A Qualitative Mapping and Evaluation of an Aerospace Supply Chain Strategy

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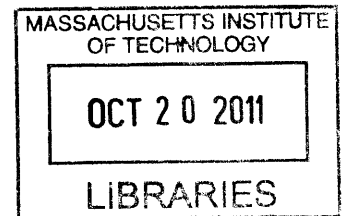
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ABSTRACT

An effective supply chain is critical to the success of the products and services sold by companies. Companies must have an explicit understanding of what the supply chain strategy is in order to evaluate it. While most organizations have well-documented business strategies, they lack the same for their supply chain strategy. The methodology proposed by Perez-Franco, Singh, and Sheffi (2011a; 2011b) is a way to evaluate a supply chain strategy by using interviews, surveys, and discussions. The goal for this project was to test the applicability of the Perez-Franco et al. methodology to the aerospace industry through an applied case. We conducted a qualitative mapping of the supply chain strategy for a specific satellite program in Lockheed Martin Space Systems (LMSS). This thesis research is the first time the methodology has been applied and tested with a company in the aerospace industry.

As a whole, LMSS has increased focus on their supply chain, and works to directly align their supply chain with their business objectives. For our case, we selected a specific project within the Space Systems division that lacks an explicitly stated supply chain strategy and has a potential gap with objectives.

Through our research, we found that the Perez-Franco et al. methodology is applicable to the aerospace industry. As a result of this case application, we propose and present potential deviations and additions to build upon the methodology that yields interesting insights. The results with LMSS revealed areas of disagreement identified through evaluating themes of support, consistency, and sufficiency. Additionally, the methodology allowed us to conduct a diagnostic of the supply chain strategy against business goals. The primary conclusion in the diagnostic was a perceived conflict between quality and affordability initiatives. This is the key recommendation that the company should investigate further to locate the root cause(s) of the disagreement. Outcomes from this case show that the methodology can be applied to a wide number of industries.

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1. INTRODUCTION

The global outsourcing wave has continued to gain momentum, leading to increasingly complex supply chains. Because of this trend, supply chains have much larger impacts on businesses than in previous generations. Extensive research has been done on how to optimize models and manage the physical aspects of these networks. However, evaluating the firm's supply chain strategy, largely made up of the actions and activities performed, has been neglected in research until recently. This change in research coincides with the increasing importance of supply chains requiring that they align with the general business strategy.

Perez-Franco, Singh, and Sheffi (2011b) have proposed a methodology "to conduct an assessment of the firm's current supply chain strategy." In order to evaluate a supply chain strategy, one has to be able to discuss it in concrete terms. Therefore, Perez-Franco, Singh, and Sheffi (2011a) have also proposed a methodology for "captur[ing] and express[ing] a firm's supply chain strategy." These are usually referred to as distinct phases of a larger methodology for the development of the supply chain strategy, namely the Capture Phase and Evaluation Phase. By using the Capture Phase of the methodology, we are then able to evaluate the effectiveness of an aerospace firm's supply chain strategy. In their development of this method, they have applied it to a number of different industries; however, it has not been assessed in the aerospace sector (Perez-Franco, 2010; Perez-Franco, *et al.*, 2011b).

As an aerospace company, Lockheed Martin Space Systems is quite aware that an effective supply chain is critical to the success of the many products the company produces. Increased focus and demands on the company's supply chain necessitate a strategy that directly aligns with business objectives and expectations to deliver robust, high-quality products to customers in a timely manner. However, recent shifts in production and procurement policy

bring about the need for an evaluation of the supply chain approach for potential gaps with the current business strategy. One main change that has occurred is the consolidation of procurement specialists to a centralized location with a focus across different product programs. Traditionally, this role had been done within each program individually with little cross-program communication. Furthermore, affordability goals are driving the company towards alternative approaches to supply chain management. Lockheed's main customer, the U.S. Government, has increasing concerns over costs due to the tightening of the Federal Budget leading to cuts in government spending.

1.1 The Nature of the Problem

The key research focus for this thesis is the applicability of the capture and Evaluation Phases from the Perez-Franco *et al.* methodology to the aerospace industry (2011a; 2011b). Specifically, it is used to understand the effectiveness of the current supply chain strategy of a low-volume, highly regulated aerospace program in supporting its current and future business strategies. While the Space Systems division encompasses many products, we are applying the methodology to a single, new project. For purposes of masking the identity of this project, from here on it shall be referred as LMT-11. LMT-11, like many other projects, lacks an explicitly stated existing supply chain strategy.

In order for LMT-11 to stay competitive and to be able to keep selling their product to their customers, they have to have a responsive supply chain to take advantage of any potential changes or adjustments to the aerospace industry. It is difficult to get to where a company wants to be without knowing where it is today. Therefore, LMT-11 must understand its current supply chain strategy in order to adapt to any necessary changes that might occur through the course of doing business.

1.2 Research Objective

By looking at a specific project within Lockheed Martin's Space Systems division, LMT-11, our research project's goals are the following:

- Test the applicability of the Perez-Franco *et al.* methodology to the aerospace industry

- Evaluate the current supply chain strategy of LMT-11. This includes capturing the supply chain strategy as reflected in procedures and activities that support the business.

- Diagnose how LMT-11's current supply chain strategy fits with the company's overall business strategy.

Primarily, our project is concerned with how well the Perez-Franco *et al.* methodology works in the aerospace industry. Secondarily, we will also seek to provide recommendations to allow LMT-11 to decide what steps to take with their supply chain strategy and make any changes the company deems necessary.

2. LITERATURE REVIEW

2.1 Applicable Literature on the Methodology

The literature is rich with ideas and concepts of strategic initiatives that companies should pursue. There are numerous methods to display how a company's supply chain strategy is doing quantitatively through performance measures and models such as network optimization. However, a review of the literature has shown a lack of research in evaluating a supply chain through qualitative measures. Evaluating the merits of a supply chain strategy is not a simple task, in part "due to its elusiveness and complexity, but also due to the fact that a supply chain strategy cuts across diverse functional areas, and to the current lack of agreement in literature about what criteria should be used to evaluate a supply chain strategy" (Perez-Franco, *et al.*, 2011a).

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From our research, we were able to find literature arguing for "the importance of alignment of business strategies with supply chain strategies in the improvement of the overall performance and profitability of business" (Mitra & Bhardwaj, 2010, p. 49). It is well-known that companies often have major gaps between their highest level of business strategy and their supply chain strategy. The prevalent approach is to build up a supply chain strategy after the business strategy has been defined (Mitra & Bhardwaj, 2010). However, Mitra and Bhardwaj believe that this approach results in a difficult integration of powerful supply chain models into an already developed business strategy. Thus, this limits the ability to optimize the supply chain for the overall organization as it must now fit into an already defined role. The problems that arise are three-fold: 1) "developing a supply chain strategy without a true understanding of the business strategic intent may lead to unnecessary costs and losses," 2) "duplication or redundancy of resources in the operational model development, and hence diluting and weakening the supply chain strategy," and 3) "confusing or conflicting communication to the organization owing to different objectives because of strategic misfit between strategies" (Mitra & Bhardwaj, 2010, p. 50). Nevertheless, Mitra and Bhardwaj only address the importance of aligning the supply·chain strategy and business strategy. The methodology offered by Perez-Franco *et al.* provides *a way* to evaluate the supply chain, thus filling a gap in Mitra and Bhardwaj's approach.

In trying to understand where a strategy originates from, Michael Porter writes, "Strategy…may have evolved implicitly through the activities of the various functional departments,…the sum of which rarely equals the best strategy" (1998, p. xxi). Additionally, Porter points out that in order to formulate a future competitive strategy the first steps are to understand current implicit strategy and to evaluate what implied assumptions are being made

about the industry and business (1998, p. xxvii). Perez-Franco *et al.* (2011b) proposed a set of criteria purposefully designed for the evaluation of a supply chain strategy to determine the effectiveness of the current sum of activities. However, in order to evaluate, the strategy itself has to be explicitly understood. Such understanding is relatively rare, they argue, as "a search in the supply chain management literature for methods to express a firm's supply chain strategy in an actionable manner yields scant results" (Perez-Franco, *et al.*, 2011a). Therefore, Perez-Franco *et al.* (2011a) put forth an additional method that uses grounded activity, as Porter suggests, as the basis for eliciting the tacit supply chain strategy.

2.2 Applicable Literature on the Aerospace Industry

Within the aerospace industry, research has been conducted on how to measure the physical movement and effectiveness of supply chains. However, in our research, we have not come across any means on how to conceptualize and evaluate an aerospace's supply chain strategy.

In terms of supply chain strategies, Fisher believes that supply chains have to be either efficient or responsive depending on the characteristic of product (1997). Fisher claims that efficient supply chain strategies are a good match for functional products, and responsive supply chain strategies are a good match for innovative products. Satellites should be regarded as innovative products as they are advancing the fields of science and technology. As a result, a responsive supply chain strategy is appropriate for LMT-11. However, this conclusion merely dictates what type of strategy LMT-11 should employ and does not identify how to obtain such a strategy.

Other research uncovers additional strategies for aerospace companies to gain competitive advantages. Rose-Anderson, Baldwin, Ridgway, Allen and Varga (2009)

investigated how innovation and competitive advantage could be enhanced through the transformation of knowledge and learning. They utilized complex supply chain "Activity Networks based on in-depth interviews." While they used a similar methodology to Perez-Franco *et al.* for data collection – interviews – their focus was on improving innovation to gain a competitive advantage and not on eliciting the tacit supply chain strategy. Rose-Anderson *et al.* successfully applied the interview methodology to the aerospace industry to elicit data leading to the creation of their model. We believe this approach lends credibility to the methodology of using interviews to elicit the supply chain strategy in the aerospace industry.

On the whole, supply chain strategy researchers have focused on quantitative methods. Tannock, Cao, Farr, and Byrne (2007) used simulations to help "assess performance" in increasingly complex supply chains in the aerospace sector. While this approach will show the physical aspects of the supply chain, it fails to evaluate the human aspect of strategy. Tannock *et al.* point out that the aerospace industry has "intricate interrelationships between businesses that can operate at several levels in the supply chain" (2007). This highlights the importance of aligning supply chain strategy with the business strategy. However, this evaluation is difficult to complete without first capturing the tacit supply chain strategy.

We can conclude that the literature lacks an actionable methodology that existing aerospace firms can use to capture and evaluate their supply chain strategy. The following section will describe how we applied the steps outlined in Dr. Perez-Franco's Ph.D. dissertation to the aerospace industry using LMT-11 as a case study.

3. METHODOLOGY

For the purpose of the Methodology, our reference was Perez-Franco's Ph.D. dissertation (2010) titled *A Methodology to Capture, Evaluate and Reformulate a firm's Supply chain*

strategy as a Conceptual System. The Capture and Evaluation Phases outlined in his dissertation were completed on the LMT-11 project. The Capture Phase consists of a series of interviews and the creation of a Functional Strategy Map (FSM). The FSM shows how the supply chain activities are used to create the overarching strategic themes. The Evaluation Phase uses the Functional Strategy Map to create a survey. This survey is then used to generate a series of evaluation matrices, which we refer to as Heat Maps. A Heat Map is a matrix that codes the data from the surveys in order to highlight areas of both conflict and support. Further details on the methodology for these two phases can be found in Perez-Franco (2010). We have summarized the main steps below along with a number of notable deviations from his work, most of which were imposed by constraints that arose throughout the project.

3.1 Capture Phase Methodology

Unless otherwise cited, all the following steps were adapted from Perez-Franco (2010). Any direct quotes are indicated by quotation marks. Step numbers do not necessarily correspond to Perez-Franco's (2010) methodology because some steps were consolidated or removed. A summary of the deviations to the methodology will be provided in section 3.2.

Step 1: Choose Respondents

Respondents are chosen based on ensuring a breadth of both supply chain hierarchy and functionality. For hierarchy, personnel are divided into three levels:

- Level 1: "...Individuals at the lowest hierarchical level involved in the process of crafting the business strategy of the firm" (p. 103).

- Level 2: "...Individuals who report to Level 1 individuals. This is to say, by definition, they do not participate directly in crafting the strategy, although they might provide input..." (p. 103).

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- Level 3: "…Individuals that report to level 2 individuals" (p. 103).

The goal is to have roughly half of the respondents from Level 2 with the rest split between Level 1 and Level 3. Level 1 people tend to be too strategic minded while Level 3 individuals are too mired in the day-to-day activities of the business. Therefore, Level 2 workers are best suited for getting information to generate the supply chain strategy.

Step 2: Conduct Interviews

Weiss (1995) states that there are seven reasons to conduct a qualitative interview study, which are: 1) developing detailed descriptions, 2) integrating multiple perspectives, 3) describing process, 4) developing holistic description, 5) learning how events are interpreted, 6) bridging intersubjectivities, and 7) identifying variables and framing hypotheses for quantitative research (Weiss, 1995). Interviews should be conducted either in person or via telephone and attempt to achieve reasons two through five from Weiss (1995).

Each interview should last for no more than an hour and consists of the following three main areas:

- Placement Questions: The goal is to warm the respondents up with easy questions such as what is their current role, how long have they been in the industry, etc.

- Open Questions: The goal is "to find out about the tacit supply chain strategy… [by] inquiring about the activities that individual performs" (p. 107).

- Semi-Open Questions: The goal here is to either revitalize a dying discussion or "to explore particular areas of interest that may have been mentioned previously" (p.109).

It is critical to stay factual throughout the interview and ensure that the answers are based on actual activities. The objective is to extract accounts of actual activities and not what the individual may want to do or is supposed to do. If the interview becomes too strategic, it is

guided back to the activity by asking how those strategic ideas are accomplished. Conversely, if it is too muddled in the details of day-to-day business, it should be brought back to a more strategic level by asking why those activities are done. The ideal scenario for extracting the supply chain strategy is found by balancing the strategic and activity discussion. See **Exhibit 1** in the Appendix for the interview guide that was used for this step.

Holstein and Gubrium (1995) view active interviewing as a form of interpretive practice involving respondent and interviewer as they articulate ongoing interpretive structures, resources, and orientations. "Active interviewers" do not just merely coax their respondents into preferred responses to their questions. Rather, they converse with respondents in such a way that alternate considerations are brought into play. Interviewers may explore incompletely articulated aspects of experience, encouraging respondents to develop topics in ways relevant to their own experience. The objective is not to dictate interpretation but to provide an environment conducive to the production of the range and complexity of meanings that address relevant issues, and not be confined by predetermined agendas (Holstein & Gubrium, 1995, p. 17).

In an interview, as opposed to a normal conversation, only the researcher asks most of the questions and in doing so tries to keep the interview primarily focused on the research question without aggressively controlling the conversation. The interviewer guides the conversation by asking follow-up questions that pursue the topic of research. Such follow-up questions are intended to obtain depth, detail, and subtlety, while clarifying answers that are vague or superficial. It is the interviewer's responsibility to signal the interviewee about the level of depth that is wanted (Rubin & Rubin, 2005, p. 112). This level of depth is achieved in Perez-Franco *et al.* methodology by asking "How" and "Why" as discussed above.

Step 3: Identify Tacit Areas of Activity

The goal of analyzing the interviews is to identify the tacit areas of activities. This is accomplished by listening to the recordings of the interviews to identify the following: areas of activity, activities within each area, and the means that support each activity.

Step 4: Create Partial Maps

Partial maps are constructed by combining the tacit areas of activity from all of the interviews based on commonality. The activities within each area are combined in a hierarchical map, with the area of activity as the parent and the activities as the children. The means are not displayed but rather are used as evidence that the activities are actually occurring. **Figure 1** shows the relationship between these various hierarchy levels. The main structure includes three hierarchical categories, in order of parent to children:

- Strategic Themes: High level themes which are the essence of how a company views its business strategy.

- Functional Themes: Areas of activity which support the strategic themes.

- Operational Themes: The activities that support each area of activity.
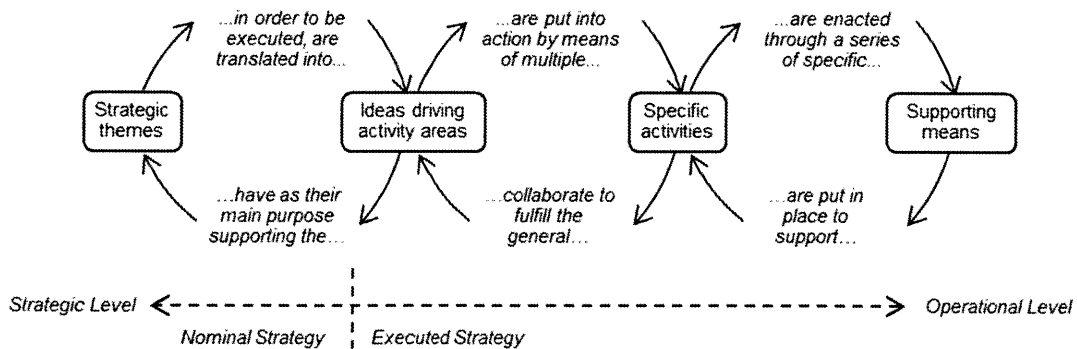
Figure 1 – Relationship of Themes, adapted from Perez-Franco *et al.* (2011a)

Step 5: Validate Partial Maps

The Partial Maps are reviewed one at a time with employees to validate each map. Typical revision changes include the following: wording and phrasing; misconceptions between

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groups or people; and missing activities. The latter two require some discussion and probing to ensure any modifications are grounded on actual activity.

Step 6: Assemble the Functional Strategy Map

The Functional Strategy Map is completed by combining all of the partial maps into one hierarchical document. The Strategic Themes, provided from a strategic guide from the company, act as the highest level parent, thus creating three levels. **Figure 2** highlights the structure for how this should be put together.
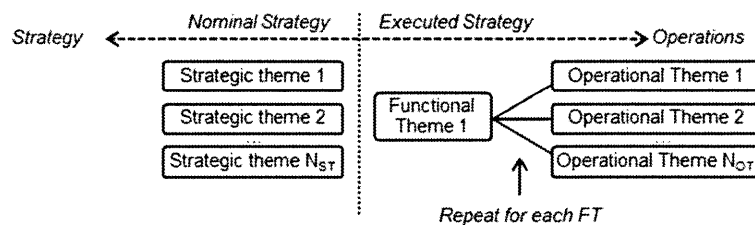
Figure 2 – Functional Strategy Map Structure, adapted from Perez-Franco *et al.* (2011a)

3.2 Deviations of the Capture Phase Methodology

In this section, we discuss the deviations from the Perez-Franco (2010) Capture Phase methodology. The following detail each deviation that occurred:

1. It is recommended that two to three dozen interviews are conducted, depending on the number of areas of interest (Perez-Franco, 2010, p.103). In the case of LMT-11, we identified 19 potential individuals to interview. Unfortunately, there was a lower-than-anticipated response rate within the allotted time, and only ten interviews were conducted. While the Perez-Franco *et al.* methodology has in the past been applied to as few as twenty-two interviewees, this is the lowest number of participants that the methodology has been tested with.

2. As part of the ten interviews conducted with LMT-11, two were with the thesis project's sponsors. In the past, only one project sponsor has been chosen to

participate in the interviews. Given our low participation level, it was required to interview both project sponsors to increase our sample size by twenty-five percent. The project sponsors might introduce a potential bias as they were more familiar with the reasoning behind the methodology and what was to be extracted from the interviews than the other interviewees. However, it was necessary to include them due to the low level of participation achieved.

3. In Perez-Franco's research (2010), a single researcher collected and analyzed the data. However, in our case, we decided to divide work with each one of us conducting and analyzing half of the interviews. Each author was unaware of who the other interviewed and had no access to the other's transcripts. Each of us identified the tacit areas of activity independently on our individual base of interviewees. Afterwards, we joined the analysis together to create the partial maps and consolidated common activities and functions between the two researchers. These partials maps ultimately are used to create the Functional Strategy Map.

4. Many gaps existed in the partial maps from insufficient breadth stemming from lower than anticipated participation. One of the project sponsors at LMT-11 conducted quick interviews with individuals who could fill in the gaps and complete the partial maps. The sponsor had been briefed on the methodology and understood to look for ideas grounded in activities.

5. LMT-11 was unable to provide a document showing their business strategy for use in the Functional Strategy Map as Strategic Themes. Therefore, we derived the Strategic Themes from the interview data.

6. The final deviation from the Capture Phase methodology was the elimination of the Functional Strategy Map validation step. The partial maps had already been validated and completed by project members at LMT-11 prior to being combined into the Functional Strategy Map. Therefore, there was minimal value for validating the Functional Strategy Map given the time constraints we were operating under.

3.3 Evaluation Phase Methodology

The Evaluation Phase builds off the Capture Phase using the Functional Strategy Map as the basis for the creation of a survey and subsequent analysis. As with the Capture Phase, the Evaluation Phase steps, unless otherwise cited, were adapted from Perez-Franco (2010). Step numbers do not necessarily correspond to Perez-Franco's (2010) methodology because some steps were consolidated or removed. A summary of the deviations to the methodology will be provided in section 3.4.

Step 1: Prepare Survey

The survey's goal is to elicit which areas are in conflict or agreement. This is achieved by testing the following three interactions between Functional Strategy Map themes:

- **Consistency**: Explores to what extent each theme within a level is compatible with the other themes in the same level, as displayed in **Figure 3**.
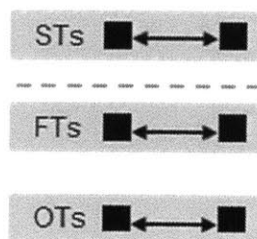
Figure 3 – Consistency Relationship, Source: Perez-Franco *et al.* (2011b)

An example of a consistency question between two themes is the following: *"Ensuring the quality of the program is compatible with reducing the number of defects for the program."* The following answer choices were provided to the responders:

1. Yes, it is totally compatible

2. It is somewhat compatible

3. It is somewhat incompatible

4. No, it is totally incompatible

5. I'm not sure about this one

- **Support**: Explores to what extent the lower level activities support their parent theme as displayed in **Figure 4**.
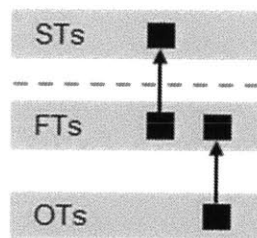
Figure 4 – Support Relationship, Source: Perez-Franco *et al.* (2011b)

An example of a support question between the strategic and functional themes is the following: *"Maintaining the long-term success of the program is compatible with making decisions based on long-term benefits."* The following answer choices were provided to the responders:

1. Yes, it is totally compatible

2. It is somewhat compatible

3. It is somewhat incompatible

4. No, it is totally incompatible

5. I'm not sure about this one

- **Sufficiency**: Explores to what extent has the individual theme been achieved as an objective.

An example of a sufficiency question for a strategic theme is the following: *"To what extent are <u>we achieving</u>: ensure the quality of the program."* The following answer choices were provided to the responders:

1. *Completely*

2. *Mostly*

3. *Somewhat*

4. *Not at all*

5. *No, it is detrimental*

Due to the fact some questions require specific knowledge of the job function, the questions were divided into one of three groups: general, subcontracts, and quality. Two separate surveys were created which combined the general with the questions pertinent to the two job areas. The questions within the specific functions explored the compatibility within the Operational Themes relevant to that function.

Step 2: Administer Survey

The surveys are sent to all the individuals identified during the interview phase as well as others within the supply chain. They should be administered via an online survey tool such as Survey Monkey (www.surveymonkey.com). The respondents should be given ten calendar days to complete and return their survey answers.

Step 3: Consolidate Survey Answers

The answers are organized into matrices with one theme on the row and another on the column. The responses to the three types of questions are each aggregated into two groups: any

degree of positive relationship and any degree of negative relationship. Next, the number of respondents for each group is then entered into the duplicate matrices for analysis. **Figure 5** identifies the method for converting the survey results into the matrix heat map.

FT-ST Matrix		Functional Themes			
		1	2	3	4
Strategic Themes	1	$Q1_{1,1}$	$Q1_{2,1}$	$Q1_{3,1}$	$Q1_{4,1}$
	2	$Q1_{1,2}$	$Q1_{2,2}$	$Q1_{3,2}$	$Q1_{4,2}$
	3	$Q1_{1,3}$	$Q1_{2,3}$	$Q1_{3,3}$	$Q1_{4,3}$
	4	$Q1_{1,4}$	$Q1_{2,4}$	$Q1_{3,4}$	$Q1_{4,4}$

Figure 5 – Translating Survey Results to Heat Map Guide, Source: Perez-Franco *et al.* (2011b)

Step 4: Identify Top and Bottom Values

Extreme values, which represent where the themes are in strong conflict or agreement with each other, are identified. Here, we chose to highlight the top and bottom 10% within each survey area.

Step 5: Derive Insights

Patterns are identified. For example, certain themes found are in constant conflict or agreement with others. A few central concepts might immediately be identified as repeat offenders. They will show up as conflicting in multiple survey interaction groups

Step 6: Discuss with the Client

The focus should be on the areas of conflict derived from the analysis. Throughout the discussion, the client is asked probing questions on the conflict such as: why is there a trade-off, why is it not considered necessary, etc. These questions intend to get the employees to think about, among other things, whether these trade-offs are technical, mental, or physical as well as why does a trade-off have to exist.

3.4 Deviations of the Evaluation Phase Methodology

In this section, we discuss the deviations from the Perez-Franco (2010) Evaluation Phase methodology. The following detail each deviation that occurred:

1. In terms of survey respondents for LMT-11, the initial list included the original nineteen people identified for interviews plus an additional ten people, for a total of twenty-nine individuals. Out of those, only nine attempted the survey, and only eight completed the entirety of it. Perez-Franco *et al.* (2011b) did not specify the ideal number of survey respondents; however, the goal should be to validate with a larger selection of people. Low participation in this phase introduces the risk of overweighting only a few voices within the organization.

2. Eight of the nine survey takers from LMT-11 were in procurement and subcontracts focused roles. The remaining individual was from the quality organization. These facts amplified the risk that the responses are predominately from the view of procurement and will need to be analyzed with this consideration. Furthermore, the Quality Assurance specific questions of the survey were not analyzed as there was only the one respondent from Quality Assurance team. We did not feel a single responder to those questions would provide an adequate analysis. Therefore, we were only able to analyze the general and procurement survey questions that this individual completed.

3. While creating the survey questions, a new consistency question was tested. Consistency is meant to test to what extent are the themes compatible with each other (Perez-Franco, 2010, p.141). This is to say, how well does the theme work with the other themes within its same level? In addition to this, a downward

consistency set of questions was created by asking how compatible the strategic

themes are with the functional themes. While this is similar to the criterion of

support, it differs because it explores the compatibilities of the parent to child;

instead of the child to parent on support.

4. The usual method for delivering the survey is via an online tool such as Survey

Monkey. This allows the respondents to save their progress and complete the

survey in pieces, at their leisure. Due to concerns from Lockheed Martin's export

control group, it was necessary to use their internal survey tool. This internal tool

required that the survey be completed in one sitting and therefore could not be

taken over multiple sittings. The procurement survey contained 359 questions and

the quality survey had 201 questions. As a result, this obstacle gave rise to the risk

of fatigue and frustration from having to take the survey all at once.

4. RESULTS

We will present the results attained from applying the methodology to the LMT-11

project with the deviations necessitated by the constraints levied on our thesis. A detailed

discussion of the findings follows the Results section.

4.1 Outcome of the Capture Phase

After conducting the interviews, the data were compiled to identify common areas of

strategic importance. We decided to use word-cloud software to present an easy, visual analysis

of the data by highlighting common words that appeared throughout the interviews (see **Exhibit**

2 in the Appendix). This word-cloud facilitated the creation of an outline of themes, which eased

the process of segregating data into common groupings. Once we had identified common

themes, we returned to the methodology proposed by Perez-Franco *et al.* for the creation of the

Partial Maps. These were then validated by LMT-11 personnel. **Figure 6** illustrates the

relationship of the Operational Themes to their parent Functional Theme in the Partial Map

format.
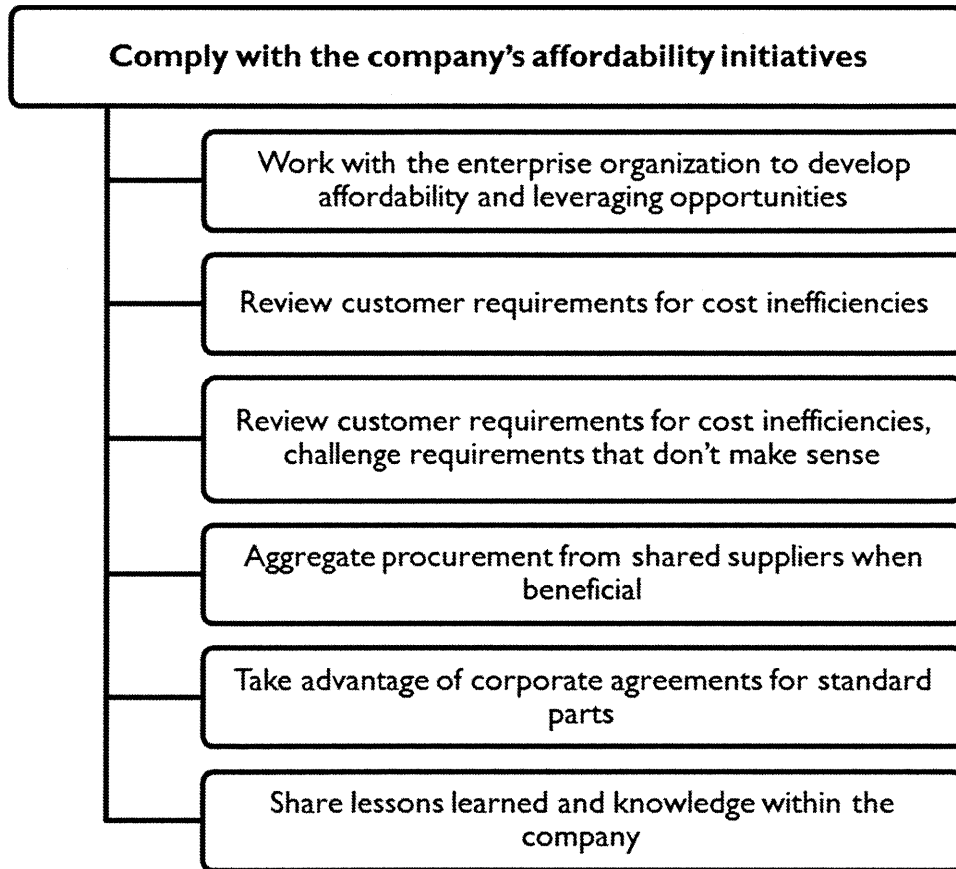
Figure 6 – Example of a LMT-11 Partial Map

Combining these Partial Maps led to the creation of the Functional Strategy Map. For

LMT-11, 16 Functional Themes and 81 Operational Themes were identified and verified. **Figure**

7 is a sample of the Functional Strategy Map with the key strategic themes being shown:

The entire Functional Strategy Map is presented in **Exhibit 3** in the Appendix.

Figure 7 – Functional Strategy Map (Highlight)

Operational ←-- Functional ---┌--→ Strategic

Operational	Functional	Strategic
Validate requirements/analysis in Preliminary Design Reviews		
Finalize and validate space vehicle/component design in the Critical Design Reviews		
Conduct additional formal program reviews as required to verify manufacturing capabilities, test readiness, and other critical elements	Reduce the number of defects	Ensure the quality of the program
Drive out issues early through Engineering Development Unit builds		
Rigor in establishing long-term corrective action on defects		
Implement internal corrective action process to encourage program personnel to bring forward issues and drive process improvements		
Utilize Corrective Action Board to aggressively address systemic issues		

Use earned value management as a tool to track schedule and cost		Maintain the affordability of the program
Utilize monthly reports to evaluate cost and schedule performance		
Utilize integrated subcontract management team to manage technical and schedule aspects of subcontracts	Manage team performance	
Use metrics as a tool for awareness		
Establish quantitative measures and metrics to measure team and hold team accountable to these		
Ensure team is focused on appropriate activities		

Flow program plans as required by the subcontract agreement to suppliers		Execute and deliver successfully
Manage support personnel at supplier sites	Act as the voice of the customer to suppliers	
Prioritize requests through time phasing		
Manage process flow to communicate unique program requirement changes		

Spend time resolving manufacturing issues through problem solving methods		Maintain the long-term success of the program
Approve designs that fulfill specifications	Produce a Technically Compliant Product	
Involve Quality Assurance in drafting and approving requirements and specifications		
Involve Quality Assurance in Development Evolutions		

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A written document detailing LMT-11's business strategy was not provided until after the Evaluation Phase had been completed. Therefore, from our analysis of the interview data, we inferred there are four strategic themes that are the basis for LMT-11's core strategy. These themes– "Ensure the Quality of the Program," "Maintain the Affordability of the Program," "Execute and Deliver Successfully," and "Maintain the Long-Term Success of the Program"– were presented to employees during the validation meeting. Participants verified that these are the themes that employees see as driving LMT-11's high-level strategy.

4.2 Outcome of the Evaluation Phase

The purpose of the Evaluation Phase is to give members of the LMT-11 project an opportunity to assess the supply chain strategy from their own understanding and knowledge of their business (Perez-Franco, *et al.*, 2011b). Although we found many positive relationships amongst the supply chain activities, the results of the survey do show areas of disagreement within the interactions of sufficiency, support, and consistency. The results are displayed visually in matrices that code the data from the surveys, which we call Heat Maps. The top ten percent of values within each matrix are identified with checkmarks, which indicate strong support between the two themes. The bottom ten percent of values is identified with X's, which indicate a lack of support or potential conflict. Themes with neutral interactions are shown with blanks. For reference, the following abbreviations were used for our Heat Maps: ST = Strategic Theme, FT = Functional Theme, and OT = Operational Theme. See **Exhibit 4** in the Appendix for a complete legend of the themes for the surveys. The following are the key interaction discords for the supply chain strategy:

4.2.1 Sufficiency Findings

Figure 8 illustrates to what extent each of the strategic themes is satisfied according to the employees. As is evident in the figure, "Maintaining the Affordability of the Program" (ST2) is currently not being achieved to a high degree. The respondents of the survey believe that LMT-11's affordability strategy is only somewhat meeting the needs of the program.
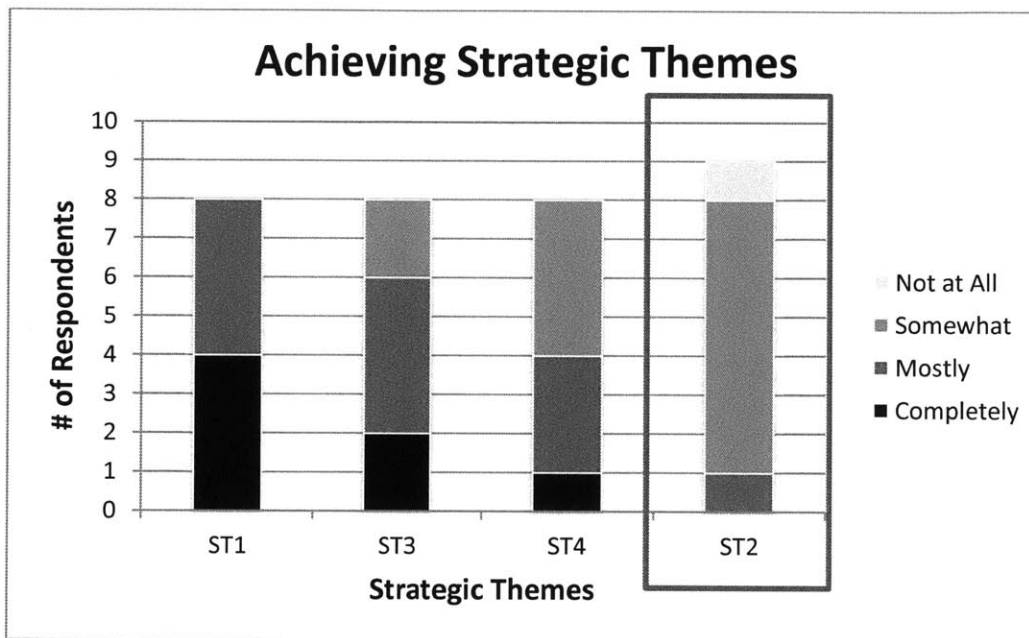
Figure 8 – Sufficiency: Measuring Achievement of Strategic Themes (Issues are highlighted in the box)

Figure 9 illustrates to what extent employees perceive the functional themes are satisfied. Notice that opinions were divided for: "Maintaining a Completely Transparent Program to Supply Chain Partners" (FT14). Survey respondents provided inconsistent views to what extent this is accomplished. Furthermore, the Functional Themes: "Complying with the Company's Affordability Initiatives" (FT6), "Working with Suppliers to Reduce Costs" (FT7), and "Creating Partnerships with Suppliers" (F12) are all only somewhat satisfied according to the LMT-11 team.

Achieving Functional Themes

# of Respondents

Not at All / Somewhat / Mostly / Completely

Functional Themes: FT4, FT3, FT5, FT14, FT8, FT1, FT10, FT13, FT9, FT11, FT15, FT2, FT6, FT7, FT12
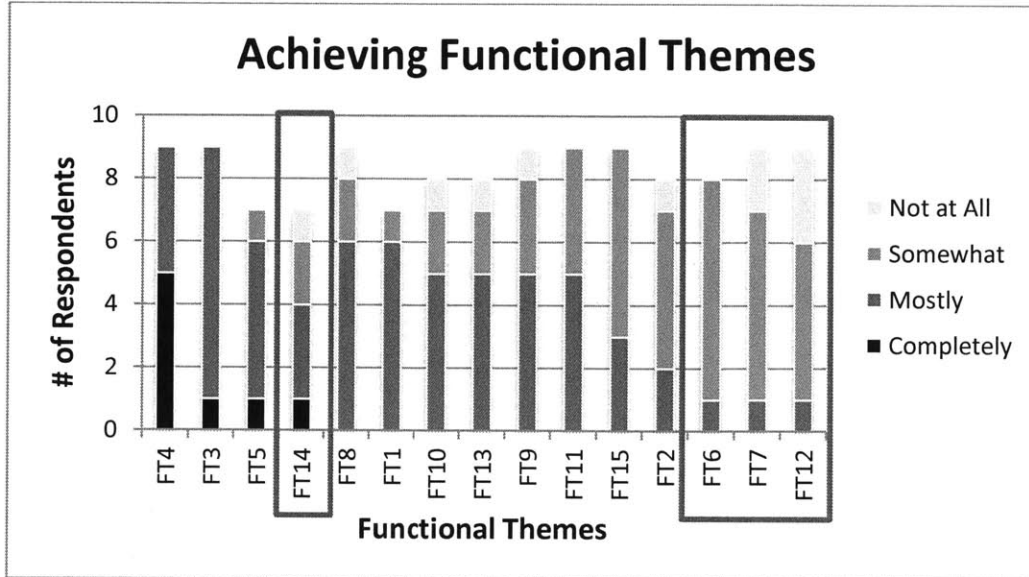
Figure 9 – Sufficiency: Measuring Achievement of Functional Themes(Issues are highlighted in the boxes)

4.2.2 Support Findings

The surveys also showed how certain functional themes were not supporting key strategic themes, as shown in **Figure 10**. The checkmarks indicate a strong positive relationship; whereas, the X's represent strong negative relationships between the themes. First, the functional theme of "Producing a Technically Compliant Product" (FT4) does not help "Maintain the Affordability of the Program" (ST2). In addition, "Complying with the Company's Affordability Initiatives" (FT6) and "Working with Suppliers to Reduce Costs" (FT7) do not help the strategic theme of "Ensure the Quality of the Program" (ST1).

	FT1	FT2	FT3	FT4	FT5	FT6	FT7	FT8	FT9	FT10	FT11	FT12	FT13	FT14	FT15
ST1	✓	✓	✓	✓	✓	✗	✗	✓	✓		✓	✓	✓		✓
ST2		✓	✓	✗		✓	✓	✓	✓			✓	✗	✓	✓
ST3	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✗
ST4	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓

Figure 10 – Heat Map: Support of Strategic Themes through Functional Themes

According to the framework presented in Perez-Franco *et al.*, Operational Themes (OT) are expected to support Functional Themes (FT). In the case of LMT-11, **Figure 11** shows how specific operational themes do not support their parental functional themes. "Acting as the Voice of the Customer to Suppliers" (FT3) lacks support from the following operational themes:

- "Flowing Program Plans as Required by the Subcontract Agreement to Suppliers" (OT7)

- "Managing Support Personnel at Supplier Sites" (OT8)

- "Prioritizing Requests through Time Phasing" (OT9)

- "Managing Process Flow to Communicate Unique Program Requirement Changes" (OT10)

In addition, "Working with Suppliers to Reduce Costs" (FT7) is lacking support for the following operational themes:

- "Minimizing Lead Time through Parallel Testing" (OT18)

- "Converting some Source Control Drawings to Heritage Parts when Possible" (OT19)

Lastly, the survey showed that "Maintaining the Affordability of the Program" (FT16) did not have the support of the following operational themes:

- "Bidding Competitively for Commodity Parts" (OT40)

- "Evaluating Development and Testing Costs for Alternative Suppliers" (OT41)

- "Utilizing Long-Term Agreements for Volume Pricing" (OT42)

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	OT7	OT8	OT9	OT10	OT18	OT19	OT40	OT41	OT42	OT43	OT44	OT45	OT46	OT47	OT48
FT3	✗	✗	✗	✗											
FT7					✗	✗									
FT16							✗	✗	✗	✓	✗			✓	

Figure 11 – Heat Map: Support of Functional Themes Through Operational Themes (Highlight)

4.2.3 Consistency Findings

The consistency survey questions helped to identify the level of compatibility between two specific themes. As mentioned before, the checkmarks indicate a strong positive relationship; whereas, the X's represent strong negative relationships between the themes. **Figure 12** illustrates that "Maintaining the Affordability of the Program" (ST2) is incompatible with the following Functional Themes:

- "Producing a Technically Compliant Product" (FT4)

- "Resolving Quality Anomalies" (FT5)

Also the survey revealed that "Ensuring the Quality of the Program" (ST1) is contrary with "Complying with the Company's Affordability Initiatives" (FT6)

	FT1	FT2	FT3	FT4	FT5	FT6	FT7	FT8	FT9	FT10	FT11	FT12	FT13	FT14	FT15	FT16
ST1	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓		
ST2	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓		✓			✓	✓
ST3	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓		✗
ST4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Figure 12 – Heat Map: Consistency of Strategic and Functional Themes

We also looked at the consistency of relationships between the Operational Themes of a single parental Functional Themes. For "Manage the Deployment of Subcontracts" (FT18), there are a number of activities that are incompatible with each other. "Conducting Competitive Bids to Identify the Most Qualified Supplier" (OT20) is clashing with the following Operational Themes:

- "Ensuring Appropriate Staffing is in Place" (OT22)

- "Executing Agreements in a Timely Manner" (OT23)

In addition, "Ensuring the Designs and Requirements are Flown Down Correctly" (OT21) is contradictory with "Ensuring Appropriate Staffing is in Place" (OT22).

5. DISCUSSION

5.1 Interpretation of LMT-11 Findings

The following discusses the interpretation of LMT-11's results as mentioned previously.

5.1.1 Assessment of the Capture Phase

The conceptualized supply chain strategy obtained from the Capture process, and validated by the LMT-11 team, was deemed by them as a fair representation of what the supply chain strategy is. While the initial partial maps contained many gaps, they provided a good framework and starting discussion point with the employees. The gaps were filled in by additional discussion between the project sponsors and members of the supply chain to capture the breadth of activity. The resulting Functional Strategy Map was viewed successful because everyone involved from LMT-11's side reached an agreement on the strategic, functional, and operational themes.

In addition, a number of grievances and opportunities for improvement were identified through the process (see **Exhibit 5 & 6** in the Appendix). For example, some interviewees felt that the supply chain strategy needs to "continue to standardize information flow to all subcontractors" and "combat shrinking high-reliability domestic supplier base." Because these grievances are not actual activities for the group to support, they are not included in the Functional Strategy Map. Nevertheless, they do offer insights to what LMT-11 can do to improve the supply chain strategy. Along the same lines, a number of opportunities were also identified such as "apply[ing] lessons learned from and to other programs" and the "need to communicate the supply chain strategy to the team." Clearly, LMT-11 has a tacit supply chain

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strategy for its business, but not all employees are aware of what it is. Now, the Functional

Strategy Map can aid in the awareness of the Supply Chain Strategy.

5.1.2 Assessment of the Evaluation Phase

From our research of LMT-11, we believe that the supply chain revolves around four key

premises: technical innovation, product quality, project affordability, and on-time delivery. The

survey results showed that most LMT-11 employees viewed this trade-off: affordability versus

the other three premises (see **Figure 13**).These trade-offs appear to be the underscored mentality

at LMT-11. But, in our opinion, this trade-off does not have to be a tenet. For example, Toyota

Motor Corporation decided to apply the principles of their Toyota Production System (TPS) to

the manufacturing of Formula-1 cars. Using TPS, Toyota Motorsports is able to reduce

production time, increase quality, and decrease costs. Formula-1 vehicles are renowned for

required precision in engineering and low-volume production, much like what it takes for

products in the aerospace industry (Hanlon, 2005). Therefore, it is reasonable to posit that LMT-

11 could achieve affordability initiatives while also improving quality and meeting time

constraints. We suggest LMT-11 should not view affordability as a trade-off, but rather seek

ways to innovate, so that all Strategic Themes are met.
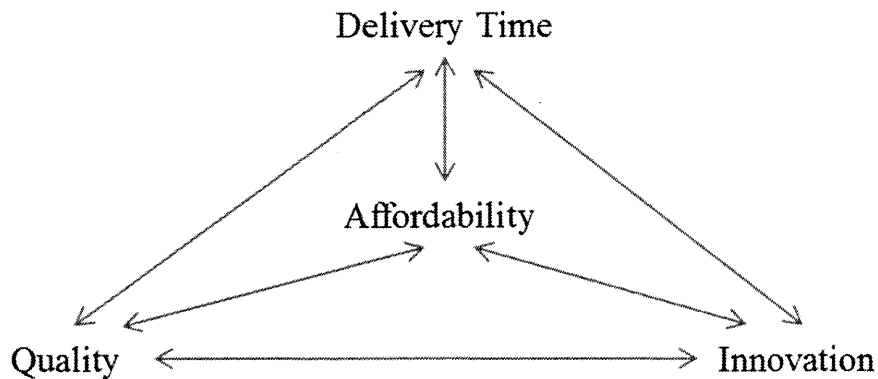
Figure 13 – Four-Way Trade-Off Map

Sufficiency Discussion

The shortcomings displayed previously in **Figure 8** and **Figure 9** strongly suggest that affordability is presenting a challenge to LMT-11's supply chain strategy and is not being completely achieved. This may be because a number of new initiatives for affordability have just begun and are in the early stages of development.

Additionally, LMT-11 project members reported that transparency for supply chain partners is achieved for major suppliers, but not all. Project members of LMT-11 believe that it depends on the size of the supplier and how integral the parts are to the project. According to the team, LMT-11 cannot justify the cost of maintaining transparency of smaller suppliers.

Support Discussion

Employees agreed with the themes of conflict shown previously in **Figure 10** and **Figure 11** and were not surprised by the results. This leads to verisimilitude validity to the findings. The general feeling was that based on this, actionable takeaways could be developed to help improve the supply chain strategy.

Through discussions with LMT-11's employees, we found that many believe most of the Operational Themes identified in **Figure 11** do support their Functional Theme. However, the results of the survey contradict this point of view. This highlights a potential gap with what the company *wants to do* versus *what they actually do*. It is unclear why LMT-11 would verbally contradict the survey results and deem the above mentioned Operational Themes to be necessary. This issue is an area that the company should further investigate to make sure everyone is in agreement as to where LMT-11 stands. Also, respondents felt that some of the Operational Themes supporting affordability initiatives could potentially help reduce costs for the program,

but were not seen as necessary to do so. This logic continues to display the issue of how affordability is creating conflict.

Consistency Discussion

As evident in **Figure 12**, many of the same conflicts that were apparent in the Sufficiency and Support sections are found here as well. It was viewed that there exists a perceived trade-off between maintaining the affordability and preserving the quality of the project. There is the perception that this trade-off has to exist. During the discussion, the employees recognized that the trade-off does not have to entail a zero sum game. The car company, Toyota, was brought up as an example by LMT-11 employees where both quality and affordability are maintained.

During the meeting, there was general consensus from LMT-11 that many of these incompatibilities between activities could be avoided. The employees felt that it should be up to management to develop and articulate an effective course of action for ensuring "proper staffing and execution."

5.1.3 Assessment of the Alignment with LMT-11's Business Strategy

A company's supply chain strategy should be consistent with the company's business strategy (Perez-Franco, *et al.*, 2011a). Relating back to the problem statement of this thesis, assessing the effectiveness of LMT-11's current supply chain strategy in supporting its business strategies, we can now connect the supply chain's strategic themes to LMT-11's business strategy.

Lockheed Martin Space System's mission, as provided by the thesis sponsors, is "to be known for exceptional program performance, superior customer relationships, anticipatory customer advocacy, and systems of systems innovation." The company feels that to achieve this mission statement the following goals should be met:

- Establish Market Leadership

- Drive Operational Excellence

- Deliver Financial Performance

The supply chain's four strategic themes align with these goals. Establishing Market Leadership fits with "Maintain the Long-Term Success of the Program" (ST4). Drive operational excellence is supported by "Ensure the Quality of the Program" (ST1) and "Execute and Delivery Successfully" (ST3). Lastly, Deliver Financial Performance aligns with "Maintain the Affordability of the Program" (ST2). However, there appears to be a gap with "superior customer relationships" and "anticipatory customer advocacy" from the mission statement. No strategic theme addressing the customer was found during the Capture Phase with LMT-11 employees. The Evaluation Phase found one functional theme that does address the customer, "Act as the Voice of the Customer" (FT3). The survey results showed that this theme was being mostly achieved, but the Operational Themes were not supporting this Functional Theme. We believe that LMT-11 should examine the potential of including customer satisfaction as a strategic theme because it appears to be critical to their mission. This concludes what pertains to the LMT-11 project. What follows is the discussion of applying the methodology to the aerospace industry.

5.2 Insights from Applying the Methodology

From our analysis, we are able to identify three different areas of the methodology to discuss: assessment of the methodology to the aerospace industry, deviations that occurred during the application, and possible additions to the methodology.

5.2.1 Applicability of the Methodology to the Aerospace Industry

Using LMT-11 as a case study, we feel that the methodology was successfully applied to the aerospace industry. The feedback from our thesis sponsors and LMT-11's employees suggests that the process has been useful and effective. For example, during one of the discussion meetings, one LMT-11 employee said "that there are definitely takeaways from the findings that we as a company can look into and possibly find ways to improve." There was consensus from the LMT-11 group on the issues presented through the discussions including the grievances and opportunities as well as the Evaluation Phase results. They agreed that this is a good representation of what their grounded supply chain strategy is and the conflicts currently present. It is important to mention that the Heat Maps and Functional Strategy Map were aggregations of LMT-11's employees' voices and were not colored by our opinions. In fact, the LMT-11 team saw these deliverables as excellent guides for aligning their business.

5.2.2 Lessons Learned from the Deviations of the Methodology

As mentioned in the Methodology section, we followed the steps outlined by Perez-Franco *et al.* with a few notable deviations. These deviations all emerged through the process and were not done with intent. The goal of this section is to provide guidance on the impact of each deviation and how we think they affected the final outcome.

The deviations that we felt had a positive impact on original methodology and could be considered for future applications are as follows: separate data collectors, bridge the partial map gaps by a project sponsor, and forego the Functional Strategy Map validation meeting.

1. Separate Data Collectors: In our view, having two data collectors conducting interviews simultaneously helped to increase the productivity. We ensured that we had a common understanding and framework so as to minimize differences in the

interview process. The net result was that the interviews and analysis of them were completed in almost half the time as an individual attempting the same amount of work. The analysis from the researchers was combined into the partial maps, which were then validated by the employees to remove any sort of misconceptions that arose.

2. Bridge Partial Map Gaps by a Project Sponsor: The project sponsor used the common framework to ensure there was consistency with the data as they collected it for the Partial Map gaps. We felt this framework worked well despite the low level of participation that we had. The contribution of the project sponsor were consistent with our own analysis plus had the added benefit of creating a more complete map. However, it should not be required if a larger sample size that covers the breadth of the supply chain can be obtained.

3. Forego the Functional Strategy Map Validation Meeting: Lastly, the step to validate the Functional Strategy Map appears to be redundant. The Functional Strategy Map is only the compilation of the previously validated Partial Maps, and as a result, another validation meeting should not be necessary. Considering the difficulty in aligning employees' schedules for a meeting, the elimination a meeting should be considered a positive improvement.

We believe certain deviations from the Perez-Franco *et al.* methodology provided a neutral impact to the process: include multiple project sponsors in the interview, derive the Strategic Themes from the interview data, and add vertical consistency survey questions.

1. Include Multiple Project Sponsors in the Interview: Despite the fact the project sponsors were aware of the overall methodology, we do not believe they were privy

to enough of the details to allow them to guide their answers towards their biases. Additionally, by asking for ideas grounded in actual activity, we were able to eliminate any risk of their bias entering the project.

2. Derive the Strategic Themes from the Interview Data: Because LMT-11 did not provide the written business strategy before the end of the Capture Phase, we had to derive them from the interview data. The derived Strategic Themes were validated by LMT-11 employees during discussions. Overall, we feel that this didn't add or detract from the process although it offered an interesting comparison when we finally did receive their documented business strategy.

3. Add Vertical Consistency Survey Questions: The last neutral deviation was the use of vertical consistency questions in the Evaluation Phase (ST compatible with FT). These questions are very similar to the "FT supports ST" questions and yielded very similar results. Having said that, the similar results show that the data has validity, which is an applicable use. Otherwise, they provide very comparable data and can be used as substitutes for each other.

The final group of deviations we felt had a negative impact on the methodology: limited number of participants, majority of survey respondents from a single group, and the survey had to be completed in one sitting.

1. Limited Number of Participants: The small sample size in both the Capture and Evaluation Phases limited the breadth of supply chain activity data for eliciting the supply chain strategy. This was partially mitigated by having the project sponsor complete the gaps in the Partial Maps; however, the lack of participation in the Evaluation Phase limited the insights that could be derived from the matrices. Limited

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amounts of data and opinions should be seen as a negative as there is risk of missing key aspects and overweighting certain areas more than others.

2. Majority of Survey Respondents from a Single Group: Along those same lines, since eight of the nine survey respondents were from the same functional area, the survey analysis did not provide a balanced view from the organization. This issue definitely overweighs certain voices within the organization and causes the overall project to lose some of its global applicability.

3. Survey had to be Completed in a Single Sitting: Finally, LMT-11 required the use of their internal survey system due to export control concerns. This system required the survey to be completed in its entirety in one sitting. Not all participants completed the whole survey and of those that did, many complained about the fatigue. We feel that this could have a negative impact on the quality of answers as people would not put in the required effort and consistent thought to their answer choices especially as many questions sound similar in nature. One way to mitigate this risk would have been to break the survey into smaller pieces so each piece could be done individually.

5.2.3 Possible Addition to the Methodology

In our Evaluation Phase discussion with LMT-11, a common reflection was that many employees thought about the survey questions as trade-offs and less along the support and consistency framework. They would think about the trade-off between the two themes and then pick the answer they thought best fit. We propose that it is worthwhile to survey the trade-offs to understand where people view situations as zero-sum games. An example of the question framework would be the following: *To what extent is there a trade-off between Theme 1 and Theme 2?* Answer Choices: *1) Not at all, 2) A little bit, 3) Somewhat, 4) A lot, or 5) Completely.*

During the results meeting, the presenter can start a discussion about what type of trade-off exists – mental, physical, or technical – and what resource or value is traded.

5.3 Suggestion for a Fast-Track Approach to the Capture Phase

The authors believe that there exists the potential to create a Capture Phase that could be completed under a month as an initial study for supply chain focused projects. The goal would be to provide a supply chain strategy baseline for companies that do not have an explicitly stated one. The ultimate output would be the best result for a minimal amount of effort with the goal of providing guidance on where to focus.

Step 1: Identify Key Individuals – Only identify individuals in areas of concern for the main project. In a specific area, two or three respondents should provide an adequate coverage for the analysis.

Step 2: Conduct Interviews – These can be conducted via phone and should target ~30 minutes per interview. The interview can be completed in this time by focusing solely on the Introduction and Open Questions regarding activities.

Step 3: Identify Tacit Areas of Activity – Completed with the same methodology as cited.

Step 4: Create Partial Maps – Completed with the same methodology as cited.

Step 5: Validate Partial Maps – Completed with the same methodology as cited with the understanding that this is not meant to be 100% inclusive of all activities.

Step 6: Assemble Functional Strategy Map – Completed with the same methodology as cited.

6. CONCLUSION

The three goals outlined for this research project were successfully met. Through our testing with LMT-11, we found that the Perez-Franco *et al.* methodology is applicable to the

aerospace industry. For the Capture Phase of the methodology, we were able to elicit the tacit supply chain strategy. This enabled us to evaluate and diagnosis how well the current supply chain strategy for LMT-11 fits with the project's documented business strategy.

As identified by the LMT-11 employees, we were able to pinpoint affordability as the primary source of contention between themes, as seen in **Figure 13**. This is the key result that the company should investigate further to locate the root cause(s) of the disagreement. As previously mentioned, Toyota has shown that possible to effectively sustain cost initiatives while also improving quality and delivery time. Additionally, even though the survey identified some themes that lacked support, the discussions with LMT-11 employees were contrary to these findings. As a result, this is another area for LMT-11 to explore and find a way to create consistency across the organization. Finally, this research diagnostic found that LMT-11's business strategy included customer collaboration as a main tenet. It was not found as one of the main Strategic Themes for the supply chain strategy. LMT-11 should then enquire whether customer relations should be a higher focus. These are the three conclusions from the Evaluation Phase of the LMT-11 supply chain strategy.

As LMT-11 employees stated in meetings, several actionable items were found, such as exploring the trade-off between quality and affordability in the supply chain. Identifying these trade-offs will allow LMT-11to engage in introspection and change management via paradigm shifts. The results of the Evaluation Phase provide the inputs for LMT-11 to pursue a reformulation of their supply chain strategy.

From discussions with Dr. Perez-Franco, we know the methodology has not yet been applied to a highly regulated and low-volume industry before the start of this thesis. In general, the aerospace industry appears to be driven more by product innovation and less by process

innovation. Despite these characteristics, we have been able to show how the methodology can be used in an industry besides those previously tested. Because of this, we feel that the methodology is robust enough to have a more broad application.

From our experience, we found many serendipitous results that we believe can help refine the nascent Perez-Franco *et al.* methodology. First, certain deviations to the original methodology can be successfully incorporated into future applications of this process: separate data collectors, project sponsor bridging the partial map gaps, and foregoing the Functional Strategy Map validation meeting. Secondly, we also think that the addition of a trade-off question can be beneficial to understanding to how employees interpret the conflicts between themes. Last of all, the Fast-Track Approach that we outlined can be used as a prequel to endeavors that require a qualitative understanding of a company's tacit supply chain strategy.

7. APPENDIX

Exhibit 1: Interview Guide for Methodology – Adapted from Perez-Franco

Introduction (~2 minutes)

Hi, _____, this is _____, calling from MIT's Center for Transportation and Logistics. How are you doing today? ↻

Thanks for agreeing to talk with me, and thanks for your time. As you may know, this interview is part of a research project we are conducting with Lockheed Martin regarding the supply chain strategy of the Project. The interview will take no more than 1 hour. I remind you that:

- Your answers will be treated anonymously. Your name will not be linked to any answer.
- We have signed a confidentiality agreement with Lockheed.
- The interview is voluntary. You have the right to decline to answer any given question,
- I understand we have your consent to record this interview. Is that correct? ↻ I remind you that have the right to revoke this permission at any time.

Do you have any questions? ↻ (Answer the questions, if any). Let's proceed.

Positioning questions (~7 minutes):

1) **How long have you been in the aerospace industry?**

   Encourage them to speak at length about their experience, to warm them up and build rapport. Follow up with questions like

   - **How long have you been with Lockheed Martin?**
   - **How long have you been in your current position?**

2) **Help us locate you in the big picture. To which function, department or area does your current position belong?**

3) **Help us understand how involved you are with the supply chain strategy of the Project. Would you describe your position as one that participates directly in crafting this strategy?** *(Make a note of whether they answer Yes or No to this question.)*

Open section (~30 minutes):

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Pursue interesting areas in the form of a conversation. Pay attention to what the respondent says, and try to understand it, and ask follow up questions.

If the respondent answered "No" to question 3 above, then ask the questions below.		*If the respondent answered "Yes" to question 3 above, then ask the questions below.*
Only section (~30 minutes) *Ask about the activities of the <u>individual</u>. Select one or more of the following to get a conversation going, and keep it going:* **1A) What are the main activities of your position? What are your responsibilities?** **1B) Typically, what are the activities that receive most of your time and attention?** **1C) Think of a typical week or month. What are the things that take most of your time and attention?** - o - **Now, about your department / function / area.** **2A) What are the main activities of your team?** **2B) What are the activities that receive most of your time and attention as a team?** *Use the probe questions provided below.*		***First section (~20 minutes)*** *Find out about who reports to the individual:* **1A) Could you tell me which positions report to you? (As you listen, make a list.)** **1B) For each position X, ask: What would you say are the key activities of X?** *Use the probe questions provided below.* ***Second section (~10 min)*** *Ask about the activities of the individual:* **2A) Now, back to you. What are the main activities of your position?** **2B) What are the activities that receive most of your time and attention?** **2C) Think of a typical week or month. What are the things that take most of your time and attention?** - o - **Now, about your department / function / area.** **3A) What are the main activities of your team?** **3B) What are the activities that receive most of your time and attention as a team?** *Use the probe questions provided below.*

During the course of this conversation, try to move the conversation from the individuals to the function, and try to keep it anchored on concrete activities and the goal behind these activities.

- *For interesting things, ask:* "**Tell me more about X**".
- *When the respondent is getting vague, ask:* "**Can you give me an example of X?**"
- *If the conversation is getting lost in operational details, ask:* "**What is the purpose of this?**", *or* "**What is the philosophy/idea behind this?**"
- *If the conversation is getting too strategic, ask:* "**How do you implement this?**", *or* "**How do you ensure this happens**", *or* "**How do you enable this?**", *depending on the subject.*

Structured section (~20 minutes)

(You may pick and choose from the following questions. Ask only those that seem relevant to the respondent's area and position, and only those that address things that have not been answered before during the course of the conversation.)

1. *Opportunities and challenges (ask together or separately, as deemed appropriate):*
   o **What would you say are the biggest opportunities facing you today?**
   o **What would you say is the biggest challenge facing your function today?**
2. **What would you say is your business?** *(your as in the area's business)*
   o **What is it that you sell? What value do you provide the customer?**
   o **What is your value proposition?**
3. **Who is your customer?** *(your as in your function's customer, either internal or external)*
   o **What are the needs of these customers?**
   o **Do you divide customers in categories? Do you serve them differently?**
4. *Is there a strategy:*
   o **Would you say there is a strategy guiding the supply chain for the Project?**

Wrap Up (~1 minute)

That's pretty much what I had to ask you. Thank you very much for your time. I really appreciate your answers and your time. I hope I can contact you with follow up questions after I have analyzed our conversation. Do you have any questions? ☼ (Answer the questions, if any Thanks again!

Exhibit 2: Interview Results Word-Cloud

The word-cloud was created using the following web site with our transcribed interviews:

http://www.wordle.net/create

Operational <--- Functional --┌--> Strategic

Validate requirements/analysis in Preliminary Design Reviews

Finalize and validate space vehicle/component design in the Critical Design Reviews

Conduct additional formal program reviews as required to verify manufacturing capabilities, test readiness, and other critical elements

Drive out issues early through Engineering Development Unit builds

Rigor in establishing long-term corrective action on defects

Implement internal corrective action process to encourage program personnel to bring forward issues and drive process improvements

Utilize Corrective Action Board to aggressively address systemic issues

Reduce the number of defects

Ensure the quality of the program

Use earned value management as a tool to track schedule and cost

Utilize monthly reports to evaluate cost and schedule performance

Utilize integrated subcontract management team to manage technical and schedule aspects of subcontracts

Use metrics as a tool for awareness

Establish quantitative measures and metrics to measure team and hold team accountable to these

Ensure team is focused on appropriate activities

Manage team performance

Maintain the affordability of the program

Flow program plans as required by the subcontract agreement to suppliers

Manage support personnel at supplier sites

Prioritize requests through time phasing

Manage process flow to communicate unique program requirement changes

Act as the voice of the customer to suppliers

Execute and deliver successfully

Spend time resolving manufacturing issues through problem solving methods

Approve designs that fulfill specifications

Involve Quality Assurance in drafting and approving requirements and specifications

Involve Quality Assurance in Development Evolutions

Produce a Technically Compliant Product

Maintain the long-term success of the program

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Operational ←--- Functional --⌐--→ Strategic

Evaluate schedule impact from red flag events

Approve red flag solutions that satisfy requirements

Lead Material Review Board activities for nonconforming items

Participate in Failure Review Board to resolve test anomalies

Conduct Corrective Action Board to review trends and resolve quality issues

→ Resolve quality anomalies

Work with the enterprise organization to develop affordability and leveraging opportunities

Review customer requirements for cost inefficiencies

Challenge requirements that don't make sense

Aggregate procurement from shared suppliers when beneficial

Consolidate purchasing for high volume or dollar parts to Denver

Take advantage of corporate agreements for standard parts

Share lessons learned and knowledge within the company

→ Comply with the company's affordability initiatives

Minimize lead time through parallel testing

Convert some SCDs to heritage parts when possible

→ Work with suppliers to reduce costs

Conduct competitive bids to identify most qualified supplier

Ensure the designs and requirements are flown down correctly

Ensure appropriate staffing is in place

Execute agreements in a timely manner

Deal with exceptions quickly

→ Manage the deployment of subcontracts

Ensure the quality of the program

Maintain the affordability of the program

Execute and deliver successfully

Maintain the long-term success of the program

Functional Strategy Map, Part 3 of 4

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Operational items	Functional	Strategic

Manage the execution of subcontracts:
- Hold suppliers accountable
- Evaluate and reward supplier performance
- Monitor suppliers in different development cycles
- Manage the activities of integrated product teams
- Ensure subcontract hardware is delivered to the program on the date needed
- Ensure timely review and response to Supplier Data Requirements List submittals

Manage change requests:
- Approve changes through review boards
- Decide how to best incorporate changes
- Filter the different reporting pieces of the product team to have one uniform voice
- Modify and renegotiate contracts to reflect changes as needed
- Pre-coordinate changes with program approvers

Manage supplier issues:
- Manage exceptions to Statement of Work, Compliance Documents, and program requirements
- Ensure closure of technical issues
- Ensure potential impacts are successfully mitigated in a timely manner
- Flow potential changes to supply chain for impact assessment consistently

Control the costs of the program:
- Bid competitively for commodity parts
- Evaluate development and test costs for alternative suppliers
- Utilize long term agreements for volume pricing
- Manage cost through realistic understanding of requirements
- Develop leverages in prime contracts
- Manage modifications to requirements & specifications to minimize impacts across program
- Manage risk and opportunities across the program
- Develop an understanding of cost drivers
- Clarify baseline requirements and quickly resolve exceptions

Strategic:
- Ensure the quality of the program
- Maintain the affordability of the program
- Execute and deliver successfully
- Maintain the long-term success of the program

Operational ← - Functional - -┐- -→ Strategic

Ensure the quality of the program

Maintain the affordability of the program

Execute and deliver successfully

Maintain the long-term success of the program

Create partnerships with suppliers

- Make every effort to utilize reliable and compliant suppliers
- Pursue alternative sources for alternative suppliers and key technologies
- Integrate schedule and process structure with subcontractor
- Create open communication channels from customer to supplier

Ensure on-time delivery with the appropriate level of quality

- Utilize integrated subcontract management team to manage technical and schedule aspects of subcontracts
- Communicate to customer change requests that impact schedule, cost, and/or risk
- Utilize Integrated Product Teams to manage technical and schedule aspects of components and assemblies
- Utilize formal evaluation process to select the optimal supply base for the program
- Address cost/schedule issues through cross-functional meetings

Maintain a transparent program to supply chain partners

- Invite the customer to most of the meetings
- Require from suppliers information on their personal company investment
- Share information on schedule, risk, and cost with the customer routinely
- Conduct monthly Program Management Reviews with customer and major partners

Make Decisions based on long-term benefits

- Consider up front investment if it will reduce future costs if supported by business case
- Provide on-site help to subcontractors when required
- Build high quality test units to flight-ready specs
- Wring out problems early in the program to minimize delays later

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Exhibit 4: Evaluation Results Legend

	Strategic Themes
ST1	Ensure the quality of the program
ST2	Maintain the affordability of the program
ST3	Execute and deliver successfully
ST4	Maintain the long-term success of the program

	Functional Themes
FT1	Reduce the number of defects
FT2	Manage team performance
FT3	Act as the voice of the customer to suppliers
FT4	Produce a technically compliant product
FT5	Resolve quality anomalies
FT6	Comply with the company's affordability initiatives
FT7	Work with suppliers to reduce costs
FT8	Manage the deployment of subcontracts
FT9	Manage the execution of subcontracts
FT10	Manage change requests
FT11	Manage supplier issues
FT12	Create partnerships with suppliers
FT13	Ensure on-time delivery with the appropriate level of quality
FT14	Maintain a completely transparent program to supply chain partners
FT15	Make Decisions based on long-term benefits
FT16	Control the costs of the program

	Operational Themes
OT1	Use earned value management as a tool to track schedule and cost
OT2	Utilize monthly reports to evaluate cost and schedule performance
OT3	Utilize integrated subcontract management team to manage technical and schedule aspects of subcontracts
OT4	Use metrics as a tool for awareness
OT5	Establish quantitative measures and metrics to measure team and hold team accountable to these
OT6	Ensure team is focused on appropriate activities
OT7	Flow program plans as required by the subcontract agreement to suppliers
OT8	Manage support personnel at supplier sites
OT9	Prioritize requests through time phasing
OT10	Manage process flow to communicate unique program requirement changes
OT11	Work with the enterprise organization to develop affordability and leveraging opportunities
OT12	Review customer requirements for cost inefficiencies
OT13	Challenge requirements that don't make sense
OT14	Aggregate procurement from shared suppliers when beneficial
OT15	Consolidate purchasing for high volume or dollar parts to Denver
OT16	Take advantage of corporate agreements for standard parts
OT17	Share lessons learned and knowledge within the company
OT18	Minimize lead time through parallel testing
OT19	Convert some Source Control Drawings to heritage parts when possible
OT20	Conduct competitive bids to identify most qualified supplier
OT21	Ensure the designs and requirements are flown down correctly
OT22	Ensure appropriate staffing is in place
OT23	Execute agreements in a timely manner
OT24	Deal with exceptions quickly
OT25	Hold suppliers accountable

OT26 Evaluate and reward supplier performance
OT27 Monitor suppliers in different development cycles
OT28 Manage the activities of integrated product teams
OT29 Ensure subcontract hardware is delivered to the program on the date needed
OT30 Ensure timely review and response to Supplier Data Requirements List submittals
OT31 Approve changes through review boards
OT32 Decide how to best incorporate changes
OT33 Filter the different reporting pieces of the product team to have one uniform voice
OT34 Modify and renegotiate contracts to reflect changes as needed
OT35 Pre-coordinate changes with program approvers
OT36 Manage exceptions to Statement of Work, Compliance Documents, and program requirements
OT37 Ensure closure of technical issues
OT38 Ensure potential impacts are successfully mitigated in a timely manner
OT39 Flow potential changes to supply chain for impact assessment consistently
OT40 Bid competitively for commodity parts
OT41 Evaluate development and test costs for alternative suppliers
OT42 Utilize long term agreements for volume pricing
OT43 Manage cost through realistic understanding of requirements
OT44 Develop leverages in prime contracts
OT45 Manage modifications to requirements & specifications to minimize impacts across program
OT46 Manage risk and opportunities across the program
OT47 Develop an understanding of cost drivers
OT48 Clarify baseline requirements and quickly resolve exceptions
OT49 Make every effort to utilize reliable and compliant suppliers
OT50 Pursue alternative sources for alternative suppliers and key technologies
OT51 Integrate schedule and process structure with subcontractor
OT52 Create open communication channels from customer to supplier
OT53 Utilize integrated subcontract management team to manage technical and schedule aspects of subcontracts
OT54 Communicate to customer change requests that impact schedule, cost, and/or risk
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OT56 Utilize formal evaluation process to select the optimal supply base for the program
OT57 Address cost/schedule issues through cross-functional meetings
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OT59 Require from suppliers information on their personal company investment
OT60 Share information on schedule, risk, and cost with the customer routinely
OT61 Conduct monthly Program Management Reviews with customer and major partners
OT62 Wring out problems early in the program to minimize delays later
OT63 Provide on-site help to subcontractors when required
OT64 Build high quality test units to flight-ready specs
OT65 Consider up-front investment if it will reduce future costs if supported by business case

Exhibit 5: Grievances Identified from Interviews

- No dedicated resources for Earned Value Management, it burdens current employees

- Modifications from Critical Design Review are flowing down late

- Need to continue to standardize information flow to all subcontractors

- Not much proactive communication between functional organizations for spec updates

- Have to be concerned with cost, schedule, and technical but one cannot be preferred

- Key supplier finished Preliminary Design Review and Critical Design Review on time, having some schedule issues now

- Requirements driving high supplier costs

- Combat unanticipated problems through firefighting rather than through a specific code of conduct

- Lack of data flow for program unique requirements

- Lack of Quality Assurance involvement when marketing does some early activities

- Cumbersome process for SIP

- In some cases the design matures before formal review

- Challenge from buyers not being in the same facility

- Challenge from competing priorities with exception reviews

- Perceived growth of requirements by suppliers due to changes made

- Combat shrinking high-reliability domestic supplier base

Exhibit 6: Opportunities Identified from Interviews

- Figure out how to become cost efficient through opportunities to reduce costs

- Need to communicate the supply chain strategy to the team

- Improve change management - live off the same practice and make them approvers for changes

- Majority of exceptions were just clarification of wording within the Source Control Drawings

- Have to make the engine perfect, cannot repair it once it is launched

- Optimistic they've developed a low risk approach to execution of the program

- Assess current metrics and determine if they are value-add

- Need more interest/focus from management in defining priorities

- Opportunity to apply lessons learned from and to other programs

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