls are coordinated. On the other hand, when it is exercising its role as preserver of core competencies, the principal OROM objective is its principal institutional objective: to optimize the acquisition, allocation, and retirement of the various assets available to the center, including human assets (the workforce), physical assets (facilities, equipment, systems, and software), and instructional assets (policies, requirements, standards, and guidance).

6.2 Extended Organizations

6.2.1 Overview

All the examples used in this report are instances of collaborative projects involving multiple partners, or entities, with overlapping responsibilities (see, for example, Table 6-1). The collection of these entities for purposes of executing a project¹³ is referred to herein as a "project's extended

¹³ We use the term "project" in this connotation to refer to both programs and projects, as defined in NPR 7120.5, NASA Space Flight Program and Project Management Handbook.

organization,” because in addition to contributing to the same project, each is an independent organization with its own set of strategic objectives and performance requirements. The center that hosts the project (e.g., GSFC in the case of the JWST project) must communicate with the project’s extended organization in a manner that satisfies the strategic objectives of NASA while also respecting the strategic objectives of each of the contributing entities. Other centers within the project’s extended organization (e.g., JPL, ARC, JSC, MSFC, and GRC in the case of JWST) also must communicate with the other entities they interface with.

Table 6-1. Distribution of responsibilities among the principal entities within the JWST Project (from NASA and Google web sites)

Entity	Responsibility
NASA Centers	
Goddard (GSFC)	Manages the JWST project and provides Integrated Science Instrument Module (ISIM) components
Jet Propulsion Lab (JPL)	Manages the Mid-Infrared Instrument
Ames (ARC)	Detector technology development
Johnson (JSC)	Provides observatory test facilities
Marshall (MSFC)	Mirror technology development and environmental research
Glenn (GRC)	Cryogenic component development
Industry Partners	
Northrop Grumman (NGC)	Prime Contractor
Ball Aerospace	In charge of building the mirrors
COM DEV International	In charge of the Fine Guidance Sensor (FGS)
Academic Partners	
Space Telescope Science Inst.	Science and Operations Center at Johns Hopkins University
University of Arizona	In charge of building the New Infrared Camera (NIRCam)
International Partners	
European Space Agency (ESA)	Provides the Near Infrared Spectrograph, Mid-Infrared Instrument Optics Assembly, and the Ariane Launch Vehicle
Canadian Space Agency (CSA)	Provides the Fine Guidance Sensor/Near Infrared Imager and Slitless Spectrograph

As a rule, each NASA center participates in many projects and therefore has responsibilities to interface with the extended organization for a variety of projects, as shown in Figure 6-1. For convenience, we refer to the collection of all the entities that interact with Center 1 as the “extended organization.” The center’s extended organization includes not only entities with which the center interacts on project planning and execution, but also entities within the agency administration that provide direction and administrative support to the center.

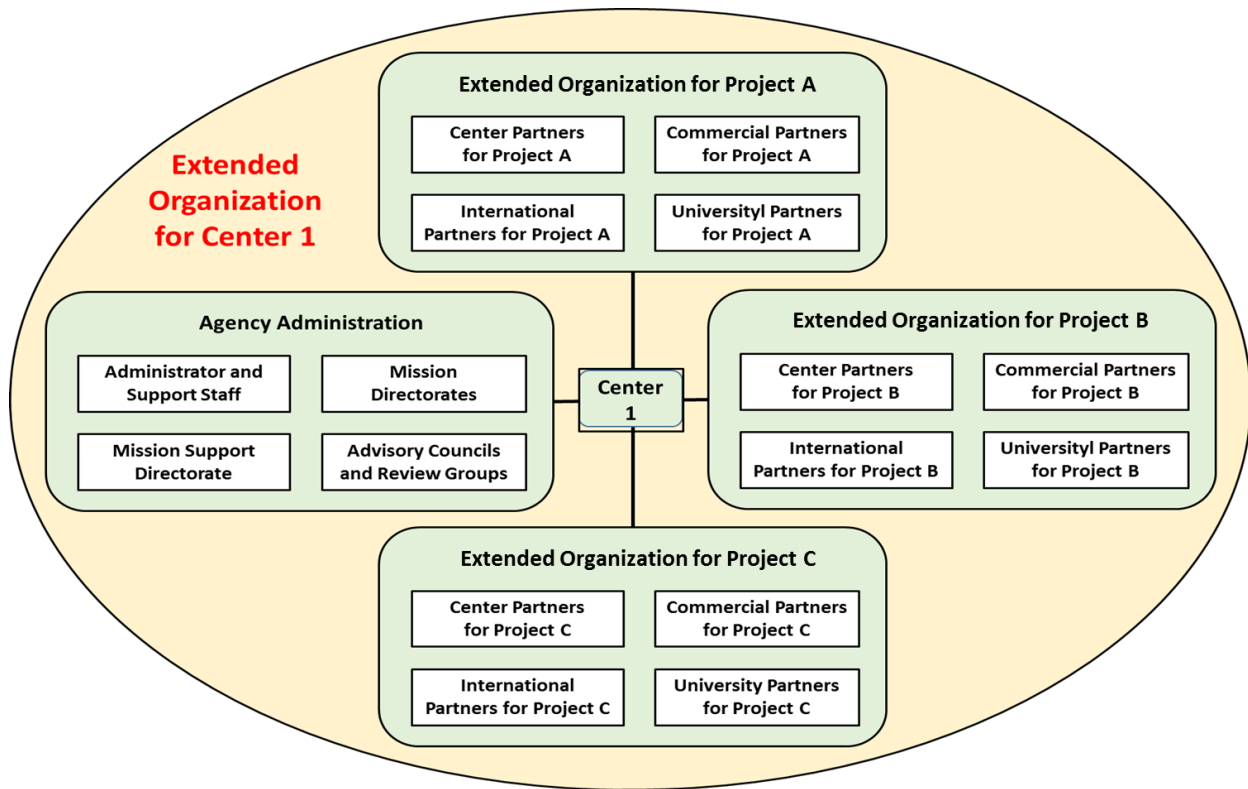


Figure 6-1. The extended organization of a NASA center

The success of such extended-organization endeavors depends upon the establishment of communication protocols that promote consistency of approach across the entities, sharing of information while protecting that which is proprietary, and seamless integration of the products.

6.2.2 Relationship of Each Center to the Other Entities in the Center's Extended Organization

In its support roles, each center acts as its own self-contained organization with its own set of objectives to be achieved, as an integrator of risk and opportunity information emanating from the other entities in the center's extended organization, and as an element of the projects' extended organizations charged with helping to ensure that NASA's strategic objectives are achieved.

These roles are illustrated schematically in Figure 6-2, where NASA's strategic objectives are taken as an example of the executive-level objectives that each center supports. In this figure, the executive-level strategic objectives are divided into three types:

- Those that are principally programmatic in nature and are allocated to centers by the mission directorates
- Those that are more institutional in nature and are managed by designation of the Administrator within centers and within the Mission Support Directorate.
- Those that are required of all agencies in the Federal Government and are typically managed at the executive level.

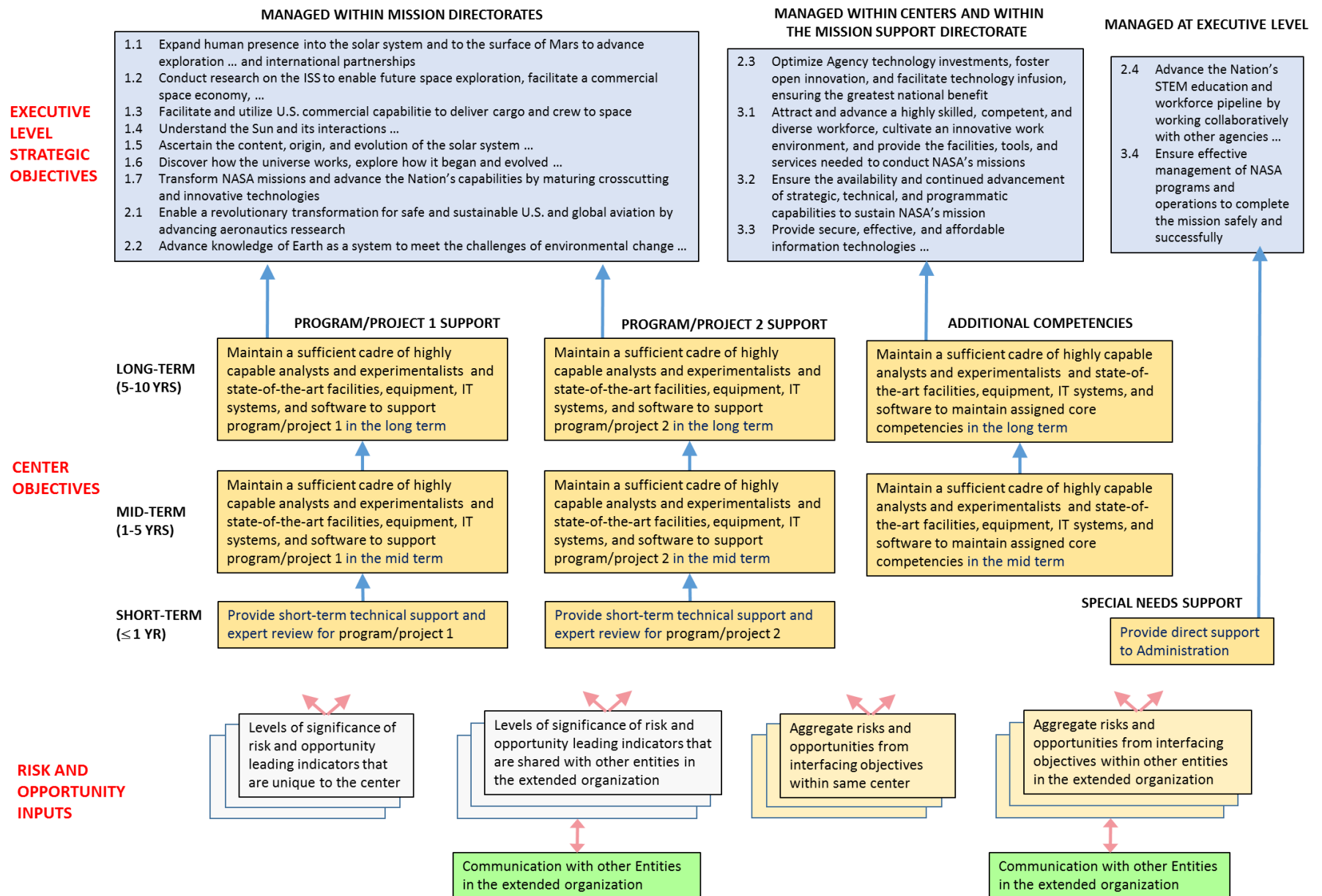


Figure 6-2. NASA example of how each center takes risk and opportunity inputs from a variety of entities and supports multiple strategic objectives of the agency

Correspondingly, the objectives of each center within the agency can be divided into three types that mirror the categories that apply to the higher-level strategic objectives:

- Support of specific programs and projects that are assigned to the center in service of the agency's mission
- Provisions for additional institutional capabilities needed to maintain the center's core competencies
- Support of mandates that are required of all agencies.

The risks, opportunities, and leading indicators associated with these types of objectives tend to cut across each center's extended organization. This cross-cutting aspect is illustrated in the lower part of Figure 6-2, which depicts the inputs from the center's extended organization that are needed to perform the roll-up, or aggregation, of risks and opportunities within the center. These risk and opportunity inputs are divided into the following categories:

- Individual risk scenarios, opportunity scenarios, and associated leading indicators that are unique to the center
- Individual risk scenarios, opportunity scenarios, and associated leading indicators that affect not only the center in question, but also other entities in the center's extended organization
- Aggregate risks and opportunities for objectives that are unique to the center
- Aggregate risks and opportunities for objectives that emanate from, or are shared with other entities in the center's extended organization

6.2.3 OROM Organizational Structure for a Center's Collaborative Projects

Experience has shown [11] that for OROM to be practiced successfully in projects that have multiple partners, there needs to be a multi-organizational, integrating OROM team for each project that prepares the overall risk management plan and oversees the management of risk and opportunity. The integrating team is responsible for identifying risks that cross over the interfaces between entities (i.e., between centers, contractors, and other partners) and/or that emanate from those interfaces, for conducting preliminary analyses to assess the likelihoods and potential impacts, and for assigning primary ownership. When the origin of an interfacing or cross-cutting risk initiates from an action or inaction of a particular entity within the project's extended organization, ownership is typically assigned first to that entity. If the entity lacks authority to act upon the risk, it is elevated to a higher level within the chain of authority. Frequently, risk ownership is assigned at project level if the process of resolving the risk requires action at that level. Thereafter, the OROM team monitors the resolution process, which may involve the improvement of existing controls, establishment of new controls, or formulation and implementation of a mitigation plan.

To flesh out and monitor interfacing and cross-cutting risks and opportunities, the OROM team may establish various sub-groups. The number of subgroups or their particular names is not that important. What is important is that their responsibilities with respect to one another are clearly defined and the schedules under which they operate are coordinated.

For example, there may be separate working groups and management boards established for each organizational unit, for each program/project, and for each center, as shown in Figure 6-3. Risk and opportunity (RO) working groups for each entity would have responsibility for identifying, analyzing, and recommending controls and mitigations to reduce risks pertaining to the entity's objectives in the collaborative project. They would meet on a regular, scheduled basis with their corresponding RO management board to share risks and opportunities that affect the entity and review decisions made by the management board about how to respond to them. They would also meet with the working groups of the other entities in the project's extended organization at regularly schedule meetings organized by the project, to discuss and evaluate risks and opportunities that are of mutual interest. Although not specifically shown in the figure, informal communications between the working groups of different entities could also occur between scheduled meetings when there is a need to discuss technical issues in an *ad-hoc* manner.

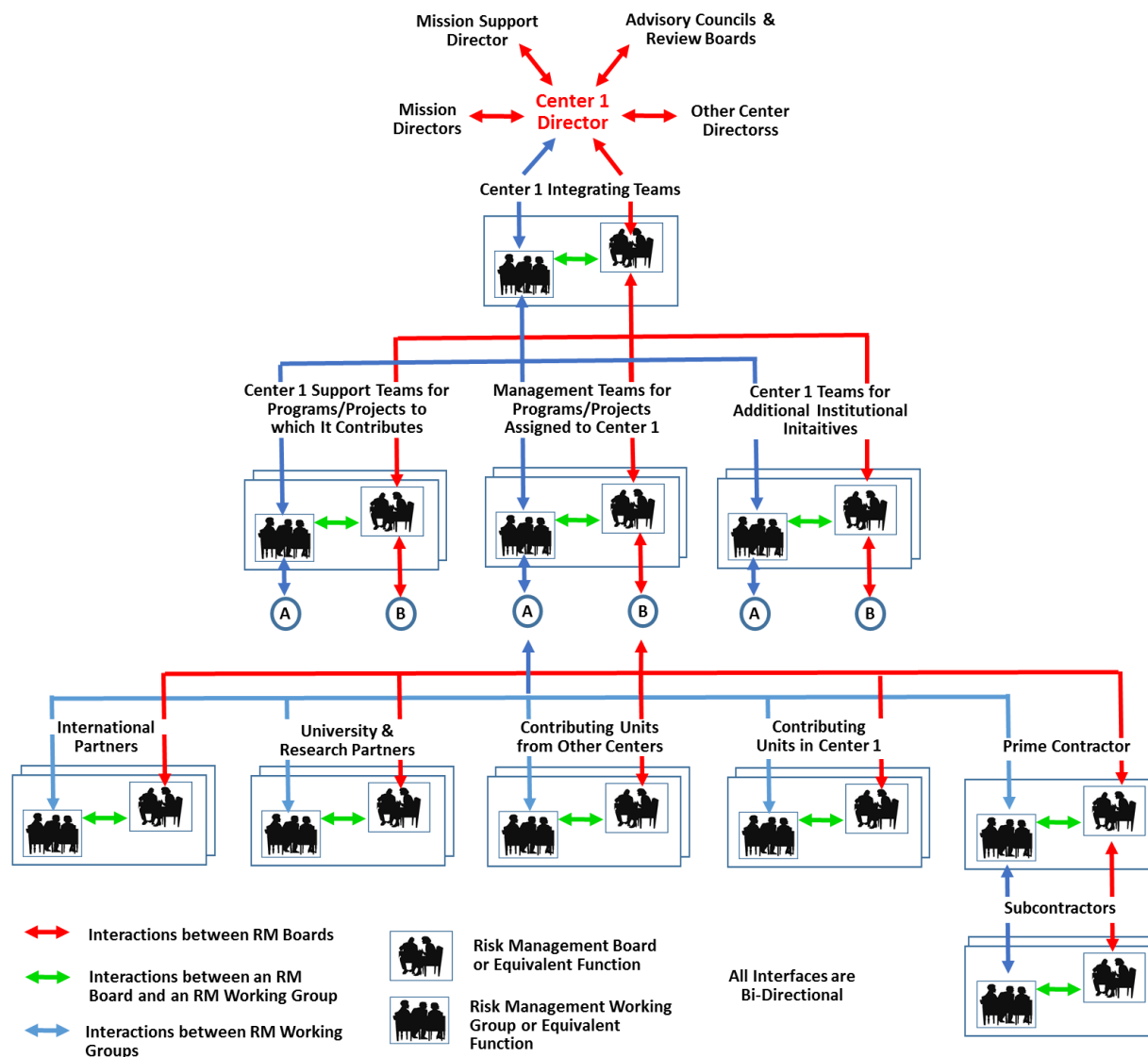


Figure 6-3. A representative OROM organizational chart for a center that contributes to multiple collaborative projects

RO management boards for each entity would have responsibility for prioritizing the risks and opportunities identified and reported by the entity's RO working group, determining the kind of response needed, assigning ownership, monitoring progress, and approving changes of status. Typical responses for risks would include, for example, (1) accept, (2) mitigate, (3) watch, (4) research, (5) elevate, or (6) close. Changes of status would typically involve movement from one kind of response to another, and could involve elevating the response (e.g., from accept and watch to mitigate) or lowering the response (e.g., from accept and watch to close). They would also meet on a regularly scheduled basis with the management boards of the other entities at meetings organized by the project to organize and adjudicate risks and opportunities that are of mutual interest.

The center, in addition to supporting the collaborative projects that are assigned to it, has additional responsibilities that include contributing to other projects, executing designated institutional initiatives to maintain its core competencies, and communicating with other centers that have similar responsibilities for other collaborative projects, with the mission directorates that assign program/project responsibilities to the center, with the Mission Support Directorate that has institutional oversight at the executive level, and with the advisory councils and review boards that provide an evaluation function at executive level. These interfaces are also shown in Figure 6-3.

The principal goal of the OROM structure, which cannot be overemphasized, is for all entities to be involved in the OROM process by having technical representation in a working group and/or managerial representation in a management board. This far-reaching intent is necessary to achieve the buy-in that is needed in all parts of the project's extended organization.

6.2.4 Challenges of Creating and Managing an Integrated OROM Database

As discussed in Section 5.8.3, wherever there is a need for OROM oversight and communication between entities, there is also a need for an integrated database that incorporates OROM information across these entities. At the top level of a collaborative project, the integrated database should typically include the information in the risk and opportunity templates, the owner for each risk and opportunity, the organizational entities that are involved, corresponding working groups and management boards, change plans, change history, and status.

While ideally the integrated database for a collaborative project should capture all risks and opportunities for all the participating entities, some entities may already have an established risk management process and database that they do not want to give up. To facilitate acceptance of the process, exceptions to the principal of a totally integrated database may have to be made. For example, some entities may need their own version of the database because they do not have network connectivity. Periodically (perhaps weekly), they might provide a copy of their database updates for uploading into the main database. Other entities may have concerns about proprietary information and not want to have all their data available to all participants. It may be decided that such entities may maintain their own separate database as long as they enter risks and opportunities into the main database that have the potential to degrade the capability performance at the program/project level. These entities would be aware of how their risk and opportunity data affect the project as a whole by virtue of having access to the main database.

Because of the cross-cutting nature of collaborative project risks and opportunities, there is also a need for reduced, summary databases that integrate OROM information at higher levels of the organization. For example, there should be a repository of data at the center level covering those

aspects of OROM that cut across the collaborative projects within the center’s extended organization. Similarly, there should be a data repository at executive level covering the aspects of OROM that cut across the centers, mission directorates, the Mission Support Directorate, and management councils.

6.3 OROM-Informed Acquisition, Allocation, and Retirement of Resources across a Center’s Extended Organization

6.3.1 Objectives-Based Distribution of Human, Physical, and Instructional Assets

An important function of OROM, in its institutional mode of operation, is to assist each center in the budgeting of key resources across the extended organization. The key resources to be budgeted, as shown in Figure 6-4, include human assets (personnel trained and experienced in different skill areas), physical assets (supporting facilities, IT systems, other systems, equipment, and software), and instructional assets (supporting policies, requirements, standards, and guidance documents). The budgeting involves more than costs. In addition to satisfying cost constraints, the final distribution of assets must reflect the intent of the agency’s strategic objectives that are inherited by the center, including: successful support of programs and projects that support the strategic objectives, maintenance of core competencies in specified strategic areas, promotion of strategic partnerships, and sharing with the public through strategic education initiatives. The tools for achieving this strategic distribution of assets are both quantitative and qualitative.

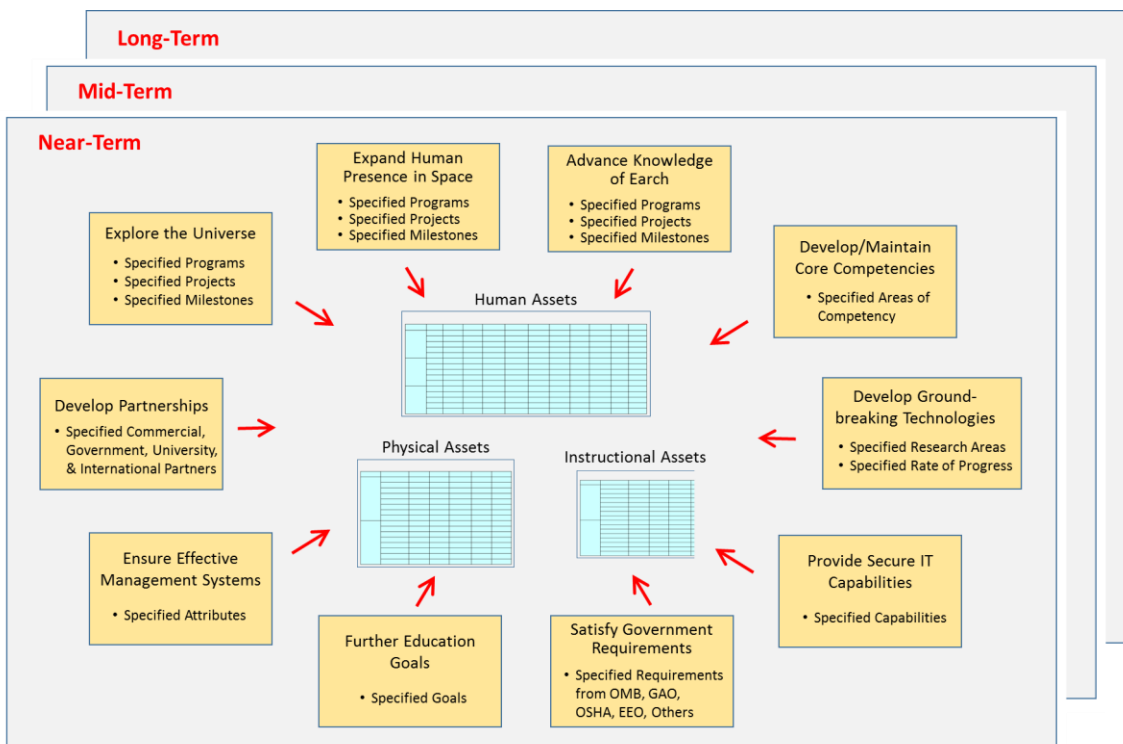


Figure 6-4. The success of the center’s inherited strategic objectives is dependent on the “right-sizing” of the resources available to the center (both internal and external)

6.3.2 Representative Templates for Distributions of Allocated Assets

Representative templates that may be used for displaying the distribution of allocated assets are provided in Table 6-2. These templates include both current and projected distributions. The projected distributions refer to the predicted allocation of assets in the near-term (~1 year), mid-term (~5 years), and long-term (~10 years), assuming the current plan is implemented. The specific entries in Table 6-2 are discussed in the following three subsections.

Human Asset (Workforce) Distribution

The success of any organization (whether an entity in a center's extended organization or the extended organization itself) depends upon the ability to hire and maintain a skilled workforce. Since several of the strategic objectives inherited by centers pertain to diversification of the workforce through formation of partnerships with other domestic agencies, commercial enterprises, universities, and international agencies, it is necessary for the proper skills to be maintained in all the contributing entities of the center's extended organization. The particular skills to be preserved have to be matched to the needs of the programs and projects that the center is supporting, as well as to the additional core competencies that the center is required to maintain.

Table 6-2 (a) illustrates conceptually the type of information needed to evaluate the status of the workforce across the center's extended organization. It includes the number of equivalent persons (EP) at different skill levels for each skill area that is needed and for each entity that contributes. Skill level designations on the scale of 1 to 5 can be interpreted, for example, as follows (typical of industry standards):

- 5 – Expert in area. Typically the area lead. Understands all aspects of system and has extensive practical experience.
- 4 – Senior member of area. Knowledgeable in most aspects. Leads projects. Substitutes for area lead when needed. Self-starter. Understands most or all of system. High degree of practical experience.
- 3 – Junior member of area. Owns specific areas of responsibility. Needs continuous coaching. Self-supporting once tasks assigned. Responsible engineer on some components. General knowledge of system.
- 2 – Group apprentice. Minimal experience but shows competency in areas that have been tried. Does not work alone. Understands key aspects of system. Some practical experience.
- 1 – Brand new to area. Entry-level tasks. Minimal contribution. Some knowledge of the general workings of the system. Limited practical experience.

Each combination of skill area, skill level, and contributing organizational entity is referred to herein as a workforce category.

Table 6-2. Templates for distribution of human (workforce), physical, and instructional assets.

Long-Term

Mid-Term

Near-Term

(a) Current and Projected Workforce

Organizational Entities Included in the Compilation	Skill Area	Skill Levels	Current Number of Available EP's	Projected Number of EP's Available for Spec. Term
All Entities in Extended Organization	Area 1 (e.g., Propulsion Design)	All	XX	TBD
		3, 4, and 5	XX	TBD
		5 Only	XX	TBD
	Area 2 (e.g., Information Technology)	All	XX	TBD
		3, 4, and 5	XX	TBD
		5 Only	XX	TBD
	Etc.			
	Center 1 (Center of Interest)	Same Breakdown of Skill Areas and Skill Levels		
Etc., as enumerated in (d)				

(c) Current and Projected Instructional Asset

Contributing Entity	Instructional Area	Instructional Asset	Current Content Relevant to Center 1 Objectives	Projected Content for Specified Term
All Entities in Extended Organization	Area 1 (e.g., Acquisition Management)	Policy Directive #1	XX	TBD
		Proc. Reqt. Doc. #1	XX	TBD
		Standard #1	XX	TBD
		Guidebook #1	XX	TBD
	Area 2 (e.g., Equal Opportunity)	Policy Directive #1	XX	TBD
		Proc. Reqt. Doc. #2	XX	TBD
		Standard #2	XX	TBD
		Guidebook #12	XX	TBD
Etc.				
Center 1 (Center of Interest)	Same Breakdown of Operational Ability Measures, Support Areas, and Support Assets			
Etc., as enumerated in (d)				

(b) Current and Projected Physical Assets

Organizational Entities Included in the Compilation	Operational Ability Measure	Support Area	Support Asset	Current Ability Relevant to Center 1 Objectives	Projected Ability Relevant to Center 1 Objectives	
All Entities in Extended Organization	Capability	Area 1 (e.g., Propulsion Testing)	Facility #1	XX	XX	
			System #1	XX	XX	
			Equipment Item #1	XX	XX	
			Software Item #1	XX	XX	
		Area 2 (e.g., Information Technology)	Facility #2	XX	XX	
			System #2	XX	XX	
			Equipment Item #2	XX	XX	
			Software Item #2	XX	XX	
		Availability	Area 1 (e.g., Propulsion Testing)	Facility #3	XX	XX
				System #3	XX	XX
				Equipment Item #3	XX	XX
				Software Item #3	XX	XX
	Area 2 (e.g., Information Technology)		Facility #4	XX	XX	
			System #4	XX	XX	
			Equipment Item #4	XX	XX	
			Software Item #4	XX	XX	
Etc.						
Center 1 (Center of Interest)	Same Breakdown of Operational Ability Measures, Support Areas, and Support Assets					
Etc., as enumerated in (d)						

(d) Example Entities

Organizational Entities Included in the Compilation		
Center 1 (Center of Interest)	Contractor 1 (Onsite)	University Partner 1
Center 2 (Other Center)	Contractor 2 (Onsite)	University Partner 2
Center 3 (Other Center)	Contractor 1 (Offsite)	International Partner 1
Center 4 (Other Center)	Contractor 2 (Offsite)	International Partner 2
Etc.		

Physical Asset Distribution

Because the strategic objectives of the agency include both organizational objectives (programs and projects) and national policy objectives (e.g., the well-being of the agency's commercial, educational, and international partners), it is necessary not only for workforce allocations to be considered in a holistic manner across the extended organization, but also for the distribution and utilization of physical assets to be so considered. As mentioned earlier, physical assets in the present context include supporting facilities (including test facilities), IT and other systems, equipment, and software.

Table 6-2 (b) illustrates conceptually the type of information needed to evaluate the status of physical assets across the center's extended organization. It includes the capability and availability of each asset to be used to satisfy the center's objectives, broken out according to the support area that it addresses and the entity that owns it.

The specifications of "capability" and "availability" in this template are expressed verbally rather than numerically (although numerical information may be included in the verbal descriptions). This is different from the specification of EP's in the allocation of human assets, which is strictly numerical. Both terms, capability and availability, are specifically referenced to needs for satisfying the center's objectives. For example, the capability of a propulsion test facility to test small components is not a relevant capability if its use for the center is only for testing of full-up systems. Likewise, the availability of a propulsion test facility for purposes other than those needed by the center and its extended organization are not relevant and do not need to be tracked. In a larger sense, the description of the capability and availability of a physical asset is equivalent to a statement of its ability to meet the center's performance and availability requirements.

Instructional Asset Distribution

Since NASA's mission is dynamic and the means it uses to achieve its objectives change from time to time (e.g., as a result of the increasing complexity of its missions or the occurrence of break-through technology advancements), its instructional documents frequently need to be updated or superseded. Similarly, the instructional documents for entities that partner with NASA may need to be revised or superseded to be consistent with NASA's policies and requirements, and one of NASA's responsibilities will be to audit the contents of the partners' instructional documents. As noted earlier, instructional documents include policy directives, procedural requirements, standards, and guidance documents.

Table 6-2 (c) illustrates conceptually the information needed to characterize the status of instructional assets relevant to the center's operation and the operation of its partners. It includes the content required of instructional documents in various instructional areas over the near-term, mid-term, and long-term. Again, the content is expressed verbally rather than numerically, and only content relevant to the center's objectives need be entered in the template.

6.3.3 Asset Risks, Opportunities, and Risk/Opportunity Scenario Statements

In addition to the risks and opportunities associated with the successful performance of the center's designated programs and projects, there is a separate category of risks and opportunities associated with the center's human, physical, and instructional assets and its obligation to maintain its

mandated core competencies. Both types of risk have to be considered in the overall assessment of whether a center is achieving all its objectives.

Risks of future asset shortages and imbalances can arise from various sources. Following, for example, is a list of risks that could affect the viability of the workforce by causing people to leave prematurely:

- If funding is cut or a program is retired earlier than expected, people might seek more stable work alternatives.
- If a program is extended beyond its planned timeframe, the impact of retirements may become more important.
- If in-house competition for qualified persons increases, people might transfer to other organizations to increase their opportunities.
- If market competition for qualified persons increases, people might accept positions with other companies with higher pay.
- If local economic conditions degrade, people might move to another part of the country.
- If a contractor or partner develops financial problems, that entity might not be able to maintain its workforce.
- If people are required to work longer hours on a continuing basis, people might seek positions that are less stressful.

Other risks can affect the viability of the workforce by increasing the number of qualified persons that are needed to achieve the center's objectives beyond those that are available. For example:

- If domestic or international political priorities mandate an acceleration of the schedule or an increase in the scope of the objectives, there might be a need for more qualified people.
- If an important task in a project falls behind schedule because of unexpected difficulties, there might be a need for an increased allocation of people to that task to get it on schedule again.

There are also events that could lead to opportunities pertaining to the workforce. For example:

- If funding is increased due, for example, to favorable economic conditions, it may be possible to attract persons with unusually high qualifications by offering higher salaries or other monetary incentives.
- If market competition for qualified persons decreases, it may be possible to attract qualified persons without offering higher salaries or other monetary incentives.

Risks that could affect the viability of physical and instructional assets include, for example, the following:

- If a facility has to be shut down unexpectedly due to an accident, malfunction, or the mandate of a watchdog organization, its availability to the center may disappear.
- If another program that requires use of the facility suddenly gains high national priority, the availability of the facility for the center's use may decrease.

- If a catastrophic accident on the scale of the Challenger or Columbia accident occurs within the space program, the agency's policies and procedural requirements may have to be changed to respond to findings of the ensuing review board.
- If a revolutionary new technology becomes available offering new opportunities previously not thought possible, the agency's standards and guidebooks may have to be rewritten to accommodate the new technology.

Obviously, the last of these encompasses both a risk and an opportunity, for while there is a risk that the instructional documents may have to be rewritten, leading to increased cost and/or schedule implications, there is simultaneously an opportunity for implementing improved technology.

For asset risks and opportunities, it is useful to expand upon the risk and opportunity scenario statement structure presented in Section 4.4.2 to include information about the effect of the risk or opportunity on assets in the extended organization. Following is a specialized form of risk/opportunity scenario statement that satisfies the general format but is specifically applicable to risks and opportunities affecting assets in the center's extended organization:

“ Given *[a specified set of current conditions and current/projected trends]*,
 ... there is a possibility that *[a specified departure event or set of departure events]* may occur,
 ... affecting the *[[envisaged or required] availability, capability, and/or content of specified human, physical, and/or instructional assets]*,
 ... resulting in a noteworthy *[decrease or increase]*
 ... in the center's likelihood of being able to meet *[a specified center objective or set of objectives]*.”

The risk/opportunity scenario statement above recognizes that there are several ways in which a departure event can affect the viability of the human, physical, and/or instructional assets for the center's extended organization. The event can result, for example, in a positive or negative change in:

- The number of experienced personnel available to the extended organization in various workforce categories
- The number of experienced personnel needed by the extended organization in various workforce categories to meet the center's objectives
- The availability and capability of physical assets under the purview of the extended organization
- The availability and capability of physical assets needed by the extended organization to meet the center's objectives
- The content of instructional assets needed by the extended organization to meet the center's objectives

These variants are encompassed in the risk/opportunity scenario statement within the phrase “[envisaged or required] availability, capability, and/or content of specified human, physical,

and/or instructional assets.” Note that while each of the variants is different from the others, they all lead to a common result: an imbalance or gap (either positive or negative) between the assets in the extended organization and the assets needed to satisfy the center’s objectives.

6.3.4 Leading Indicators of a Center’s Health

In addition to the leading indicators cited in Section 4.4.3 and 4.4.4 and those listed in Table 4-1, there is a separate category of leading indicators associated with the center’s ability to maintain its mandated core competencies. For example, the following is a subset of workforce-related leading indicators recommended for NASA use by the National Academy of Public Administration (NAPA) in 2007 [22].

- Median age of workforce
- Number of uncovered full-time equivalents (FTE)
- Ratio of fresh-out hires to total hires
- Ratios of civil service persons to contractors and supervisors to staff
- Center-by-center use of workforce incentives such as flexible work schedule, bonuses, and subsidized student loan payments.
- Percentage of people participating in training over the past year
- Number of turnovers and absenteeism
- Overall productivity rating
- Employee perceptions/assessments of management, e.g. from 360 degree feedback and *Best Places to Work* survey
- Number and severity of disciplinary actions
- Number of unfair labor practices and Equal Employment Opportunity (EEO) complaints
- Ranking in *Best Places to Work in the Federal Government*, diversity element

These were devised by NAPA to be indicators of the health of a center, and in particular indicators of the risk of not being able to maintain a robust workforce.

Similar lists can be postulated for physical assets and instructional assets. For example, the following list of attributes can be thought of as leading indicators of the health of a center with respect to the availability and capability of an organization’s physical assets:

- Median age of facilities
- Maintenance history of facilities
- Scale factors for testing
- Unaddressed cybersecurity threats
- History of changes to policies and procedures that affect the availability of a facility

6.3.5 Correlations between Internal Leading Indicators and Gaps in the Distributions of Human, Physical, and Instructional Assets

Important correlations exist between leading indicators that were cited earlier, such as schedule and cost margins, and gaps in the distributions of human, physical, and instructional assets. These

correlations make it possible to develop a risk- and opportunity-based plan for acquiring, allocating, and retiring a center's human, physical, and instructional assets.

To illustrate by way of example, suppose that there happens to be a shortage of skilled personnel available to the prime contractor for the Next Generation Space Telescope project in the area of cryogenics for cooling systems, and suppose that, based on current trends and expected future events, the shortage is projected to worsen during the next 5 years. When this information is factored into the scheduling for development and testing, it may be found that the margin for the completion of the buildup of the integrated system is less than the trigger value for significant concern (i.e., the response trigger value as defined in Section 4.5.1). When this information is transferred to the risk roll-up template (Table 5-6), it may be found that there is intolerable risk of not being able to satisfactorily achieve the following strategic objectives that the center is committed to:

- Objective 1.6: Discover how the Universe works, explore how it began and evolved ...
- Objective 3.1: Attract and advance a highly skilled, competent, and diverse workforce ... needed to conduct NASA's missions

Observe that in this example, the following entry on the workforce template for the center's extended organization:

- Number of people in skill category 4 or 5 in the skill area of cryogenics working for the prime contractor

is directly related to the following leading indicator:

- Schedule margin for integration

and thereby has been identified as causing two of the center's top objectives (listed above) as having an intolerable risk of not being satisfactorily achieved.

In addition, it should be apparent that the same sort of correlation can exist between entries on the physical and instructional asset template, the leading indicators pertaining to margins, and the center's top objectives. For example, if a certain testing facility is not available when needed or lacks certain needed capabilities, the schedule margin for completion of testing may be intolerably low, thereby having the same effect on the center's top objectives.

Likewise, the distributions of human, physical, and instructional assets can affect the ability to take advantage of opportunities that may arise in the future. For example, having a few skilled researchers available to conduct innovative research in a pioneering propulsion technology may lead to an opportunity to utilize that technology to expand the agency's objectives related to exploration of our solar system or to accomplish its current objectives more quickly or at less cost.

6.3.6 Optimization of the Acquisition, Allocation, and Retirement of Human, Physical, and Instructional Assets

Optimization of the plan for acquiring, allocating, and retiring human, physical, and instructional assets is an iterative process that utilizes the correlations between assets, leading indicators, and the center's objectives. The optimization process is summarized in Figure 6-5 and proceeds as follows:

- The center’s objectives and associated risks, opportunities, and corresponding leading indicators are identified as in Section 5.

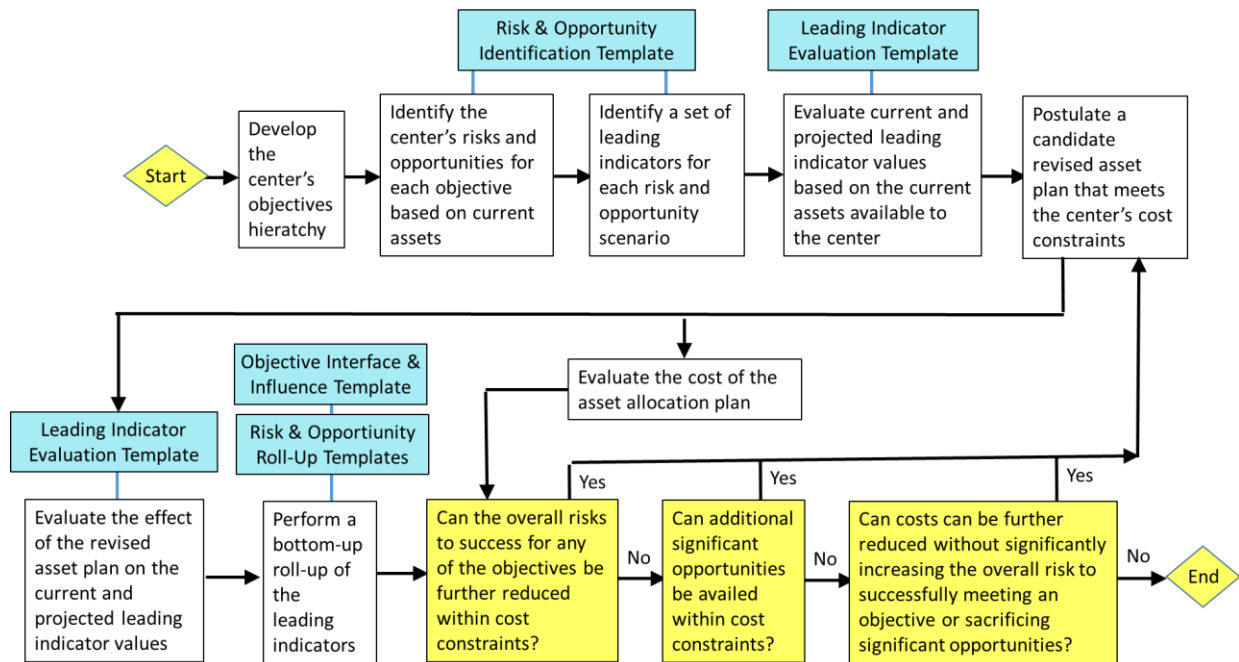


Figure 6-5. Outline of the steps in the iterative process for optimizing asset distributions based on costs and current and projected values of leading indicators

- An asset allocation plan that is postulated to meet cost constraints is proposed using the templates in Section 6.3.2.
- The effect of the allocation plan on the current and projected leading indicator values is evaluated based on the discussion in Section 6.3.5, using the Leading Indicator Evaluation Template (Table 5-3).
- The risks and opportunities are rolled up to the center’s top-level performance objectives using the Risk and Opportunity Roll-Up Templates (Tables 5-6 and 5-9).
- The cost of implementation of the asset allocation is evaluated using traditional cost accounting methods.
- Modifications to the asset allocation plan are considered to determine whether the balance between overall risk and opportunity exposure and overall cost can be improved.

The iterative process may continue until any of the following conditions occurs:

- The overall risks to success cannot be further reduced within cost constraints.
- Additional significant opportunities cannot be availed within cost constraints.
- Costs cannot be reduced without significantly increasing the overall risk or sacrificing significant opportunities.

The iterative process is illustrated in more detail in Figure 6-6. As part of its graphical display, Figure 6-6 includes the Leading Indicator Evaluation Template originally presented in Table 5-3, modified to include not only performance risk indicators but also asset and UU risk indicators.

6.3.7 Relevance to Provider Acquisition Decisions Made by Centers

The processes described earlier in Section 6.3 can be applied to assist the center in selecting providers such as prime contractors and other suppliers. The process of deciding between alternative providers is determined in large part by the amount of risk versus the amount of opportunity that each brings to the table in helping the center achieve its objectives. The steps that a center needs to implement in order to make a rational selection are similar to those described in the earlier subsections, but with a focus on the risks and opportunities that are brought by each provider. Very briefly, these steps are as follows:

- Identify the risk and opportunity scenarios that are introduced by allocating the selected tasks to the provider.
- Identify and evaluate the associated leading indicators.
- Integrate the risk, opportunity, and leading indicator information for the provider with the corresponding risk, opportunity, and leading indicator information that is already in the OROM templates.
- Perform the roll-up of risks and opportunities using the roll-up templates including the risks and opportunities introduced by the candidate provider.
- Determine which candidate provider maximizes the likelihood of the center being able to achieve its objectives.

The steps are similar to those in Figure 6-5, except that new risk and opportunities introduced by a new candidate provider are taken into account and the iterative process is not exercised.

It is anticipated that more information and guidelines on the use of OROM processes to select between alternative providers will be developed as part of future work.

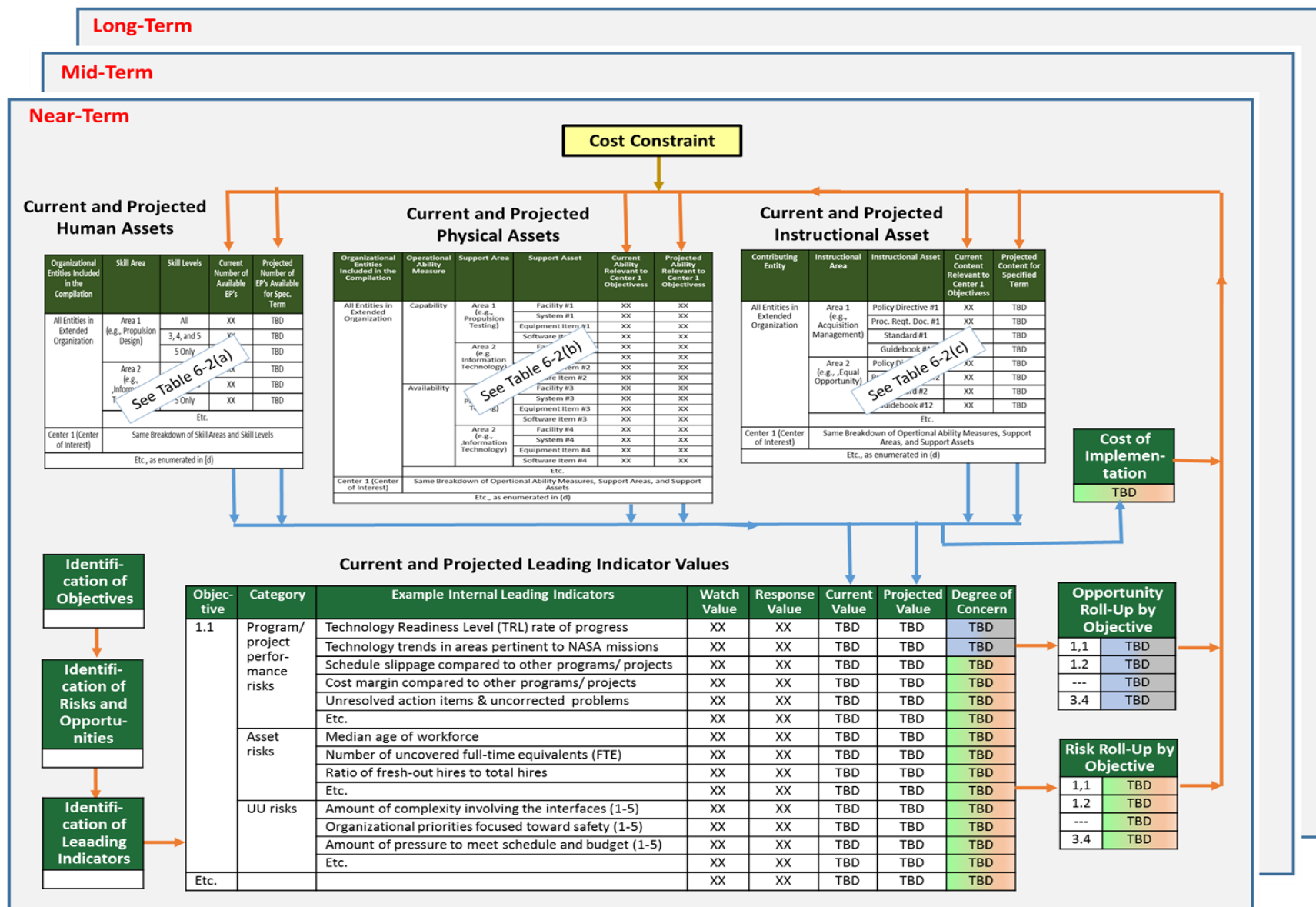


Figure 6-6. Illustration of iterative process for optimizing asset distributions based on costs and current and projected values of leading indicators

7. A Brief Overview of the Potential Integration of OROM with Agency-Wide Capability Assessments and Program Reviews

This section discusses how OROM in general and the OROM templates in particular can interact with important strategic initiatives and other agency-wide activities currently practiced within NASA, including the Technical Capability Assessment Team (TCAT) process, the Capability Leadership Model (CLM) process, and the Baseline Performance Review (BPR) process.

7.1 Technical Capability Assessment Team (TCAT) and the Capability Leadership Model (CLM)

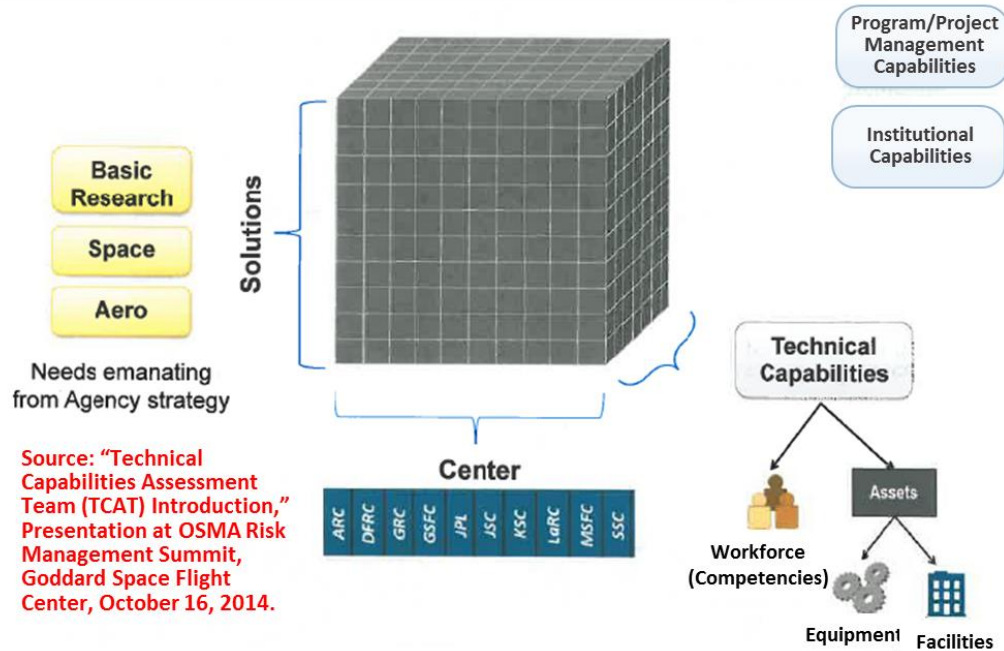
The NASA Technical Capability Assessment Team (TCAT) was sponsored by Headquarters up until its conclusion in 2015 to assess technical capabilities and priorities across the agency. Those capabilities were defined as a combination of workforce talent, specialized facilities and infrastructure, as well as unique tools and techniques. As discussed in [23], the TCAT used an analytical method to determine alignment of NASA's technical capabilities with the agency's long-term strategic needs, the mission directorates' near-term needs, and the centers' identity and values. The purpose of the TCAT was to establish a more efficient operating model that maintains a minimum set of technical capabilities to meet current and future mission needs while accommodating portfolio changes that occur periodically.

As shown on the upper-left of Figure 7-1, the TCAT approach was based on using a three-dimensional model that included technical capabilities as one dimension, centers as a second dimension, and solutions as a third dimension. In this context, technical capabilities included all of the assets (equipment and facilities) and human resources (NASA workforce and contractors) utilized to meet NASA technical objectives. Solutions refer to the present and future portfolio content (programs, projects, systems, subsystems, activities, initiatives) that results from decomposition and implementation of the agency's objectives. One of the ultimate objectives of the TCAT approach was to use its analytical model to assist in the right-sizing of NASA's workforce and assets.

As discussed in [24], the recent TCAT assessments at NASA on particular capabilities highlighted the need to address capabilities from an agency-wide perspective. As a result, NASA senior management has adopted a Capability Leadership Model (CLM). The intent of that model is to strategically address how to build a strong foundation to support NASA missions; advance capabilities intrinsic to NASA to meet long-term needs; optimize deployment of capabilities across centers; transition capabilities from government to the private sector; and eliminate capabilities when appropriate. In particular, the model approach targets those capabilities that need (a) greater coordination and alignment across mission directorates and centers, and (b) an integrated strategy toward advancement for future agency objectives.

The current CLM approach at NASA is based on a designated capability leader being assigned for each of 19 technical disciplines and 6 research areas. They are collectively referred to here as the CLM team. Their responsibilities are to advise various management councils of the agency in various areas such as helping to ensure proper alignment of capabilities across missions and centers, establish tasking plans based on executive-level roadmaps and strategic needs, determine

The TCAT's exploration of the relationships between solutions, capabilities, and organizational entities ---



- **Solution:** The systems, subsystems, and activities that result from the decomposition of Agency objectives. Solutions refer to current and future portfolio content and are budget and portfolio neutral
- **Technical Capability:** All of the assets and workforce (FTE/WYE) meeting a technical need. This type of capability is directly related to the specifics of NASA's current and future portfolio content.
 - Usually consists of a Technical Capability title and definition, along with detailed information on the assets and workforce that constitutes the capability.

Figure 7-1. Relationship between the TCAT process and the Objectives Interface and Influence Template (Part 1 of 2)

--- can provide most of the information for preparing the OROM Objectives Interface and Influence Template

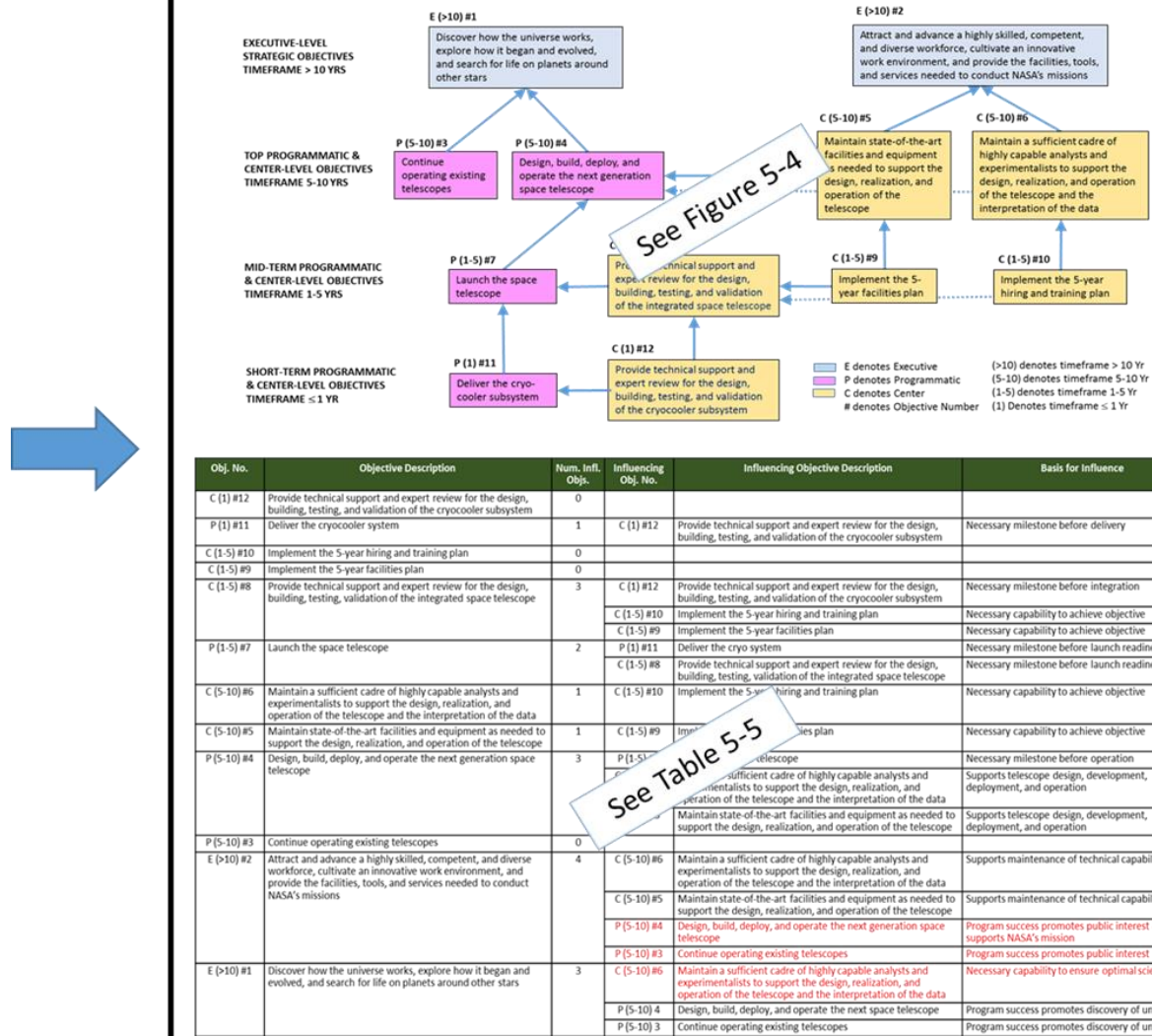


Figure 7-1. (Part 2 of 2)

gap areas for advancement and strategic investment, advise on capability sizing and strategic hiring across all centers, assess opportunities for capability investments and divestments, solicit innovative ideas from other capability areas related to themes that are common among them, and establish standards and specifications.

There appear to be two ways in which the OROM approach described in this report can interact synergistically with the CLM/TCAT approach. One involves a transfer of information from the CLM team to the OROM team, and the other involves a transfer of information in the opposite direction. Specifically, what CLM can provide to OROM is an understanding of all the interfaces that exist between the centers' institutional initiatives, the centers' mission support activities, the mission directorates' programs and projects, and the agency's strategic objectives. Conversely, what the OROM team can provide to the CLM team is an assessment of how risks and opportunities contribute to the right-sizing of the workforce and other assets.

The first interaction, from CLM/TCAT to OROM, is illustrated in Figure 7-1, and in particular by the arrow connecting the left side of the figure to the right side. In its role of mapping NASA's present and future technical capabilities with each center and with each solution, the CLM team members are in a unique position to ascertain a complete definition of the interfaces that exist between the centers' institutional initiatives, the centers' mission support activities, the mission directorates' programs and projects, and the agency's strategic objectives. The lower right part of Figure 7-1 illustrates how this information could assist the OROM team in constructing its Objectives Interface and Influence Template.

The second interaction, from OROM to CLM/TCAT, is illustrated in Figure 7-2, which shows how the two processes may interact with respect to the right-sizing of human and physical assets. While it may appear at first glance that the OROM role in optimizing the development, allocation, and retiring of these resources, as described in Section 6.3.6, is duplicative of the CLM intent to right-size NASA's workforce and assets, the two are more complementary than duplicative. The OROM focus is on incorporating a means for balancing risks and opportunities into the right-sizing process, a focus that is unique to OROM. The service that OROM can provide to CLM, in this regard, is an accounting of the uncertainty associated with possible future events. It is hardly arguable that the planning for future workforce and other assets should include a reasonable assessment of the uncertainties reflected in risks and opportunities, and therefore, OROM should be an essential part of this CLM function.

7.2 Baseline Performance Review (BPR)

The Baseline Performance Review (BPR) is NASA's monthly senior performance management review of programs, projects, and activities. Its intentions are to integrate agency-wide communication of performance metrics and analysis results, to highlight cross-cutting issues that impact performance and affect risk, and to enable senior management to quickly address issues. The BPR also meets requirements for quarterly progress reviews contained in the Government Performance and Results Act: Modernization Act (GPRAMA).

In its present form, the BPR tends to concentrate on current issues much more than risks (potential future problems) and accordingly it tends to have a shorter-term focus than the TCAT initiatives. As stated in [25], "the BPR is the culmination of all of the agency's regular business rhythm performance monitoring activities, providing ongoing performance assessment between key

decision points. Within the NASA governance model, the BPR is distinct from the decision-making Strategic Management, Program Management, and Mission Support Councils, [and] is ‘action-oriented’ to improve performance and inform agency decision authorities of issues needing attention.”

OROM tends to have a longer-term focus than the BPR, but there is also a component of it that deals with short-term performance objectives, as measured by success or failure in achieving “annual performance goals” (see Section 4.1.1). Therefore, the relevance of OROM to BPR in its present form is mainly limited to short-term performance. Of course, the BPR could, in the future, undergo a change to a longer-term, more strategic performance evaluation perspective. If that were the case, the interfaces between OROM and BPR would have a larger scope.

Within this more tactical approach to performance evaluation, there are areas where OROM and BPR can interface. As shown on the left side of Figure 7-3 and discussed in [26], the activities of the BPR process include information gathering, both through questionnaires sent to all areas within NASA and through person-to-person interactions at the actual review meetings. This information can help populate the OROM Risk and Opportunity Template, the Leading Indicator Evaluation Template, and the Risk and Opportunity Roll-Up Templates, as shown on the right side of the figure. The usefulness to OROM could be increased substantially, however, if the questions addressed were extended so as to solicit information not only about the nature and status of issues perceived by each organizational unit, as is presently done, but also about the identification, characterization, and status of leading indicators. Most importantly, information about existing margins within each mission execution domain (cost, schedule, technical, and safety) and their trends over time would be valuable to the OROM process.

It is also likely that OROM could provide useful information to the BPR process in the area of aggregating the assessment from program/project level to directorate and center levels. As discussed throughout this report, the OROM process can be exercised both for the agency as a whole and also for individual entities within the agency. As shown in Figure 7-4, the OROM Risk and Opportunity Roll-Up Templates and High-Level Display Template, when exercised at the directorate and center levels, lead to rankings of the likelihood of success in achieving each top objective of each directorate and center. These rankings could provide useful information to the BPR in its attempt to provide an “assessment aggregate roll-up” for each directorate. The same could be done for centers, if the BPR process were to seek an assessment aggregation for centers, and for the agency as a whole.

The OROM balancing of risks and opportunities in the optimization analysis for human and physical resources ---

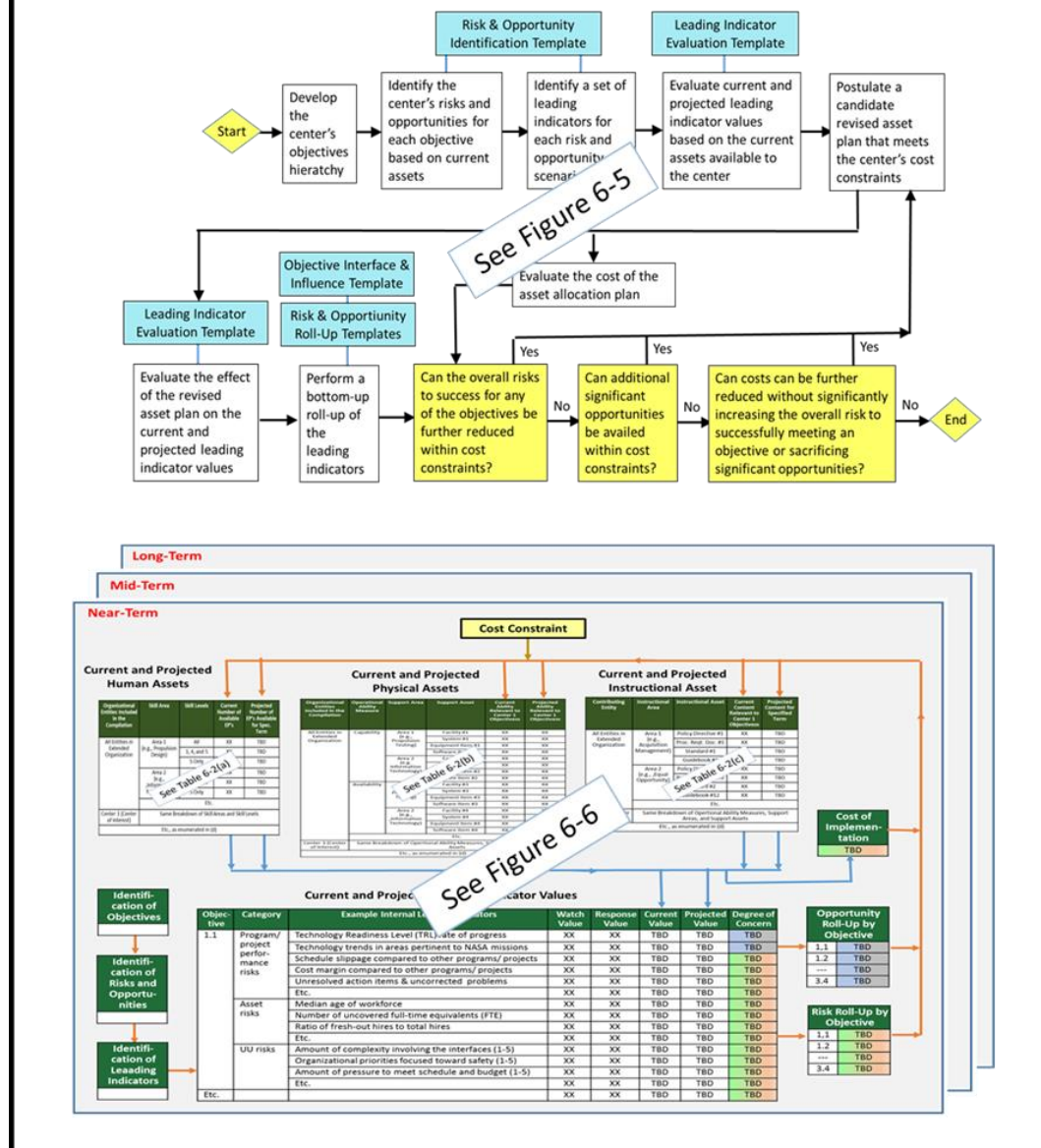


Figure 7-2. Relationship between OROM risk-and-opportunity-based asset optimization process and TCAT asset right-sizing objective (Part 1 of 2)

--- can assist the TCAT objective of right-sizing workforce and assets



1. Making decisions - transparency of data, analysis, and decisions is critical across the Agency, and with stakeholders
2. Institutionalizing TCAT process
3. Learning and adjusting as we go
4. Integrating with other initiatives - improving our operating model as we right-size our capabilities.

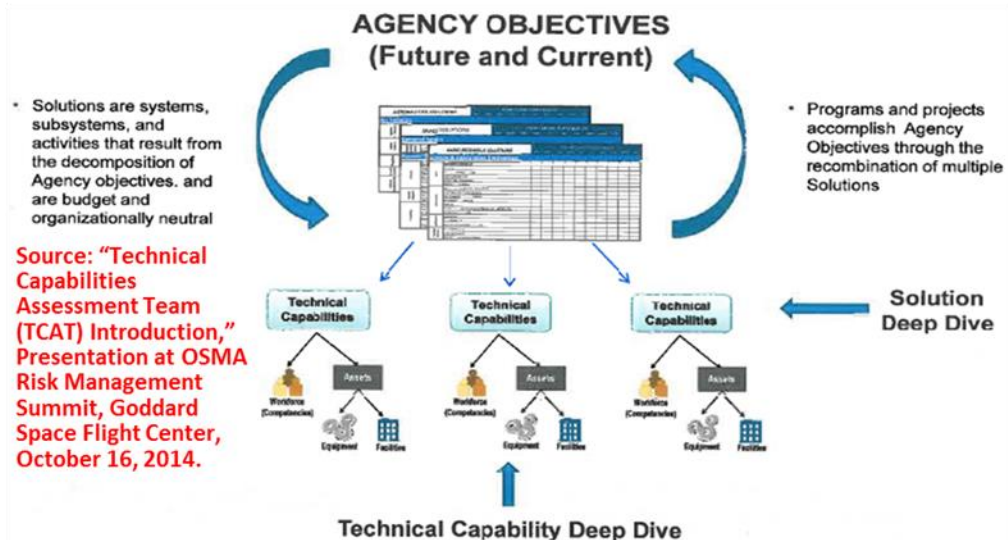


Figure 7-2. (Part 2 of 2)

The BPR's access to programs/projects and responses to its questionnaire ---

BPR Project Questions

Project Name = XX	Questions	Thresholds	Project	Program	Mission Directorate	COMMENTS
Technical Performance	Are your top-level requirements stable and baselined?	G = Yes, Y = less than 10% requirements not stable or baselined, R = more than 10% requirements not stable or baselined	G	G	G	
	Are you on track to meet your top-level requirements?	G = Yes, Y = less than 10% requirements not on track, R = more than 10% requirements not on track	G	G	G	
	Are there any actual or pending changes to technical requirements that could cause a request for waiver?	G = No, Y = one change, R = more than one change	G	G	G	
	Are technical reserves sufficient? (e.g., mass, power, etc.)	C = Yes, Y = one not sufficient or a positive change is required, R = more than one not sufficient or a change will be required to meet the allocation	G	G	G	
Risk Performance	What is your overall risk posture (5 x 5 matrix)?	G = all green, Y = any yellow but no red, R = any red	R	R	R	
	Are risk postures manageable (5 x 5 matrix)?	G = can be resolved within available resources, Y = can't be resolved by project but can with other resources, R = only resolvable by Agency resources	R	R	R	
	Are technologies sufficiently mature at this point, or are they expected to be mature in time, per program/project plans?	G = yes, Y = one is no, R = more than one no	G	G	G	

Source: "Overview of the Baseline Performance Review (BPR)," Presentation by the NASA Office of Chief Engineer, Program Management Challenge, February 2012.



Technical Cross-Cutting Example

Capability of Communications Networks			
Issue Description: The aging communications infrastructure is a concern because of cost to upgrade, who will pay and what if any effect on missions there could be in the interim			
Mission Directorate Impact			
ARMD	ESMD	SMD	SOMD
• NA	• A long-term, flexible, interoperable, extensible communication architecture is critical for future exploration.	• Both the DSM and the NEN are critical to SMD mission operations. Both systems have experienced failure of old components and are short on maintenance funds.	• Sustainment and modernization plans under development include strategies for increased efficiencies.
Agency Actions and Status (Estimated Completion)			POC: XX
<ul style="list-style-type: none"> SCaN has completed an Agency integrated communications architecture definition and roadmap - briefings provided to the SCaN BoD, SMC, and Acting Administrator. Trade studies will be performed as needed to support approaching architecture decision points. DSN Strategy is to extend 70m lifetime beyond 2015 and gradually replace them with arrayed assets and optical communications by 2025. An independent LCC analysis of array alternatives concluded that 34m antennas were lowest cost and risk. SCaN decision memorandum completed. To support near term missions, two additional 34m antennas initiated for Canberra complex for network robustness. SN Ground System Sustainment (SGSS) awarded Aug 2010. Project SRR planned for April 2011. CxP and SCaN team members working together in international forums to guide international standards to meet future exploration demands. Near Earth Network pursuing incremental modernization, including strategic partnerships with other agencies/industry, SCaN initiated study of alternatives for deployment of Ka-based operational capability. Expect issue closure upon successful completion of N SGSS SRR. 			

Figure 7-3. Relationship between the BPR information gathering processes and the populating of various OROM templates (Part 1 of 2)

--- should be able to provide information to help populate, for near-term objectives, OROM's Risk and Opportunity Identification Template,

Blue typeface denotes repeated instances of leading indicators

Obj. No.	Objective Description	Scen. Type	Scen. No.	Scenario Statement	Leading Indicator Number	Leading Indicator Description
P (1) #11	Deliver the cryocooler subsystem	Risk	1	Given the cryocooler system subcontractor's less-than-adequate performance to date including several missed milestones and overall management problems, there may be a significant delay in the delivery date for the cryocooler system	1	Remaining schedule reserve for cryocooler development
					2	Remaining cost reserve for the program that can be allocated to cryocooler development
					3	Severity of unresolved technical issues for cryo development (scale 1-5)
					4	GAO evaluation of cryocooler development problems (scale 1-5)
C (1-5) #10	Implement the 5-year hiring and training plan	Risk	2	Given current and projected trends in the attrition and the current and projected state of competition, the available talent of recent graduates, the available talent may not match the needs identified in the 5-year plan	5	Number of retirements of qualified optics analysis & testing experts
					6	Number of retirements of qualified integrated analysis & testing experts
					7	Number of qualified optics analysis & testing recent graduates
					8	Competition for recent optics graduates, e.g. from the military (rank 1-5)
C (1-5) #9	Implement the 5-year facilities plan	Risk	3	Given the complexity of needed technical changes and the space telescope and the changing requirements for test facilities, the facility needs 5 years from now may differ significantly from the 5-year plan resulting in capability shortcomings	9	Number of significant design modifications required to date
					10	Complexity of design (rank 1-5)
					11	Complexity of integration and testing (rank 1-5)

--- OROM's Leading Indicator Evaluation Template,

Objec. No.	Leading Indicator Number	Leading Indicator Description	Risk, Opp., or Infl. Risk	Scen. No.	Lead. Ind. Watch Value	Rationale or Source	Lead. Ind. Resp. Value	Rationale or Source	Lead. Ind. Current Value	Rationale or Source	Lead Ind. 1-Yr. Projected Value	Rationale or Source	Leading Indicator Level of Concern
P (1) #11	1	Remaining schedule reserve for cryocooler development	Risk	1	50% of plan	Historically correlated with moderate likelihood of overrun	10% of plan	Historically correlated with high likelihood of overrun	0% of plan	As reported by GAO	0% to 30% of plan	The schedule reserve for cryo development diminished from 5 months to 0 months in the past year, but there is enough schedule reserve in other tasks to divert manpower to the cryocooler development task so as to regain its positive reserve	Significant
	2	Remaining cost reserve for the program that can be allocated to cryocooler development	Risk	1	50% of plan	Historically correlated with moderate likelihood of overrun	10% of plan	Historically correlated with high likelihood of overrun	10% of plan	As reported by GAO, 60% of last year's program cost reserve remains. Assuming that 50% of the cost reserve has to be allocated to cryo development, a remaining reserve of 10% will be allocated to cryo devel.	30% to 50% of plan	More cost reserves will become available in 2016, according to the GAO. Also, JPL's analysis of subcontractor performance trends projects that cryocooler development will not be delayed by more than 7 months, making it likely that integrated testing will begin on time (February 2016).	Marginal
	3	Severity of unresolved technical issues for cryocooler development (scale 1-5)	Risk	1	2	Any nontrivial unresolved technical issue requires watching	3	Unresolved issues include (1) failure of compressor to perform to specification when brazed to spacecraft; (2) validation of replacement valves in cold-head assembly during vacuum testing; (3) cryocooler generated vibration possibly exceeding permissible levels	3	Unresolved issues include (1) failure of compressor to perform to specification when brazed to spacecraft; (2) validation of replacement valves in cold-head assembly during vacuum testing; (3) cryocooler generated vibration possibly exceeding permissible levels	1 to 3	Resolution of these technical issues has to be verified by as-fown testing of prototype assemblies, which will occur during 2015. Successful results are expected but, as with any test, success is not guaranteed beforehand.	Marginal
	4	GAO evaluation of cryocooler development problems (scale 1-5, 1=very low confidence, 5=very high confidence)	Risk	1	4	When confidence is high but not very high, watchfulness is needed	2	When confidence is low, a response is needed	3	GAO report: "During the past year, delays have occurred on every element and major subsystem schedule—especially with the cryocooler—leaving all at risk of negatively impacting the overall project schedule reserve if further delays occur."	3 to 5	JPL's analysis of subcontractor performance trends, cited above, suggests that GAO's concerns may be resolved within the next year.	Marginal

--- and OROM's Risk and Opportunity Roll-Up Templates

Objec. No.	Objective Description	Type of Scen.	Lead. Ind. No. or Infl. Obj. No.	Description of Leading Indicator or Influencing Objective	Composite Indicator	Lead. Ind. Concern or Objec. Aggr. Risk	Aggregate Risk of Objective	Rollup Rationale
C (1) #12	Provide tech. support & expert review for design, building, testing, validation of the cryo subsystem	None	None	None	None	Concern	Risk	No risks entered
P (1) #11	Deliver the cryocooler subsystem	Risk	1	Remaining schedule reserve for cryocooler development	None	Concern	Risk	Although the remaining schedule reserve for the cryocooler development is red (surpassing the response trigger), the overall risk of not meeting the objective of delivering the cryocooler subsystem is yellow (marginal) because: 1. The cryocooler development schedule can be accelerated by diverting additional budget & manpower to this task from other tasks whose reserves are not at risk (note that the divertible remaining cost reserve from other tasks is yellow, not red) 2. JPL's analysis of subcontractor performance trends projects that development will not be delayed by more than 7 months, making it likely that integrated testing will begin on time (February 2016)
			2	Remaining cost reserve for the program that can be allocated to cryocooler development	None	Concern		
			3	Severity of unresolved technical issues for cryocooler development (scale 1-5)	None	Concern		
			4	GAO evaluation of cryocooler development problems (scale 1-5, 1=very low confidence, 5=very high confidence)	None	Concern		
			C (1) #12	Provide technical support & expert review for design, building, testing, validation of cryocooler subsystem	None	Concern		

Figure 7-3. (Part 2 of 2)

Completion of the OROM Risk and Opportunity Roll-Up Templates for near-term objectives for each division and center ---

Objec. No.	Objective Description	Type of Scen.	Lead. Ind. No. or Infl. Obj. No.	Description of Leading Indicator or Influencing Objective	Composite Indicator	Lead. Ind. Concern or Objec. Aggr. Risk	Aggregate Risk of Objective	Rollup Rationale
C (1) #12	Provide tech. support & expert review for design, building, testing, validation of the cryo subsystem	None	None	None	None	Concern	Risk	No risks entered
P (1) #11	Deliver the cryocooler subsystem	Risk	1	Remaining schedule reserve for cryocooler development	None	Concern	Risk	<p>Although the remaining schedule reserve for the cryocooler development is red (surpassing the response trigger), the overall risk of not meeting the objective of delivering the cryocooler subsystem is yellow (marginal) because:</p> <ol style="list-style-type: none"> 1. The cryocooler development schedule can be accelerated by diverting additional budget & manpower to this task from other tasks whose reserves are not at risk (note that the divertible remaining cost reserve from other tasks is yellow, not red) 2. JPL's analysis of subcontractor performance trends projects that development will not be delayed by more than 7 months, making it likely that integrated testing will begin on time (February 2016)
			2	Remaining cost reserve for the program that can be allocated to cryocooler development	None	Concern		
			3	Severity of unresolved technical issues for cryocooler development (scale 1-5, 1=very low confidence, 5=very high confidence)	None	Concern		
			4	GAO evaluation development problem (scale 1-5, 1=very low confidence, 5=very high confidence)	None	Concern		
			C (1) #12	Provide technical support & expert review for design, building, testing, validation of cryocooler subsystem	None	Concern		



--- and completion of the OROM High-Level Display Template for near-term objectives for each division and center ---

Objective Index	Objective Description	Risk to Objective	Opportunity	Drivers	Responses
C (1) #12	Provide tech. support & expert review for devel. of the cryo. subsystem	Tolerable	Insignificant	None	None
P (1) #11	Deliver the cryocooler subsystem	Marginal	Significant	<ul style="list-style-type: none"> • Cryocooler schedule reserve • Subcontractor management issues • Compressor performance for braised unit • Thermal vac. testing of cold head assy. 	<ul style="list-style-type: none"> • Redistribution of resources • Increased project oversight • Braising mod. testing XX • Cold head assy vac. testing XX

Figure 7-4. Relationship between the Risk and Opportunity Roll-Up and High-Level Display Templates and the BPR assessment aggregation process (Part 1 of 2)

--- can provide greater assurance that the BPR roll-up to division and center levels is defensible

Assessment Aggregate Rollup Example



Status: – 1 project rated **Red** overall – SMD#1
 – 26 missions in development; 5 are **Yellow** overall: AAA#1, BBB#2, CCC#1, QQR and Solar Flare (newly yellow)
 – 55 operating missions in prime or extended.

Technical:

- Kepler loss of RWA#4 may result in loss of additional science. Options being assessed.
- Optocoupler failures.

Schedule:

- ZZI launch Jun 26th.
- Polar launch Sep 6th

Cost:

- Reimbursable funding challenges for AAA#1

Programmatic:

- External budget profile commitments lacking.
- Access to Space: New medium-class LV providers need certification.

Watch list Items: • Potential fabrication issues impacting project performance.
 • Memory chip delaminations on multiple boards.

Center Summary Example

Source: "Baseline Performance Review: NASA's Monthly Performance Update and Independent Assessment Forum," Presentation by Sandra Smalley, NASA, OCE, to National Defense Industrial Assn., 2013.

Technical Authority/Mission Support/Institutional Institutional Risk to Mission

Budget/Finance:

- Grants reconciliation and transition: The ORR for the Phase 2 transition is scheduled for Nov 30th; will complete Center transition activities.

Workforce:

- Early Career Hiring: FY13 - 66 on-board;

Acquisition:

- Contractor Support: Consolidated Agency contracting approach being pursued. "Authorization" to seek services on another contract granted but is not expected to save resources and requires unnecessary actions.

Figure 7-4. (Part 2 of 2)

8. Examples of the Use of OROM Results for Informing Risk Acceptance Decisions

8.1 Overview

The purpose of Section 8 is to demonstrate how OROM can help inform risk acceptance decisions at key decision points for programs and projects that serve multiple strategic objectives. Such objectives (and the associated performance requirements) may span multiple mission execution domains (e.g., safety, technical, cost, and schedule) as well as multiple government or other stakeholder priorities (e.g., tech transfer, equal opportunity, legal indemnity, and good public relations). Since the risks of not meeting the top-level program/project objectives may imply risks of not meeting the organization's strategic objectives, risk acceptance decisions at the program/project level have to include consideration of organization-wide risk and opportunity management.

The example pursued in this section is based on the Department of Defense's Ground-Based Midcourse Defense (GMD) program as it existed in an earlier timeframe (about 13 years ago). In the time that has passed since then, a significant body of information about the GMD program has become available to the public through openly published reviews performed by the Government Accountability Office (GAO) and the DoD Inspector General (IG). One of the advantages of using the GMD program as an example is that the information needed to pursue it is comprehensively reported and available in the open literature.

Although this example is not from NASA, it provides lessons that are directly relevant to many of NASA's programs that involve risk and opportunity tradeoffs across multiple objectives. This is particularly true, for example, for the NASA Commercial Crew Transportation (CCT) program. Apart from the obvious differences in the mission objectives (one being space exploration, the other being defense against missiles), they share the following competing goals:

1. Develop an operational capability quickly.
2. Make the system safe and reliable.
3. Keep costs within budget.
4. Develop partnerships with commercial companies.
5. Maintain public support.

However, in one case (CCT), the plan for achievement of the mission objective emphasizes the second goal (safety and reliability) whereas in the other case (GMD), the plan emphasizes the first goal (rapid deployment). Taken together, they represent an interesting study of the importance of OROM in helping the decision maker to reach a risk acceptance decision that reflects his or her preference for one goal without neglecting the other goals.

8.2 Example: DoD Ground-based Midcourse Missile Defense in the 2002 Timeframe

The GMD program was initiated in the early 1980s by the Reagan Administration under a different name, and is now managed by the Missile Defense Agency (MDA) under DoD. It is a system-

of-systems designed to intercept and destroy enemy ballistic missiles during ballistic flight in the exoatmosphere after powered ascent and prior to reentry. The individual systems within the system-of-systems include ground and sea-based radars; battle management command, control, and communication (BMC3) systems; ground-based interceptor (GBI) boost vehicles; and exoatmospheric kill vehicles (EKVs). The main providers of these systems are Raytheon, Northrop Grumman, and Orbital Sciences, and the prime contractor is Boeing Defense, Space & Security. The program is now projected to cost \$40 billion by 2017 [27], a sharp escalation from its initial cost estimate of \$16-19 billion [28].

In 2002, in an effort to achieve the rapid deployment goals of the George W. Bush Administration, the Secretary of Defense exempted MDA from following the Pentagon's normal rules for acquiring a weapons system [29]. The upshot, according to the DoD Inspector General (IG) [30], was that the EKV did not go through the milestone decision review process and product development phase. These activities are normally mandated "to carefully assess a program's readiness to proceed to the next acquisition phase and to make a sound investment decision committing the DoD's financial resources." For the product development phase, the program is assessed "to ensure that the product design is stable, manufacturing processes are controlled, and the product can perform in the intended operational environment." As a result of waiving these processes for the GMD system, according to the IG, "the EKV prototype was forced into operational capability" before it was ready. Furthermore, according to the IG, "a combination of cost constraints and failure-driven program restructures has kept the program in a state of change. Schedule and cost priorities drove a culture of 'use-as-is' leaving the EKV as a manufacturing challenge."

Complicating the decision to suspend standard review and verification practices, the program was already subject to a variety of quality management deficiencies. Before and after that decision was announced, concerns had been expressed by the GAO [31] about quality management within a number of DoD programs, including the GMD program. These concerns included nonconformances, insufficient systems engineering discipline, insufficient oversight of the prime contractor activities, and relying on subtier suppliers to self-report without effective oversight. These deficiencies, among others cited by GAO, led to the installation of defective parts, ultimately resulting in substantial increases in both schedule and cost.

The decision to proceed to deployment with an unproven EKV was made because of the primacy of Objective 1 at the time the decision was made. The operating assumption was that the system could be deployed in a prototype form and later retrofitted as needed to achieve reliability goals.

For this example, the principal objective of the program is to rapidly achieve a robust, reliable, and cost-effective operating GMD system. The following three contributing objectives apply:

- Objective 1.1: Rapidly deploy a robust operational GMD system. In this context, the term "robust" implies a system that is able to withstand any credible environment to which it may be exposed prior to launch, during launch, and during intercept.
- Objective 1.2: Rapidly achieve a reliable operating GMD system. The term "reliable" refers to the ability of the system to identify, intercept, and destroy its targets with a high probability of success.

- Objective 1.3: Achieve a cost-effective operating GMD system. The term “cost effective” refers to the ability to deploy and maintain a robust operational system and achieve consistently high reliability within the established funding limits for the program.

8.3 Relevance of the Example to the NASA Commercial Crew Transportation Program

The objective of the CCT program is to develop the capability to use a commercially provided system to transport crew to low-earth orbit, including to the International Space Station (ISS). This objective has faced several challenges over the past two or three years. As stated by Administrator Bolden in 2013 [32], “Because the funding for the President’s plan has been significantly reduced, we now won’t be able to support American launches until 2017. Even this delayed availability will be in question if Congress does not fully support the President’s fiscal year 2014 request for our Commercial Crew Program, forcing us once again to extend our contract with the Russians.” Clearly, while safety and reliability has always been a priority at NASA, the Administrator was concerned about the problem of having to be dependent on the Russians for transport capability for longer than necessary, while facing budget cuts that could prolong the problem.

Before a system can be developed and American launches can occur, it is necessary for there to be a stable set of certification requirements, including engineering standards, required tests, analyses, and protocols for verification and validation. The development and implementation of these requirements entails a number of steps:

- Consultation between NASA and the providers leading to an agreement on the requirements to be implemented
- Review of the set of requirements by the NASA technical authorities and by independent review groups, such as the Aerospace Safety Advisory Panel (ASAP)
- Approval of the set of requirements by the NASA approval authority
- Implementation by the providers
- Formulation of a case by the providers that the requirements have been implemented correctly and successfully
- Review of the case by the technical authorities and independent review groups
- Approval of the implementation by the NASA approval authority

It is noteworthy that at its quarterly meeting with NASA on July 23, 2015, ASAP was highly supportive of the efforts of the CCT Program (also referred to as the Commercial Crew Program, or CCP) in executing its responsibilities, while being cognizant of the challenges. Quoting from [33]: “This Program has all the challenges inherent in any space program; it is technically hard. In addition, it has the challenge of working under a new and untried business model—engaging with two commercial partners with widely varying corporate and development cultures, each bringing unique advantages and opportunities and each presenting differing aspects to be wrestled with. This challenge is compounded by budget and schedule pressures, appropriation uncertainties, the desire to remove crew transportation to the ISS from dependency on Russian transportation as soon as possible, and the fixed-price contract environment. Given all of these challenges, the Panel sees considerable risk ahead for the CCP. Fortunately, competent and clear-headed professionals

(in whom the Panel has great confidence) are dealing with these risks. However, the risks will only increase over time and test the skills at all management levels.”

The principal objective of the CCT program may be considered to be the rapid achievement of a certified, operational CCT capability within reasonable cost. For this example, that top objective (denoted as Objective 1) may be subdivided into the following three contributing objectives:

- Objective 1.1: Develop, review, and approve a set of CCT certification requirements within a designated near-term timeframe (e.g., by 2015 or 2016).
- Objective 1.2: Develop and build an operational certified CCT system within a designated near-term timeframe (e.g., by 2017 or 2018).
- Objective 1.3: Achieve a CCT system and perform a designated number of flights within a designated cost (e.g., the amount of funding expected from Congress).

The similarity between these programmatic objectives and those in Section 8.2 for the GMD example is evident. Therefore, the role that OROM can play in assisting risk acceptance decision making for the CCT program should be similar to the role outlined for the GMD program in the following subsections.

8.4 Example Details

8.4.1 Risk Tolerances and Risk Parity

Restating one of the main themes of this report, the framework for OROM calls for factoring risk tolerance into the analysis processes that accompany the development of requirements. To avoid imbalance between the competing goals that will later be regretted, it is necessary for there to be a process for eliciting the decision maker’s risk tolerances in an objective, rational manner, and incorporating these tolerances into the evaluation of the plan. As discussed in Sections 4.3.1, 4.3.2, and 4.5.1, risk tolerance may be accounted for through the development of the following OROM-generated items:

- Risk parity statements
- Risk watch and response boundaries
- Leading indicator watch and response triggers

Risk parity statements are elicited from the decision maker. Each risk parity statement reflects a common level of pain from the decision maker’s perspective. Thus, each reflects the decision maker’s view of an even tradeoff between objectives.

The objectives for this example and a suggested format for a cumulative risk parity table are illustrated in Figure 8-1. The following statements of cumulative risk, taken from the table in Figure 8-1, are parity statements because each of them corresponds to the same level of discomfort (i.e., rank 2):

- Risk Parity Statement 1 (Discomfort Level 2): We are 50% confident that it will take no more than X1 months to complete initial deployment of the system.

- Risk Parity Statement 2 (Discomfort Level 2): We are 80% confident that it will take no more than X2 months to complete initial deployment of the system.
- Risk Parity Statement 3 (Discomfort Level 2): We are 50% confident that it will take no more than X3 months before the system is 80% reliable.
- Risk Parity Statement 4 (Discomfort Level 2): We are 80% confident that it will take no more than X4 months before the system is 80% reliable.

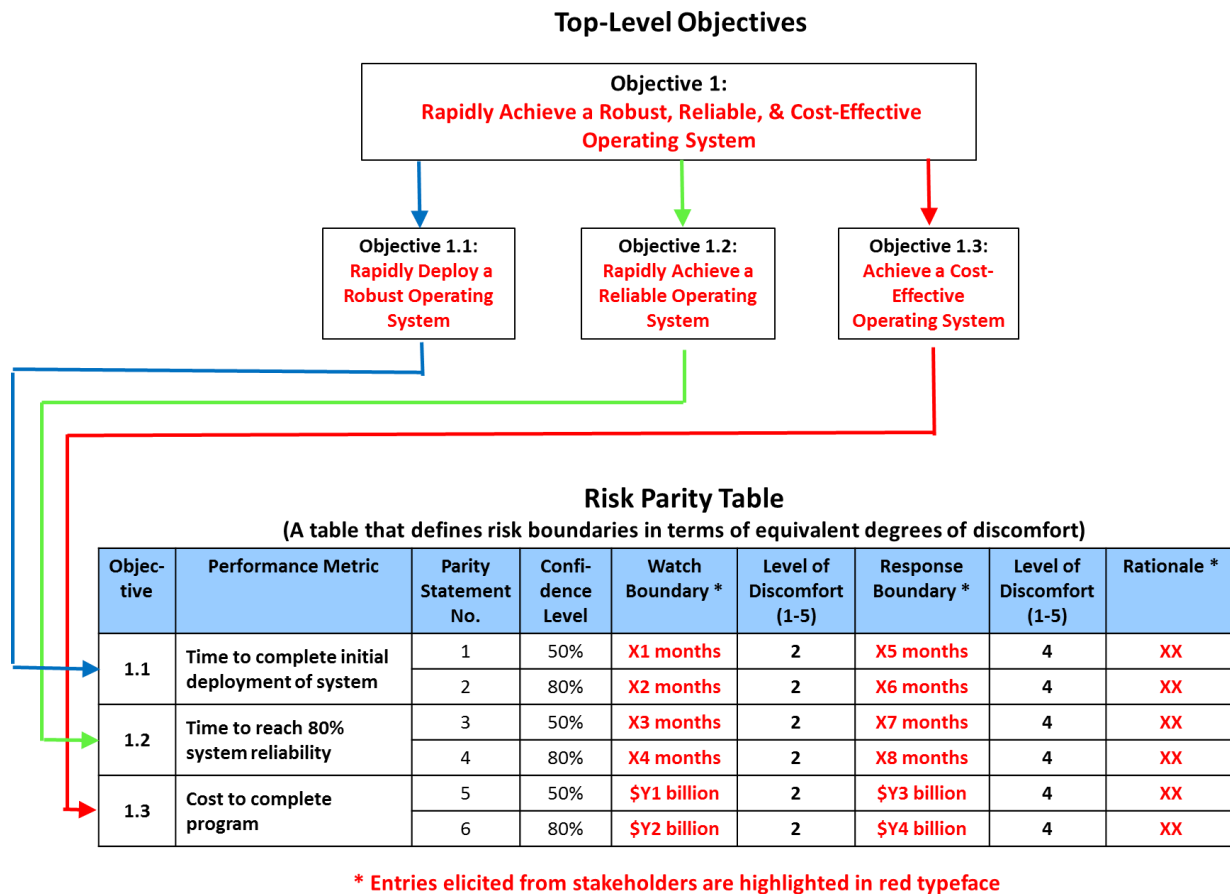


Figure 8-1. Objectives and hypothetical cumulative risk parity table for GMD example

- Risk Parity Statement 5 (Discomfort Level 2): We are 50% confident that the total cost to deploy the system and achieve 80% reliability will be no more than \$Y1 billion.
- Risk Parity Statement 6 (Discomfort Level 2): We are 80% confident that the total cost to deploy the system and achieve 80% reliability will be no more than \$Y2 billion.

Similarly, the following parity statements also evolve from the table in Figure 8-1 and have a rank 4 level of discomfort:

- Risk Parity Statement 1 (Discomfort Level 4): We are 50% confident that it will take no more than X5 months to complete initial deployment of the system.

- Etc.

The first set of parity statements at rank 2 discomfort constitute watch boundaries for the cumulative risk, and the second set at rank 4 constitute response boundaries.

8.4.2 Risks and Leading Indicators

Based on the information provided in Section 8.2 for the GMD program, two risk scenarios suggest themselves. The first emanates from quality management control concerns in the 2002 timeframe and affects all three objectives: rapid deployment, reliability attainment, and cost effectiveness. The second results from the suspension of standard controls, combined with the challenging nature of kinetic intercept at hypersonic speeds, and affects the latter two objectives.

Example risk scenario statements and corresponding example leading indicators are shown in Figure 8-2. The leading indicators for each risk are representative of the sources of concern cited by GAO and by the DoD IG, as summarized in Section 8.2. Those listed for the first risk scenario in Figure 8-2 are based on the following observation provided in [34]:

“Quality management system deficiencies identified by GAO and DoD OIG reports include:

- Inconsistent process review at key decision points across programs,
- Quality metrics not consolidated in a manner that helps decision makers identify and evaluate systemic quality problems,
- Insufficient workforce knowledge,
- Inadequate resources to provide sufficient oversight, and
- Ineffective supplier oversight.”

Those listed for the second risk scenario are based on technology readiness level (TRL) and experience from other programs and projects, which can serve as an indicator of potential future problems for the present program. These indicators pertain to the principal factors that have tended to produce reliability, schedule, or cost impacts and UU risks for complex programs.

8.4.3 Leading Indicator Trigger Values

Parity between cumulative risks can be stated in terms of parity between leading indicators. As discussed in Section 4.5, trigger values for leading indicators of risk are developed by the OROM analysts and are used to signal when a risk is reaching a risk tolerance boundary that was established by a decision maker. When there are many leading indicators, as is typically the case, various combinations of the leading indicators are formulated to act as surrogates for the cumulative risks. These combinations were referred to as composite leading indicators in Section 5.6.4.

To simplify this example, we combine the leading indicators in Figure 8-3 into three composite indicators, as follows:

- Composite indicator A, termed “Quality Management Ranking”: A composite of leading indicators 1 through 8 with a ranking scale of 1 to 5.

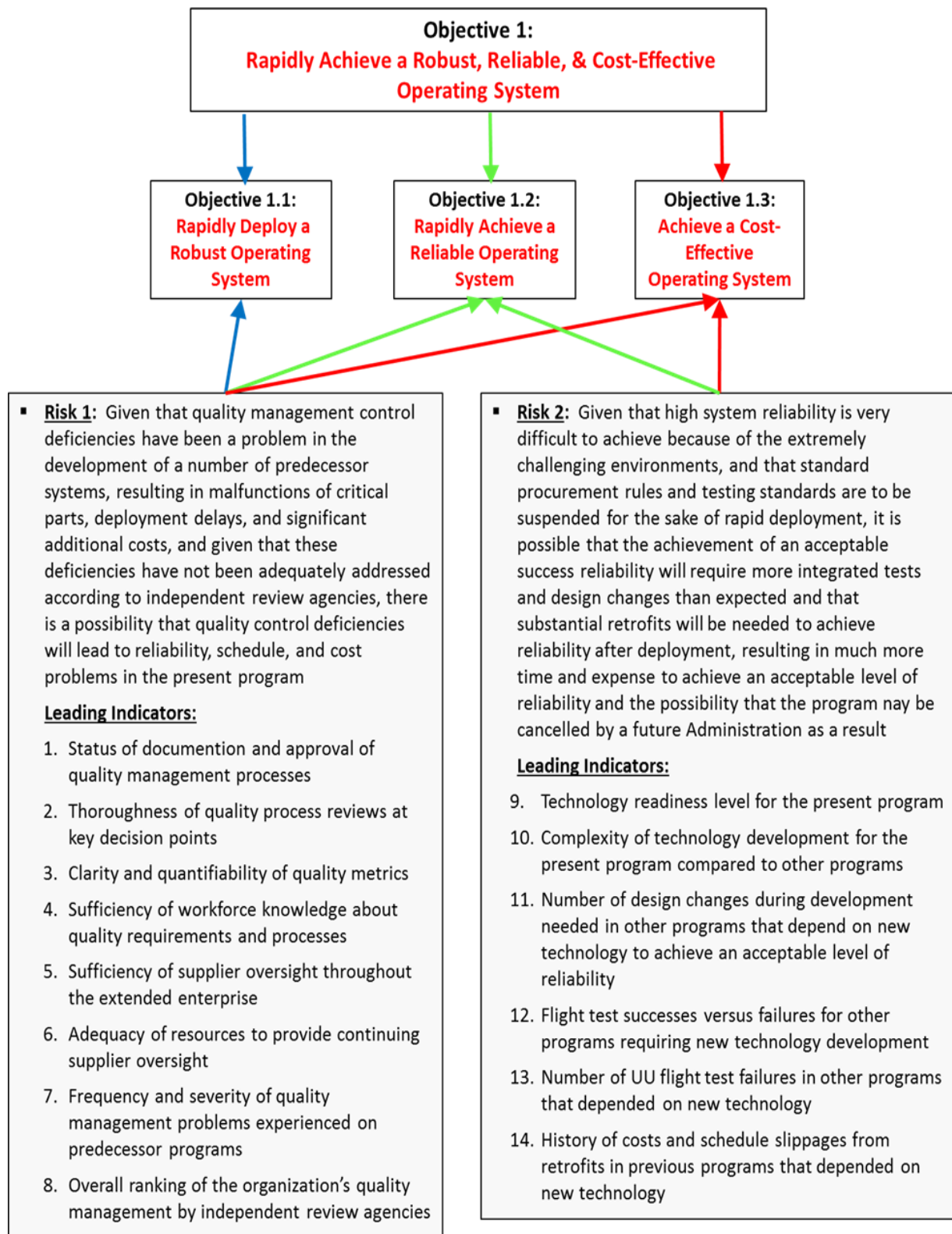


Figure 8-2. Risks and leading indicators for GMD example (2002 timeframe)

- Composite indicator B, termed “Technology Readiness Ranking”: A composite of leading indicators 9 through 11 with a ranking scale of 1 to 5.
- Composite indicator C, termed “Previous Success Ranking”: A composite of leading indicators 12 through 14 with a ranking scale of 1 to 5.

It is assumed that as a part of the OROM analysis, formulas have been derived for combining the 14 leading indicators in Figure 8-2 into these three composite indicators, but these formulas are left unstated for purposes of this example.

Figure 8-3 illustrates how parity statements for composite leading indicators may substitute for parity statements for cumulative risks. The lower table in the figure leads to the following leading indicator parity statements corresponding to watch triggers (level of discomfort rank 2):

- Leading Indicator Parity Statement 1 (Discomfort Level 2): The watch boundary for the time to complete initial deployment of the system is consistent with a value of 1.5 for the quality management composite indicator.
- Leading Indicator Parity Statement 2 (Discomfort Level 2): The watch boundary for the time to reach 80% system reliability is consistent with a value of 4.0 for the quality management composite indicator.
- Leading Indicator Parity Statement 3 (Discomfort Level 2): The watch boundary for the time to reach 80% system reliability is consistent with a value of 4.0 for the technology readiness composite indicator.
- Leading Indicator Parity Statement 4 (Discomfort Level 2): The watch boundary for the time to reach 80% system reliability is consistent with a value of 4.0 for the previous success composite indicator.
- Leading Indicator Parity Statement 5 (Discomfort Level 2): The watch boundary for the cost to complete the program is consistent with a value of 3.5 for the quality management composite indicator.
- Leading Indicator Parity Statement 6 (Discomfort Level 2): The watch boundary for the cost to complete the program is consistent with a value of 3.5 for the technology readiness composite indicator.
- Leading Indicator Parity Statement 7 (Discomfort Level 2): The watch boundary for the cost to complete the program is consistent with a value of 3.5 for the previous success composite indicator.

Similar leading indicator parity statements evolve for level of discomfort rank 4:

- Leading Indicator Parity Statement 1 (Discomfort Level 4): The response boundary for the time to complete initial deployment of the system is consistent with a value of 1.0 for the quality management composite indicator.
- Etc.

Risk Parity Table

(A table that defines risk boundaries in terms of equivalent degrees of discomfort)

Objective	Performance Metric	Risk Parity Statement No.	Confidence Level	Watch Boundary *	Level of Discomfort (1-5)	Response Boundary *	Level of Discomfort (1-5)	Rationale *
1.1	Time to complete initial deployment of system	1	50%	X1 months	2	X5 months	4	XX
		2	80%	X2 months	2	X6 months	4	XX
1.2	Time to reach 80% system reliability	3	50%	X3 months	2	X7 months	4	XX
		4	80%	X4 months	2	X8 months	4	XX
1.3	Cost to complete program	5	50%	\$Y1 billion	2	\$Y3 billion	4	XX
		6	80%	\$Y2 billion	2	\$Y4 billion	4	XX

Leading Indicator Parity Table

(A table that defines leading indicator trigger values in terms of equivalent degrees of discomfort)

Objective	Performance Metric	Lead. Ind. Parity Statemt No.	Risk Parity Statement No.	Composite Leading Indicator	Comp. Lead. Ind. Description	Watch Trigger (1.0.-5.0)	Response Trigger (1.0.-5.0)	Rationale
1.1	Time to complete initial deployment of system	1	1, 2	A	Quality Mgmt.	1.5	1.0	XX
		2	3, 4	A	Quality Mgmt.	4.0	3.0	XX
1.2	Time to reach 80% system reliability	3	3, 4	B	Tech. Readiness	4.0	3.0	XX
		4	3, 4	C	Previous Success	4.0	3.0	XX
1.3	Cost to complete program	5	5, 6	A	Quality Mgmt.	3.5	2.5	XX
		6	5, 6	B	Tech. Readiness	3.5	2.5	XX
		7	5, 6	C	Previous Success	3.5	2.5	XX

* Entries elicited from stakeholders are highlighted in red typeface

Figure 8-3. Hypothetical composite leading indicator parity table for GMD example

The trigger values in the leading indicator parity table indicate that quality management is less of a concern for the objective of rapidly deploying a robust operating system than for the objectives of rapidly achieving a reliable operating system and of completing the project in a cost-effective manner. Thus, a quality management watch trigger value of 1.5 is posited to be adequate for achieving rapid deployment, whereas corresponding technology readiness and previous success watch trigger values of 4.0 are needed to rapidly achieve reliability goals. Furthermore, only slightly lower values are needed to keep operating costs down. These entries reflect the fact that the deployment plan calls for bypassing most obstacles that would normally impede early deployment (including quality management provisions such as milestone decision reviews), whereas quality management issues not addressed prior to deployment could create substantial risks after deployment. The above discussion, and any other pertinent observations, would normally be included as rationale in the last column of the table.

8.4.4 Example Template Entries and Results

Having developed risk scenario statements for each objective, the associated leading indicators, and the associated parity statements, it is now possible to develop templates similar to those in Sections 5.5 through 5.7 to complete the analysis. For example, Tables 8-1 and 8-2 show, respectively, how the Leading Indicator Evaluation Template and the High-Level Display Template might appear for the GMD example, based on the information provided in the preceding

subsections. The results indicate that there was (in 2002) significant risk after deployment owing to the combination of quality management deficiencies, flight test failures for predecessor systems, the complexity of the EKV system, and the probable need for a substantial number of retrofits.

Table 8-1. Leading Indicator Evaluation Template for GMD example (2002 timeframe)

Objective	Comp. Ind. No.	Comp. Ind. Descrip.	Risk, Opp., or Intr. Risk	Scen. No.	Comp. Ind. Watch Value	Rationale or Source	Comp. Ind. Resp. Value	Rationale or Source	Comp. Ind. Current Value	Rationale or Source	Comp. Ind. 1-Yr. Projected Value	Rationale or Source	Comp. Ind. Level of Concern
1.1 Rapidly deploy a robust oper. system	A	Quality	Risk	1	1.5	XX	1.0	XX	2.0	XX	2.0	XX	
1.2 Rapidly achieve a reliable operating system	A	Quality	Risk	1	4.0	XX	3.0	XX	2.0	XX	2.0	XX	
	B	Readiness	Risk	2	4.0	XX	3.0	XX	1.5	XX	2.0	XX	
	C	Prev. Succ.	Risk	2	4.0	XX	3.0	XX	2.0	XX	2.0 to 2.5	XX	
1.3 Achieve a cost-effective operating system	A	Quality	Risk	1	3.5	XX	2.5	XX	2.0	XX	2.0	XX	
	B	Readiness	Risk	2	3.5	XX	2.5	XX	1.5	XX	2.0	XX	
	C	Prev. Succ.	Risk	2	3.5	XX	2.5	XX	2.0	XX	2.0 to 2.5	XX	

Table 8-2. High-Level Display Template for GMD example (2002 timeframe)

Objective Index	Objective Description	Risk. to Objective	Drivers	Sugggested Responses
1.1	Rapidly Deploy a Robust Operating System		None	None
1.2	Rapidly Achieve a Reliable Operating System		XX	XX
1.3	Achieve a Cost-Effective Operating System		XX	XX

While hypothetical, the example results are consistent with the decision maker's belief that in addition to early deployment, long-term reliability and cost effectiveness are important objectives. To put it another way, the decision maker's parity statements are the main determinant of the outcome.

8.5 Implications for Risk Acceptance Decision Making

Results such as those in Table 8-2, based on the decision maker's risk tolerances, would seem to indicate that the aggregate risks for two of the three objectives are intolerable and that the program should probably not proceed as currently formulated. The results also indicate the principal sources (drivers) of the risks and the corrective actions (suggested responses) that would tend to make the intolerable risks more tolerable. The principal risk driver in the case of the GMD example would be the decision to exempt the managing organization from following certain standards and rules, including the verification and validation processes normally followed prior to deployment of a system. Inadequate qualification testing for the integrated system and lack of milestone reviews are two of the principal issues to be addressed by corrective action.

The next step would be to assess the aggregate risks for all three objectives assuming the corrective actions were implemented. If such evaluation indicated that none of the aggregate risks remained red (as, for example, in Table 8-3), a logical decision might be to request an iteration from the prime contractor and reschedule the key decision point to a later date.

Table 8-3. High-Level Display Template for GMD example after adopting corrective actions that balance the risks to the top-level objectives

Objective Index	Objective Description	Risk. to Objective	Drivers	Suggested Responses
1.1	Rapidly Deploy a Robust Operating System		XX	None
1.2	Rapidly Achieve a Reliable Operating System		XX	None
1.3	Achieve a Cost-Effective Operating System		XX	None

Overall, achievement of a balance between the competing objectives of timeliness, safety/reliability, and cost requires an honest appraisal of the decision maker's tolerances in each area. As the 2002-timeframe GMD example shows, it is easy for risk acceptance decisions to be made based on what is perceived to be the most pressing objective at the time without considering the longer-term objectives that will become more pressing in the future. The use of OROM guards against this tendency, thereby making today's decisions more inclusive of short-term, mid-term, and long-term needs.

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Appendix A.

Administrator's Letter to NASA Employees, April 19, 2013

NASA and the Importance of Risk

NASA has achieved great things for our nation by embracing bold challenges while managing the risks to the things we build, and the people who test and put them to use. While we are never pleased when things go wrong, throughout our history NASA's explorer spirit has led us deeper into the unknown where we continue to learn as much from our failures as our successes. One of the things that impress me most about our workforce is the willingness of so many to dream big, think outside the box, and take risks. In fact, a major reason behind NASA's ranking as the best place to work in government is our first place ranking in the category of leadership and employee empowerment. Your vision, expertise, and courage to take risks are what set this agency apart. Whether you are part of the team that helped land Curiosity on Mars, or are assembling the parts to the next generation spacecraft...whether you are reaching out to the public through education and social media or working in a field office, your ideas, ingenuity, and initiative are keeping NASA in the forefront of exploration and innovation.

Much of the time, we work in an environment where the consequences of not getting things exactly right are very high. The good news is that our processes and culture are well adapted to doing these things very well. We must not lose that. Human spaceflight and flagship science missions can sometimes be a dangerous business. But, as I have said before, when you do stuff that nobody else has ever done, you have to be willing to accept risk. We have to be willing to do daring things. Put another way, **risk intolerance is a guarantee of failure to accomplish anything of significance.**

Discovery has and will continue to be our guiding star! One of our significant lines of business is inventing and demonstrating new technologies, tools, and techniques that will allow our nation to lead humanity outward from our planet, and do so sustainably, more effectively, and often at lower cost. We may not always know the ideal path to the objective when we take the first steps, but as long as we move forward intelligently, keep our people safe, and back each other up we will be able to adjust as we go along and make faster progress toward the objectives.

Let me give you an example of what I mean. Most of you have heard of the Morpheus Project. This small project was formulated at JSC as a way to develop, understand, and demonstrate some new technologies and to build the capabilities of our work force in a rapid engineering cycle environment – in the vernacular, learn fast, fail forward. I am sure some might think of Morpheus as a failure since a significant piece of hardware crashed and burned while under test. Contrary to this view, I regard Morpheus as a success and here is why:

- From the beginning, the team worked to an aggressive, but thoughtful plan to move forward and learn fast.
- They accomplished a lot and learned a lot in a short time without much money.
- After many successes (and a few failures) they lost the test vehicle during a flight.
- The Morpheus test vehicle could have been built with more fault tolerance so that it wouldn't have crashed, but doing so would have required a much more complex system design and a longer build and test process and would have slowed the pace of learning.
- An increased risk of losing hardware was the price paid to learn fast.

All that said, the team did a good job of planning for the safety of their people so that when the worst did happen, no one was hurt. As a learning organization, I think we reacted properly to the crash. The team had identified and accepted the loss of vehicle risk and no one was pilloried for the loss. The center leadership moved quickly to establish an engineering investigation to understand what happened and to learn from it. At the agency level, we let it be known that we endorsed that approach and would not convene a formal mishap investigation. No one likes to lose equipment, but we recognized that failure is

part of the price of learning and acted accordingly. As long as we ensure that our people are protected we can manage and tolerate failures as part of the price of progress.

Morpheus is but one case in point. As we prepare to undertake the many challenges offered in the President's 2014 budget for our agency, I ask you to continue to think about how we can identify and seize opportunities to make progress quickly and affordably, identify and manage risks, learn fast and adapt our plans to take the next steps. While we do this, we must constantly balance our risks and rewards and always, always put the lives and safety of our people first.

Charlie B.

Appendix B. Acronyms

AoA	Analysis of Alternatives
BPR	Baseline Performance Review
CLM	Capability Leadership Model
COSO	Committee of Sponsoring Organizations
CRM	Continuous Risk Management
EP	Equivalent Person
EXT	External
GAO	Government Accountability Office
GPRAMA	Government Performance and Results Act Modernization Act
HST	Hubble Space Telescope
IG	Inspector General
INT	Internal
IR	Infrared
IRM	Institutional Risk Management
ISS	International Space Station
ITAR	International Traffic in Arms Regulations
JPL	Jet Propulsion Laboratory
JWST	James Webb Space Telescope
OMB	Office of Management and Budget
OROM	Organizational Risk and Opportunity Management
P(LOM)	Probability of Loss of Mission
PRA	Probabilistic Risk Assessment
RIDM	Risk-Informed Decision Making
RM	Risk Management
RO	Risk and Opportunity
SAE	Society of Automotive Engineers
SOFIA	Stratospheric Observatory for Infrared Astronomy
STEM	Science, Technology, Engineering, and Mathematics
TCAT	Technology Capability Assessment Team
TRL	Technology Readiness Level
UU	Unknown and/or Underappreciated

Appendix C. Definitions

Annual Performance Indicator – A desirable outcome within the agency’s objectives hierarchy having a timeframe of 1 year or less

Baseline Performance Review – An internal, bottom-up assessment of how well the agency has performed against its strategic goals and other performance metrics, such as cost, schedule, contract, and technical commitments

Continuous Risk Management – A specific process for the management of risks associated with implementation of designs, plans, and processes

Cumulative Opportunity – The likelihood and benefit of being able to meet a specified element in the agency’s objective hierarchy more satisfactorily than originally planned, or to meet a new goal or objective that better promotes the agency’s mission

Cumulative Risk – The likelihood of not being able to meet a specified element in the agency’s objective hierarchy, and the degree to which the element is not satisfied

Extended Enterprise – A program, project, or coordinated activity that involves multiple partners, or entities, with overlapping responsibilities. In addition to contributing to the same program/project/ activity, each partner is an independent enterprise with its own set of strategic objectives and performance requirements.

Extended Organization – The collection of organizational units that interact with a center. The center’s extended organization includes the entities in all the extended enterprises with which the center interacts on program/project planning and execution, as well as other entities within or outside the agency that provide direction and administrative support to the center.

Internal Controls – The set of policies and procedures that management uses to help programs, projects, and other activities within the organization to achieve results and safeguard the integrity of their operation

Lagging Indicator – A traceable measure that is quantifiable and correlates with the past performance of the organization with respect to one or more of its objectives

Leading Indicator – A traceable measure that is quantifiable, correlates as a predictor of the likelihood of future success of one or more of the agency’s objectives, and is actionable

Multi-Year Performance Goal – A desirable outcome within the agency’s objectives hierarchy having a timeframe of 1 to 5 years (commonly referred to at NASA as simply “Performance Goal”)

Objectives Hierarchy – A tree-like structure of desired outcomes starting at the top with long-term strategic goals and progressing down to short-term tactical accomplishments (commonly referred to at NASA as “Strategic Performance Framework”)

Opportunity – The possibility of an existing goal, objective, or desired outcome being met more efficaciously, or a new goal, objective, or desired outcome becoming feasible.

Opportunity Scenario – A specific sequence of possible events that, if they should occur, would lead to an opportunity to either increase the likelihood of achieving an element in the agency’s objectives hierarchy or open the possibility of defining a new objective that coincides with the agency’s mission

Opportunity Scenario Statement – A statement characterizing an opportunity scenario in terms of one or more conditions, enabling events or potential advances, affected entities, actions, benefits, and objectives affected

Organizational Risk and Opportunity Management – The methods and processes used by organizations to manage risks and seize opportunities related to the achievement of their objectives

Parity Statement – A statement that defines risk and opportunity boundaries in terms of equivalent levels of discomfort or comfort

Performance Indicator – A type of lagging indicator that measures the efficiency and effectiveness of past actions with respect to accomplishing performance objectives

Portfolio – A set of programs, projects, institutional assets, and other activities and resources that implement the high-level goals and objectives within the strategic plan

Response Boundary – A measure of the likelihood and severity of a risk scenario or the likelihood and potential benefit of an opportunity scenario that would suggest that an action is imminently needed. A risk response boundary marks the boundary between “marginal” and “intolerable” risk, and an opportunity response boundary marks the boundary between “marginal” and “significant” opportunity.

Response Trigger Value – A measure of a leading indicator that would suggest that an action is immediately needed. A leading indicator response trigger signals when a risk is progressing from “marginal” to “intolerable” or when an opportunity is progressing from “marginal” to “significant.”

Risk – The possibility of a goal, objective, or desired outcome not being met.

Risk-Informed Decision Making – The use of risk analysis results to inform the selection of decision alternatives and to assure effective approaches for achieving goals and objectives

Risk Scenario – A specific concern, characterized as a sequence of possible events, that is perceived as presenting a risk to the ability to achieve an element of the objectives hierarchy

Risk Scenario Statement – A statement characterizing a risk scenario in terms of one or more conditions, departure events, affected entities, and consequences

Strategic Goal – A desirable strategic outcome within the agency’s objectives hierarchy having a timeframe of 10 years or beyond

Strategic Objective – A desirable strategic outcome within the agency’s objectives hierarchy having a timeframe of 5 to 10 year or less

Strategic Performance Evaluation – The evaluation of an organization’s performance with respect to the achievement of its strategic goals and objectives

Strategic Plan – A document used to communicate with the organization the organization's goals and objectives, the actions needed to achieve them, the means for implementing those actions, and all of the other critical elements developed during the planning exercise

Strategic Planning – An organization's process of defining its strategy, or direction, and making decisions on allocating its resources to pursue this strategy. It may also extend to control mechanisms for guiding the implementation of the strategy.

Watch Boundary – A measure of the likelihood and severity of a risk scenario or the likelihood and potential benefit of an opportunity scenario that would suggest that an action should be considered but is not imminently needed. A risk watch boundary marks the boundary between “tolerable” and “marginal” risk, and an opportunity watch boundary marks the boundary between “insignificant” and “marginal” opportunity.

Watch Trigger Value – A measure of a leading indicator that would suggest that an action should be considered but is not imminently needed. A leading indicator watch trigger signals when a risk is progressing from “tolerable” to “marginal” or when an opportunity is progressing from “insignificant” to “marginal.”

