STRATEGIES FOR MITIGATING NASA'S SUPPLIER VIABILITY RISK

REPORT NS106T1

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Executive Summary

Commercial and government organizations are susceptible to operational disruptions caused by the loss of viability of one or more of their suppliers.[1] The National Aeronautics and Space Administration (NASA) is no exception, as it has programs that involve unique components and design requirements, single-source parts, and highly regulated materials.

LMI assessed NASA's supply chain risks based on the characteristics of NASA's line of business and surveys of representative NASA supply chains. LMI developed recommendations for possible mitigation strategies when a supplier's viability was at risk. Our assessment followed a three-phased approach:

- We researched and assessed best practices for identifying and mitigating supply chain risks.
- We developed a methodology for assessing the level of supply chain risk associated with the loss of contractors and suppliers. The methodology is based on the likelihood and consequences of specific risks.
- We provided recommendations for mitigation approaches that are specific to NASA.

To gain a better understanding of the NASA organization and its supply chains, we attended a NASA supply chain quality assurance conference and surveyed supply chain managers at four NASA programs. The survey responses revealed three general trends:

- NASA supply chain risk mitigation policies are driven primarily by individual programs.
- Constant communication is the principal means of managing supply chain risks related to diminished supplier viability.
- Efforts to evaluate the viability of suppliers stress past performance in terms of on-time delivery and quality.

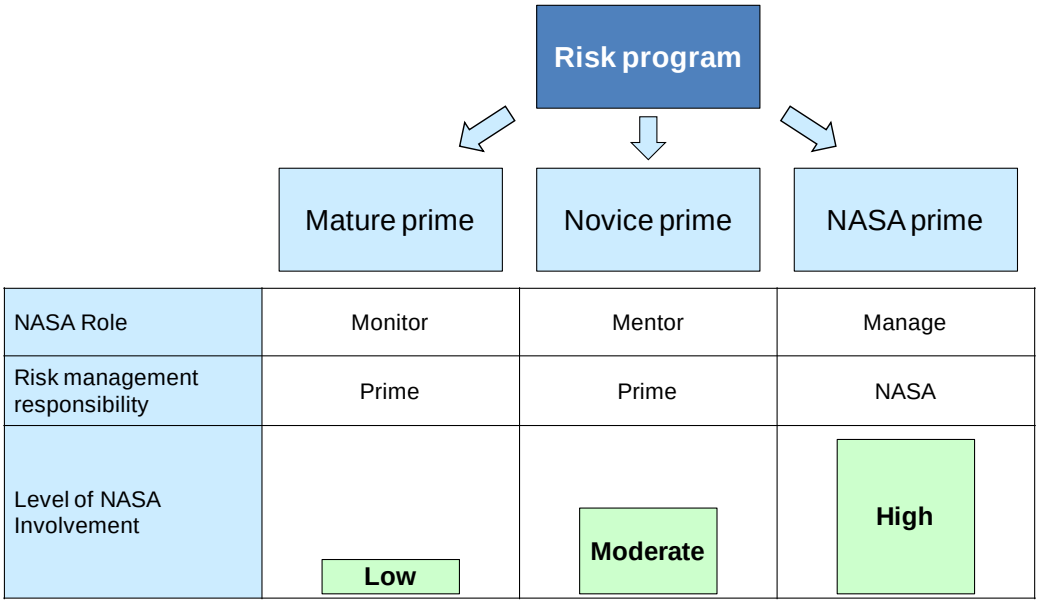
[1] Suppliers may lose viability for any number of reasons, but we found that NASA is most susceptible to supplier bankruptcy; mergers, acquisitions, or divestitures; contract defaults; and regulatory non-compliance.

We collected industry best practices based on a literature review of more than 40 sources and interviews of industry supply chain management professionals. We used this information to develop five risk identification techniques and five risk mitigation strategies. Our final recommendations are supported by a business case analysis of each strategy, and we suggest policy, process, and contract language improvements that would aid in the implementation of each strategy.

We offer a specific recommendation for a supplier viability management structure for NASA:

- Evaluate suppliers based on risk likelihood and consequence.
- Segment suppliers by the type of program management and define roles and responsibilities for NASA and its prime contractors, as illustrated in Figure ES-1.[2]
- Prioritize mitigation actions based on the type of program management.
- Engage the NASA supplier base in phases.
- Use a common structure for managing program and enterprise risks.

Figure ES-1. Risk Management by Program Management Type



[2] In Figure ES-1, a "mature prime" is defined as a contractor that has a well developed supplier management program. A "novice prime" is defined as a contractor that does not have a well developed supplier management program.

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Chapter 1
Overview

In recent years, commercial and government entities have experienced program disruptions due to the loss of one or more suppliers. Supplier viability addresses whether a given supplier can reliably provide products and services despite economic and programmatic conditions. Absence of supplier viability may be manifest in terms of business-related events, such as bankruptcy, or process-related events, such as insufficient capacity. Supplier viability can have a substantial negative effect on a company's operations over a broad range of programs.

The National Aeronautics and Space Administration's (NASA's) supply chains are particularly susceptible to such effects. As the only U.S. government agency responsible for the nation's civilian space program and aeronautics and aerospace research, NASA manages and executes a wide range of distinct and technically complex multiyear programs.

Many of NASA's programs involve unique components and design requirements, as well as highly regulated materials. Because NASA carries a significant portion of single-source critical parts[1], the failure of an individual supplier can significantly affect a NASA program. If the supplier is used on several programs, the impact can negatively affect NASA's enterprise operations. NASA's supply chains also are susceptible to shifts and instability in program funding, which can make it difficult to build enduring relationships with suppliers. In addition, visibility beyond the prime contractor to sub-tier suppliers is often challenging.

TASKS AND APPROACH

We followed a three-phased approach to assess NASA's supply chain risks and develop recommendations for mitigation strategies.

- First, we researched and assessed best practices for *identifying and mitigating supply chain risks*. We conducted surveys of managers in NASA's Logistics Division and gathered data to analyze specific supply chains for the Space Shuttle Program, including those for the Multiplexer De-Multiplexer subsystem, auxiliary power unit, and ground support systems. We also examined supply chains that support the International Space Station Program's orbital replacement units. We gathered data from a literature search of more than 40 documents and conducted interviews with NASA,

[1] A "critical part" is defined as a part without which the NASA mission cannot be completed. Similarly, a "critical supplier" is a supplier that provides a critical part and who is the only certified source of the part.

government, and commercial supply chain risk experts. We assessed best practices from across the aerospace and other industries and analyzed their effectiveness and applicability to NASA. We then determined and provided the top five identification and top five mitigation practices for application to NASA's supply chains.

- Second, we developed a *methodology for assessing the level of supply chain risk* associated with the loss of contractors and suppliers, based on the likelihood and consequences of specific risks. We then identified primary supplier risks and provided NASA-specific tables for assessing both risk likelihood and risk consequences based on metrics that we developed. We also provided a risk matrix for prioritizing suppliers' viability in terms of their risk to NASA programs, so that actions can be taken on those that represent the greatest threat to operations.

- Third, we provided recommendations for *mitigation approaches*. Based on the best practices we identified in our research, we developed a mitigation plan that included a business case analysis that described the pros and cons of each approach. We also developed recommendations for the policy and business process changes necessary to implement the suggested mitigation approaches. We then provided procurement and contracting methods necessary to implement each suggested mitigation strategy.

SCOPE

In this study, we focused on the risk of losing suppliers because of a business- or process-related cause, including the following:

- Supplier going out of business due to bankruptcy
- Supplier making a business decision to discontinue production or services
- Effects of mergers, acquisitions, or divestitures
- Supplier or sub-tier contractual default
- Supplier's inability to meet or accommodate changes in regulatory requirements
- Supplier capacity constraints
- Extensive supplier certification time.

The following one-time events and technical risks were outside the scope of this study:

- Natural disasters
- Man-made disasters
  - Vandalism
  - Terrorism
- Labor issues
- Non-compliant products or poor quality assurance
- Counterfeit parts
- Technical issues
- Programmatic issues.

Chapter 2
Data Gathering

To fully understand the high-level risks associated with NASA's supply chain and the viability of NASA's suppliers, we began with background research, attending a NASA conference and surveying several representatives from NASA supply chains. Based on an initial literature search and a series of interviews of industry professionals, we investigated industry best practices related to supplier viability management.

NASA Supply Chain Quality Assurance Conference

Several of our team members attended the 5th Annual NASA Supply Chain Quality Assurance Conference at NASA Goddard Space Flight Center on October 18-19, 2011. The conference theme, "Managing Risks to Assure Mission Success," focused on supplier risk management. Representatives from NASA and its suppliers attended, and each community contributed to presentations and discussions on how to improve supplier management.

Our attendance at the conference provided us with a clearer picture of supplier risks, identification techniques, and mitigation strategies, from both a NASA and NASA supplier perspective. Based on our observations from the conference, we know that NASA strives to be proactive about supplier risk management, utilizes set processes for supplier and supply chain risk assessment and identification, and continues to seek improvements to its current risk mitigation strategies. The conference also helped us identify representative supply chains that would yield additional insights into NASA's supply chain risk management practices.

Representative Supply Chains and Survey Responses

We developed a survey to collect input from a select group of NASA supply chain managers. Observations from the Supply Chain Quality Assurance Conference informed the development of the survey questions.

The survey sample consisted of four programs:

1. Ground Support Systems, Space Shuttle Program
2. Multiplexer De-Multiplexer, Space Shuttle Program

3. Auxiliary Power Unit, Space Shuttle Orbiter

4. Orbital Replacement Unit (ORU) Spares, International Space Station Program.

The survey served to elicit responses in the following three areas:

- The challenges NASA supply chains face with respect to maintaining supplier viability.
- Mitigation activities that have been undertaken, or are being undertaken, by NASA supply chain managers to reduce the risk of a supply chain disruption attributed to diminished supplier viability.
- Activities that have been undertaken, or are being undertaken, by NASA supply chain managers to identify suppliers who are at an increased risk of losing their viability.

Table 2-1 highlights two challenges NASA must consider when devising mitigation strategies associated with supplier viability risk. All of the survey respondents face long lead times (up to 4 years) and extended periods for replacing lost suppliers (up to 5 years).

Table 2-1. NASA Supply Chain Challenges

Challenge	Ground Support Systems, Space Shuttle Program	Multiplexer De-Multiplexer, Space Shuttle Program	Auxiliary Power Unit, Space Shuttle Orbiter	ORU Spares, International Space Station Program
Order lead-times	◆ 6 weeks (common components) ◆ 6 months (long lead-time)	◆ 6 weeks (common components) ◆ 6 months (long lead-Time)	◆ 12–18 months	◆ 1–4 years (ORUs) ◆ Few days–few months (consumables)
Supplier replacement	◆ 6–12 months	◆ 1–12 months (item dependent) ◆ Irreplaceable (certain parts)	◆ 5+ years ◆ May be impossible	◆ Significant cost

The survey respondents' efforts to identify suppliers with viability issues, in anticipation of an operational disruption, are summarized in Table 2-2.

We divided the responses into two general practice areas:

- Monitoring actions
- Supplier rating schemes.

For example, the Ground Support Systems, Space Shuttle Program, employs a supplier rating scheme to assess viability issues. The supplier rating schemes focus on past performance related to quality assurance, rather than tracking selected predictive indicators associated with supplier viability. For the managers of the Multiplexer D-Multiplexer program, constant communication s (i.e., monitoring) with the supplier works best.

When the monitoring of suppliers viability falls to the prime contractor, routine communication with suppliers appears to be the most common practice.

Table 2-2. NASA Supply Chain Risk Identification Activities

Ground Support Systems, Space Shuttle Program	Multiplexer De-Multiplexer, Space Shuttle Program	Auxiliary Power Unit, Space Shuttle Orbiter	ORU Spares, International Space Station Program
◆ Past performance–focused ◆ On-time delivery ◆ Quality	◆ Constant communications with suppliers works best	◆ In 1990s tried predictive process, which failed ◆ In 2004, conducted supplier survey—mixed results ◆ Regular communications has always worked best	◆ Responsibility belongs to prime contractor ◆ NASA participates in quarterly review

Table 2-3 summarizes the activities the respondent programs have undertaken, or are currently undertaking, to mitigate the supplier viability risks. The responses fell into two general categories:

- Supplier communications
- Enhanced inventory management techniques.

Table 2-3. NASA Supply Chain Risk Mitigation Activities

Mitigation	Ground Support Systems, Space Shuttle Program	Multiplexer De-Multiplexer, Space Shuttle Program	Auxiliary Power Unit, Space Shuttle Orbiter	ORU Spares, International Space Station Program
Supplier communications	◆ (No data)	◆ Constant communications by prime contractor with suppliers to identify support issues before they affect the program	◆ Prime contractor requires suppliers to provide 120-day advance notice of any loss of capability	◆ Boeing must notify NASA of any supplier issues ◆ NASA participates with Boeing in reviews of their suppliers
Inventory management techniques	◆ Minimum: 9 × average monthly demand ◆ Maximum: 24 × average monthly demand ◆ Adjustments made for longer lead-time items	◆ Minimum stock levels based on order lead-times and demand history	◆ Ordered two spare APUs for each orbiter	◆ Placed orders to cover expected lifecycle (ORUs)

The survey responses revealed three general trends:

1. NASA policy, as it relates to supply chain risks associated with diminished supplier viability, is driven by the individual program.

2. Respondents seem to be most comfortable with "constant communication" as the principal means of managing supply chain risks related to diminished supplier viability.

3. Efforts to evaluate the viability of suppliers stress past performance in terms of on-time delivery and quality.

These three trends, which reflect NASA's approach to managing risk, are not consistent with the industry best practices. It is our experience that a "uniform" approach to risk management is the best, as it yields consistent positive results across an organization.

Constant communication is an essential element of supplier management; however, an overreliance on communication and personal relationships can push risk-related decision making down to lower levels in the organization, undermining an established system of risk governance.

Finally, although past performance in terms of on-time delivery and quality are widely used to evaluate suppliers, past performance is not the only valid metric for evaluating future supplier viability.

LITERATURE SEARCH

General Research

To identify and assess supply chain risk management best practices, we conducted a literature review and assembled more than 40 academic articles and reports on both commercial and government organizations. Our literature review emphasized the aerospace industry. Case studies, such as the example of Cisco in the *X-SCM: The New Science of X-treme Supply Chain Management*,[1] were also helpful in defining risks and risk mitigation tools and techniques.

We extracted several more strategies and best practices that help organizations identify, understand, prioritize, address, and monitor different types of supply chain risk. Our search focused on best practices relating to supplier viability, including business- and process-related events. We also found numerous publications that provided practical strategies to mitigate risks relevant to NASA's business environment.

[1] Lisa H Harrington, Dr. Sandor Boyson, and Dr. Thomas M. Corsi, *X-SCM: The New Science of X-treme Supply Chain Management*, September 23, 2010 (Routledge; 1 edition).

Supply Chain Risk Leadership Council

We concentrated much of our literature review on documents available through the Supply Chain Risk Leadership Council. As a current council member, LMI continuously works with member companies, such as Boeing, Cisco, FedEx, and other industry leaders, to share products and research. The Supply Chain Risk Leadership Council's August 2011 report, *Supply Chain Risk Management: A Compilation of Best Practices*, provided relevant strategies for risk identification and mitigation across a broad range of supply chain risks.

Supply Chain Council Database

The Supply Chain Council's database generated numerous resources that outlined best practices for identifying and treating supply chain risk. In particular, the Supply Chain Council's Supply Chain Operations Reference (SCOR®) model is a widely accepted evaluation framework for supply chain activities and their performance. The Supply Chain Council itself is comprised of nearly 1,000 corporate members, and our review of the resources in the database provided current best practices in risk identification and mitigation practices from across the industry.

COMMERCIAL INTERVIEWS

Supplier viability and risk management is a widely employed practice in the commercial sector. We interviewed several people who are familiar with industry best practices and who had specific experiences with supplier viability management. From these interviews, we identified some general findings regarding successful supplier viability management programs.

Manage from the Enterprise

Suppliers often work with multiple units within a company or organization; however, the viability of the supplier is not dependent on any one business unit. The viability of suppliers should, therefore, be managed by the enterprise. This avoids duplication of effort across business units and allows a complete view of how the supplier serves its customer. Enterprise management of suppliers also promotes a more strategic relationship between the supplier and the customer.

Scope the Program

Most organizations work with hundreds, if not thousands, of tier 1 (or prime) suppliers, and each supplier is subject to a wide variety of risks. But the definition of critical suppliers often includes tier 2 and higher suppliers that provide critical technology or capacity-constrained materials. Attempting to manage every risk for every supplier would require resources that far outweigh any benefits. Supplier

viability programs are often scoped to focus on the most critical risks, using the available resources as effectively as possible.

Suppliers should be prioritized based on their value to the customer organization. Value is typically measured by the total volume of business conducted with the supplier and the criticality of materials the supplier provides. Focusing on the more critical suppliers puts the risk management program's emphasis where a supplier problem could have the greatest impact.

Likewise, the focus should be on the types of risk most likely to cause problems for an organization. By narrowing the types of risk that are of concern, a program can focus on monitoring and mitigating activities.

Finally, the program should leverage existing supplier management programs to avoid duplication of effort and overburdening suppliers with data requirements.

Understand Risk Detection Limitations

The more successful risk-management programs recognize that risk, by its very nature, involves uncertainty. Due to this uncertainty, no risk management method can predict and mitigate every risk event. Our interviewees recognize this and build a capability to respond to unforeseen events into their programs. Unforeseen events can be caused by a lack of data visibility or inaccurate data, as well as changes in market forces over time. Understanding these limitations helps build a program that provides the most protection, while recognizing the need for a rapid response to unforeseen events.

Relationships Are Better Than Metrics

According to all those we interviewed, all successful supply chain risk management programs use metrics to monitor supplier health, but they also foster positive relationships with critical suppliers. Since suppliers are more familiar with their specific market and financial situations, they are in a much better position to predict problems in their operations or with their suppliers. For this reason, a good working relationship with critical suppliers is a better method for monitoring for risk than using standard financial metrics. Of course, building a good relationship takes time.

Mitigation Is Supplier and Situation Dependant

All those we interviewed expressed an opinion that the best choice of mitigation action depends heavily on the supplier and situation. The decision to direct more business to a supplier to help their cash flow or to stop business with the supplier and migrate to a more reliable source can hinge on a wide range of factors. For this reason, it is not possible to build a standard mitigation response to a given risk. Successful programs often have a suite of developed mitigation actions that they can employ alone or in combinations to address problem suppliers.

Chapter 3
General Findings

We leveraged data gathered from our attendance at NASA's supply chain quality assurance conference, survey of NASA supply chain managers, literature search, and commercial interviews to offer an approach to supplier risk management that is dependent on program structure. We defined a list of supplier viability risks that are specific to NASA. We then assessed best practices for identifying and mitigating those supply chain risks.

Segmenting Suppliers by the Type of Program Management

A well developed supplier management program includes the following:

- A supplier classification system based on supplier performance
- Regular monitoring of supplier performance, including quality and delivery
- Regular monitoring of supplier financial health
- Defined risk mitigation actions with systematic follow-up activities
- Supplier mentoring programs
- Sub-tier supplier site visit programs.

NASA has a mixture of programs that are managed by either NASA or a prime contractor. It is inevitable that NASA and its various prime contractors will have different approaches to supplier risk management and even different capabilities. Further, NASA's primes may have supply management programs at different stages of development.

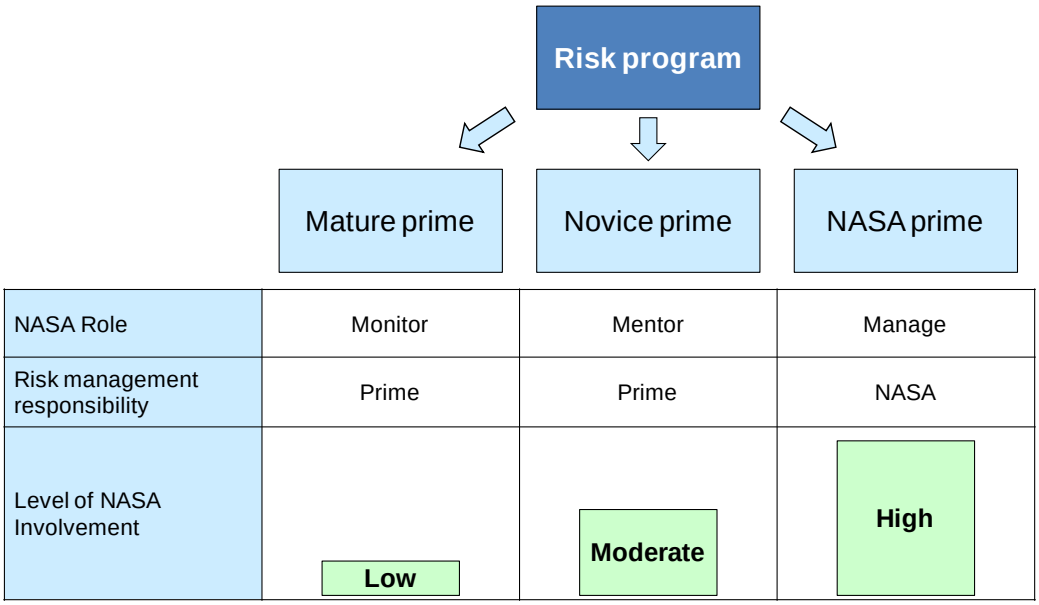
As such, NASA has three basic program structures:

- Programs led by a prime contractor with a well developed supplier management program, which we will define as a "mature prime"
- Programs led by a prime contractor without a well developed supplier management program, which we will define as a "novice prime"
- Programs led by NASA.

Being classified as “mature” does not mean a contractor has been in existence for a long time or has experience with large number of contracts. The classification is solely defined by the development and reliability of the contractor’s supplier management program.

The three basic program structures are important, because the approach to managing supplier viability and risk changes depends on the structure, as shown in Figure 3-1.

Figure 3-1. Risk Management by Program Management Type



A prime contractor has responsibility for supplier risk, since it holds the supplier contracts. The contractor may operate its own supplier risk management processes, but it must be able to provide NASA with the specific reports and metrics it requires. When the prime contractor is a *novice* prime (i.e., the contractor does not have a well-developed supplier management program), NASA should take more control over the monitoring of supplier viability to supplement the prime contractor’s capabilities. Naturally, if NASA is the prime integrator for a program, then NASA must take full responsibility for supplier viability management.

SUPPLIER RISKS

Today’s volatile market presents new financial, geopolitical, regulatory, and operational risks. These risks can lead to problems, such as supply chain disruptions, delays, system failures, forecasting errors, and procurement issues. Using our observations from the NASA supply chain conference and the results of our survey of NASA supply chain managers, we compiled a list of supplier viability risks

that are specific to NASA.[1] NASA's supplier viability management should initially focus on risks to supplier financial health, including the following:

- Bankruptcy
- Supplier leaves business
- Mergers and acquisitions
- Contract default
- Regulatory non-compliance.

This focus can expand over time to include additional areas of risk in the supply chain; but initial activity should be limited to these types of risk to allow a manageable program scope.

TOP 5 RISK IDENTIFICATION TECHNIQUES

Based on information on best practices that we compiled during our literature search and through interviews from across the aerospace and other industries, we identified the following proven risk identification best practices:

1. Use publically available data, information available in-house, and data provided during the solicitation process to identify risks before suppliers are selected.

2. Identify critical suppliers and monitor them closely. Performing supplier viability management can be overwhelming for large programs and enterprises. To narrow the scope of the problem, identify suppliers that have the greatest effect on the business.

3. In addition to closely monitoring critical suppliers, maintain relationships with suppliers in order to gain additional visibility into supplier risks. Tailor the relationships, including any contact plans or data collection, based on the level of perceived risk.

4. Use metrics (not just past performance) to anticipate supplier viability warning signs.

5. Ask the right questions. Utilize period reviews, surveys, or site visits to collect information about suppliers. The periodicity of review, scope of surveys, and number of site visits should be tailored based on the criticality of the supplier and their perceived risk level.

[1] As mentioned in Chapter 1, we considered only business- and process-related risk events.

TOP 5 RISK MITIGATION STRATEGY

In addition to using proven techniques to identify supplier risk, we noted the following proactive commercial risk mitigation strategies that can be used to anticipate and avoid supplier risks before they occur:

1. *Perform initial and ongoing supplier due diligence investigations.* This includes using past performances and publically available data to evaluate suppliers before they are selected and throughout program execution. The evaluation of a supplier's risk should not rely solely on data provided by the supplier.

2. *Follow risk assessment processes for new and existing suppliers.* Understand the impact of a particular supplier on a program. Perform risk assessments on critical suppliers. This should include requiring the supplier to provide routine reports on key financial metrics, such as those described in Chapter 4, and visiting suppliers to perform on-site assessments.

3. *Develop relationships with suppliers that focus on risk management.* Grow existing relationships with suppliers to motivate them to continuously improve their risk management capabilities and encourage information sharing. Form relationships with new suppliers to build trust early. Having a number of close working relationships with suppliers helps prepare for situations when risk mitigation calls for joint response actions, renegotiating contracts, or investigating new sources. This may also include negotiating the option to procure data, methods, and tools, or making a lifetime buy from key suppliers.

4. *Establish an enterprise-level team responsible for managing supplier risk.* The team would be responsible for providing policy, oversight, and guidance associated with supplier risk management. The team would disseminate tools, encourage best practices, and and coordinate supplier risk management efforts at lower tiers of the organization. The team would be available to assist prime contractors with corrective action plans and mitigation strategies.

5. *Develop a centrally hosted database of supplier profiles.* The profiles contain supplier data collected through the acquisition process (such as past performance references and information about the supplier risk management program), metrics reporting, site visit results, survey results, and risk assessments. The profiles should be shared across programs.

Before providing mitigation recommendations to NASA, we must first evaluate the commercial best practices as they apply to NASA. Then, we must consider how NASA would be involved in the implementation of each mitigation practice. These tailored risk mitigation actions are explained by program management type in Chapter 4.

BUSINESS CASE ANALYSIS

We evaluated each commercial risk mitigation strategy as it applies to NASA. For each strategy, we considered a qualitative business case assessment and outlined the advantages and disadvantages of each approach. (A more robust analysis would include a detailed cost analysis, but it would also require access to financial data.)

The advantages and disadvantages of each strategy are summarized in Table 3-1.

Table 3-1. Mitigation Strategy Business Case Analysis

Mitigation strategy	Pros	Cons
Perform initial and ongoing supplier due diligence investigations.	Promotes proactive risk detection.	Adds terms to new contracts. Requires resources and systems for monitoring.
Follow risk assessment processes for new and existing suppliers.	Prioritizes risk mitigation resources.	Metrics may not be available for all suppliers (e.g., public versus private companies).
Develop relationships with suppliers, focusing on risk management.	Promotes risk management collaboration. Incorporates suppliers in the risk management team.	Relationships take time and resources to develop.
Establish an enterprise-level team responsible for managing supplier risk across the NASA enterprise.	Removes the responsibility of supplier risk management from an individual program's management team. Builds a knowledge-base and the capability for risk management. Team could be staffed with personnel from NASA centers to get a broad perspective and capture lessons learned from across the enterprise.	Need full-time equivalents to staff the team.
Develop a centrally hosted database of supplier profiles.	Allows for the sharing of supplier performance and risk information across NASA (and beyond). Permits supplier performance trend analysis.	Requires resources and systems for monitoring. Need to decide where best to host the database.

In general, taking action to mitigate supplier risk requires NASA to commit resources to support any monitoring and mitigation activities. While resource requirements differ among the strategies, none of the strategies would require an excessive number of new resources relative to the benefits.

The quantitative benefits of effective risk management are difficult to calculate; however, there are clear qualitative benefits to NASA in protecting programs from supplier failure. There are also additional benefits to be gained by improving the

visibility of supplier performance across the enterprise and building better enterprise-level relationships with suppliers.

Effective supplier risk management requires people with supporting tools. By working with its suppliers to mitigate risk, NASA will have better tools to manage suppliers, reduce program delays due to failed suppliers, and improve long-term relationships with key suppliers.

Applying these supplier risk identification and mitigation approaches will bring about benefits at the program level and the effects can be aggregated to the enterprise level. (This concept of using a common structure for managing program and enterprise risks is further explained in Chapter 5.)

DEPTH OF RISK MITIGATION

A common concern for a supplier risk management program is determining how deeply to monitor and mitigate supplier risk within the supply chain. Maximum risk mitigation would lead programs to engage with suppliers as deeply as possible within the supply chain; however, constraints stemming from privity of contract and program office resources will limit the feasible depth of engagement.

The challenge is that critical suppliers may be two, three, or more tiers into the supply chain, and NASA and its prime contractors may not have the ability to influence suppliers at that level. In addition, the number of suppliers can grow exponentially at each succeeding tier within the supply chain, thus creating severe workload limitations.

These limitations make it imperative for NASA to prioritize suppliers based on their criticality. Just as we recommend that NASA focus risk management resources on critical items, where a disruption in the supply can significantly impact the program, we recommend NASA determine which suppliers at lower tiers in the supply chain warrant monitoring or mitigation actions. In other words, NASA should consider including a next tier supplier when that supplier is providing a component or technology that is critical to the program.

Management of suppliers deeper in the supply chain should be consistent with the overall risk management program in terms of monitoring and mitigation methods, as well as the responsibilities for engaging the suppliers. NASA should consider the risk management expertise available within the supply chain and work with prime and sub-tier suppliers to ensure that risk is sufficiently managed without duplication of effort.

Chapter 4
Methodology for Risk Quantification and Mitigation

Based on the supplier risks identified for NASA, we defined metrics needed to gauge the consequences and likelihood of those risks, and then developed a risk matrix for prioritizing suppliers in terms of their risk to NASA programs.

RISK ASSESSMENT

A risk assessment of a supplier or list of suppliers provides a systematic way to evaluate potential supply chain problems related to suppliers. Risks can be characterized by two quantities:

1. Consequence—a measure of the severity of the possible risk
2. Likelihood—a measure of the probability of the occurrence of each risk.

For this study, we identified a method NASA can use to classify the consequence and likelihood associated with the loss of a particular supplier. The method involves the use of simple, objective criteria to quantify the likelihood and consequence of experiencing program impacts associated with supplier viability.

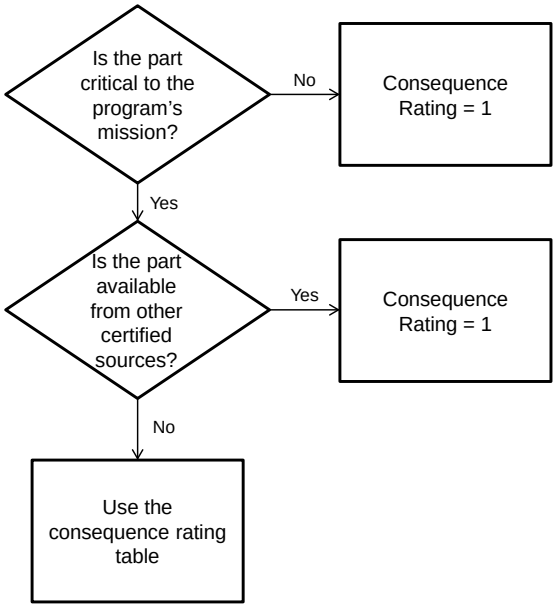
We provide a quantitative method with specific numeric thresholds associated with the risk levels. The thresholds may be adjusted to suit the needs of individual programs, provided the adjusted thresholds are consistent with qualitative definitions we provide for the consequence and likelihood levels. This consistency is needed if ratings are to be aggregated across programs to provide an enterprise-level perspective of risk.

Risk Consequences

Risk consequence measures the effect of a particular risk. In the case of supplier viability, risk consequence is synonymous with the impact of a supplier's failure on a program. The consequence is directly related to the criticality of the items provided by the supplier to the program's mission. In general, if the loss of supply for an item will affect the success of the mission, then the item is critical.

We recommend assessing supplier risk consequences based on a decision tree, which considers the criticality of the part[1] being supplied and the number of certified suppliers that can provide that part. This decision tree is shown in Figure 4-1.

Figure 4-1. Consequence Rating Decision Tree



If a supplier is not critical or has multiple sources, then its consequence rating is 1. If the supplier is critical, then we use a metric that consists of the number of days of supply for the item that NASA has in its inventory, divided by the amount of time (in days) needed to certify and start receiving the same product from a new supplier. For items with significant technical complexity, the time to certify and start production with a new supplier should be multiplied by 1.2 to reflect uncertainty involved in complex production.

The consequence rating for suppliers—on a 1-to-5 scale—is based on the schema defined in Table 4-1. The rating represents the severity (or impact) of a supplier's loss of viability.

[1] If a supplier provides multiple parts, consider the one that is most critical to the program.

Table 4-1. Risk Consequence Rating Scheme

Consequence rating	Qualitative consequence rating definition	Criticality index[a]
1 (Low)	◆ Minor cost increase that can be absorbed within budget ◆ Minor schedule variance with no milestone impacts ◆ Minimal reduction in technical performance	>1.5
2 (Minor)	◆ Cost exceeds budget, but sufficient funds are available ◆ Schedule slip, but no major delivery impact ◆ Minimal reduction in technical performance	1.2 to 1.5
3 (Moderate)	◆ Cost exceeds budget and funding increase may be necessary ◆ Significant schedule slip that is partially recoverable at program level ◆ Some operational requirements may not be met	1.0 to 1.2
4 (Significant)	◆ Cost exceeds budget and funding increase is necessary ◆ Significant slip in schedule and delivery likely to be impacted ◆ Mission success questionable	0.8 to 1.0
5 (Severe)	◆ Large funding increase necessary ◆ Major impact to schedule ◆ Mission success unattainable	<0.8

[a] Inventory (in days)/certification time (in days).

Risk Likelihood

Risk likelihood is defined as the probability or frequency that a risk may occur. In terms of supplier viability, risk likelihood represents the level of certainty that a supplier will experience a loss of viability. Likelihood is based on the set of metrics which we define in Table 4-2.

Table 4-2. Metrics for Assessing Risk Likelihood

Metric	Definition
Altman Z-score	Z-score is a financial metric used to predict corporate bankruptcy. The Z-score calculation includes company earnings, assets, debt, sales, and working capital. We explain the calculation of the Z-score in Appendix A.
Program budget/schedule	An assessment of the subject program's actual budget and schedule compared to planned budget and schedule. Delayed programs and restricted funding can frustrate suppliers and hurt company cash flow.
Percentage of business with NASA	The portion of the supplier's overall business that is with NASA. Companies with a high portion of business with NASA are at greater risk from NASA program and budget changes.

Table 4-2. Metrics for Assessing Risk Likelihood

Metric	Definition
Regulatory burden	A qualitative assessment of suppliers operating in a highly regulated industry or working with highly regulated materials and products. Companies subject to multiple regulations are more at risk of disruptions caused by regulatory changes.
Supplier margin	The net profit of the supplier. Companies with higher profit margin are less likely to experience financial failures.
M&A postulated	A qualitative assessment of the potential for a supplier to be involved in a merger or acquisition. Corporate priorities can change after a merger or acquisition, impacting the service to NASA.
Percentage of off-shore suppliers	The portion of suppliers used that are foreign in origin. Foreign companies are less likely to have readily available financial data and are a higher risk due to cultural differences in sharing risk exposure information.
Percentage of small business suppliers	The portion of suppliers that are small businesses. Small businesses tend to have a lower tolerance for financial problems and are more likely to experience a financial failure.

Because the Altman Z-score is a proven predictor of financial failures, we recommend starting the supplier assessment with a Z-score calculation and assigning likelihood points based on the results, as shown in Table 4-3.

Table 4-3. Z-Score Likelihood Points

Supplier type	Z-score	Likelihood points
Public company	>2.99	0
	between 1.81 and 2.99	5
	<1.81	10
Private company	>2.90	0
	between 1.23 and 2.90	5
	<1.23	10

Suppliers can receive likelihood points of 0, 5, or 10 points based on their Z-score. If a supplier receives 10 points based solely on its Z-score, then the supplier is considered high risk, and no further evaluation is necessary. If a supplier receives a 0 or 5 based on their Z-score, it is still necessary to assess that supplier against the other metrics in Table 4-2.

If the financial data required for the Z-score calculation is unavailable, such as for a private company, assign at least 5 likelihood points for the Z-score metric. To anticipate the event when a supplier is unable to or will not provide the financial data necessary for the Z-score calculation, introduce a contract requirement for

the supplier to provide the data. If the supplier cannot provide the data or is unwilling to agree to the contract term, NASA can purchase financial reports from financial monitoring companies, many of which provide reports on private firms. As an example, Dun and Bradstreet maintains "Private Company Insight Reports" that offer key company data for more than 250,000 U.S. private companies, including financial data for up to 3 years.

We assigned likelihood points to the remaining metrics based on low and high risk criteria. If a supplier has a low risk for a particular metric, it receives 0 points for that metric; if a supplier has a high risk for the metric, it receives the corresponding points, as shown in Table 4-4.

Table 4-4. Additional Metric Likelihood Points

Metric	Risk level	Risk criteria	Likelihood points
Program budget/schedule	Low	At or below budget, on time or ahead of schedule	0
	High	>10% over budget or behind schedule	1
Percentage of business with NASA	Low	<50%	0
	High	>50%	3
Regulatory burden	Low	No	0
	High	Yes	3
Supplier margin	Low	>5%	0
	High	<5%	3
M&A postulated	Low	No	0
	High	Yes	1
Percentage of off-shore suppliers	Low	<10%	0
	High	>10%	1
Percentage of small business suppliers	Low	<25%	0
	High	>25%	1

Once points are determined for each of the nine metrics, the sum of the points for a supplier then becomes its total likelihood rating. This rating is converted into a 1-to-5 score using the scale in Table 4-5. The score represents the likelihood a supplier will encounter a viability risk.

Table 4-5. Risk Likelihood Rating Scheme

Risk level	Qualitative likelihood rating definition	Likelihood rating
Nearly certain = 5	Most always encountered; practically unavoidable event.	Risk score of 10 or more
Highly likely = 4	Expected to occur; typically occurs in efforts of a similar nature	Risk score of 6 to 9
Possible = 3	Even likelihood of occurrence; often encountered in similar efforts	Risk score of 4 to 5
Unlikely = 2	Hypothetically possible, but uncommon in programs of similar type	Risk score of 2 to 3
Very unlikely = 1	Rarely encountered; standard practices will effectively avoid event	Risk score of 0 to 1

The risk consequence rating scheme in Table 4-1 and risk likelihood rating in Table 4-5 are intended to be a starting point for NASA's risk assessment of its suppliers. This study did not include a review of NASA programs to ensure that the ranges are appropriate for NASA's suppliers. With additional analysis, the criteria provided can be tuned to allow an appropriate distribution of the suppliers into the various risk levels for consequence and likelihood.

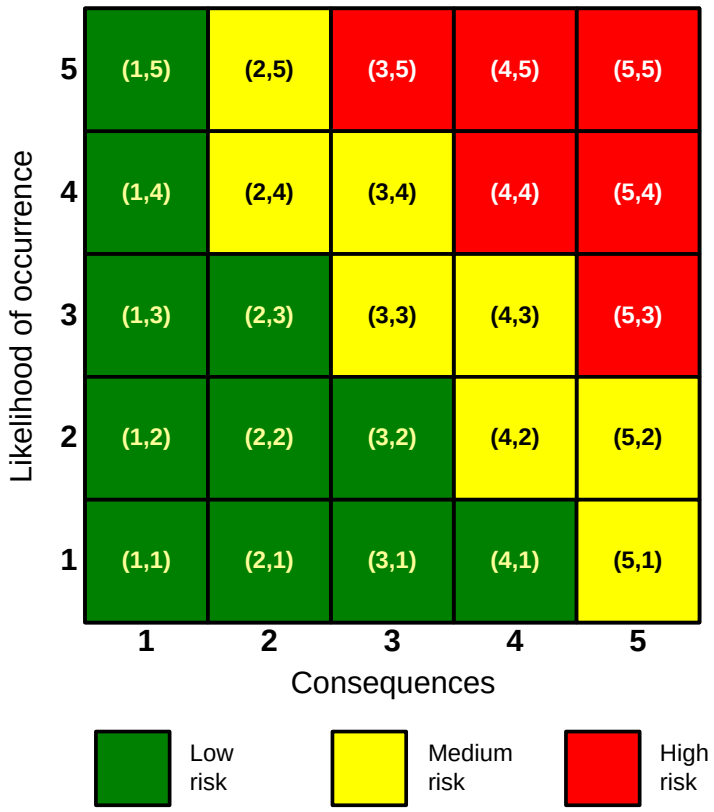
Risk Matrix

Consequence and likelihood together can be used to identify the risk each supplier presents to the program. Using the 1-to-5 ratings for consequence and likelihood, the risk of a particular supplier can be plotted on the matrix shown in Figure 4-2.

The matrix can be used to visualize the risks for individual suppliers in relation to one another, prioritize the order in which each is addressed, and plan ways to mitigate each risk. Based on its placement in the matrix, a supplier is determined to have a low, medium, or high risk of failure. Suppliers that fall into the green range are considered low risk; suppliers that fall into the yellow range are considered a moderate risk; and suppliers that fall into the red range are considered a high risk.[2]

[2] Notice that a supplier with a low consequence rating will always be a low risk, no matter how likely the risk is to occur. For this reason, we calculate a supplier's consequence rating first and can eliminate the likelihood rating calculations for suppliers in this category.

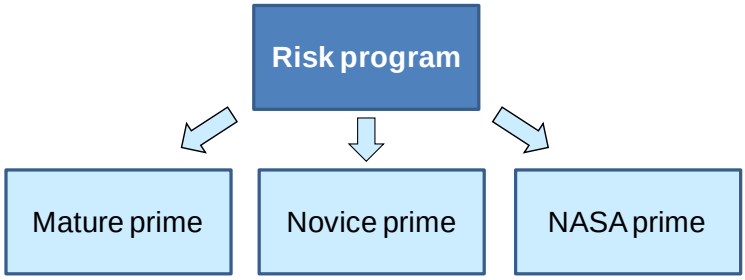
Figure 4-2. Supplier Risk Matrix



Tailored Risk Mitigation Actions

The mitigation actions, if any, applied to a supplier should be based on the supplier's risk level, as calculated using the consequence and likelihood measures described above. The mitigation actions that NASA employs should also be tailored based on the program management structure described in Chapter 3. The depth of NASA's involvement will increase based on the level of risk and the extent to which NASA can rely on the prime contractor—if there is one—to manage risks associated with supplier viability. Figure 4-3 shows an example of mitigation actions that are a function of risk level and program management structure.

Figure 4-3. Risk Mitigation by Program Management Type



High Risk	Likelihood	(4) Implement corrective action plan	(4) Implement corrective action plan (4) Employ NASA supplier risk team	(4) Employ NASA supplier risk team (3) Renegotiate contracts (3) Provide consulting support
	Consequence		(3) Start contracting new source (3) Make lifetime buy (3) Obtain data, drawings, tooling	(3) Start contracting new source (3) Make lifetime buy (3) Obtain data, drawings, tooling
Medium Risk	Likelihood	(1) Increase supplier monitoring	(2) Increased supplier monitoring (2) Require more frequent /detailed reporting	(2) Increased supplier monitoring (2) Require more frequent /detailed reporting (3) Counsel supplier
	Consequence		(3) Investigate new source	(3) Investigate new source
Low Risk	Likelihood	(1) Conduct ongoing supplier due diligence (2) Conduct routine supplier performance reporting (3) Develop relationships with suppliers		
	Consequence			

[a] The numbers to the left of each action in Figure 4-3 represent their mapping to the top five risk mitigation practices listed in Chapter 3.

For any risk level, the mitigation strategies for that risk level, as well as any below it, should be implemented.

Chapter 5
Recommendations and Conclusion

NASA would benefit from an effective enterprise supplier management capability, but this capability needs to fit within NASA's business needs and programmatic goals.

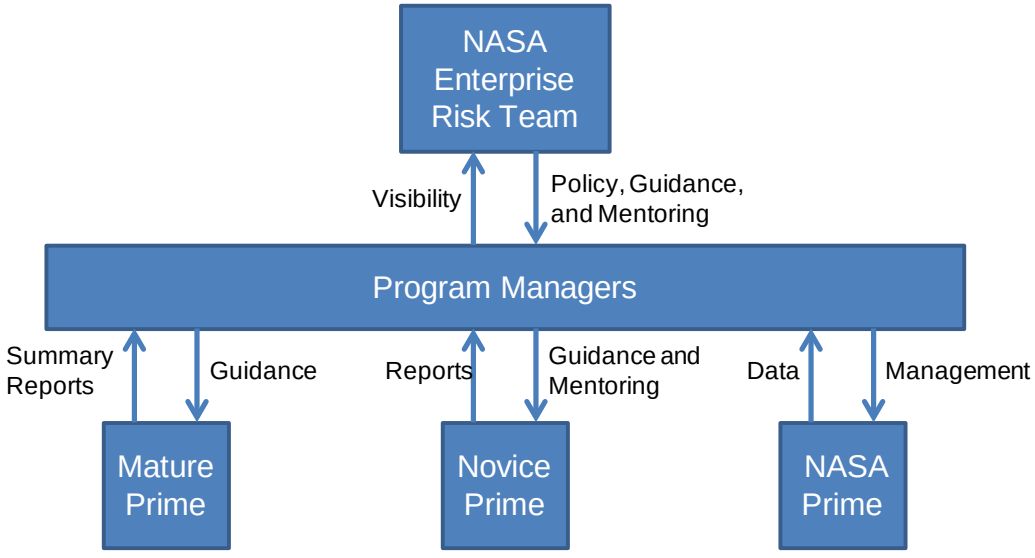
IMPLEMENTATION RECOMMENDATIONS

To implement the five top mitigation strategies, supplier viability management must be embraced at all levels of the enterprise. This will require the implementation of policies and processes throughout the supply chain. In this section, we outline several supporting policies and processes that may be used, along with some suggested additions to the existing procurement and contracting processes.

Governance

NASA should establish a three-tiered governance structure, as shown in Figure 5-1: NASA's enterprise supplier risk team, NASA program managers, and the prime for a particular program.

Figure 5-1. Governance Structure for Supplier Management



These are the players that, to various degrees, will perform and implement the risk mitigation strategies.

Supporting Processes

The following processes will aid in the implementation of the recommended mitigation strategies:

1. *Establish a NASA enterprise-level supplier risk team with a formal charter and roles and responsibilities.* The team is responsible for overall supplier risk program management and mitigation actions. The team develops standard risk management practices and tools. It also ensures that the supplier profile database is up-to-date and utilized across the enterprise.

2. *Share risk management practices with primes according to their specific needs*. This effort would focus on the novice and NASA primes. The NASA supplier risk team would mentor novice primes in developing a mature supplier risk management system. For NASA primes, the NASA supplier risk team would ensure NASA program managers are aware of and leverage standard risk management practices and tools. The primes can share the processes with suppliers that have sub-tier suppliers.

3. *Prioritize suppliers based on funding and criticality.* Establish a process for building relationships with critical suppliers that is consistent with the Federal Acquisition Regulations. Perform periodic visits to critical supplier sites to collect metrics and foster relationships. The organization performing the site visits would depend on the type of program management involved, as shown in Table 5-1.

4. *Establish a regular process for collecting and aggregating data and metrics for suppliers.* Store the information in a central supplier profile database that is hosted in a place where it can be utilized and shared across the enterprise.

Table 5-1 summarizes the roles of the prime and NASA with respect to the processes described above.

Table 5-1. Roles of Primes and NASA in Supporting Processes

Supporting processes	Role of NASA enterprise supplier risk team	Role of NASA program manager	Role of mature prime	Role of novice prime	Role of NASA prime
1. Establish a NASA enterprise-level supplier risk team.	Perform	Follow resulting policy and guidance	Follow resulting policy and guidance	Follow resulting policy and guidance	Follow resulting policy and guidance
2. Share risk management practices with primes.	Develop	Perform	Receive minimal guidance	Receive substantial guidance	Receive substantial guidance
3. Prioritize suppliers and build relationships.	Provide guidance	Provide assistance to prime, as necessary	Perform	Perform with guidance from NASA supplier risk team.	Perform
4. Establish process for data collection.	Provide guidance and aggregate data	Receive data; assist with data collection, as necessary	Collect data in own format Provide summary to NASA Report quarterly (or monthly for high risk suppliers)	Collect data in NASA format Provide summary to NASA, with additional detail as needed Report quarterly (or monthly for high risk suppliers)	Collect data in NASA format Provide detailed reports to NASA Report monthly

Supporting Policies

NPD 7500.1 can be modified to support the proposed mitigation strategies. Potential language for inclusion under the policy section of NPD 7500.1 is shown below:

> Programs and projects will include supplier risk identification and mitigation procedures in accordance with applicable guidance.

Procurement and Contracting Approaches

The following procurement and contracting procedures will also support a proactive supplier viability management program:

1. *Integrate risk mitigation into NASA's sourcing process*. Add language to procurement documents requiring prime contractors to provide a description of their supplier risk management processes. Evaluate the responses relative to the "mature prime" criteria described in Chapter 3. Utilize the proposed risk metrics and supplier risk matrix during the procurement process—before a supplier is selected.

2. *Use the supplier profile database for analysis and evaluation*. Once a supplier profile database is established, use it and any past performance references to evaluate prime contractors and their sub-tier suppliers. The database should enable NASA program managers to evaluate potential suppliers during source selection. The database should also enable NASA program managers and the NASA supplier risk team to track trends in supplier viability.

3. *Incorporate contract language that requires metrics reporting*. The metrics should support NASA's role based on the type of program management. For a mature prime, NASA will need access to high-level data for the monitoring role (for example, results of risk assessments, identified risks, and mitigation plans). For novice prime and NASA Prime, NASA will need access to the detailed data used in performing assessments and developing mitigation actions, for example: names of sub-tier suppliers and associated demographics, business, and financial data.

   Prime contractors can collect the data according to their own supplier risk management processes, as long as they can translate the information and provide it in a format that is preferred by NASA.

   As discussed in Chapter 3, the range and depth of data NASA should pursue will depend on a number of factors including analytic capacity, privity of contract, and the nature of relationships within the supply chain.

4. *Incorporate contract language that states NASA reserves the right to become involved in a supplier's risk management process as necessary*. Privity of contract will limit the level of NASA's direct access to processes and data; however, appropriate language can allow NASA to obtain as much information as possible to serve as the ultimate owner of program risk.

These processes, policies, and procurement and contracting approaches will vary depending on whether NASA or a prime contractor is managing the program.

SUPPLIER VIABILITY MANAGEMENT STRUCTURE FOR NASA

We recommend NASA consider a supplier viability management structure that consists of five basic elements as shown below. We describe each element in detail on the following pages.

- Evaluating suppliers based on risk likelihood and consequence.
- Segmenting suppliers by the type of program management.
- Prioritizing mitigation actions based on program management.

- Engaging the NASA supplier base in phases.
- Using a common structure for managing program and enterprise risks.

Evaluating Suppliers Based on Risk Likelihood and Consequence

We recommend NASA follow a risk assessment approach that evaluates the likelihood of supplier failure and the consequence to NASA if that failure occurs. As explained in Chapter 4, the assessment of likelihood utilizes a set of metrics; but, ultimately, it is converted to a 5-point scale to reflect uncertainty in the metrics themselves and to support a simplified assessment. Similarly, a consequence rating (which considers the criticality of the part being supplied and the number of certified suppliers that can provide the part) is assigned to suppliers and is also based on a 5-point scale.

Together, the likelihood and consequence ratings can be used to identify the risk each supplier presents to a program. The pair of ratings can be used to plot suppliers on a risk matrix to visualize supplier risks in relation to one another, to prioritize the order in which each is addressed, and to plan ways to mitigate each risk.

Segmenting Suppliers by the Type of Program Management

NASA's level of involvement in its supplier risk management depends on the management structure of the program, as defined in Chapter 3. For example, supplier reporting frequency will be different for a prime that has a well developed supplier risk management program compared to one that does not. In addition, NASA's risk management responsibilities will be different, depending on whether NASA or a prime contractor is the lead integrator for a program. Whether monitoring, mentoring, or managing the supplier risk for a program, NASA should always play some role in the overall supplier risk management plan and this role should be determined at the start of the program.

Prioritizing Mitigation Actions Based on Program Management

Mitigation actions are highly dependent on the specific supplier, the risks they face, and other situational elements. In selecting appropriate mitigation actions for medium- or high-risk suppliers, NASA should consider the program management structure. The depth of NASA's involvement will increase based on the level of risk and the extent to which NASA can rely on the prime contractor—if there is one—to manage risks associated with supplier viability. We provided a methodology for assessing the level of risk and developing tailored mitigation actions in Chapter 4.

Engaging the NASA Supplier Base in Phases

NASA and its prime contractors work with thousands of suppliers; therefore, it is unreasonable to expect NASA to be able to monitor and manage each supplier for risk exposure. That is why NASA and its prime contractors should approach supplier risk management in a phased approach that addresses suppliers according to their criticality.

We recommend the following order for addressing supplier risk:

1. Sole-source, critical part suppliers
2. Sole-source, high volume ($) suppliers
3. Multiple source, critical part suppliers
4. Multiple source, high volume ($) suppliers
5. Long-term suppliers
6. Other suppliers.

This phased approach will allow NASA to address the highest risk areas in its supply chain, while developing a knowledge base for supplier risk management within NASA Headquarters.

Who takes action in terms of engaging the supplier base will depend on the type of program management. Under routine circumstances, mature primes will work with their suppliers independently. Novice primes will take the lead when working with their suppliers, with guidance from the NASA supplier risk team. NASA primes will engage the suppliers directly.

As discussed in Chapter 3, the depth to which NASA should engage the supplier base will depend on a number of factors, including analytic capacity, privity of contract, and the nature of relationships within the supply chain.

Using a Common Structure for Managing Program and Enterprise Risks

NASA needs two levels of supplier viability management: at the program level and at the enterprise level. We recommend NASA assess supplier viability risk at the program level and aggregate the results to the enterprise level. This can be done by assigning a criticality weight to each program that reflects the importance of the program to NASA's overall mission. The program weights should be percentages that all sum to 100 percent.

Each supplier's consequence rating can then be multiplied by the weights of all programs the supplier supports. So the total consequence rating for a supplier becomes:

Equation 5-1. Total Consequence Rating

$$Consequence_{total} = \sum Consequence_{program} \times Weight_{program}.$$

The likelihood of supplier risk should be consistent across programs and at the enterprise level, so it does not need an aggregation method. Additional information on this calculation and an example are included in Appendix B.

Following this approach, NASA will be able to conduct a single assessment of suppliers to capture the risk at the program and enterprise levels. This reduces the burden on suppliers and program managers, while providing a consistent method for evaluating and tracking risk exposure.

The methodology for risk analysis at the program level presented in this report is intended as a guide—individual program managers may tailor the risk criteria ranges and other values as they deem appropriate. Thus, program results aggregated at the NASA level will convey the perspectives of the individual programs. Provided that the program tailoring is consistent with the standard definitions in Table 4-1 and Table 4-5, the aggregated results should be sufficiently consistent to enable analysis at the enterprise level.

CONCLUSION

Like other commercial and government organizations, NASA's supply chains are vulnerable to supplier viability risk, in terms of business- and process-related events. Monitoring specific supplier viability risks (beginning with a supplier's financial health and eventually growing to other areas of risk), evaluating the likelihood and consequences of risks for each supplier, following risk identification best practices, and implementing key risk mitigation strategies will allow NASA to alleviate supplier risk for individual programs first, and then roll benefits up to the NASA enterprise level.

Appendix A
Calculating a Z-Score

The Z-score model[1] uses financial statement ratios and multiple discriminate analysis to assess a company's risk of going into bankruptcy. The Z-score has proven to be an accurate tool for predicting financial distress and is widely used as a risk assessment tool. There are two Z-score calculation methods, one for publicly traded companies and one for private companies.

Z-Score for Public Companies

The Z-score calculation for publically traded companies is shown in Equation A-1.

Equation A-1. Z-Score Calculation for Publically Traded Companies

$$Z = 3.3\frac{EBIT}{Total\ Assets} + 1.2\frac{Net\ Working\ Capital}{Total\ Assets} + 1.0\frac{Sales}{Total\ Assets} + 0.6\frac{Market\ Value\ of\ Equity}{Book\ Value\ of\ Debt} + 1.4\frac{Accumulated\ Retained\ Earnings}{Total\ Assets}$$

where Z is the Z-score for the company
and *EBIT* is earnings before interest and taxes.

In practice, Altman found that a score between 1.81 and 2.99 indicates that a firm is having financial difficulty and a score below 1.81 predicts bankruptcy.

Z-Score for Private Companies

Because privately owned companies have different financial structures, there is a different Z-score calculation for private companies. That calculation is shown in Equation A-2.

[1] Stephen Ross, Randolph Westerfield, and Jeffrey Jaffe, *Corporate Finance*, 5th Edition, Irwin/McGraw-Hill, 1999. Edward Altman developed the Z-score model for predicting corporate bankruptcy.

Equation A-2. Z-score Calculation for Private Companies

$$Z = 0.717\frac{Net\ Working\ Capital}{Total\ Assets} + 0.847\frac{Accumulated\ Retained\ Earnings}{Total\ Assets} + 3.107\frac{EBIT}{Total\ Assets} + 0.420\frac{Book\ Value\ of\ Equity}{Total\ Liabilities} + 0.998\frac{Sales}{Total\ Assets}$$

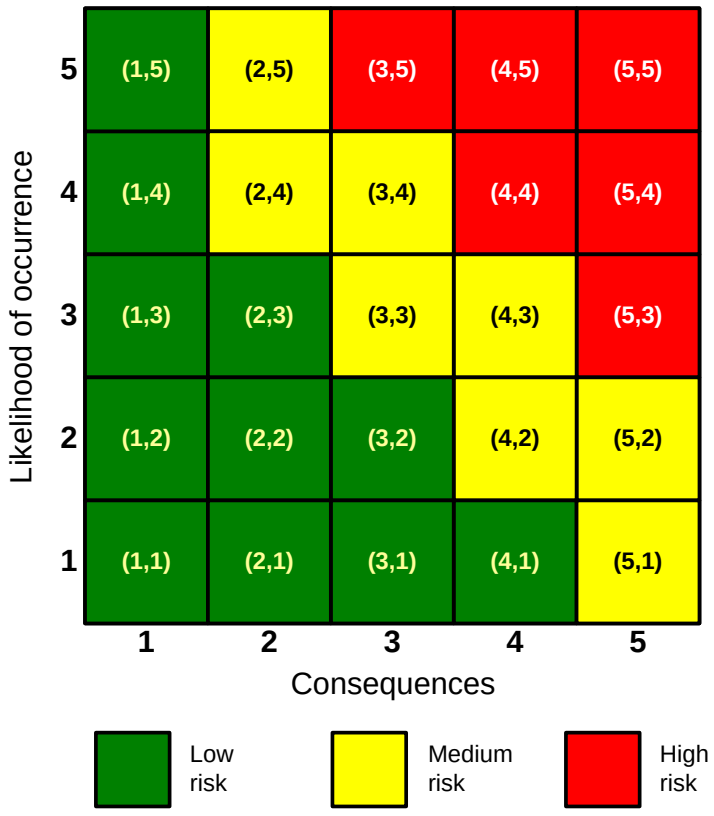
The results for private companies are interpreted differently, as well. A Z-score below 1.23 predicts bankruptcy, a score between 1.23 and 2.90 indicates financial difficulty, and a score above 2.90 indicates the firm is financially healthy.

Appendix B
Risk Aggregation

NASA needs two levels of supplier viability management: at the program level and at the enterprise level. The framework we are recommending for NASA to manage supplier risk can be used at both. This is a useful approach to allow program level assessments to be used to evaluate the total risk to NASA.

Our recommended risk assessment approach is based on an evaluation of a supplier's likelihood of failure and the consequence of failure to the NASA program's mission. The likelihood and consequence ratings for the supplier are then plotted using a matrix, as shown in Figure B-1.

Figure B-1. Recommended Risk Assessment Matrix



To aggregate this assessment from the program level to the enterprise level, we need to understand how the perspectives of likelihood and consequence differ at those two levels. The likelihood of supplier failure does not change from the program perspective to the enterprise perspective. In other words, the likelihood is an assessment of the supplier's financial health, and the financial health is in no way

dependant on who is observing the supplier. For this reason, the same likelihood assessment of a supplier can be used at both the program and the enterprise levels.

The consequence of a supplier failure, on the other hand, changes in two ways as we move from a program to an enterprise perspective. The first consequence change is in the importance of the individual program to the NASA enterprise mission. A supplier failure that can significantly impact a program may not be a large concern at the enterprise level if the program is not critical to NASA's mission. Likewise, a supplier failure that has a moderate impact on a program may have a large impact at the enterprise level if that program is critical to achieving NASA's enterprise goals. So, the consequence of failure must be weighted by the importance of the program to the enterprise.

The second way the perception of consequence changes at the enterprise level is by the number of programs a supplier supports. While a supplier failure may have a moderate impact on a specific program, the impact at the enterprise may be severe if that supplier is supporting multiple NASA programs.

We recommend a consequence aggregation method that accounts for the ways that consequence changes at the enterprise level. The recommended approach is based on assigning a weight to each NASA program. Each supplier's consequence rating can then be multiplied by the weights of all programs the supplier supports. So the total consequence rating for a supplier is shown in:

Equation B-1. Calculation for Total Consequence Rating

$$Consequence_{total} \qquad Consequence_{program} \times Weight_{program}$$

ASSIGNING PROGRAM WEIGHTS

Not all NASA programs are equal in their importance to the NASA mission. To recognize the relative importance of the programs in aggregating risk, we assign a percentage weight to each program, with the total of program weights across the NASA enterprise summing to 100 percent.

This weighting approach achieves two goals. First, it puts the program level consequence of failure into an enterprise perspective based on the importance of the program. Second, the enterprise consequence of a supplier failure is increased as the supplier supports more programs.

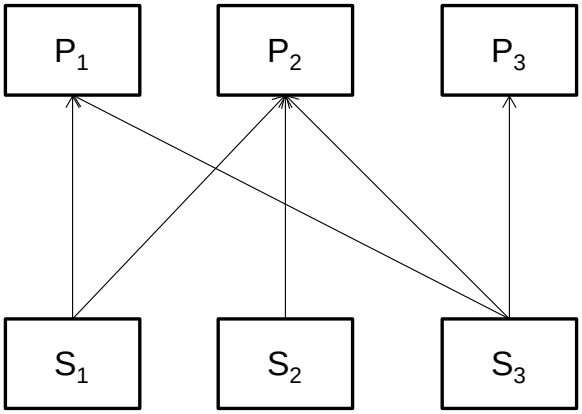
CALCULATING ENTERPRISE CONSEQUENCE

Calculating the consequence of a failure at the enterprise level is then a matter of summing the program consequences and program weights for a given supplier. Note that the program consequences for a supplier can differ across programs. The same supplier can be providing a critical technology to one program and common commercial parts to another. This is a simple summation calculation to arrive at the total enterprise consequence of a supplier failure.

AGGREGATION EXAMPLE

The following example, illustrated by Figure B-2, illustrates our recommended approach.

Figure B-2. Aggregation Example



In this example, there are three programs (P_1, P_2, and P_3) and three suppliers (S_1, S_2, and S_3). S_1 supports P_1 and P_2; S_2 supports P_2; and S_3 supports P_1, P_2, and P_3.

In an evaluation of the significance of the significance of each program to NASA's overall mission, P_2 has been weighted to reflect its greater importance, followed by P_3 and then P_1, as shown in Table B-1.

Table B-1. Program Weights

Program	Weight
P_1	20%
P_2	50%
P_3	30%

According to our approach, the first step is assessing the suppliers' risk at the program level. The program risk ratings for these suppliers are shown in Table B-2:

Table B-2. Program Risk Ratings

Supplier	Likelihood[a]	P_1 Consequence[b]	P_2 Consequence[b]	P_3 Consequence[b]
S_1	3	4	3	N/A
S_2	4	N/A	5	N/A
S_3	5	3	3	3

[a] The likelihood ratings are based on the schema defined in Chapter 4, Table 4-5.

[a] The consequence ratings are based on the schema defined in Chapter 4, Table 4-1.

Given this information, the enterprise consequence ratings for each supplier are as follows:

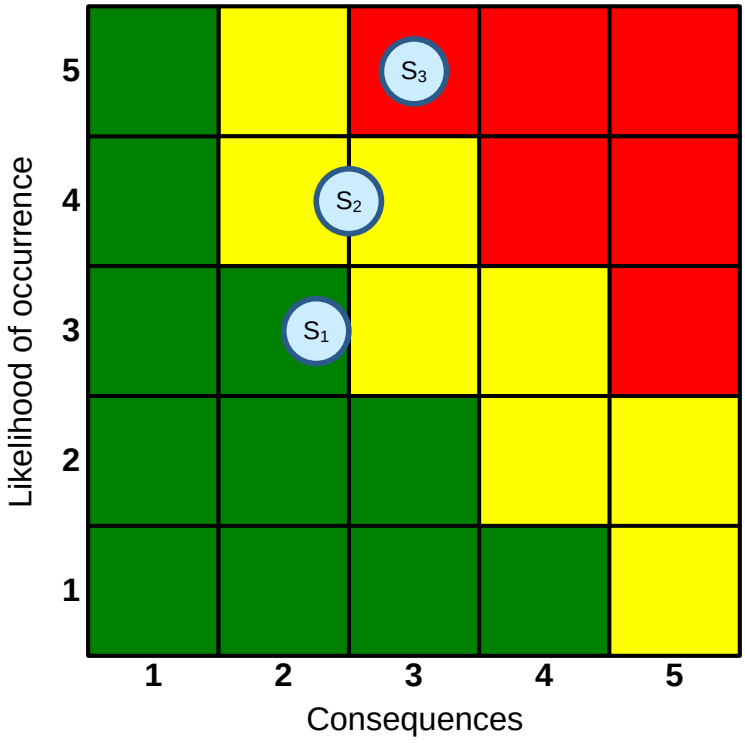
$$S_1 = 4 \times 20\% + 3 \times 50\% = 2.3$$

$$S_2 = 5 \times 50\% = 2.5$$

$$S_3 = 3 \times 20\% + 3 \times 50\% + 3 \times 30\% = 3.0$$

When plotted in the risk assessment matrix (see Figure B-3), we can see that S_3 shows the highest risk to the enterprise due to the number of programs the supplier supports, even though it only exhibits a moderate risk to any program.

Figure B-3. Aggregation Example Plotted in the Risk Assessment Matrix



Appendix C
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Orbital Replacement Unit (ORU) Spares, International Space Station Program.

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