 <b>Independent Verification &amp; Validation Program</b>	<b>Guidelines for Risk Management</b>	<b>S3001 Revision: B Effective Date: March 25, 2009</b>
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Revision	Description of Change	Author	Effective Date
Basic	Initial Release	Kenneth Costello	01/24/2008
A	Update IV&V Program Risk Review Process, Risk Closure Section	Kenneth Costello	06/16/2008
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<b>REFERENCE DOCUMENTS</b>	
Document	Title
IVV QM	IV&V Quality Manual
IVV 09-4	Project Management
IVV 09-4-2	Work Instruction for IV&V Services Lessons Learned
NPR 8000.4	Risk Management Procedural Requirements
T2006	Risk Review Template

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## **1.0 Purpose**

The purpose of this document is to provide guidelines that allow for the creation of a consistent and documented method of performing risk management within the NASA IV&V Program.

## **2.0 Scope**

The guidelines in this document apply to risk management performed on any NASA IV&V Project.

## **3.0 Definitions and Acronyms**

### **3.1 Candidate Risk**

A candidate risk is an identified concern that is pending adjudication/validation by NASA IV&V Program/Project management or the governing Risk Board.

### **3.2 Consequence**

A consequence is the quantitatively or qualitatively expressed outcome of a future occurrence, such as a loss, injury, disadvantage, or gain.

### **3.3 Consequence Category**

A consequence category describes a functional area in which a risk can impact a project. Consequence categories used in this document are safety, performance, cost, and schedule.

### **3.4 Consequence Statement**

A consequence statement is a single phrase or sentence that describes the key undesirable outcome of the current condition.

### **3.5 Contingency Plan**

A Contingency Plan is a response plan designed to limit the consequence of risk realization when the primary mitigating actions prove ineffective.

### **3.6 Impact Horizon**

Impact horizon allows for the categorization of impact time frames in relation to the current date. It represents an abstract time frame in which the risk may occur. Impact horizon values can be near, mid, or long term.

### **3.7 Impact Time Frame**

Impact time frame represents the time when the risk may occur. Impact time frame consists of two pieces of data: a sunrise date that indicates the earliest time the risk could occur, and a sunset date that indicates the latest time the risk could occur.

### **3.8 Issue**

An issue is a risk that has occurred and has become a problem. An issue is an undesirable event that has occurred and its occurrence cannot be stopped or directly controlled.

### **3.9 IV&V Program Risk Review**

The objective of the IV&V Program Risk Review is to provide a venue for IV&V Projects to communicate to the NASA IV&V Program Manager any risks that may impact the NASA IV&V Program. These reviews are intended to inform and elicit feedback from the NASA IV&V Program Manager regarding the risks and associated handling plans. These reviews can be held at such venues as In-Progress Reviews (IPRs), Senior Leadership Meetings, or Functional Organization Council Reviews (FOCRs).

### **3.10 IV&V Project Team Member**

IV&V Project Team Members are personnel assigned to work on an IV&V Project. IV&V Project Team Members can be NASA civil service employees or contractors. IV&V Project Team Members are responsible for bringing potential risks to the attention of their Project Leads (PLs). IV&V Project Team Members may also be requested to assist or perform risk analysis to determine the consequence and likelihood associated with a risk. IV&V Project Team Members may also collect data to assist in the monitoring and tracking of a risk.

### **3.11 Likelihood**

Likelihood is the probability of a specified outcome.

### **3.12 Priority Score**

The Priority Score is numerically represented by a cross-reference of the likelihood and consequence scores of a risk plotted on a Risk Matrix.

### **3.13 Problem**

A problem is an adverse situation that exists now. A problem is a risk that has already occurred or is certain to occur, and is no longer classified as a risk. Reactive management (not risk management) is necessary to deal with a problem, because a problem can lead the project into new risks. See also Section 3.9, *Issue*.

### **3.14 Risk**

A risk is a measure of the potential inability to achieve a goal or target within defined safety, cost, schedule, and technical constraints. A risk has two components: the likelihood of failing to achieve a particular outcome, and the consequence of failing to achieve that outcome. A risk is a future event and can often be managed proactively.

### **3.15 Risk Acceptance**

A risk can be accepted when either the consequences are tolerable should the risk occur, or the risk cannot be reasonably mitigated with further action. Risks that are not fully mitigated without plans for further mitigation must be accepted.

### **3.16 Risk Analysis**

Risk analysis examines risks in detail to determine the extent of the risks and the relationships among them. Risk analysis also classifies risks into sets of related risks and ranks them according to importance. Risk analysis evaluates all identified risks to estimate the likelihood of occurrence, consequence of occurrence, and time frame for necessary mitigation actions.

### **3.17 Risk Approval**

Risk approval is the decision to validate a candidate risk. Risk approval can be performed by NASA IV&V Program/Project management, or the governing Risk Board at any level within the NASA IV&V Program.

### **3.18 Risk Assessment**

Risk assessment is the qualitative and/or quantitative evaluation of the likelihood and consequence of a risk occurring.

### **3.19 Risk Attribute**

Risk attributes are characteristics of likelihood and consequence that describe or define standard ways of assessing the consequence or success of Risk Mitigation Plan. Risk attributes are chosen during risk planning and provide meaningful information that can enable more informed control decisions.

### **3.20 Risk Board**

The objective of a Risk Board is to understand and approve risks, evaluate those risks against the costs to mitigate them, and direct/approve the risk handling approaches and risk mitigation activities.

### **3.21 Risk Classification**

Risk classification includes the processes of:

- Grouping risks into high, moderate, and low categories based on the likelihood and consequence adjective ratings (high, moderate, and low risks are respectively represented by the colors red, yellow, and green)
- Grouping risks based on shared characteristics or relationships

Risk classification helps to identify duplicate risks and supports simplifying the risk list. Affinity grouping is a form of risk classification.

### **3.22 Risk Closure**

A closed risk is one that either no longer exists (i.e., the risk has evolved into a problem or the sunset date has passed), is no longer cost-effective to track, or has been mitigated.

### **3.23 Risk Escalation**

Risk escalation is the process of raising risk attention to higher Risk Boards or other appropriate forums within the NASA IV&V Program.

### **3.24 Risk Identification**

Risk identification examines each element of a project to identify risks that may impact the NASA IV&V Program/Project, and then documents the risks found. Risk identification begins as early as possible in a successful project and continues throughout the life cycle of that project.

### **3.25 Risk Management**

Risk management is an overarching process that encompasses identification, analysis, mitigation planning, and tracking of root causes and their consequences.

### **3.26 Risk Management Planning**

Risk management planning develops and documents an organized, comprehensive, and interactive strategy for identifying and tracking root causes, developing Risk Handling Plans, performing continuous risk assessments, and assigning adequate resources.

### **3.27 Risk Management Team**

The Risk Management Team is the primary risk advisory body to the NASA IV&V Program. The Risk Management Team assesses risks and Risk Mitigation Plans. The Risk Management Team owns the risk management process and provides training on the implementation of that process. The Risk Management Team collects metrics to understand how well the risk management process is working and to identify any potential improvements in the risk management process.

### **3.28 Risk Matrix**

A Risk Matrix is a graphical representation of the likelihood and consequence scores of a risk. Sometimes called a “5x5 Matrix”, a Risk Matrix is a graph containing five rows and five columns. The rows of a Risk Matrix show likelihood scores, while the Risk Matrix columns show the consequence scores. Each cell in a Risk Matrix can be represented by a Priority Score.

### **3.29 Risk Mitigation**

Risk mitigation reduces the severity of a risk by reducing the likelihood of its occurrence, and/or minimizing the consequences of occurrence.

### **3.30 Risk Mitigation Plan**

A Risk Mitigation Plan is a document that captures the actions to be taken to reduce the likelihood of risk occurrence. This document is the output of risk mitigation planning.

### **3.31 Risk Mitigation Planning**

Risk Mitigation Planning is the process of analyzing a risk to determine actions that may be taken to reduce the likelihood of risk occurrence.

### **3.32 Risk Owner**

A Risk Owner is an individual to whom a risk is assigned. The Risk Owner is responsible and accountable for identifying, implementing, and tracking the risk mitigation approach and actions.

### **3.33 Risk Research**

Risk research is the investigation of an identified risk. Risk research continues until there is enough information to determine if risk ownership is still properly assigned, and determine the risk handling strategy (i.e., accept, watch, or mitigate the risk).

### **3.34 Risk Stakeholder**

A risk stakeholder is a person, group, or organization that is affected by a risk or a risk handling strategy.

### **3.35 Risk Statement**

A risk statement is a single descriptive statement that defines the risk's current or possible condition, and undesired consequence. The risk statement should be written in condition-consequence format. For example, given a condition, there is a possibility that a consequence may occur. The condition is defined with a single phrase that describes current key circumstances and situations that are causing concern, doubt, anxiety, or uneasiness. A condition:

- Must be a fact, or perceived to be a fact
- Must be reality-based
- Must be actionable

See Section 3.4, *Consequence Statement*, for additional information regarding how the consequence statement portion of the risk statement should be written.

### **3.36 Risk Tracking**

Risk tracking captures, compiles, and reports risk attributes and metrics that determine whether or not risks are being mitigated effectively, and whether Risk Mitigation Plans are implemented correctly.

### **3.37 Acronyms**

ECD	Estimated Completion Date
FOCR	Functional Organization Council Review
FY	Fiscal Year
IMS	NASA IV&V Management System
IPR	In-Progress Review
NPR	NASA Procedural Requirement
OSHA	Occupational Safety and Health Administration
PDR	Preliminary Design Review
PL	Project Lead
PITS	Project Issue Tracking System
QM	Quality Manual
RMS	Risk Management System
SRR	System Requirements Review

## **4.0 Procedure**

All risks and associated information shall be captured in one central repository. This repository is the Project Issue Tracking System (PITS) Risk Management System (RMS). In order to enhance the collection and analysis of risk metrics, there are two separate databases in the repository. One database is used to capture internal risks, which are associated with IV&V Projects. The other database is used to capture external risks, which are associated with development projects (only IV&V Services should be identifying external risks). In this document, references made to a risk database indicate the PITS RMS.

## **4.1 Develop Strategy**

The PL shall develop an implementation plan for conducting risk management. PLs shall identify when risk activities are performed and document the conduct of their own internal Risk Boards. An example of this may include peer reviews by the PL and contractor personnel.

The basic risk management strategy is intended to identify both technical and non-technical critical areas and risk events, and take necessary actions to handle them before they can become problems and cause serious cost, schedule, or performance consequences. PLs can extensively use typical risk sources/risk drivers to handle new risks populated throughout the project's life cycle.

Risk management uses a structured assessment approach to identify and analyze those processes and products that are critical in meeting the NASA IV&V Program/Project objectives. The PL will then develop risk handling options to mitigate the risks and monitor the effectiveness of the selected handling options. The identification of the resources required to implement the developed risk handling options is key to the success of the risk management effort.

Risk information will be included in all project risk reviews, and as new information becomes available, the PL will conduct additional reviews to ascertain if new risks exist. The goal is to continuously look for future risks in areas that may severely impact the NASA IV&V Program/Project.

## **4.2 Identify Risks**

As part of his or her management activities, a PL (or other IV&V Project Team Member) shall identify internal risks associated with his or her project. In addition to internal risks, IV&V Project Team Members shall also identify external risks.

Risks can be identified using a number of processes. This document does not define how any specific risk identification process is to be performed, as different types of projects may require different approaches. However, some of the more common approaches are listed in the following table:

Formal	Informal
System safety assessments – fault tree analysis, hazard analysis, failure modes & effects analysis	Brainstorming
Quantitative risk assessments	Test and verification
System and software engineering	Pause and learn sessions
Program planning and control – cost and schedule risk analysis	Experience – previous analysis, lessons learned, historical data
Models and simulations	

**Table 4.2.1 - Risk Identification Methods**

Risk identification depends heavily on both open communication and a forward-looking perspective. This encourages all personnel to communicate new risks and to plan beyond their immediate problems. Although individual contributions play a role in risk management, teamwork improves the chances of identifying new risks by allowing all personnel to combine their knowledge and understanding of the project.

Risk identification shall begin as early as possible and continue throughout the project life cycle, including ad hoc risk identification, as well as identification approaches captured in the IV&V Project's risk management strategy (see Section 4.1, *Develop Strategy*). The PL (or designee) shall document each risk identified to include a title, risk statement, context statement, and closure criteria as shown in Table 4.2.1, *Risk Documentation Format*. This is performed for both internal and external risks.

#### 4.2.1 Risk Documentation

The following table provides an example of a well-documented risk.

<b>Title</b>	Unexpected project churn limits IV&V analysis
<b>Risk Statement</b>	Given that the project continually releases new versions of immature artifacts, there is the possibility that IV&V may not be able to analyze the implemented system
<b>Context Statement</b>	The project is continually updating its development artifacts in a haphazard fashion. The updates are generally unplanned and catch the IV&V Project Team Members by surprise. The haphazard release approach makes it difficult for the IV&V Project Team Members to stay in sync with the development project.
<b>Closure Criteria</b>	Complete analysis of the final version of development artifacts

**Table 4.2.1 - Risk Documentation Format**

#### **4.2.1.1 Title**

The title should be written to attract attention and focus on the appropriate audience. It should answer the question “So what?”

#### **4.2.1.2 Risk Statement**

The risk statement shall generally be written in a condition-consequence format. For instance, given a condition, there is a possibility that a consequence will occur.<sup>1</sup> The risk statement should not be equivalent to the solution; thus, do not write a risk statement that provides a solution. An example of an incorrect risk statement is, “If we do not get more funding, then the project will not be able to complete the analysis.” This risk statement incorrectly implies that the only possible resolution is extra funding. The risk statement should be written in matter-of-fact, straightforward language. Avoid the excessive use of technical terms or jargon.

#### **4.2.1.3 Context Statement**

The context statement provides background on the risk and should include only facts (not assumptions). Ensure that no new risks are introduced here. When needed, cite related requirements and objectives that may be affected if the risk is realized. The context statement is important in that it captures the what, when, where, how, and why of the risk by describing the circumstances, causal factors, uncertainties, and related issues.

The context statement captures the background and additional information that does not appear in the risk statement. This information includes identification of causal factors (i.e., the potential causes of the risk that, if modified, may reduce the likelihood of the risk

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<sup>1</sup> The goal is to provide risks in the condition-consequence format; however, the previous “If X, then Y” format will continue to be accepted when the condition-consequence format does not adequately state the risk, or when a development project requires that format for an external risk. The condition-consequence format is specified by NASA Procedural Requirement (NPR) 8000.4, *Risk Management Procedural Requirements*.

occurring or remove the risk altogether) and the overall consequence for the project (if the consequence to the project is different than the direct consequence of the problem itself). A well-written context statement can serve as the starting point for the development of a Risk Mitigation Plan.

There may be times when a development project risk generates an IV&V Project risk. In these instances, it is beneficial to note the development project's risk in the context statement.

#### **4.2.1.4 Closure Criteria**

The closure criteria should document how the risk can be eliminated, or the how the likelihood of the risk can be reduced to an acceptable level. The closure criteria should be specific and measurable, and should state how the risk can be closed or eliminated. Risk closure is the goal of risk mitigation, and is the last step in the Risk Mitigation Plan.

Risks written against development projects generally do not require closure criteria from the NASA IV&V Program. The development project will provide the closure criteria. However, in some cases, the IV&V team may suggest closure criteria to assist the development project in understanding the scope of the risk. This determination needs to be made on a case-by-case basis

### **4.3 Analyze Risk**

The PL shall analyze and prioritize identified risks. The risks are analyzed to determine likelihood of occurrence, consequence, impact time frame, and impact horizon.

The likelihood can be determined in a quantitative or qualitative manner. In either case, the results of the analysis are used in conjunction with Table 4.3-1, *Risk Likelihood Criteria*, to assign a likelihood score from one to five.

Likelihood		
Score	Likelihood of Occurrence (p)	
5	Near certainty	$p > 80\%$
4	Highly Likely	$60\% < p \leq 80\%$
3	Likely	$40\% < p \leq 60\%$
2	Low likelihood	$20\% < p \leq 40\%$
1	Not likely	$p \leq 20\%$

**Table 4.3-1 - Risk Likelihood Criteria**

The consequence score is determined by assessing the consequence of the risk and assigning a consequence score from one to five based on the criteria in Table 4.3-2, *Risk Consequence Criteria*. Risks must be analyzed and scored on each separate consequence category.

CONSEQUENCE					
	1	2	3	4	5
<b>Performance</b>	Minimal consequence to objectives/goals	Minor consequence to objectives/goals	Unable to achieve a particular objective/goal, but remaining objective goals represent better than minimum success or outcome	Unable to achieve multiple objectives/goals but minimum success can still be achieved or claimed	Unable to achieve objectives/goals such that minimum success cannot be achieved or claimed
<b>Safety Human</b>	Discomfort or nuisance	First aid event per OSHA criteria	No lost time injury or illness per OSHA criteria	No lost time injury or illness per OSHA criteria	Loss of life
<b>Asset</b>	Minimal consequence: asset has no sign of physical damage	Minor consequence: asset has cosmetic damage and is repairable	Minor consequence: asset is damaged but repairable	Major consequence: asset is substantially damaged but repairable	Destroyed: asset is compromised, and un-repairable: a total loss
<b>Schedule</b>	Minimal consequence	Critical path is not slipped; total slack of slipped tasks will not impact critical path in less than 10 days	Critical path is not slipped; total slack of slipped tasks is within 10 days of impacting the critical path	Critical path slips	Critical path slips and one or more critical milestones or events cannot be met
<b>Cost</b>	Minimal consequence	Minor cost consequence. Cost variance $\leq$ 5% of total approved FY baseline	Cost consequence. Cost variance $>5\%$ but less than or equal to 10% of total approved FY baseline	Cost consequence. Cost variance $>10\%$ but $<15\%$ of total approved FY baseline	Major cost consequence. Cost variance $>15\%$ of total approved FY baseline

**Table 4.3-2 - Risk Consequence Criteria**

The highest score from these four consequence categories is then used as the final consequence score. For instance, a risk with a likelihood score of three that has safety consequence score of two, a performance consequence score of three, a schedule consequence score of four, and a cost consequence score of three would be considered a “3x4” risk (the likelihood score is three, and the schedule consequence score is four, which is the highest consequence score). If one of the consequence categories is not applicable, that consequence score is zero (i.e., if a risk has no consequence for safety, the safety consequence score should be zero).

In addition to likelihood and consequence scores, the impact time frame and impact horizon are determined. The impact time frame consists of two dates: sunrise and sunset. The sunrise is the earliest time at which the risk could occur. The sunset is the latest time at which the risk could occur (i.e., when the risk can be retired). These two values can be used to prioritize the risks in addition to the consequence and likelihood.

The impact horizon is then determined from the dates in the impact time frame using Table 4.3-3, *Impact Horizon Definition*. The impact horizon is used to help further prioritize risks according to the time frame in which they will occur. The impact horizon can be one of three values based simply on the sunrise time:

Impact Horizon	Sunrise	Sunset
Near	<2 months	<2 or 2-6 months
Mid	2-6 months	2-6 months or >6 months
Long	>6 months	>6 months

**Table 4.3-3 - Impact Horizon Definition**

Risk scoring is performed to facilitate risk review, integration, roll-up, prioritization, and summarization. Risks should be evaluated at a level of analysis that is sufficient to determine the relative importance for planning cost-effective mitigation strategies and for tracking. For example, high-likelihood, high-severity risks require a more detailed level of analysis to plan effective mitigation strategies.

External risks are analyzed in the same manner described for internal risks to determine likelihood of occurrence, consequence, impact time frame, and impact horizon. However, the likelihood and consequence criteria from the development project are used in place of the criteria depicted in this document. Additionally, development projects may not use the concepts of sunrise, sunset, and impact horizon. However, these values are still calculated and used in risk tracking and monitoring by the IV&V Project Team Members.

### 4.3.1 Prioritizing risks

Once the likelihood score, consequence score, impact time frame, and impact horizon have been determined, a risk can be prioritized by determining its Priority Score. The Priority Score is the score assigned via the Risk Matrix cell into which the risk falls. The Risk Matrix cell into which the risk falls is based on the risk's likelihood and consequence scores (see Figure 4.3.1, *Risk Matrix*). For example, a risk with a likelihood score of three and a consequence score of four would yield a Priority Score of nineteen.

L I K E L I H O O D	5	7	16	20	23	25
	4	6	13	18	22	24
	3	4	11	15	19	21
	2	2	8	10	14	17
	1	1	3	5	9	12
		1	2	3	4	5
		C O N S E Q U E N C E				

Figure 4.3.1 - Risk Matrix

Development projects may or may not have prioritization processes or criteria. If the development project has such processes, then follow those processes to prioritize external risks. If the development project does not have a prioritization process, then for purposes of this process, use the Priority Score described above to determine the level of review required for the risk.

Risk prioritization is a part of risk analysis and provides a basis for allocating handling and contingency resources, developing handling plans, and preparing individual handling tasks. Funding and

schedule constraints generally do not allow all project risks to be mitigated. Risk prioritization is vital in determining which critical risks get mitigated and when, and which risks need to be escalated to NASA IV&V Program level for determination and resolution. A key objective in prioritizing risks is to determine which risks will be fully accepted, actively controlled, closely tracked, or only watched. The risk prioritization process is closely related to the escalation process (see 4.5.1, *Communicate Risks*).

### 4.3.2 Risk Review

Once the PL has completed the analysis of the risks, the risks are submitted to the Risk Management Team for concurrence. The Risk Management Team assesses the risk for completeness and consistency. The primary intent of this review is to ensure that the risk is adequately documented to include the information captured in Table 4.3.2, *Risk Reviews*, and that the scoring is indicative of the risk statement.

At this point, the process diverges into two distinct processes. If the risk is internal, the process continues with Section 4.4, *Planning*. If the risk is external, the process continues with Section 4.5, *Communicate, Control, and Track Risks*<sup>2</sup>.

The risk review process is performed at various points throughout a risk's life cycle. The specific review performed is dependent upon the maturity and priority of the risk. The following table shows when to perform a specific review:

Maturity	Priority	Risk Management Team Review	Functional Lead Risk Board Review	NASA IV&V Program Risk Review
Risk (only)	< 8	X	X	
	>7 and <17	X	X	
	>16	X	X	X
Risk Mitigation Plan	< 8	N/A	N/A	N/A
	>7 and <17	X	X	
	>16	X	X	X

**Table 4.3.2 - Risk Reviews**

The Risk Management Team, Functional Lead Risk Board, and the IV&V Program Manager perform risk reviews. In all cases, the goal

<sup>2</sup> This approach implies that no Risk Mitigation Plan is required for an external risk. This is generally true, as it is the responsibility of the development project to determine how best to mitigate a risk. However, the NASA IV&V Program may wish to also provide a suggested mitigation approach to the development project. In these instances, this suggested approach needs to be reviewed in accordance with the process for an internal Risk Mitigation Plan.

of a risk review is to assess risks for completeness and consistency and provide initial communication of the risks to the Functional Lead and the NASA IV&V Program. Additionally, risk ownership is assigned during the Functional Lead Risk Board review.

In all risk reviews, the risk is returned to the PL or Risk Owner for corrective action if the risk does not receive concurrence.

#### 4.4 Planning

Planning decides what should be done about a risk. In this process, decisions and handling strategies are developed based on current knowledge of project risks.

The planning process is only applicable to internal risks. If the risk is external, proceed to Section 4.5, *Communicate, Control, and Track Risks*.

##### 4.4.1 Develop Mitigation and Contingency Plans

Once the initial risk review is complete, the risk then enters a planning phase. During this phase, the risk shall be further analyzed to ensure that the consequence and likelihood scores are correct, and that the risk has the correct owner. Minimally, each risk attribute (leading indicator) shall be identified for each risk. The risk attributes can be used to track the status of the risk (trending). Beyond minimum requirements, the PL or Risk Owner shall develop plans for each risk according to Table 4.4.1, *Risk Planning*.

	Priority < 8	Priority > 7 and < 17	Priority > 16
Research	Determine risk attributes for tracking. No other analysis required	Determine risk attributes for tracking. Perform research to increase confidence in scoring and to determine mitigation approaches	Determine risk attributes for tracking. Perform research to increase confidence in scoring and to determine mitigation approaches and contingency options
Plan	Document risk attributes being used for tracking.	Document mitigation approach with milestones to show likelihood reductions. Include risk attributes that will be used for trending	Document mitigation approach with milestones to show likelihood reductions. Document Contingency Plans. Include risk attributes that will be used for trending

Table 4.4.1 - Risk Planning

The research phase concludes with either risk ownership affirmation or risk reassignment, and the development of a plan that recommends the risk approach strategy as either “watch” or “mitigate”.

#### **4.4.1.1 Watch**

Risks can be watched if one of the following conditions exists:

- The risk is low priority (priority less than eight).
- Sufficient mitigation resources are not available.
- Mitigation cost is comparable to recovery costs if the risk were to occur.
- The likelihood of mitigation success is uncertain.

Watched risks can be placed on a watch list where each risk is periodically (at least quarterly) reassessed. For watched risks, the risk attributes are continually monitored for early warning of critical changes in likelihood, consequence, time frame, or other aspects.

Placing the risk on the watch list does not remove the requirement for monthly risk attribute tracking.

To watch a risk, the PL or Risk Owner shall create a metric to indicate a trend in the Priority Score or specific trigger points/dates of when the risk is to be assessed for specific conditions or attributes. When exceeded, metric thresholds are set to trigger the implementation of specific Risk Mitigation Plans or a reevaluation of the risk. Deviation of the metric from predetermined criteria may also be an appropriate risk trend indicator.

#### **4.4.1.2 Mitigate**

Risk mitigation reduces the likelihood of risk occurrence, or shifts the time frame in which the risk will occur through the execution of a predetermined set of action steps (e.g., Risk Mitigation Plan). The execution of a Risk Mitigation Plan may require

additional resources; however, the selected approach may result in an acceptable risk level.

Risk Mitigation Plans that require additional funding because they include non-baseline/non-funded work must be worked through the appropriate NASA IV&V Program process. The Risk Mitigation Plan will include the estimated cost for implementing a risk mitigation step. Approval of the Risk Mitigation Plan approves the estimated cost, but does not provide for the allocation of the costs. The allocation must be accomplished through the appropriate NASA IV&V Program process (e.g., Baseline Revision request).

It is the goal of the NASA IV&V Program to minimize risks to the lowest practical level within the allocated resources. When choosing to mitigate a risk, the following questions should be considered:

- a. Cost
  1. Is the Risk Mitigation Plan within the current funded budget and scope?
  2. How much does each mitigating option cost, and how likely are they to succeed?
  3. Is the mitigation going to cost more than the actual cost of the risk consequence?
- b. Schedule
  1. Are each of the mitigation tasks part of the in-scope work? Should they be?
  2. What tasks are new work that should be addressed through the IV&V budget processes?
  3. Who is responsible for each of the mitigating tasks?
  4. What is the consequence for the project schedule for each mitigation option?
  5. Does the risk impact a critical or significant milestone? Are there clear references to these consequences?
- c. Are all stakeholders identified and included in the mitigation planning?
- d. What is the confidence level for successful completion of each mitigation option?
- e. What is the amount of risk reduction at the completion of the Risk Mitigation Plan?

- f. What are the costs of mitigation versus the benefits and uncertainties of risk reduction?

All Risk Mitigation Plans are reviewed and concurred upon at the appropriate escalation level to determine which risk mitigation activities will be actively pursued (see Section 4.5, *Communicate, Control, and Track Risks*). Ownership of these Risk Mitigation Plans is assigned to the appropriate level for execution. If the choice is to mitigate the risk, the Risk Owner develops a detailed Risk Mitigation Plan. Each plan may have several action steps that need to be performed for effective mitigation (individual action steps should be assigned to the most appropriate IV&V Project Team Members, even though the overall plan is managed by the Risk Owner). The Risk Owner implements the Risk Mitigation Plan and oversees that all the mitigation actions are completed until the risk reaches an acceptable limit or is eliminated. At that time, the Risk Owner recommends to the appropriate owning management that the risk is accepted (residual risk remaining) or closed (risk eliminated). Based on the amount of residual risk remaining, the risk can either remain open, or move into the “watch” state.

Accepted mitigation activities are integrated into the project schedule to ensure that the schedule accounts for all task dependencies, and to monitor progress on all Risk Mitigation Plans. In some instances, a mitigation task may represent new work that requires a baseline revision (or other approval) to be processed to execute the mitigation task.

Risk Mitigation Plans are approved and controlled by the applicable Risk Board and/or NASA IV&V Program/Project management. After Risk Mitigation Plan tasks have been approved by the Risk Board and/or NASA IV&V Program/Project management and incorporated into the project master schedule, changes to the tasks or completion dates are controlled through the Baseline Revision process (see IVV 09-4, *Project Management*, for additional information). Budget requirements for risk mitigation are included in the fiscal planning process.

Risk Mitigation Plans may be graphically represented by risk waterfall charts as depicted by the example illustrated by Figure 4.4.1.2, *Risk Waterfall Chart*. On the risk waterfall chart, each mitigation task in the Risk Mitigation Plan is accompanied by exit or success criteria that provide measurable and objective evidence of task completion. Risk reduction only occurs when the resulting likelihood score is reduced as a result of task completion. The goal of risk mitigation is to reduce the risk to the closure level before the sunrise date, if possible. Each risk waterfall chart contains the risk closure level and closure date.

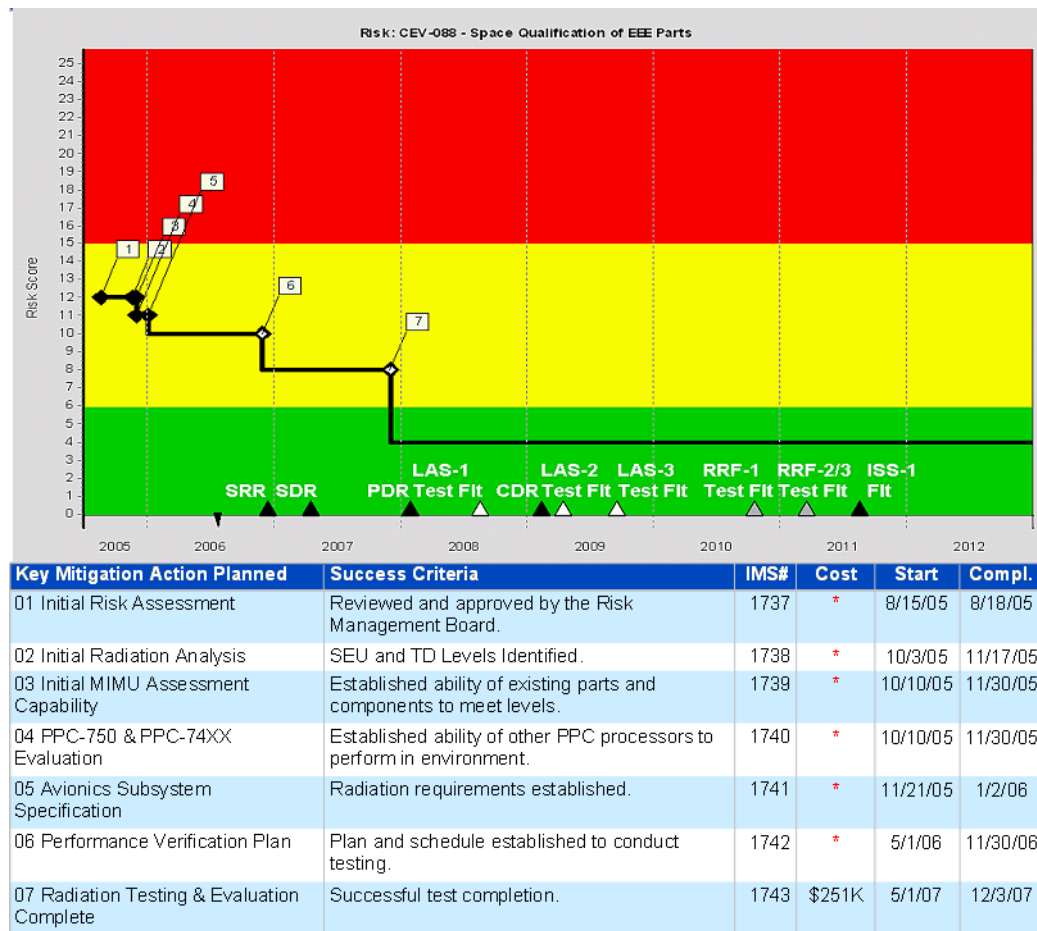


Figure 4.4.1.2 - Risk Waterfall Chart

#### **4.4.1.3 Contingency Planning**

Risks with Priority Scores greater than sixteen also require a Contingency Plan. The Contingency Plan applies in the event risk mitigation efforts fail, and the risk actually occurs and becomes a problem. This allows the NASA IV&V Program to be proactive by planning for potential problems and having Contingency Plans in place.

The Risk Owner develops the Contingency Plan and links it to the appropriate risk record. The Contingency Plan is approved by NASA IV&V Program/Project management, and it is periodically reviewed and updated as required. The development of a Contingency Plan may be waived with approval from the Functional Lead Risk Board and/or IV&V Program Risk Reviews.

Cost for the Contingency Plan is estimated and used as a cost threat against the project's budget based on its likelihood of occurrence. If the risk occurs, the risk is closed and the Contingency Plan becomes the problem resolution process. Thus, the problem is no longer monitored by the risk management process.

#### **4.4.2 Risk Handling Plan Review**

For any internal risk with a Priority Score greater than seven, the PL will discuss the Risk Handling Plan with the Risk Management Team. This step will ensure quality assurance and concurrence on the Risk Handling Plan and that contingency actions will be taken if the risk becomes a problem. The review is not an approval of the Risk Handling Plan; it is an assessment for the completeness and consistency of the Risk Handling Plan.

Communicating the Risk Handling Plan to the Risk Management Team is valuable in determining if there may be other potential risk stakeholders, ensuring that requests for risk transfers are acted upon, and raising significant concerns with the PL.

Any conflicting opinions will be discussed with the appropriate Functional Lead.

There is no requirement to generate a Risk Mitigation (or Contingency) Plan for external risks. The NASA IV&V Program is not responsible for the mitigation of external risks. The development project is responsible for mitigating its own risks. However, in some instances, the NASA IV&V Program may wish to develop a suggested mitigation approach for the development project. In these cases, the review procedure is the same as for an internal risk, and is based on the Priority Score determined in this procedure (see Table 4.3.2, *Risk Reviews*).

Internal risks with Priority Scores of less than eight do not require a Risk Mitigation Plan. However, all other risks require a Risk Mitigation Plan. Additionally, higher priority risks require a Contingency Plan. The Risk Management Team, Functional Lead Risk Board, and IV&V Program Risk Reviews evaluate developed Risk Mitigation and Contingency plans in accordance with Table 4.3.2, *Risk Reviews*.

The goal of the Risk Management Team review is to provide quality assurance and concurrence for the plans prior to their review by the Functional Lead and/or IV&V Program Risk Reviews.

The Functional Lead Risk Boards provide approval reviews, whereas the IV&V Program Risk Reviews are informational reviews only. The Functional Lead Risk Boards and IV&V Program Risk Reviews are generally led by the Functional Lead and the IV&V Program Manager, respectively. The Functional Lead Risk Boards shall approve Risk Mitigation and Contingency Plans to be presented at IV&V Program Risk Reviews. These plans may also include requirements for the creation of contingency reserves necessary for effective risk mitigation. The Functional Lead or IV&V Program Manager shall authorize the creation of contingency reserves in accordance with other applicable NASA IV&V Program procedures.

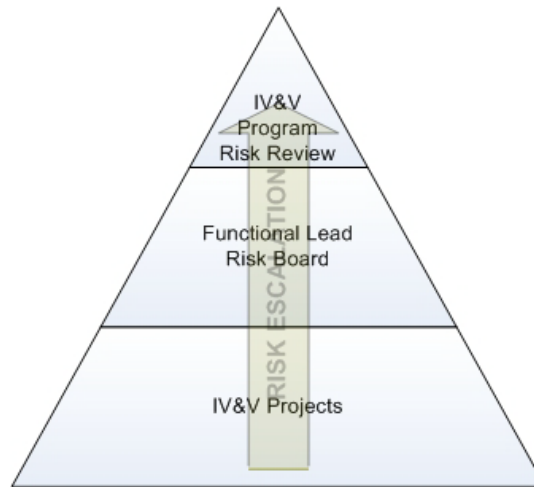
If the plans do not gain concurrence from the Risk Management Team or the Functional Lead Risk Board, they are returned to the Risk Owner for corrective action.

## **4.5 Communicate, Control, and Track Risks**

### **4.5.1 Communicate Risks**

Risk communication depends upon risk escalation. Risk escalation is the formal communication of internal risks throughout the NASA

IV&V Program and the formal communication of external risks with development projects. Risk escalation levels are represented by the Risk Boards:



**Figure 4.5.1 - Risk Escalation Levels**

This tiered approach of managing risks at the lowest appropriate level is the foundation of the NASA IV&V Program risk management process. Traceability from parent risks to child risks is maintained in the applicable risk database.

The PL shall communicate risks both horizontally (within the project) and vertically to ensure that significant risks are understood and influence key NASA IV&V Program/Project activities. All IV&V Project Team Members present their own identified risks. The PL controls, integrates, reassigns, and provides resources or guidance as necessary to ensure successful risk mitigation.

The risk escalation process establishes the top risk list for a Functional Organization by communicating risk information and status to the next risk escalation level. Risk escalation mainly results in risk prioritization, as well as proper risk integration and transfer. Risk escalation is aided by the Risk Management Team and through risk tracking and control. Each risk escalation level only evaluates, controls, and oversees those risks that require that level's attention.

Any risk has the potential to be escalated to the next level. There are several reasons for escalating a risk. In general, those reasons fall into the following four categories:

- Higher management-level awareness or decision is needed due to the potential severity or consequences of the risk. (The NASA IV&V Program has established criteria for assessing the need for escalation-based risk priority.)
- Request additional resources for effective mitigation
- Potential transfer of the risk to another organization or level (i.e., a risk identified at the project level is actually a programmatic risk, and ownership should be transferred accordingly)
- Coordination, integration, or transfer is needed with other organizations/stakeholders both inside and outside the NASA IV&V Program

Escalated risks are discussed at the next-level Risk Board. Risk escalation is either initiated by a lower level Risk Board pushing its top risks up to the next-level Risk Board, or by a higher level Risk Board pulling subordinate risks up from a lower level Risk Board.

Note that risk escalation and risk ownership are two different constructs. Risk escalation does not necessarily change ownership of a given risk, only the specific attention and focus on the risk at a given level. The Risk Owner is the individual ultimately responsible for coordination and resolution/mitigation of the risk.

In addition, any individual risk can be escalated to multiple levels simultaneously. Thus, the same risk may be escalated to the Functional Lead and IV&V Program levels simultaneously.

There are two separate, primary communication paths for escalating external and internal risks.

#### **4.5.1.1 Risk Template**

The primary form of risk communication is through the Risk Review boards. All risks presented at a Risk Review board shall conform to the NASA IV&V Program Risk Template, T2006, *Risk Review Template*.

#### **4.5.1.2 External Risks<sup>3</sup>**

All external risks, once identified and analyzed, are communicated to the Mission Directorate Lead (MDL). This can be accomplished via an IV&V Services meeting or other formal review of the risks. The goal of this communication is to ensure that the MDL is aware of the external risks that are being written prior to sending them to the development project. This communication also appraises the MDL of the status of any ongoing risks. This communication is used as risk concurrence by the Functional Lead.

All external risks are then communicated to the IV&V Program Manager. This can be accomplished during any designated IV&V Program Risk Review meeting, and should happen no less than monthly when there are ongoing risks against development projects. The goal of this communication is to ensure that the NASA IV&V Program is aware of the external risks that are being written prior to sending them to the development project. This communication also appraises the NASA IV&V Program of the status of any ongoing risks, and is used as risk concurrence by the NASA IV&V Program.

#### **4.5.1.3 Internal Risks**

All internal risks, once identified and analyzed, are communicated to the Functional Lead prior to the execution of any planning as noted in Section 4.4, *Planning*. The goal of this communication is to make the Functional Lead aware of any new risks that have been documented prior to the planning stage.

Once risk planning is complete (see Table 4.4.1, *Risk Planning*, for the types of risk planning), the plan is approved by the Functional Lead Risk Board. This only applies to risks categorized as yellow or red (see Section 4.4, *Planning*). The goal of this communication is to make the Functional Lead aware of the planned approach for dealing with risks, and to

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<sup>3</sup> At the moment, external risks only apply to risks generated by IV&V Services as an output of its analyses of development project artifacts.

provide concurrence on the Risk Handling Plan. This communication path also provides the status of any ongoing risks on that Functional Organization's top risk list.

Some internal risks are also communicated at IV&V Program Risk Reviews. Only risks that have a priority greater than sixteen are required to be reported at IV&V Program Risk Reviews. However, any risk that has significance to a Functional Lead (i.e., has been on his or her top risk list) can be communicated at IV&V Program Risk Reviews (generally, communication of these risks are for information only, and no concurrence is needed from the IV&V Program Manager).

#### **4.5.1.4 IV&V Program Risk Reviews**

The core objective of these reviews is to make the IV&V Program Manager aware of the planned approaches for dealing with risks and to provide information on Risk Handling Plans.

IV&V Program Risk Reviews provide overviews of existing risks. The overviews can be as simple as lists of risks with Priority Scores less than seventeen, and their locations on the Risk Matrix. Risks with Priority Scores greater than sixteen need to be reviewed in detail.

Programmatic risks captured by the Chief of Knowledge Management will be reviewed at Senior Leadership Meetings at the request of the IV&V Program Manager.

### **4.5.2 Control**

Risk control includes the evaluation of risk tracking reports. Risk mitigation tracking reports are evaluated for adequate progress (actual versus planned) and for validation that appropriate corrective actions for the Risk Mitigation Plans are implemented. Risk control is performed at each level of the Functional Organization's hierarchy.

In this case, control takes place at the PL level, the Functional Lead level, and at the appropriate Risk Board level depending on the categorization of the risk (see Table 4.3.2, *Risk Reviews*). Escalation to a higher level Risk Board can be used if there is significant deviation from established tracking criteria.

The following strategies can be selected during risk control:

- Continue as planned
- Invoke a Contingency Plan (the risk has become a problem)
- Re-plan (develop a new or updated Risk Mitigation Plan)
- Close or accept the risk

All decisions and directions regarding risks and Risk Mitigation Plans shall be captured in the risk database.

#### **4.5.2.1 Risk Closure**

To close a risk, the Functional Lead must concur with the closure rationale. If the residual risk has a priority greater than five (see Figure 4.3.1, *Risk Matrix*), the risk cannot be closed (either the risk must be further mitigated or the risk must be accepted). Any risk with a priority of five or less is assumed to be sufficiently mitigated and may be closed with no additional resources applied to the risk. Closed risks are only revisited to capture knowledge and lessons learned (see Section 4.6, *Lessons Learned*).

A risk may also be closed if the risk has evolved into a problem, or if the risk's sunset date has passed.

Risks can be accepted during risk control if mitigation efforts do not result in a Priority Score that is less than five, and it is determined that further mitigation is not practical.

#### **4.5.2.2 Risk Acceptance**

If a risk is accepted, no further action is required with the risk other than periodic monitoring. The risk is treated as a problem if it occurs. A risk can be accepted when the consequences are tolerable if the risk occurs, or when the risk cannot be cost effectively

mitigated with further action. Generally, if risks are not fully mitigated (Priority Score greater than five) and have no plans for further mitigation, the risks are accepted unless the selected handling strategy is "Watch". Accepted risks must be reviewed periodically (at least quarterly) to ensure that conditions/assumptions have not changed. Accepted risks could potentially be re-opened or closed based on these reviews.

Approval from the PL, affected stakeholders, and the highest level of risk escalation is required before a risk can be accepted. The ultimate decision is left up to the IV&V Program Manager for IV&V Program risks. To accept a risk, the Functional Lead Risk Board or IV&V Program Manager must concur with the acceptance rationale.

For example, the IV&V Program Manager must approve the acceptance of risks that were once top IV&V Program risks. Likewise, the MDL must approve the acceptance of risks that were once top IV&V Services risks.

The acceptance rationale must be documented in the risk database. The acceptance rationale must provide the reasons and conditions under which the risk was accepted. It is important that the rationale is clear because these are important factors considered during the periodic reviews.

### **4.5.3 Track**

The PL shall track the status of the risk and the effectiveness of risk handling actions against established metrics (previously identified risk attributes). The objective of risk tracking is to collect accurate, timely, and relevant risk information to present to the appropriate decision maker. Risk tracking is performed to measure actual versus planned progress associated with implemented Risk Mitigation Plans. Risk tracking also provides input into risk escalation process.

Each risk should already have an attribute/indicator system designed to provide early warning of changes in status. This allows management (PLs, Functional Leads, and IV&V Program

management) to respond proactively before the risk becomes a problem.

Risk tracking is not a problem-solving technique; rather, it is a proactive technique to provide a basis for developing additional risk handling options and/or approaches, updating existing risk handling strategies, and/or re-analyzing known risks. In some cases, tracking results may also be used to identify new risks and revise some aspects of risk planning.

Also, risks can change over time. Every action taken, or not taken, changes the basic facts from which each risk is derived. Continually monitoring risks and reassessing their potential consequence (i.e., repeating the risk identification, assessment, and handling steps at periodic intervals) is essential for appropriately managing risks.

#### **4.6 Lessons Learned**

When a risk is closed, the PL and the Risk Management Team shall assess the risk for inclusion in the IV&V Program Lessons Learned database. This process is documented in IVV 09-4-2, *Work Instruction for IV&V Services Lessons Learned*.

#### **5.0 Metrics/Tool**

Several metrics, as summarized in Table 5.0, *Risk Management Metrics*, are assessed periodically to evaluate the effectiveness of the IV&V risk management process. Metrics evaluated to assess the effectiveness of risk management extend beyond the data derived from the risk management process, and include various IV&V Program/Project health metrics that ascertain whether there are areas where potential risks were not identified (i.e., whether problems are arising that were not pre-identified as potential risks). This allows continuous re-evaluation of the risk management process, which increases the effectiveness and provides insight into where structured risk identification or mitigation reviews should be conducted.

The Risk Management Team tracks and reports the following four metrics as requested to IV&V Program management:

- 1) Number of risks – Tracking the number of risks by organization (categorized by criticality and graphically represented by a cumulative bar) provides indication of the health and responsiveness of the IV&V risk management process and the progression of risk handling strategies.

- 2) Risk Mitigation Plan stability – Tracking the stability of Risk Mitigation Plans provides an indication of responsiveness to critical project schedules and commitments, and is different than mitigation tardiness, which just identifies tasks that are late. Tracking Risk Mitigation Plan stability provides insight into the number of plans that are underperforming the proposed mitigations (e.g., behind schedule, over budget). Data for tracking Risk Mitigation Plan stability should be collected in conjunction with IV&V Program/Project planning to establish late completion of a major or critical mitigation step. A critical step is considered to be one tied to a step-down in Priority Score. Stability of a Risk Mitigation Plan is determined by the movement of the estimated completion date (ECD) for the critical mitigation steps (a re-plan). A critical step completed within seven days of the ECD is not considered late or a consequence for the metric. Thus, this metric only contains slips of critical steps greater than seven days. The percentage of non-moving critical tasks should be charted against the percentage of critical tasks that did move.
  
- 3) New/Open/Closed risks – Tracking new/open/closed risks on a monthly basis provides insight into the amount of risk activity occurring each month related to risk identification and mitigation efforts. Tracking new/open/closed risks indicates the length of time risks have been in the RMS (e.g., less than thirty days, thirty-one to sixty days, sixty-one to ninety days). This tracking will also include data to show the amount of time it takes to move a risk through each concurrence activity. For example, once a risk is made available to the Risk Management Team, how long does it take for the Risk Management Team to provide concurrence on the risk? This would also include information to show how many times risks are not concurred with, and how long it takes to rework them and reach concurrence. It is expected that as the RMS matures, the trend should show more risks accepted or closed than opened.
  
- 4) Mitigation Tardiness – Tracking mitigation tardiness (the number of steps re-planned or completed late) provides early indication of potential schedule risk. It also provides insight into the frequency of change requests for Risk Mitigation Plans. The thresholds for reporting tardiness are determined in the ranges of five to thirty days (green), thirty-one to sixty days (yellow), and more than sixty days (red).

Name	Description	Threshold
Number of Approved Risks by Functional Organization	Red, yellow, green count for each Functional Organization	TBD
Mitigation Plan Stability	Number of step changes	
Number of New/Open/Closed Items	Activity reporting period	
Mitigation Tardiness	Number of late tasks	

**Table 5.0 - Risk Management Metrics**

Below are some additional metrics for consideration. They may not need to be reported to IV&V Program management, but can be used to assess the performance of the risk management process:

- 1) Number of escapements – Identified issues/problems that could have been mitigated if identified early as risks.
- 2) Number of duplicate candidate or risk entries – How well risks are documented and communicated by an integrated team (ensure that risks are not being worked in parallel).
- 3) Trends in number of processes/people/production – The maturity of the project relative to the types of risks identified (may expect to see different types of risks for different milestones, System Requirements Review [SRR], Preliminary Design Review [PDR], etc.).
- 4) Number of candidates – How many candidate risks are being identified each month to provide an indication of risk focus by project personnel.
- 5) Length of time from risk identification to risk determination – The length of time it takes before a candidate risk is evaluated and either approved or rejected.
- 6) Length of time from risk to handling strategy – How long it takes for the risk handling strategy to be identified and approved once a candidate risk is approved as a risk (i.e., will it be mitigated, watched, accepted, or researched?).
- 7) Action items issued by Risk Board to Risk Owner – How well a Risk Owner is doing her/his homework prior to the Risk Board (was the Risk Owner able to anticipate questions from the Risk Board?).
- 8) Number of times Risk Boards occurred as planned – Trends in Risk Board postponements indicate if risk management may be taking a back seat to other issues.
- 9) Length of time it takes to distribute minutes from the Risk Board – The length of time that it takes for the release of the minutes from the Risk Board meeting (this provides an indication of workload).
- 10) Unfunded mitigations – Unfunded mitigation activity cost threats indicate how much risk has been accepted by not funding mitigation activities (it also may indicate the effectiveness of escalating risks to the appropriate levels for additional resources).

11) Cost threats/liens – Cost threats/liens (as a compilation of financial consequences for management reserve in the eventuality that a risk is realized [not mitigated]), aids in determining financial exposure and when to apply funds for risk mitigation, as opposed to accepting the risk. The cost threat/lien is calculated using the estimated cost consequence of the risk consequence, factored by the likelihood (percentage) of the risk occurring. The sum of all risk cost liens gives an expected consequence value to the NASA IV&V Program from risks occurring. In addition, as a risk is mitigated, the likelihood is reduced and the cost/lien to the NASA IV&V Program is reduced.