Using SCOR as a Supply Chain Management Framework for Government Agency Contract Requirements

Joseph Paxton
Office for Enterprise Innovation and Sustainability
University of Alabama in Huntsville
Huntsville, AL 35899
256-824-4284
joe.paxton@uah.edu

Brian Tucker
Office for Enterprise Innovation and Sustainability
University of Alabama in Huntsville
Huntsville, AL 35899
256-824-2957
brian.tucker@uah.edu

Abstract – This paper will present a model that uses the Supply-Chain Operations Reference (SCOR) model as a foundation for a framework to illustrate the information needed throughout a product lifecycle to support a healthy supply chain management function and the subsequent contract requirements to enable it. It will also show where in the supply chain the information must be extracted. The ongoing case study used to exemplify the model is NASA's (National Aeronautics and Space Administration) Ares I program for human spaceflight.

Effective supply chain management and contract requirements are ongoing opportunities for continuous improvement within government agencies, specifically development of systems for human spaceflight operations. Multiple reports from the Government Accountability Office (GAO) reinforce this importance. [1]-[5]

The SCOR model is a framework for describing a supply chain with process building blocks and business activities. It provides a set of metrics for measuring supply chain performance and best practices for continuously improving. This paper expands the application of the SCOR to also provide the framework for defining information needed from different levels of the supply chain and at different phases of the lifecycle. These needs can be incorporated into contracts to enable more effective supply chain management. Depending on the phase of the lifecycle, effective supply chain management will require involvement from different levels of the organization and different levels of the supply chain. [1 2]

TABLE OF CONTENTS

1. INTRODUCTION

According to Galluzzi [6], 70-80% of operational recurring costs in NASA programs are influenced by the initial phase of the product lifecycle. Furthermore, sustainment activities are delegated from the Program level to the Project Offices and typically outsourced to contractors.

Supply chain management depends on information flow from throughout the supply chain. However, dependency on your own supply chain to manage the supply chain could be disastrous. Too often, government agencies make decisions early in the lifecycle of a program to reduce immediate costs in exchange for longer term operational and sustainment costs that become out of control. One reason for operational and sustainment costs to become out of control is lack of supply chain planning early in the lifecycle and lack of Program and Agency level supply chain management activities. Much of the supply chain management responsibility is delegated, often informally, to the prime contractors who are not ultimately accountable.

In a report related to ineffective supply chain management practices within the Department of Defense [7], GAO identified three key areas of weakness and provided the criteria for being removed from the high-risk designation. The key weakness areas include:

- Accuracy of supply requirements forecasts
- Distribution of material
- Asset visibility

There is a clear need in the Department of Defense and in NASA, as well as other government agencies, to have effective supply chain management practices in place. As stewards of taxpayer money, proper and efficient use of funds is imperative. This paper suggests using the SCOR Model as a framework for structuring supply chain management activities, as well as providing a means for identifying contract requirements including, but not limited to, information flow to and from the supply chain and

[1] 978-1-4244-3888-4/10/$25.00 ©2010 IEEE
[2] IEEEAC paper #1656, Version 2, Updated November 6, 2009

dissemination of effective supply chain management practices.

2. Enterprise Supply Chain

Supply chain management can take on various meanings in different organizations. It has been referred to any one of the following or a combination thereof:

- procurement of products or services
- logistics of moving a product from one location to another
- distribution of goods or services to customers
- managing the link with one's suppliers and customers

For complex systems that are dependent on activities and issues deep in the supply chain or late in the lifecycle of a system, none of the above definitions will suffice by itself. In these cases, an enterprise approach is needed that can cover all levels of the supply chain and all phases of the lifecycle. Some of the functions of enterprise supply chain management include:

- specifying suppliers to support inter-program and inter-agency efforts
- optimizing inventory levels and locations throughout the supply chain
- executing corrective actions to improve quality and lead time issues throughout the supply chain
- processing reported data to calculate and make visible supply chain performance (provide information for decisions and actions)
- ensuring the right hardware and information is provided at the right time and in the right place
- monitoring the industrial base while producing, operating and retiring a system
- seeing performance deep in the supply chain that could indicate issues affecting system availability and readiness

By managing the supply chain from an enterprise viewpoint, several benefits can be realized. By having the perspective of multiple (and perhaps all) levels of the supply chain and visibility therein, supply chain nodes can be identified from which information needs to originate and where it needs to flow to support supply chain management functions. This high level visibility also enables inter-project, inter-program and inter-agency supply chain improvements. Suppliers that are shared can be highlighted, points of internal competition for common resources can be addressed, and investment can be made in better-performing suppliers while costs can be eliminated for under-performing ones. In supply chains of highly specialized products and services, it is often the case that suppliers far upstream in the supply chain are common among programs and systems due to their unique capabilities. Only with an enterprise view can this be realized.

Another benefit of an enterprise approach is the strategic optimization of overall inventory levels and placement. Total supply chain inventory costs can be reduced, overall lead time can be reduced and cash flow and profitability of all supply chain entities can be improved.

3. Importance of Supply Chain Management

Galluzzi defines an Exploration Supply Chain as “the integration of NASA centers, facilities, third party enterprises, orbital entities, space locations, and space carriers that network/partner together to plan, execute, and enable an Exploration mission that will deliver an Exploration product (crew, supplies, data, information, knowledge, and physical samples) and to provide the after delivery support, services, and returns that may be requested by the customer.” [6].

In a vertically integrated company, controlling the supply of parts and materials was relatively easy because it was under the umbrella of the customer organization. For example, in the early twentieth century, Ford Motor Company was vertically integrated and included operations from smelting iron ore into steel to the final assembly and delivery of a vehicle. Today, components and services are designed and manufactured all over the world. Tomorrow, human spaceflight supply chains will be spread beyond Earth to the moon and other planets.

Supply chains have become global, creating physical and cultural barriers, extending lead times and hindering the flow of information. To satisfy the customer (cost, quality, delivery), supply chains must operate effectively, efficiently and integrally. For high value products and systems such as those supporting human spaceflight, quality and delivery are critical. Quality cannot be sacrificed or human lives may be at stake. Simultaneously, problems must be identified and addressed immediately to prevent costly budget and schedule overruns.

Government agencies depend on the prime contractor and often relinquish supply chain management to them. Responsibility still lies with the agency. In NASA's case, the launch vehicle is ultimately NASA's responsibility. While they may be the customer of the prime contractors, NASA's customers are the US government, the taxpayers and the human race.

All requirements are put in a contract, including deliverables, schedules, information flow, etc. It is almost impossible to list everything that may be needed throughout the life of the contract. Any additional information typically requires a contract modification and additional cost (not including the cost of changing the contract). Relationships between government agencies and contractors must allow for flow of information that does not restrict the performance of the supply chain and needs of the agency.

4. SCOR

The SCOR model is a framework for describing a supply chain with process building blocks and business activities. It also provides a set of metrics for measuring supply chain performance and best practices for continuously improving. The primary building blocks of the SCOR model are PLAN, SOURCE, MAKE, DELIVER and RETURN. They are defined by the Supply-Chain Council as follows [8]:

- PLAN - business activities associated with determining requirements and corrective actions to achieve supply chain objectives. It is broken down into five segments for Planning the Supply Chain, Planning Source, Planning Make, Planning Deliver and Planning Return

- SOURCE – business activities associated with ordering, delivery, receipt and transfer of raw material items, subassemblies, product and/or services

- MAKE – business activities associated with adding value to products through mixing, separating, forming, machining, and chemical processes

- DELIVER – business activities associated with performing customer-facing order management and order fulfillment activities

- RETURN – business activities associated with moving material from the customer back through the supply chain to address defects in product, ordering, or manufacturing, or to perform upkeep activities

Figure 1 illustrates how these building blocks are incorporated into a supply chain ranging from a company's supplier's supplier to a customer's customer. The activities associated with Plan, Source, Make, Deliver and Return occur at multiple locations throughout the supply chain. The value of the SCOR model is to structure these activities with a standard framework, as well as provide standard metrics for measuring their performance and best practices for improving them. Each item illustrated in Figure 1 (Plan, Source, Make, Deliver and Return) consists of multiple business processes in the SCOR model. For example, the sequence of process elements in the SOURCE building block for a stocked product are shown in Figure 2. Furthermore, the SCOR model consists of specific inputs, outputs and associated metrics and best practices for each of these process elements.

The value of the SCOR model is the standardized framework it provides for modeling a supply chain that can be used independent of the industry or organization.

5. MISSION PERSPECTIVE OF THE SUPPLY CHAIN

Mission development and operations is a higher level perspective than the development of a specific launch vehicle or set of flight hardware. It can encompass the development of multiple launch vehicles with varying configurations, experiments and other cargo to fly aboard the vehicles, development of astronauts to carry out the mission, development of requirements for the mission and extensive research and development of technologies and processes to discover the unknown. From that perspective, Agency and Program level supply chain interests reach beyond traditional supply chain management practices. These supply chains can be multi-generational and consist of hardware of the utmost value. Issues and questions that must be addressed include:

- Will the program last through the planned lifecycle?
  - Will parts continue to be available?
  - Will expertise be available if parts fail (identify reason and re-design or re-mfg, etc.)?
  - Will expertise be there if mission changes and performance requirements change (on moon longer, land on asteroid vs. moon, unknowns from lessons learned during missions)?
- Can inventory throughout the supply chain be optimized to save overall (not just at a single level)?
- Are NASA expectations of primes relegated through the supply chain? Are upstream levels of the supply chain exercising supply chain management best practices?
- Is the supply chain advancing in maturity with progression through the product?
- Will mission schedule and budget be sustained through the operation phase of the lifecycle? Will the industrial base continue to meet the mission requirements?

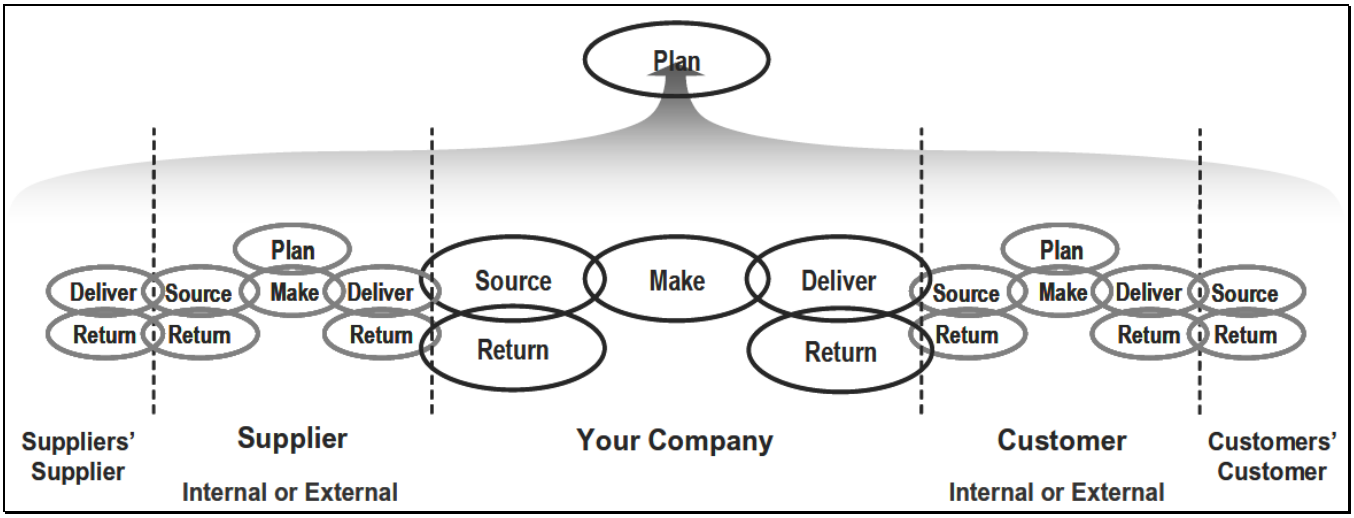

Figure 1 – SCOR Model

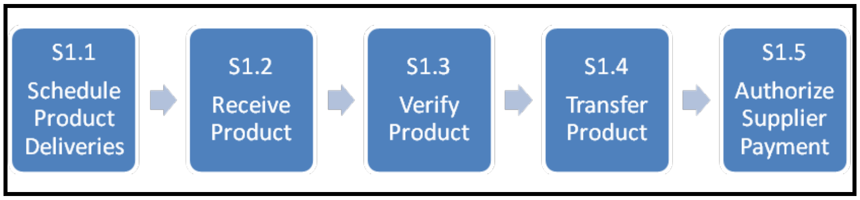

Figure 2 – Level 3 process elements of the Level 1 SOURCE process

6. Supply Chain Lifecycle Phases

The management processes below and Figure 3 illustrate how the SCOR model can be used as a framework for supply chain management activities performed from a mission development and operations perspective. As the perspective changes to a specific launch vehicle or flight hardware, the activities associated with PLAN, SOURCE, MAKE, DELIVER and RETURN transform to the traditional SCOR model. Nonetheless, the SCOR model still provides a framework for supply chain management at the mission development and operations level.

PLAN

From a mission development and operations perspective, PLAN activities performed by the supply chain management function in support of mission development would include:

- defining metrics to measure supply chain performance
- identifying what responsibilities would lie with the Agency, Program and Project offices
- ensuring that all Agency requirements and directives are satisfied

From a mission development and operations perspective, the responsibility of the PLAN activities would lie at the Agency level. However, as with the other management processes, involvement by the Program Offices, Project Offices, prime contractors and sub-suppliers will be necessary to support these activities.

SOURCE

From a mission development and operations perspective, it cannot be assumed that the supply base even exists to provide the conceptualized hardware and integration thereof. It is necessary in the early lifecycle phases, such as conceptualization, to determine if technologies and processes exist or can be developed to support the mission.

In the case of the Constellation Program, NASA conceptualized and designed the Ares I launch vehicle and is contracting out the production of it. Two methods of determining the availability, or potential availability, of technologies and processes prior to submitting a request for proposal (RFP) for a contract is to maintain what capabilities are available in the industrial base and/or submit a Request for Information (RFI). Knowing what capabilities exist in the industrial base can contribute to ensuring the concept or design will be manufacturable. Regarding the RFI, one purpose is to gain feedback from potential contractors to help with the development of the RFP. It would serve no purpose to go through the cost and time to develop an RFP only to have potential contractors not bid due to the request of something not feasible or of no interest to the contractors.

There are other benefits to remaining knowledgeable of the industrial base in addition to supporting design for manufacturability. NASA missions often require processes on the leading edge of technological capability, if not actually requiring new technologies to be developed. These new technologies and processes may be further developed for application within the Department of Defense or commercial programs, or they may remain only in support of NASA programs. The less demand for the processes or technologies, the more important it is for NASA to ensure their availability to support the long lifecycle of their own programs. Some examples of unique capabilities may include friction stir welding, specialty materials and alloys and large composite structures. Friction stir welding is continuing to be used in many applications while NASA continues to develop and push the technology to new heights. While other markets are utilizing this technology, NASA continues to increase the requirements by using it for curved surfaces and large structures. Specialty alloys are also needed to provide specific strength and weight performance, such as the aluminum-lithium alloy used for the external tank of the Shuttle and segments of the Ares I Upper Stage. A final example is large composite structures. Autoclaves large enough for curing composites for fairings on the Ares V heavy launch vehicle do not even exist today. These are only a few examples highlighting the need for NASA to monitor and maintain the capabilities of the industrial base.

In addition to knowing the capabilities of the industrial base, it is equally important to know the health of it as well. If the industrial base is not monitored and action is not taken when necessary throughout a program lifecycle and between programs, the risk of obsolescence and part unavailability increases dramatically. Obsolescence can occur due to a variety of industrial base weaknesses, including:

- reduction of multiple manufacturers – decreases available sources
- decrease in the financial liquidity of suppliers – constrains ability of suppliers to operate effectively
- dependency of suppliers on a NASA program – fluctuation in NASA's demand greatly impacts ability for supplier to operate
- evolution of technology – sources for older technologies diminish with decreasing demand

It is obvious that there is more obsolescence risk with a sole-source supplier as opposed to multiple suppliers. However, it is still necessary to monitor the industrial base for changes such as companies dissolving and resulting in a sole-supplier situation. Sole-suppliers can be beneficial at times if it is cost-prohibitive to invest in technology or capability at multiple sources. At the same time, it is necessary to know the financial stability of the sole-source provider to maintain the flow of hardware. Similarly, if a supplier is fully dependent on a NASA program and delays occur in the mission or demand is not sufficient to continue operation, the manufacturer may not be able to stay in business. There are ongoing efforts to address this by utilizing suppliers across programs and even across government agencies. Finally, a more traditional obsolescence issue is technology itself becoming obsolete due to advancement. For example, the Shuttle uses computing technology from the 1980's. This has been obsolete many times over due to the rapid advancement and adoption of new technologies. However, the older technology is still needed to support the Shuttle program and can be difficult to find sources. The system is so complex that testing and integration of new technology is cost-prohibitive. The major point to be made regarding obsolescence is that the industrial base must be monitored and action taken when necessary. It cannot be assumed that hardware will continue to be available when needed for a program that can span decades.

MAKE

From a mission development and operations perspective, MAKE carries a similar meaning. It includes the production of the flight hardware. Of particular importance from a Project, Program and Agency level is the cost and lead time of hardware up through the supply chain. While many companies are interested primarily in the tier one cost and delivery, issues that affect complex systems may arise much deeper in the supply chain. There are often many critical items and critical suppliers in NASA supply chains. For example, as previously mentioned in the case of specialty alloys, a performance problem very deep in the supply chain may result in a significant delay for the mission due to limited resources for that material. Therefore, it is necessary to know what companies are members of the supply chain (sometimes to the deepest level) and have visibility of their performance. If an issue arises, corrective action can be taken before delays impact the mission and cause extreme undue costs.

Another opportunity during the MAKE phase is to optimize inventory levels throughout the supply chain. If an enterprise view is not taken in optimizing inventory, reductions in inventory can simply result in moving the inventory up and down the supply chain out of sight of the optimizing entity. While this may reduce the cost to some, it more than likely will just move the cost. To truly reduce inventory costs, an enterprise view must be taken so inventory is only located where necessary. Typically, inventory should be located as far upstream as possible that still satisfies availability and readiness needs. It may be possible with an enterprise view to strategically locate inventory several supply chain links upstream and still meet downstream demands. The enterprise view, along with supply chain mapping, enables seeing all links of the supply chain and associated lead times and, thus, the best location and minimum amount of inventory needed to meet delivery requirements.

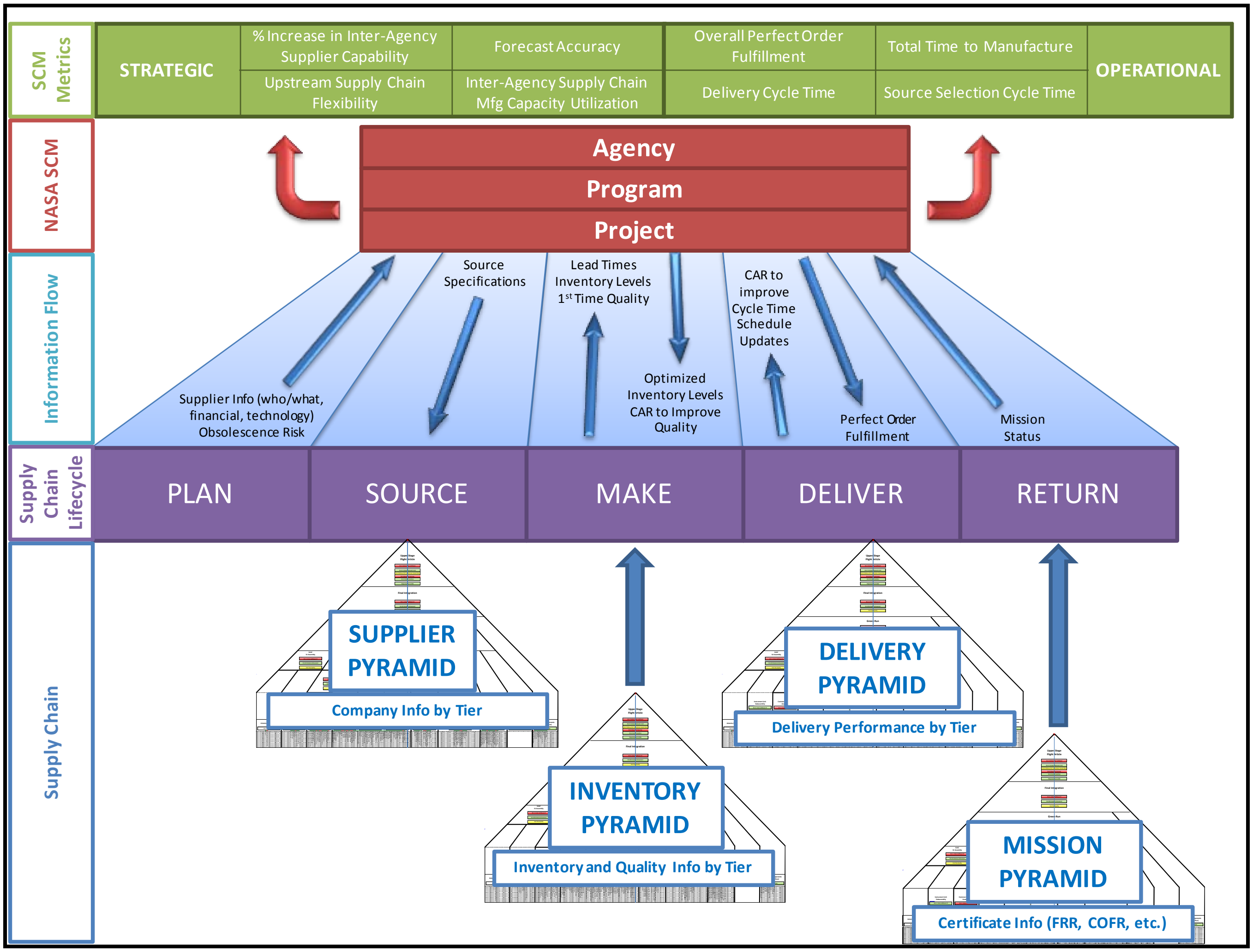

Figure 3 – Supply chain management information flow overlaying the SCOR Model

DELIVER

From a mission development and operations perspective, the Agency's interest lies with schedule compliance, logistics, cycle time improvements, and mission status tracking. As previously mentioned, GAO reports have identified numerous cases of budget and schedule overruns by government agencies. These often occur during the operation phase of the lifecycle, making schedule compliance and cycle time improvements of particular importance. During this phase, the traditional SCOR metrics are very applicable. The opportunity lies with using the metrics through multiple levels of the supply chain and taking corrective action when underperformance occurs. Delivery issues at lower levels of the supply chain can indicate future problems. Unfortunately, delivery performance by government agencies is usually only measured at the prime contract interface and requirements to take preventive measures at lower levels do not exist. Furthermore, actions taken by the prime contractors are often limited to what is explicitly stated in the contract. If there is not a contract requirement to relegate supply chain management down through the supply chain, it will most likely not occur.

Another characteristic of NASA supply chains is the parallel development of multiple complex systems that must be integrated into larger systems or programs. For example, the Ares I launch vehicle consists of three major systems: First Stage, Upper Stage and the Orion capsule. The First Stage is a variation of the boosters used on the Shuttle, while the Upper Stage and Orion are completely new systems. The on-time delivery of any one of these systems by itself is difficult. The coordination of all three is much more of a challenge. To complicate the case even further, the Constellation Program will eventually rely on the Ares I launch vehicle and the Ares V launch vehicle to liftoff within 90 minutes of each other. That will require the integration and delivery of two very complex launch vehicles to be integrated and prepared for launch with unmatched delivery requirements. With lower cost systems, inventory can provide a buffer to the time requirements. Cost and ground support resources prohibit this from happening in NASA's case.

Reaching into the operation phase of the mission, replacement parts (often Line Replaceable Units, or LRUs) must be available. Since the operation of the program can span decades, on-time delivery and availability is dependent on the sustainment of the industrial base. Not only must the industrial base exist, it must be able to perform at a level needed to meet program requirements. Tooling, processes and people must be sustained at a "ready" status to avoid additional costs and delays. Visibility of the industrial base and associated monitoring is needed to ensure this.

One final aspect of DELIVERY is that of information. Effective supply chain management relies on access to key data and information. Some of the information that may enable effective supply chain management is not normally required explicitly in the prime contract while other information is cited in the contract, but may not be delivered in a timely fashion. Much of the information not typically listed in the contract has been discussed. There are also gates throughout the lifecycle that require review of mission status prior to advancing to the next phase or approving go-ahead for launch. Examples of this in NASA's system development process include Flight Readiness Reviews and approval of Certificates of Flight Readiness. If information is not delivered on-time for these reviews, unnecessary costs and delays are incurred, as well as the need to develop plans to address open issues that were not known prior to the review.

RETURN

From a mission development and operations perspective, the RETURN phase can include recovery and refurbishment of launch vehicle components, return of experiments and data, as well as the traditional return of hardware for repair. At a higher level, the transition between missions and transfer of technology are also addressed. The return of hardware and experiments is analogous to traditional returns. However, transition between missions and technology transfer are more unusual. Industrial base sustainment is once again important during mission transition. In spaceflight, technologies and processes from previous programs are often further developed for future missions. Therefore it is imperative that key industrial base partners remain healthy and available. Sustaining that health can be difficult between programs when purchase orders are scarce. It may be necessary to continue investment through other means to maintain these resources. Technology transfer is also important. Taxpayer money is used to develop new technologies to support space exploration and efforts are made to return that investment through the commercialization of technology. A secondary benefit of technology transfer is diversifying the products available from the industrial base. Through the development of commercial products, these companies are able to become less dependent on government programs and more likely to succeed longer term.

7. Contract Implications

Referring back to Figure 3 and the previous section of this paper, there is a need for information to flow to and from the supply chain at each one of the supply chain lifecycle phases (Plan, Source, Make, Deliver and Return). By using the SCOR model to provide a framework for these phases, the information needed is more easily identified, as well as where it should originate and when it is needed. For example, information on the health of the industrial base is needed during the Source phase to identify capable suppliers, address internal competition across programs for a single supplier's capacity, and provide direction to better utilize suppliers across agencies to maintain their viability. Furthermore, industrial base information is needed during the Make and Deliver phases to ensure the availability of hardware to support ongoing missions. Lastly, the sustainability of the industrial base becomes a key factor during the Return phase as one program is retired and another begins conceptualization.

8. Summary

In summary, this paper has discussed the need for effective supply chain management, particularly for human spaceflight systems. It has also discussed an approach for and the importance of managing a supply chain from an enterprise perspective. The application of the SCOR model can be broadened to be used for this enterprise (or mission) view of the supply chain for human spaceflight programs and systems. It has also been shown that the five building blocks of the SCOR model (Plan, Source, Make, Deliver and Return) can represent lifecycle phases of the supply chain and identify the importance of specific information that needs to flow to and from the supply chain at particular phases.

References

[1] United States Government Accountability Office. *Defense Inventory: Management Actions Needed to Improve the Cost Efficiency of the Navy's Spare Parts Inventory*. GAO-09-103. December 2008.

[2] United States Government Accountability Office. *Defense Logistics: Lack of Key Information May Impede DOD's Ability to Improve Supply Chain Management*. GAO-09-150. January 2009.

[3] United States Government Accountability Office. *DOD Business Transformation: Lack of an Integrated Strategy Puts the Army's Asset Visibility System Investments at Risk*. GAO-07-860. July 2007.

[4] United States Government Accountability Office. *DOD's High-Risk Areas: Actions Needed to Reduce*

Vulnerabilities and Improve Business Outcomes. GAO-09-460T. March 12, 2009.

[5] United States Government Accountability Office. *DOD's High-Risk Areas: Actions Needed to Reduce Vulnerabilities and Improve Business Outcomes*. GAO-09-460T. March 12, 2009.

[6] M. Galluzzi & E. Zapata. *Foundations of Supply Chain Management for Space Application*. SpaceOps 2006, September, Number AIAA 2006-7234, 2006.

[7] United States Government Accountability Office. *DOD'S HIGH-RISK AREAS: High-Level Commitment and Oversight Needed for DOD Supply Chain Plan to Succeed*. GAO-06-113T. October 6, 2005.

[8] SCOR Model Reference Version 9.0. Supply Chain Council. April 2008.

ACKNOWLEDGEMENTS

The authors would like to thank Michael Galluzzi, NASA Constellation Supply Chain Manager, and John Vickers, NASA National Center for Advanced Manufacturing Manager, and Marshall Space Flight Center for their support of the research leading to this paper. The authors would also like to recognize Jacobs ESTS Group under whose subcontract this work was performed.

BIOGRAPHY

***Joseph Paxton** is a Principal Research Scientist in the Office for Enterprise Innovation and Sustainability at the University of Alabama in Huntsville. He has over 15 years experience in engineering and engineering management in private, public and state and federal government organizations. He has experience in training and implementing lean manufacturing, as well as optimizing supply chains. He has trained personnel, facilitated continuous improvement activities and coached executives in numerous industries, including automotive, electronics, medical, industrial equipment, forest products, and aerospace/defense. His most recent experience involves mapping and optimizing supply chains for the NASA Ares launch vehicle and various U.S. Army weapon systems, as well as improving manufacturing operations and demand planning processes for a major commercial/military aerospace supplier.*

Mr. Paxton is a NIST certified trainer in Principles of Lean Manufacturing, 5S, Quick Changeover, Kanban/Pull Systems, Total Productive Maintenance and Value Stream Mapping. He holds a Bachelor's degree in Mechanical Engineering and a Master's degree in Industrial and Systems Engineering with a major in Manufacturing Systems.

***Brian Tucker** is a Research Scientist in the Office of Enterprise Innovation and Sustainability at the University of Alabama in Huntsville where he provides supply chain and product life cycle management support for both private and government organizations. Mr. Tucker has over 17 years of engineering and management experience in various industries including metals, appliance, automotive, forest products, aerospace and defense. His work experience includes roles as Supply Chain Operations Lead, Supply Chain Continuous Improvement Engineer, Lean Trainer/Facilitator, Production Manager, Engineering Services Manager, Manufacturing Engineer and Quality Engineer. Mr. Tucker has a Bachelors Degree in Industrial and Systems Engineering and is currently pursuing a Master's degree in Industrial Engineering with a major in Manufacturing Systems from the University of Alabama in Huntsville.*