An Analysis of Long-Term Agreements with Suppliers in Lockheed Martin's Commercial Satellite Systems Division

by

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Abstract

Lockheed Martin designs and builds commercial satellites to customers' specifications. The customers, such as telecommunications companies and weather forecasters, are very price sensitive and, usually, award contracts to the lowest priced bids. Lockheed manufactures satellites using a combination of in-house manufacturing, purchasing, and subcontracting (for subcontract parts). The subcontract parts constitute a majority of a satellite's costs. Lockheed uses contracts and other supply management techniques to stay competitive and to keep satellite, specifically subcontract part, costs under control. Some of the subcontract part contracts are managed under subcontract agreements called long-term agreements (LTA). A small supplier pool, long turnover (for bringing these suppliers onboard), regulatory requirements, and capital-intensive nature of the industry are important considerations in evaluating these LTAs. The LTAs embody the risks inherent in project supply chains, specifically, price, currency, and supply risks. In such events, LTAs can become a liability and can lead to monetary losses or discord with suppliers. This thesis provides an overview of the satellite supply chain, analyzes supplier relations to better understand the business dynamics, and analyzes LTAs to better control the satellite input costs.

Key words: commercial satellite, contractor, long-term agreement, subcontract, Lockheed, subcontractor, LTA, satellite supply chain, contracts

Thesis Supervisor: Dr. Edgar Blanco
Title: Executive Director, SCALE Latin America

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2008-2009 has been a fantastic year for me with this thesis in the backdrop. I would like to thank Dr. Chris Caplice for the wonderful MLOG program. In the absence of relevant literature it was challenging to research satellite systems' supply chain but a fine guidance by and engaged discussions with Dr. Edgar Blanco, my advisor, and patient listening and answering by Mr. George Korizis of Lockheed Martin provided a research outlet that was both fulfilling and productive. I would like to thank Dr. Blanco and Mr. Korizis for their encouragement and support over the course of this thesis.

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1 Introduction

The space age started in 1957 with the launch of first satellite, Sputnik 1. After Sputnik, the satellite development was rapid. Within next two years, weather and communication satellites were launched. Satellites are now being used to provide services like earth observation, television, telephones, navigation, Internet, weather, climate and environmental monitoring, and space science. And the service growth continues. This growth generates demand for more satellites. However, a satellite is defense article that is also International Traffic in Arms Regulations (ITAR)-protected. As a consequence, the satellite product and technology that is sold to commercial and foreign customers is less advanced, and carefully regulated and protected. And thus, satellite manufacturers divide all satellite orders, and consequently customers, into the following two categories: commercial and government. Between these two categories, the demand for commercial satellites has been significant. See figure 1.1 for in-orbit data for satellites.

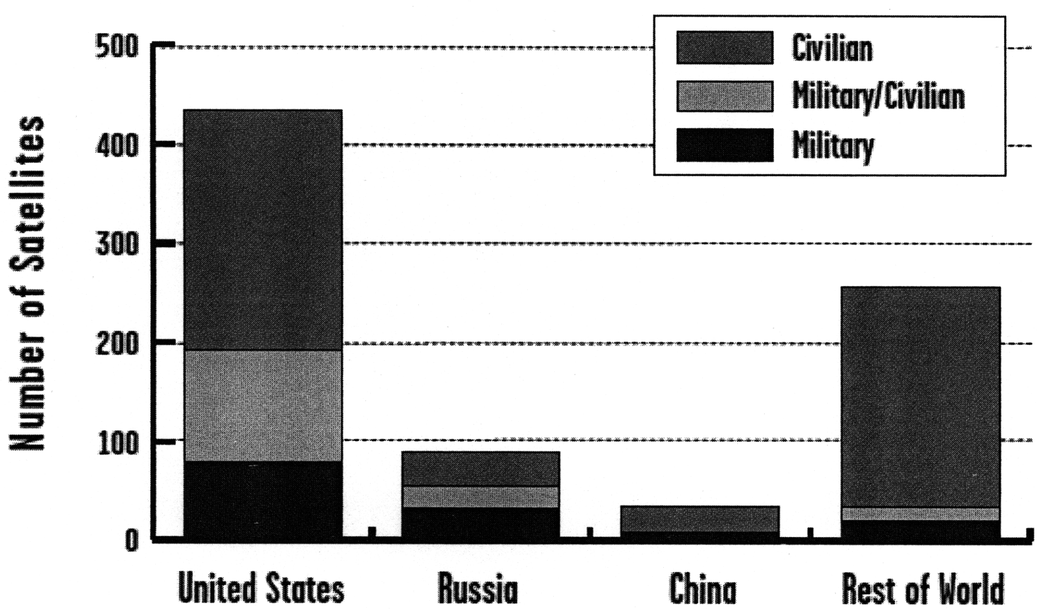

Figure 1.1. Estimate of Satellites (launch data through 4/1/2009), by Country (Source: www.ucsusa.org)

The commercial satellite product and supply chain are different from their government counterparts. The difference can be highlighted using the following three factors – 1) government systems have more regulatory restrictions in terms of where a contractor can source the subassemblies, 2) government systems are usually more technologically advanced, and 3) the government satellite sourcing process is a superset of the commercial supply chain; a government satellite is often prototyped to specification to win a contract as against a commercial satellite which contract is won on bid price.

A satellite supply chain has three stakeholders: customers (government or commercial), contractors (satellite manufacturers e.g., Lockheed, Boeing), and suppliers. From a contractor point of view, the regulatory restrictions affect government satellite supply chain choices by limiting the sourcing options (suppliers) and affect commercial supply chain choices by limiting the selling options (customers.) One more difference is the difference in commercial and government satellite ordering process. Government satellite supply chain is guided more by national interest and product performance than by competition. Commercial customers buy satellites using competitive bids and, if delivery schedule is met, price is the single most important factor. A satellite price is directly determined by the raw material or subassembly costs. These costs comprise about seventy to eighty percent of total satellite costs. Thus, effectively supply management has become very critical to stay competitive in the space industry. Strategic sourcing and partnerships are being used to keep costs low and to drive up efficiencies [1].

The satellite industry is moving toward more collaborative partnerships with suppliers to gain competitive advantage. The challenge, however, continues to be managing relationships amid complexity. The contractors try to secure the supply for the life of the projects using long-term agreements. In fact, a lot of times contractors and suppliers bid as a consortium of providers to secure a contract (project). This helps the contractor avoid getting stalemated by lack of supplies or getting stuck with a tier two or unqualified supplier.

This thesis builds on input from Lockheed Martin Space Systems Company (LMSSC), a division of Lockheed Martin Corporation. LMSSC has footprint in research, design, development, integration, and manufacture of advanced satellite systems. LMSSC, based in Denver, provides space systems for both government and commercial sector. Lockheed, a contractor, uses long-term agreements (LTA) and general pricing agreements (GPA) among other things, to keep the costs under check. LTA and GPA are both a supply and a pricing agreement between a contractor and a supplier whereby they agree on prices and quantities for a certain satellite part for a certain period of time. LTA is usually two years' long while GPA is an yearly contract. That said, GPAs and LTAs are used to procure different kind of items. GPAs are used to procure commodities while LTAs are used to procure subcontract items. Subcontract items comprise about sixty percent of a Lockheed satellite's raw material input costs. Commodities, subcontract items, contractors, and suppliers are explained at length later on in sections 4 and 5.

The need to understand and manage the satellite supply costs, and a lack of comprehensive literature on satellite systems supply chain is the motivation behind this study. The research focuses on understanding the supplier relations and long-term agreements (LTA) in the commercial satellite systems supply chain. That said, this study provides an overarching strategic supply management perspective that is relevant to government side as well.

The satellite supply chain explained in this study is a consequence of knowledge and understanding gained through relevant literature, Internet, and interviews and surveys with Lockheed and industry thought leaders. Kraljic's purchasing portfolio model is used in this study to understand and to analyze the satellite supply management and contractor-supplier relations. The focus has also been on understanding and using LTAs as a strategic sourcing tool to keep the cost of supply low, to encourage partnership, and to ensure supply for high-demand periods.

2 Review of the Literature

2.1 Contracts

Contractors should use a differentiated strategy in engaging with suppliers [2]. The focus should be on suppliers with the greatest strategic importance. When an item being sourced is not very specific to the contractor's product and a broad supply base exists, competitive bidding may be best. The Japanese lean manufacturers strategically segment their supply chain and subject to the nature of sourcing item pursue both close partnership and arms-length relationships [3]. Bakos and Brynjolfsson [4] offer economic models to establish that even if it is easy and cost effective to coordinate with a wide variety of suppliers, firms can often maximize profits by relying on fewer sources. This reduces a contractor's bargaining power but increases the incentive for a supplier to make investments which yield good paybacks for both. In designing a supplier relationships strategy, however, it is important for the contractor to consider interdependence. Supplier dependence is the degree to which a supplier relies on the business of a contractor for its revenue stream. In a study of supplier innovation in the automotive industry, Kamath and Liker [5] found that independent suppliers are motivated to innovate only when it makes economic sense. However, dependent suppliers, if they have a good idea of the kinds of innovations that a contractor values, can often be motivated to innovate in the absence of financial incentives. For a contractor, dependence refers to relying on a supplier for unique knowledge or capabilities critical to the contractor's product. It is a function of the availability of alternative sources.

2.1.1 Communication

Good communication between the contractor and supplier facilitates innovation. It helps reduce supplier uncertainty and enables the exchange of ideas to pool knowledge and experience to tackle problems jointly. The benefits are mutual. The contractor understands the supplier's capabilities and constraints better. The supplier gains a clearer perspective of the requirements and insight into what contractor values most. It also gives the supplier guidance in making competency-enhancing investments that aid its strategic positioning for future. A supplier will generally be more likely to invest resources and expend effort to pursue innovation when the contractor's technological targets are better defined.

Good communication can also lead to greater trust between the parties and when companies trust one another they can eliminate costly audit mechanisms, increasing the efficiency and value in their interactions. Research on U.S., Japanese, and Korean automakers found that high levels of trust in the supplier leads automakers to spend significantly less time working on unproductive, transaction-oriented issues [6]. The research found that better communication improved purchasing agents' efficiency, managing on average more than twice the volume of goods. Instead of just pursuing greater data exchange, the literature points out that companies should improve communication that builds trust.

2.1.2 Contract Structure

Contractors can also incentivize innovation using contracts. The contractor faces a number of options regarding contract terms, length, and number of sources. A variety of factors must be utilized to determine optimal contract structure. These include the degree of competition, the knowledge content and technological maturity of the item, the rate of technological change, and transaction costs. In cases of intense competition, the nature of supplier relationships may be inconsequential compared to market forces driving innovation. As mentioned previously, however, it may also be advantageous to intentionally limit competition by committing to a select number of sources, which can improve coordination and encourage investment in non-contractual assets. In the case of technologically mature items with minimal new knowledge content, room for innovation may be small and an arms-length, competitive approach may be best.

Transaction costs can be minimized by reducing the number of sources, keeping the contract terms simple, and by avoiding frequent negotiations. The contractor should carefully consider the market situation described above before making decisions regarding the contract variables within its control. Long-term contracts can be used to encourage innovation; the prices can be agreed upon for several years in advance avoiding costly re-negotiations. A predictable long-term demand can incentivize suppliers to invest in innovative ideas even when they might have a lengthy payback period. The contractor might not experience the cost reductions associated with supplier innovation immediately; however, the renegotiation price at a future date may be much lower than if these innovations had never occurred. The supplier gets to keep some surplus by reducing costs below the contract price and the contractor, potentially, benefits from a lower price upon eventual contract renegotiation, as shown in figure 2.1 below. In a study describing how Chrysler transformed its supply chain [3], maintains that the key to transforming suppliers into true partners is establishing means to incentivize suppliers to participate in "expanding the pie". However, sharing the pie depends on the contractor's ability to audit or estimate the supplier costs.

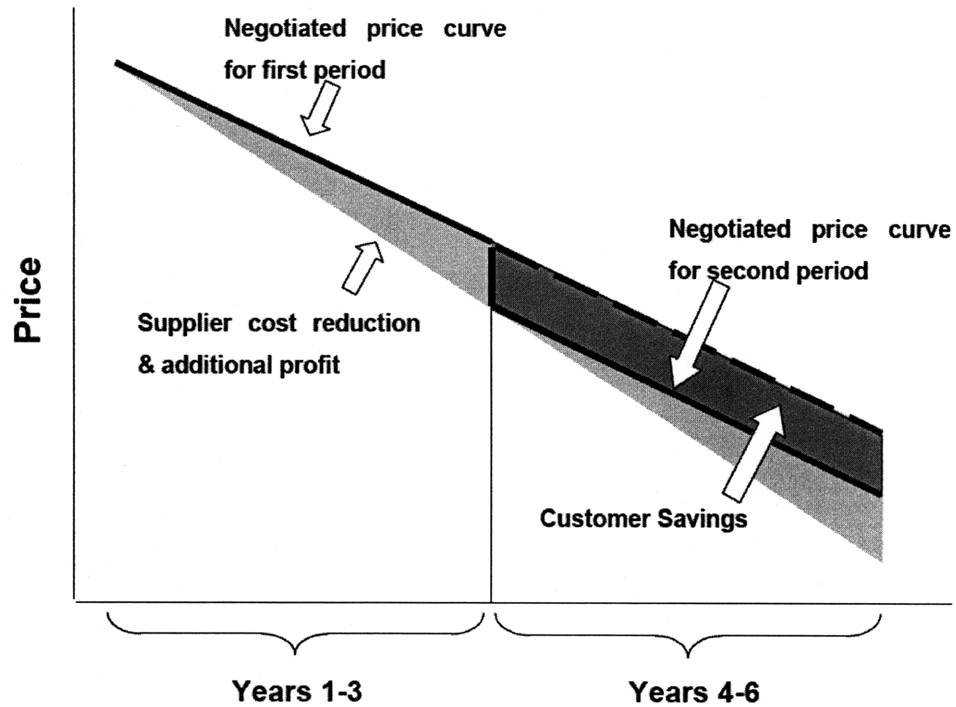

Figure 2.1. Long-Term Contracts and Pricing

On the negative side, long-term contracts may reduce the competition-induced incentive to innovate. They may also lock a contractor into a particular supplier and design. To avoid these negative consequences, Japanese companies often engage in simultaneous long-term commitments with two or three suppliers. This provides partnership, competition and flexibility because the percentage of the total contract each supplier receives is performance dependent [7]. In the satellite industry, however, dual sourcing is often not a viable option. Due to low volume, part complexity, and specialization it may not be economical to have more than one supplier. Oftentimes, there are few alternative sources possessing the necessary capabilities, and switching costs are high. And when alternative sources do exist, suppliers potentially agree to ambitious cost or performance targets in exchange for becoming the sole source for years ahead. When a supplier is the only available source, however, it is virtually guaranteed of future business. And thus, long-term contract with that supplier may not be feasible. If at all, a long-term contract would essentially just involve agreeing on prices for several years in advance rather than doing so frequently.

The two simplest and most common contract types are fixed-price and cost-plus contracts. In the former, the contractor negotiates a firm price at which it will procure the item. In the latter, the supplier receives some fixed percentage profit on top of its reported cost for producing the item. Fixed price contracts generally provide greater incentive for innovation from the standpoint that suppliers can make additional profits by reducing costs. Nevertheless, cost-plus contracts have other advantages and are also used frequently, particularly in design and development phases of projects. Due to the uncertainty involved with developing complex new technology, suppliers under fixed price contracts may charge extremely high prices to compensate for risk. They would also be prone to choose the least risk technology solutions, rather than pursue innovative new possibilities. Therefore, the contractor may opt for cost-plus contracts coupled with close monitoring of the suppliers' costs.

2.2 Potential Industry Earnings (PIE)

Every industry is part of a value chain: the chain from raw materials to the final customer [8]. Figure 2.2 illustrates a 3-tier value chain. All participants in the value chain

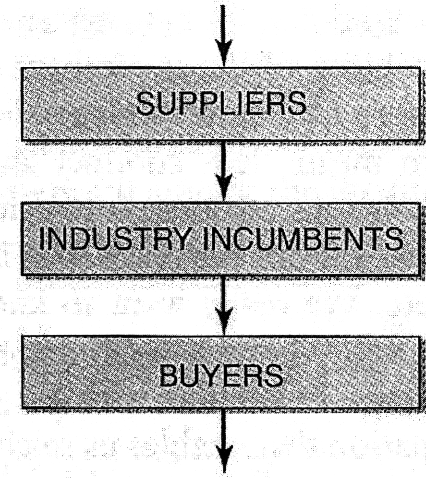

Figure 2.2. An Illustrative Value Chain

contribute to the final value it creates. Each participant would like to maximize this value, and their share therein. An industry analysis identifies the factors that determine how much value is created and how it is divided. Figure 2.3 below illustrates PIE using demand-cost curves.

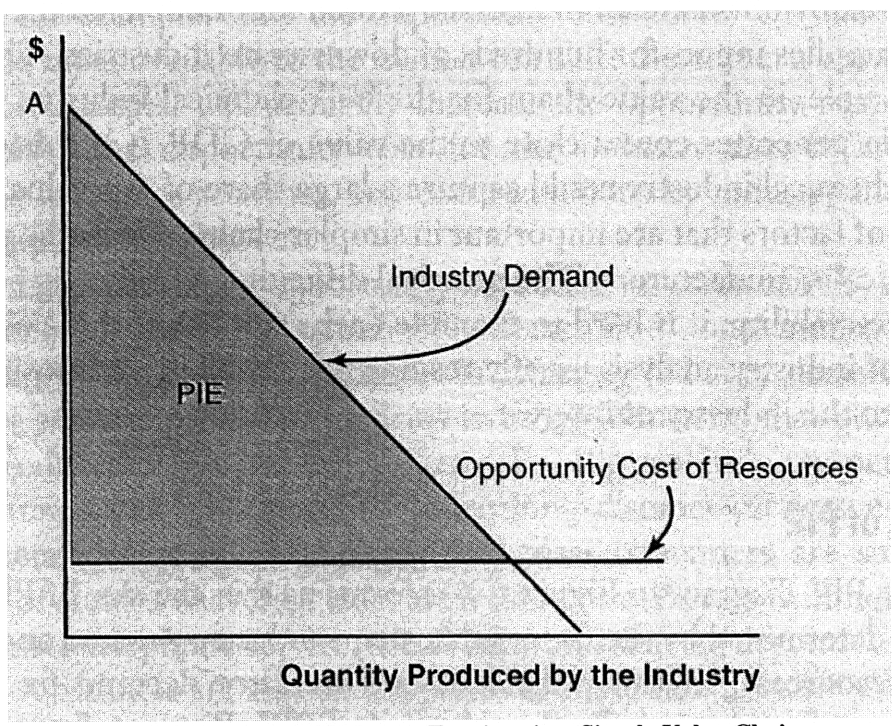

Figure 2.3. Potential Industry Earnings in a Simple Value Chain

The demand curve represents the buyer's willingness to pay for the incumbent firms' products. The line with label "opportunity cost of resources" represents the industry cost curve. Potential industry earnings (PIE) is the total value created minus the opportunity cost of resources required to produce that value, or the area defined by the industry demand and opportunity cost curves. The word "potential" is used as a modifier because an industry can rarely capture all its value.

A change in industry demand or opportunity cost of resources affects the size of the PIE. Figure 2.4 summarizes some forces that can make PIE larger. On a similar note, PIE can become smaller as well: increase in the raw material prices can lead to higher cost of resources.

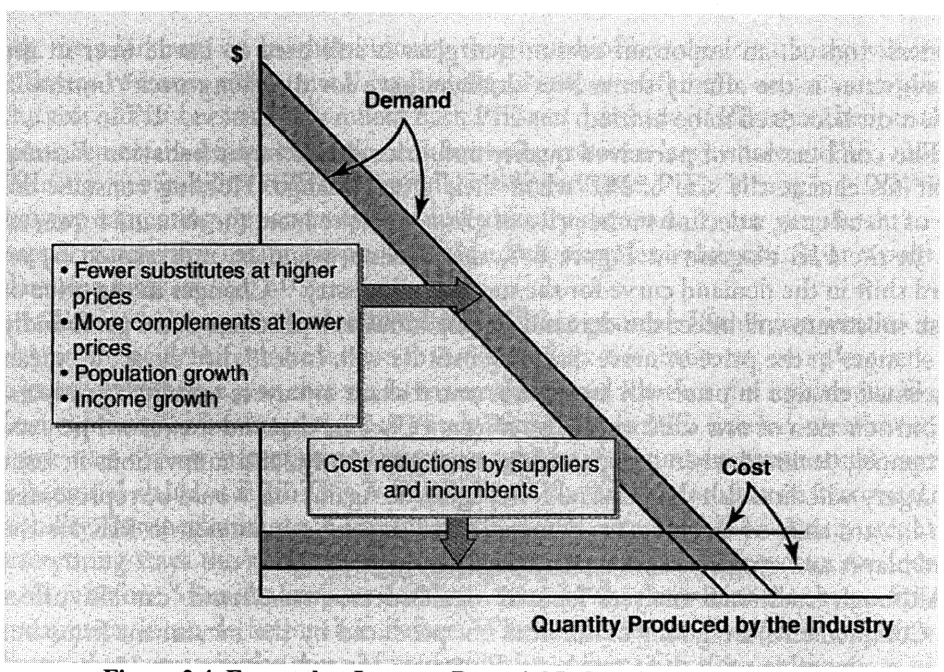

Figure 2.4. Forces that Increase Potential Industrial Earnings (PIE)

Our interest is in the dividing that PIE. Porter [9] identified four forces that determine how PIE is allocated within the value chain: competition, entry, buyer power, and supplier power. In this study we are specifically interested in vertical PIE division: a division between the buyers and suppliers. To isolate the effect of vertical division we will assume "competition" and "entry" as constant and having no impact on the PIE in the value chain.

If the supplying industry is intensely competitive, no firm in it can exert supplier power. Another way to think about this is to ask how easily a contractor could buy input from another supplier if the current supplier raises price. Most commodity products, such as copper, steel, and so on, are fairly homogenous, and contractors can easily switch supplier. Here what matters is relative strength of an individual supplier to an individual contractor. Suppliers and contractors acting as a group, however, change the market dynamic in the group or consortium's favor.

2.3 Kraljic's Purchasing Portfolio Model

In his seminal paper "Purchasing must become supply management" [10], Kraljic laid out a diagnostic and strategic framework for supply management. The diagnosis uses the following five exploratory supply questions: -

1. Are all the company divisions making a concerted effort to take advantage of opportunities?

2. Are the bottlenecks and interruptions avoidable?

3. What is the risk tolerance?

4. What are the make-or-buy policies to get a good balance between cost and flexibility?

5. How much co-operation with suppliers or competitors is best to capitalize on shared

resources?

Kraljic lays out supply strategy using a four-phase approach. First, Kraljic offers classification criteria for purchasing material requirements, figure 2.5 lists an adaptation of this criteria. A company classifies its purchased materials in terms of profit impact and supply risk. A material's strategic category can change subject to change in demand and supply patterns. The supply decisions of the strategic items needs to be made using a variety of analytic techniques which include market analysis, risk analysis, simulation and optimization models, price forecasting, and other supporting microeconomic analysis.

Procurement Focus	Main Tasks	Required Information	Decision Level
Strategic Items	Accurate demand forecasting. Detailed market research. Development of long-term supply relationships. Make-or-buy decisions. Contract staggering. Risk analysis. Contingency planning.	Highly detailed market data. Long-term supply and demand trend information. Good competitive intelligence. Industry cost curves.	Top level (e.g., vice president, purchasing).
Bottleneck Items	Volume insurance (at cost premium if necessary). Control of vendors. Backup plans.	Medium-term supply demand forecasts. Very good market data.	Higher level (e.g., department heads).
Leverage Items	Exploitation of full purchasing power. Vendor selection. Targeted pricing strategies/negotiations. Contract/spot purchasing mix. Order volume optimization.	Short-to-medium-term demand planning. Good market data. Accurate vendor data. Price rate forecasts.	Medium level (e.g., chief buyer).
Noncritical Items	Product standardization. Order volume optimization. Efficient processing.	Good market overview. Short-term demand forecasts.	Lower level (e.g., buyers).

Figure 2.5. Classifying Purchasing Material Requirements (adapted from Kraljic, 1983)

After classification, a company reviews the supply market. It assesses relative strength of existing vendors, and the availability of strategic materials. The company follows this up with evaluation of its material requirements and its ability to get desirable supply terms. Next, the company evaluates the strategic items, identified in phase one, in the purchasing portfolio matrix (see figure 2.6.)

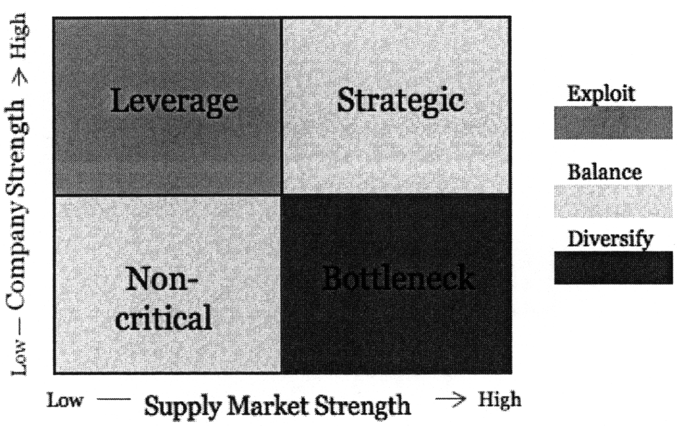

Figure 2.6. The Purchasing Portfolio Matrix (adapted from Kraljic, 1983)

When the company has a dominant market position, the best strategy is exploitation. Under low supply risk, this strategy provides the best profits. On the contrary, when the suppliers are strong, diversification is the best option. It calls for increased spending on market research, and the possibility of backward integration. "Balance" refers to a well-balanced intermediate strategy.

Finally, in the short term, for the strategic items where the supplier's strength is greater than a company's and the prescribed strategy is diversification, the company should strengthen its position by consolidating volume in a single supplier and, if possible, using supply contracts. However, to reduce long-term supply risk, the company should search for alternative suppliers or consider vertical integration. On the other hand, if the company is in a dominant position it can spread volume over suppliers, and increase spot purchases.

The fundamental assumption of portfolio models seems to be that differences in power and dependence between buyers and suppliers exist [11]. The general idea of Kraljic's model is to minimize supply risk and make the most of buying power. Still, little is known about how these concepts influence the choice for a specific purchasing strategy. We needed to gain a better understanding of how purchasing portfolio models are being used in practice and how they could be used by purchasing professionals in order to pursue effective differentiated purchasing strategies. This paper, using data from a comprehensive survey among Dutch purchasing professionals, empirically quantifies 'relative power' and 'total interdependence' for a number of portfolio-based purchasing strategies. The research findings indicate that there is no simple, standardized blue print for the application of the portfolio analysis. It requires reflecting on results, critical thinking and sophistication of purchasing management.

2.4 Power Perspective in Supply Management

A focus on buyer and supplier power is essential for a good understanding of the circumstances that a firm faces [12]. Further, it is important to understand the variables that increase or diminish this power. Cox uses economic theory, buyer's position is best defended by maintaining perfectly competitive supply markets, to argue that buyer supplier relations are inherently conflictual. And thus, any buyer supplier collaboration will come with some undertone of tension. Cox reminds that money is the reason organizations engage in an exchange relationship. The buyer and supplier choices are made based on the value each will be able to appropriate. Tension, thus, arises from the interest in expanding the organizational share of the PIE, as is laid out in PIE Framework, section 2.2 above. Cox cautions that there can be no "best practice" way of conducting buyer-supplier relationship or the exchange relationship. This relation is subject to the dynamic choices that these players make. Further, best relationship approach is a time-bound variable of uncertainty in circumstances. Only by understanding the resources that enhance and diminish the relative power of buyers and suppliers in specific exchange relationships is it possible to know the best relationship management approach.

Power defines business-to-business relationship [13]. Buying and selling are two key business competencies. On the downstream side, suppliers can obtain leverage by closing the market to competitors and by creating an information advantage over the buyers. In absence of such advantages, a supplier should seek short-term opportunities to win market-share through constant innovation or should look for opportunities to create market closure through merger and acquisition activities. On the upstream side, when the organizations are thinking about supply competence, they should use make-buy decision to augment their power. A robust make-buy methodology necessitates a good understanding of pre- and post-contractual power in buyer and supplier relationships. *The Power Matrix*, figure 2.7 below, outlines a framework to understand and interpret this power relationship.

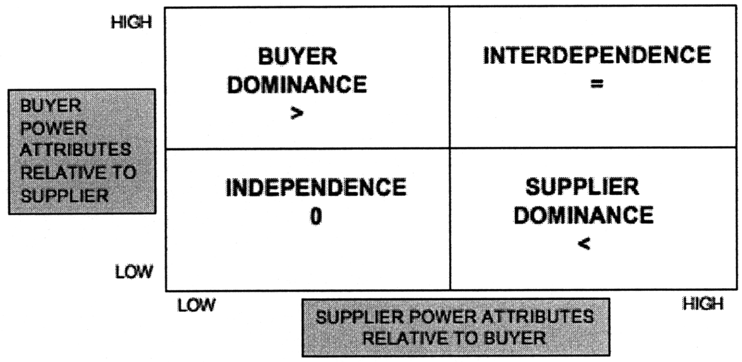

Figure 2.7. The Power Matrix (Cox, 2001)

The matrix bases the buyer-supplier relation on the relative utility and relative scarcity of resources shared between the two parties. In the *buyer dominance* box, the key criteria to evaluate the supplier are cost improvement and quality; the supplier sells at or near the marginal cost. In the *interdependence* box, both, the buyer and the supplier, need to work closely in an engaged manner because both have competencies that the other require; it is the co-innovation and profit-sharing quadrant. In *independence* box, the buyer and the supplier lack the reasons to co-innovate and there is no additional value in collaboration. And in the last, *supplier dominance* box, supplier has all the levers of power.

The key to supply competence lies in a firm's ability to figure out its correct position in *The Power Matrix* and in ability to find ways to move to a more favorable position. Figure 2.8 below provides some key attributes to consider while positioning buyer and supplier relationship using *The Power Matrix.*

Attributes of buyer power relative to supplier	Attributes of supplier power relative to supplier: Low	Attributes of supplier power relative to supplier: High
High	**BUYER DOMINANCE** ▪ Few buyers/many suppliers ▪ Buyer has high % share of total market for supplier ▪ Supplier is highly dependent on buyer for revenue with limited alternatives ▪ Supplier switching costs are high ▪ Buyers switching costs are low ▪ Buyers account is attractive to supplier ▪ Supplier offerings are commoditised and standardised ▪ Buyer search costs are low ▪ Supplier has no information asymmetry advantages over buyer	**INTERDEPENDENCE** ▪ Few buyers/few suppliers ▪ Buyer has relatively high % share of total market for supplier ▪ Supplier is highly dependent on buyer for revenue with few alternatives ▪ Suppliers switching costs are high ▪ Buyer switching costs are high ▪ Buyers account is attractive to supplier ▪ Supplier offerings are not commoditised and customised ▪ Buyer search costs are high ▪ Supplier has significant information asymmetry advantages over buyer
Low	**INDEPENDENCE** ▪ Many buyers/many suppliers ▪ Buyer has relatively low % share of total market for supplier ▪ Supplier is not dependent on buyer for revenue and has many alternatives ▪ Supplier's switching costs are low ▪ Buyer's switching costs are low ▪ Buyer's account is not particularly attractive to supplier ▪ Supplier offerings are commoditised and standardised ▪ Buyer search costs are relatively low ▪ Supplier has only limited information asymmetry advantage over buyer	**SUPPLIER DOMINANCE** ▪ Many buyers/few suppliers ▪ Buyer has low % share of total market for supplier ▪ Supplier is not at all dependent on the buyer for revenue and has many alternatives ▪ Supplier switching costs are low ▪ Buyer switching costs are high ▪ Buyers account is not attractive to the supplier ▪ Supplier offerings are not commoditised and customised ▪ Buyer search costs are very high ▪ Supplier has high information asymmetry advantages over buyer

Figure 2.8. The Attributes of Buyer and Supplier Power (Cox, 2001)

The buyer dominance box is the ideal position for a buyer. Specifically, the buyer supply competence should seek ways to eradicate "isolating mechanisms" that build supplier power and ensure that the supplier market is always highly contested; that way the buyers can ensure that the suppliers receive only normal returns.

Both the Kraljic and the Cox approaches are equivalent. An item is strategic or bottleneck subject to supply landscape. And a supplier is dominant subject to a particular item.

3 Industry Background

Aerospace, and the commercial satellite systems therein, is a high technology industry engaged primarily in the production of aircraft, missiles, and space systems. Satellite manufacturing, rocket manufacturing, launch services comprise the three space systems sub-segments. In the U.S., the satellite manufacturing sub-segment is dominated by Boeing's satellite systems division and Lockheed Martin's space systems segment. In Europe, Alcatel and Astrium, an EADS subsidiary, are the big players.

Figure 3.1 provides the hierarchical view of the aerospace industry and figure 3.2 lists out a limited view of space systems industry.

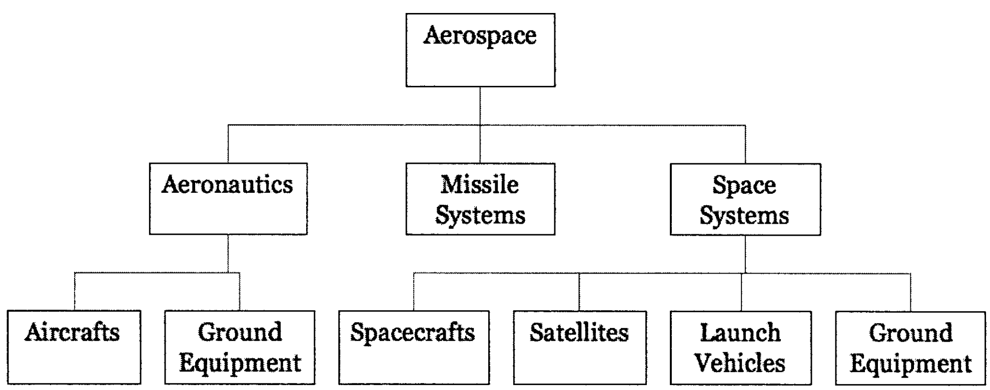

Figure 3.1. The Aerospace Industry

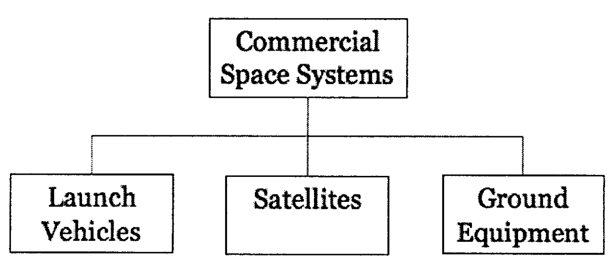

Figure 3.2. Commercial Space Systems

International Traffic in Arms Regulations (ITAR) forms the backdrop of the industry. ITAR regulates US contractors, for example, Lockheed is precluded from competing in many business opportunities outside of the US. ITAR issues limit outsourcing to foreign suppliers. Regulation also limits vertical integration between contractors and suppliers that can lead to captive capacity, because sometimes the suppliers are required to be able to work with various contractors (rather than just one.)

Entry barriers in the satellite industry are quite high in terms of technology and technical know-how. A satellite is arguably one of the most complex and technologically sophisticated products that can be produced by any industry, requiring a command of a wide array of technologies, production processes, organizational structures, and supplier networks. All players in this industry have operated over a long period time and have developed unique resources and capabilities that are difficult to imitate. For these reasons, the entry barriers are very high for the satellite systems industry. Thus, it is very difficult for new entrants to enter. Most often, the new entrants are government-sponsored companies. Government sponsored space programs are usually strategic rather than competitive in nature. Over the time these government-sponsored programs build a supply capacity that is then made available to the outside competitive market. This is one way some of the suppliers enter the market. This trend is especially visible in China and Japan, where the national governments have pushed hard to enter aerospace industry. All in all, governments play a major role in the satellite industry. The lingering presence of state governments in the ownership structure of EADS (European Aeronautic, Defense and Space Company) and the more participatory nature of many European governments in industrial policy may indirectly impact industry independence and flexibility, and influence its responsiveness to market conditions.

Suppliers in this industry are very specialized due to the high technology content of their products and services, which must be designed and produced to exacting requirements and quality specifications. Unlike the case in many industries in the commercial sector, it is very difficult to switch suppliers due to extremely high re-qualification costs and asset-specificity involving high investment costs that are not transferable [14].

Another key feature of the industry is the offsets. Offsets are concessions where, in the event of an overseas procurement, the contractor compensates the purchasing country, or the customer, for a perceived loss to the economy. Offsets are mostly required for sales to foreign governments; more than 150 countries have offset policies. Offset costs (to contractors) range from about 2% to 5% or even more in some areas; i.e. at 3%, $30M is budgeted for offset for each $1B of contract value. U.S. does not have a formal offset policy. Most countries have formal offset policies, including almost all U.S. trading partners. Some offset arrangements that also require the transfer of technology to foreign firms can potentially change the supplier landscape [15]. Such offset agreements should be considered strategically as a change in supplier landscape is of immense interest to the subcontract managers evaluating and negotiating LTAs. The offsets can work to a contractor's advantage as well. For example, in one arrangement Lockheed was forced to take on a new role of improving foreign suppliers because of pressure from their customers. Lockheed spent a significant amount of time, money and effort over a decade to increase their ability to work with international suppliers. Lockheed has received a major payback from this process. This international exposure has made them more attractive to other customers and thus boosted their edge in the highly competitive space systems market.

4 Overview of Satellite Demand and Configuration

A satellite is a very complex and a highly engineered system which costs in excess of hundred million dollars to make. A satellite lasts about 15 years and satellite delivery lead time is about 30 months. The annual satellite demand, commercial and non-commercial, is about a hundred. Figure 4.1 below lists out historical and forecasted figures for all kinds of satellites launches from 1995 to 2014; about 25 to 30 percent of this demand is in the commercial sector. The satellite demand comes from the government and commercial customers, e.g. defense, broadcasting, telecom, and broadband data services companies. During a satellite's lifetime, product reliability is the key quality criterion. Any reliability issue can lead to loss of trust, loss of future business, and order cancellations. In November 2002, PanAmSat cancelled an order it had placed with Boeing Satellite Systems for a BSS-702. The cancellation was due to concern about solar array power problems in some in-orbit BSS-702s. Boeing was no longer using the same *reflectors* on new BSS-702s but the degree of confidence in the BSS-702 had been lost [16].

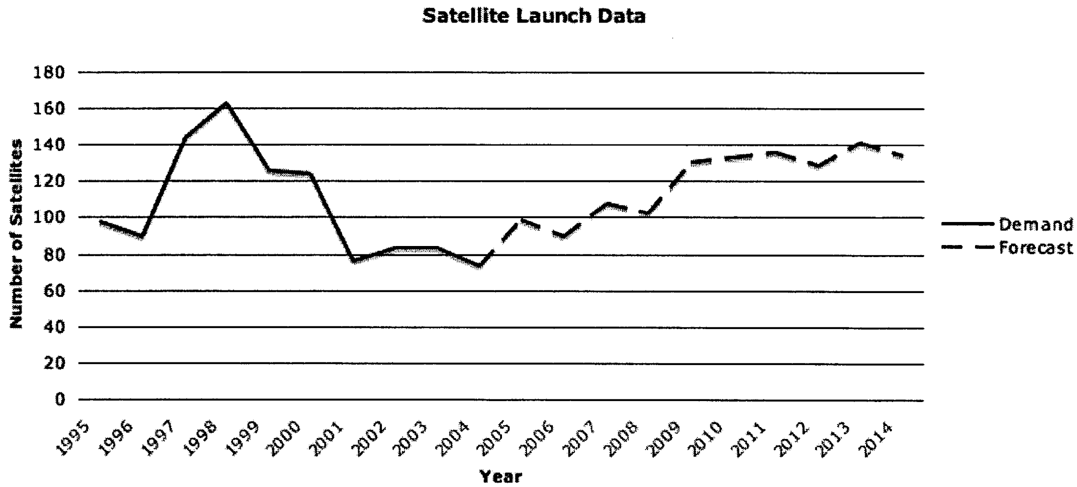

Figure 4.1. Annual Satellite Launch Numbers

For Lockheed, a satellite integrator and manufacturer, a satellite is an assembly of the following three part types – in-house manufacturing, commodities, and subcontract parts. See figure 4.2 for an illustrative view of satellite part types –

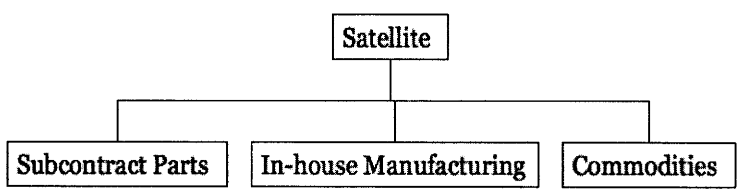

Figure 4.2. Satellite Assembly

Lockheed, and likewise most contractors, build some satellite parts in-house. The in-house manufactured parts are similar to the subcontract parts except that they are not outsourced. The in-house manufacturing is a legacy capacity that is carried on due to efficient manufacturing capability. This also works as a negotiating lever with the suppliers.

Commodities are high volume and low cost items that contractors buy in bulk from suppliers. Oftentimes, contractors have corporate level agreements to cover commodity purchases, the annual agreements are known as general pricing agreements (GPAs). Commodities usually have a shorter procurement lead-time than the subcontract parts.

Subcontract items are a part of satellite that contractors outsource, or subcontract, to suppliers. These suppliers are also called subcontractors. The subcontract items are low volume and high costs items. A typical subcontract part costs anywhere between $250,000 and $3 million dollars. Satellite subcontract parts make up about 60% of the satellite costs. Essentially, subcontract item costs makes up majority of satellite cost and contractors have high stake in keeping these costs low. Satellite subcontract part examples: *Receivers, Command Receivers, Earth Sensors, Sun Sensors, Antennas, Reflectors, Beacons, Structures, Harness Assemblies, Cabling, Switch-bank Assemblies, Converters, TWT (traveling wave tube).* Each of these subcontract parts have a delivery lead time in the range of four to twelve months.

5 Satellite Systems' Supply Chain

The satellite systems supply chain comprises three key parties – customers, contractors, and suppliers. Customers develop requirements and submit requests for proposal to contractors. Contractors prepare the bids. These bids are cost and delivery estimates. The costs are obtained from LTAs, in-house manufacturing, and GPAs. If an LTA is not available, the contractor sends out bids to qualified suppliers for subcontract items. The supplier responses feed into the final bid that the contractor makes to the customer. Contractors reply with bids; the contractors mostly bid by themselves but sometimes the contractors form a consortium with other contractors and suppliers, leveraging different strengths. Finally, the customer awards the bid and the contractor builds to design. Figure 5.1 below illustrates satellite systems supply chain inter-relationships and flow.

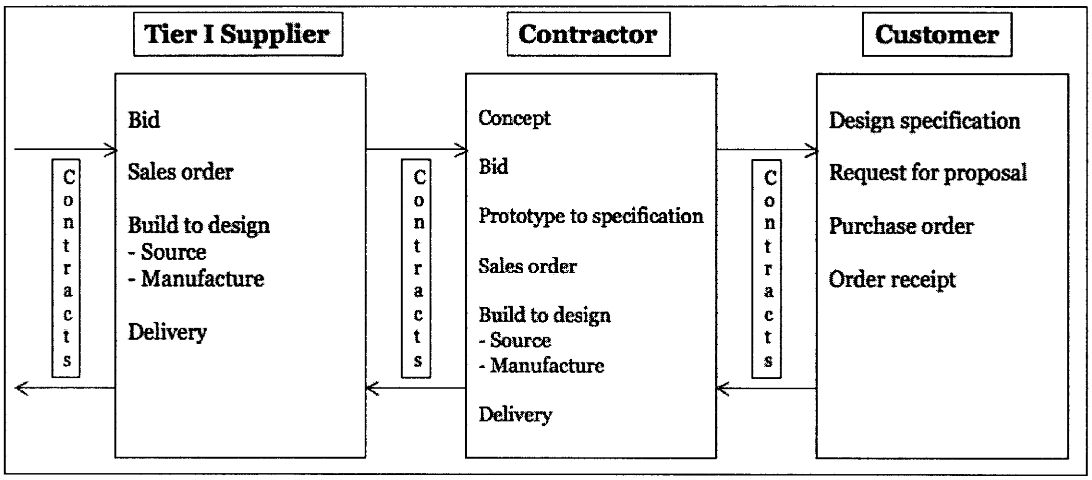

Figure 5.1. Key Supply Chain Layers and Activities

5.1 Key Partners

5.1.1 Customers

Satellite customers can be broadly divided into two categories – government, and commercial. The government customer often comes with a variety of restrictions. For example, the contractor may not be allowed to subcontract outside of the country, the technology and order information may be classified. The government customer may limit its business to specific contractors rather having an open market bid for the satellite projects. A lot of the above may not apply to the commercial customer. However, governments restrict the capability of the satellites available to the commercial customer, and the entities to whom these satellites can be sold. The commercial customer is a non-U.S. government customer like a foreign government, or a broadcasting and a communication company. The commercial satellites are standard satellites and thus the concept and prototyping steps in the supply chain are skipped: the contractors bid to customer's specification and, subject to some negotiations, are awarded bids to manufacture. In case of foreign government orders, offsets may play a significant role in the bid award.

5.1.2 Contractors

The contractor is a systems integrator at the top of the space systems manufacturing value chain. The satellite systems business is dominated by a handful of large aerospace manufacturers or contractors – Lockheed Martin, Northrop Grumman, Raytheon, Boeing, and EADS Astrium. Northrop and Raytheon are largely government contractors. Lockheed, Boeing and EADS have a good footprint in both the government and the commercial sector.

Lockheed has undertaken a whole range of supplier management actions, such as collaborating closely with their suppliers, building long-term relationships, and improving suppliers. Applying these principles while internationalizing the supplier base leads to a situation in which the company ends up working to help improve firms that are or will be their competitors.

5.1.3 Suppliers

Satellite suppliers supply one or more subcontract parts. These suppliers are mostly located in the US, Europe, and Japan. Here is list of a few suppliers along-with the parts they supply: EADS Astrium, Thales Group, SAAB Space (acquired by RUAG), NEC, MELCO (Mitsubishi Electric Corporation), L-3 Communications, ATK, Applied Aerospace, Vanguard, General Electric Aircraft Engines (GEAE), Rolls-Royce, Honeywell and Pratt & Whitney. Some of these suppliers, like EADS Astrium, and Thales Group are competitors as well. These suppliers are also called Tier-1 suppliers, since they are important to and directly contribute to the operations of the contractors. Further upstream, there are the tier-2 and tier-3 suppliers who provide fairly commoditized products to the tier-1 suppliers.

5.2 Order Management Process

Customers send request for proposal (RFP) and design specifications to contractors. The contractors estimate the cost to build to this specification. This cost estimation takes input from commodity price contracts, in-house manufacturing cost estimates, and supplier subcontract item prices. The subcontract item prices are available in the LTA documentation. However, Lockheed does not have LTAs for all subcontract parts. The cost estimate for subcontract parts for which LTAs are not available is done using RFP process. Lockheed sends out RFPs to the prospective suppliers. The supplier bid responses are evaluated and bids are awarded to suppliers which are binding on Lockheed and suppliers subject to Lockheed winning the customer contract. After Lockheed has a complete cost estimate, Lockheed replies to the customer RFP. The bid process may differ between commercial and government satellite supply chains. The government supply chain has some additional steps like product concept, and prototype to specification that are not required in the commercial satellite. A contractor may prototype to specification and, subsequently, demonstrate that prototype if it is a government customer.

Associated with the satellite bid proposals is the process of supplier selection. This selection depends on the following factors –

1. LTA: when Lockheed has LTA for a certain subcontract part with a supplier it is obligated to use that supplier. In such a case, supplier bid process is not used, instead the LTA supplier is contacted for supply commitment and locked in LTA prices are used to do cost estimation. LTAs ensure quality supply and controlled sourcing costs even in times of high demand.
2. Price: other than LTA, supplier bid price is the main criterion used to select a supplier. Note that supplier bidding is done only in the absence of an LTA supplier or when an LTA supplier is unable to meet the delivery schedule or capacity requirements.
3. Customer: sometimes customers may demand specific suppliers. For example, for KU-bands, a customer might want Lockheed to go to Thales only and not to L3 or any other supplier even if there is some cost benefit. Lockheed may make a pitch about another supplier, the customer may consider it or reject it despite that cost differential.

4. Regulation: satellite Systems is a heavily regulated industry. The government may not allow certain suppliers.
5. Schedule: supplier's ability to meet the delivery schedule, along-with cost and quality, is the key criterion to award a bid to a supplier. An average subcontract item delivery lead time is about four to fourteen months. Oftentimes, to meet the schedule requirements an order may be split as well. Say for Harness Assemblies, the order may be split between two suppliers – one providing the payload, and the other providing bus and propulsion.

If Lockheed wins the contract, it builds to the design specification. It is a 26 to 30 month process which involves in-house manufacturing and sourcing, which is a combination of sourcing subcontract items, sourcing from subcontract suppliers under agreed upon prices, and sourcing commodities. The suppliers similarly involve their suppliers, called Tier-2 suppliers, in this process. Lockheed sends suppliers a detailed and exact specification, it is more detailed than the one used during the bid process. During the satellite manufacturing process there may be a change request from the customer. Such a request can lead to change in prices if the changes are significant or affect design. If the change request affects a subcontract part, Lockheed passes on the design changes to the supplier. Lockheed can cancel supplier delivery by making partial payment (applicable till that stage); supplier payments are usually made in installments beginning purchase order signing date.

5.3 Distinguishing Features of the Supply Chain

1. Design to specification: each satellite is a unique product; each satellite is designed to manufacture. Subcontract parts like *structures* cannot be ordered until about four months into the satellite manufacture because the design is not fixed until then. Similarly, most satellite subcontract parts are design sensitive and have to be ordered during the manufacturing process. This affects and shapes the supply chain design.
2. No maintenance and repair of the hardware: satellite hardware, once it is launched, is not accessible for repair. And thus, a lot of spare capacity is built to fail-proof a satellite. This extra capacity, like extra *reflectors*, adds costs to an already expensive satellite.
3. Very high switching costs: switching costs are the costs that are associated with changing to another supplier. This element has an immediate and direct cost, that of searching for new suppliers and qualifying them but also indirect costs that include the costs related with training the supplier and reaching a relationship of a desired level. Switching costs are relatively high due to the costs that relate to developing the relationship and integrating operations. Generally, it is difficult to change a supplier with whom the company has close relationship and shares information and proprietary knowledge.
4. Very long lead-time: because a satellite is designed and manufactured to specification, like pointed out above, and because each subcontract part has a long sourcing lead time, the overall satellite delivery lead time – time required for sourcing and assembly – becomes very long. On an average, a satellite is manufactured in a time window of about two to two and a half years.

5. Small supplier base: the satellite supply management practices are additionally shaped by a small number of suppliers located in certain geo-political landscape.
6. Regulatory restrictions: in addition to the supplier selection and industry regulations listed in sections 5.2 and 3 respectively, there are logistical barriers, such as government certification requirements, that are both costly and time consuming for the contractor. The different configurations of major components need regulatory certification.
7. Low cost sourcing trend also shapes the supply chain. Contractors are trying to find their way through low cost countries, mainly in Eastern Europe and in Asia. Outsourced manufacturing for satellites provides companies with access to cheaper but high quality parts and assemblies. This practice also enables access to government projects in those countries. The structure of satellite supply chains, however, is influenced more by the non-US governments (customers) than by the need to source from the lowest cost suppliers. The non-US government orders are often awarded with conditions like transferring manufacturing and technology to the ordering country.

5.4 Strategic Supply Management

A key characteristic of the space system supply chains is the sheer complexity of today's satellite. A satellite is a highly engineered, high value, low tolerance to risks product. The final satellite assemblers rely on suppliers to build and integrate considerably complex assemblies. Supplier management in the space industry therefore takes on additional importance in terms of cost competitiveness and the quality and performance of the final product. The satellite systems industry contractors such as Lockheed have to respond (looking downstream in the supply chain) to the supplier management efforts of their major customers and (looking upstream) manage extensive supplier networks of their own. The Lockheed suppliers are totally responsible for the product quality and are responsible to manage and improve the quality of lower tiers.

Suppliers manufacture one or more subcontract items. These suppliers are spread across geographies, especially, the US, Europe, and Japan. The supplier base for most satellite parts is usually small. Usually, this supplier base is restricted one to three suppliers. Sometimes there is only one qualified subcontractor in the market; a qualified subcontractor is a contractor certified and trusted supplier. Product complexity, strict quality and regulatory standards, and very high capital requirements ensure that this equation does not change very often. The very high upfront capital investments and knowledge barriers make it a difficult market to enter. And thus it is rare for an independent supplier to enter the market. The small supplier base and component criticality drives high channel collaboration in this industry. Contractors use LTAs or competitive bidding to source subcontract parts that are supplied by two or more suppliers. This is not possible when a single monopoly supplier supplies a part; the monopoly suppliers use their bargaining power and charge a high price. Lack of supplier diversity is not very favorable to the contractors who, along-with governments, often take steps to change a single supplier landscape. Sometimes, the contractors also keep some in-house manufacturing capacity primarily to use it as a bargaining tool to reduce the supplier power. Contractors can also push their suppliers because they have market power and better access to capital.

5.4.1 Long-Term Agreements (LTA)

The satellite supply chain supplier landscape hardly changes (because national interests prevent companies from failing.) Thus, supplier relations become key to manage sourcing. Complexity and competition drive this contractor supplier relationship. Competitive bidding is often the sourcing strategy. And, a lot often, contractors and suppliers get into long-term agreements to better collaborate. Section 6 expands on LTAs.

5.4.2 Single Source Supplier

A single-supplier is not a stable supplier landscape. Such a market composition is considered very risky that Lockheed, or other contractor, and government work together, or on their own, to avoid. A monopoly supplier comes with two risks –

1. Supply risk: a monopoly supplier may not be able to supply a part due to capacity or strategic reasons. Further, any risk to a monopoly supplier's manufacturing capacity can significantly delay a satellite. Recently, a single source Italian supplier's manufacturing facility was affected by earthquake and that put pressure on Lockheed's delivery and build schedule.
2. Price risk: a monopoly supplier can charge a price that is non-competitive and thus reduce the chances of Lockheed's winning a customer contract.

Lockheed sometimes finds itself in single-source relationships with suppliers. These relationships are problematic and costly. These situations occur because there are no other suppliers with the necessary capabilities, or because developing, qualifying, and maintaining more than one source for complex, low volume components or subsystems would be equally costly. As a result, Lockheed becomes highly dependent on these suppliers. When they perform poorly, Lockheed's only option is to spend more money to help them. This often involves sending engineering teams to these suppliers to help them improve their processes, which consumes considerable amounts of resources and time. Although considerable collaboration occurs between Lockheed and such suppliers, the relationships are not often characterized by trust-based partnerships. If Lockheed requires design modifications later in a contract, single-source suppliers tend to charge extremely high rates to make the changes [2].

5.4.3 Qualifying a Supplier

This applies to non-qualified suppliers. A non-qualified supplier is a supplier that has subcontract part manufacturing capability but with whom Lockheed has never subcontracted. It is costly to qualify a new supplier. Each of the supplier processes has to be audited and certified. The cost for qualification differs from supplier to supplier and can go up-to $200,000 or more. At suppliers request or on its own Lockheed may send the supplier an estimate of the on-boarding or qualification cost. This cost may be shared between Lockheed and the supplier, or either party may choose to fund the qualification subject to its strategic needs: supplier because it wants to do business with Lockheed; Lockheed because it is in its strategic interest (for example, due issues with the current supplier or due to other supply and price risks.) A government's strategic decision may also lead to a decision to qualify a new supplier – such a decision is usually supported by government funding as well. A supplier is evaluated using a qualification method. A supplier can be evaluated using the following criteria: engineering know-how, financially stability, on-orbit history, currency, capacity, part specification, government approval (banned countries list), and ITAR information – whether the hardware is ITAR controlled.

5.4.4 Developing a New Supplier

It is developing supply capacity from bottom up. It is more like growing in-house manufacturing capacity. It is rare but if a strategic need arise Lockheed may choose to develop a new government sponsored, or a joint venture, supply capacity. It takes years to develop a new supplier and to get it up to speed.

6 Long-Term Agreements (LTA)

Contractors try to secure their supply for the life of the project but they also don't want to create a completely captive, vertically integrated supply chain for the fear of conflict of interest and loss of demand aggregation. Lockheed uses LTAs to better manage its subcontract part supply. These contracts are used to secure supply for a long term while simplifying the contractor supplier communication.

LTAs help avoid the costly and time consuming bid process every time a customer order is taken. Historically prices don't go down and thus it is better to lock them as low as you can. This industry sees no real economies of scale. So, quantity does not become a factor in the contracting process; that makes contracting easier because complex forecasting is not required, a general guidance is good enough. Lockheed did not have subcontracting until mid-90s. At Lockheed, LTAs are the responsibility of an individual subcontract manager. A subcontract manager works out a contract proposal and then involves the engineering and quality team. Finally, the LTA proposal is taken to management for approval and an agreement is worked out. An LTA can be based on an existing order or it can be an independent process triggered by anticipated demand.

6.1 LTA Features

An LTA is an agreement for a specific subcontract part. LTAs specify price, quantity, terms and conditions, renegotiation terms, and currency terms. Some LTAs have quantities specified (usually maximum) while some don't. Lockheed uses the supplier as 'sole source', as long as the LTA supplier can fulfill the subcontract part demand. LTAs also list a payment schedule. Lockheed can exit an order-in-execution under LTA at different times with partial payments (payments applicable till that stage). These LTAs are written with price variations in mind. The supplier can renegotiate any significant raw material price changes. Additionally, the LTAs are written taking currency fluctuations into account. Currency fluctuations are managed by changing the dollar price such that the foreign currency price stays firm (so that the current price in foreign currency is close to the LTA price in foreign currency at the time of writing the LTA.)

LTAs are about two-years long contracts. These LTAs can be renewed at the end of terms if both parties agree. LTAs are re-negotiable and terminable. In that sense, these are very flexible contracts that make business easy by providing a ready and mutually agreed structure and rules of engagement.

6.2 LTA Feasibility

It is difficult to predict demand and prices over the LTA time period. If the business does not have a good understanding of satellite demand and supply, LTAs are likely to be very inaccurate and can lead to unexpected loss or gain. Economic cycle data and price forecasts of raw materials are necessary to make informed LTA decisions.

Budget, performance, schedule pressure, and technological obsolescence can lead to design changes in a satellite. LTAs are not always possible due to such part design changes. These changes may require a lot of rework which can lead to significant change in cost and thus make the LTA prices irrelevant. Often, LTA advantages may not be realized because of implementation issues. In fact, multiplicity of change requests can strain contractor supplier relationship.

Lockheed's experience on LTAs for complex subassemblies has been mixed. Lockheed at one time had LTA for *harness assemblies* but that did not work out well because of too many design changes, the LTA was not implementable. And thus, for some parts, like *harness assemblies*, Lockheed does not expect LTAs. But on the other hand, even in difficult assemblies (that have frequent design changes) history can be used to craft LTA in such a manner that the likely changes are appropriately documented or provided for in certain clauses. For example, Lockheed has LTAs for 30-something variations of *reflectors* (*reflectors* are a part of antenna structure and have a twelve to twenty four month delivery lead time). For *structures* (twelve month lead time) LTA Lockheed specifies the baseline, and then builds additions or changes into the cost during order execution.

LTAs are unattractive when the supplier capability (financial, delivery performance) is questionable. Also, single source suppliers (monopoly situation) normally do not sign such agreements, since it does not provide them any benefit or leverage.

6.3 LTA Risks

LTA is a mutually agreed and terminable at will agreement. Price fluctuations, currency fluctuations, and design changes are the big risks to an LTA from a cost perspective. All these situations can change the subcontract sourcing cost significantly and dent Lockheed's margin on the satellite product. Historically, if the raw material prices rise and suppliers feel pressure to deliver to contractors at the LTA price, they request Lockheed to increase the price payable to meet that shortfall. Lockheed, subject to proper case being made, would honor such requests.

6.3.1 Currency Fluctuations

The customer pays a fixed price per satellite. Lockheed prices its satellites based on cost to manufacture. An increase in cost to manufacture is a significant risk to Lockheed's profitability. Since LTA prices are used to estimate the cost to manufacture, any change to these prices can potentially affect Lockheed's bottomline. Lockheed's suppliers, however, demand additional payments when the currency exchange rate becomes unfavorable to them. Lockheed pays suppliers using USD. The LTAs are also written with dollar amounts as prices. And thus while Lockheed's payables for subcontract items stay the same the supplier's receivables can swing with currency fluctuations. These fluctuations can affect the supplier in the following manner: -

1. Supplier's currency appreciates against the contractor's currency – the supplier is worse off as the accounts receivable from the contractor declines; LTA price becomes less attractive to the supplier.
2. Supplier's currency depreciates against the contractor's currency – the supplier is better off as the accounts receivable from the contractor increases; LTA price become more attractive to the supplier.

Suppliers are concerned about their currency appreciating and thus affecting their receivables. This is a risk for the suppliers to manage. However, Lockheed's experience is that this is not true. In fact, severe currency changes lead to price changes. When the supplier is better off, the LTA price is honored but when the supplier is worse off, the supplier requests for a price plus an additional amount to make up for the loss. Lockheed usually honor such requests. Since the price change cannot be passed onto customers, Lockheed bottomline is affected. The satellite prices remain fixed downstream. Any adjustment made to the supplier is made from the Lockheed's potential profits. These currency fluctuations can be managed in the following three ways –

Manage by exception – this method suggests wait and watch. Rather than actively managing currency risks, wait for the suppliers to request a payment for any losses incurred due to currency fluctuations and then evaluate and approve or reject them. This approach has three issues – 1) the suppliers are increasingly demanding currency cover and may not agree to it or they may request a guaranteed approval for currency losses, 2) Lockheed doesn't gain when the supplier currency depreciates, and 3) the currency risk is managed but not avoided. And thus oftentimes, a subcontractor will end up sourcing a part at higher than a budgeted price. Such a change impacts the satellite manufacturing cost.

Normalized rates – another method of managing currency risks is by tying LTA price to an exchange rate, *X*, and an exchange rate range, *Y* to *Z*. If the exchange rate goes above or below this range, a price different than the LTA price is charged. This price is normalized using the rates *X*, *Y*, and *Z* in the following manner. If the exchange rate stays between *X* and *Y*, the LTA price is used; however, if the rate goes above *Z* or falls below *Y* then multiply the LTA price with the following factor –

Z or *Y* divided by *X*

A variation of this method can be used to manage the currency risks. This approach is similar to 'Manage by exception' except that Lockheed now stands to gain on supplier currency depreciation.

Hedging – Industry, in general, manages currency risks by hedging. A lot of global companies with global footprint avoid currency surprises by hedging. It is a potential method to manage the currency risks to satellite subcontract agreements as well. A significant benefit of hedging is that price variations are completely avoided. Of all the three options listed here, contractor's cost of manufacturing a satellite is not impacted only when hedging is used to manage currency fluctuations.

6.3.2 Commodity Price Fluctuations

A satellite requires a variety of scarce and expensive raw materials, e.g., titanium, and composite materials. These materials may have a certain procurement risk and long lead times. E.g. Russia is a major titanium producer and the lead-time for titanium forgings is about twenty-six weeks [18]. A safe bet will be to keep a good safety stock but high raw material costs make such a policy uneconomic. The supply chain design should account for scarce raw materials. The contractors can secure more favorable prices by limiting its supplier base and by directing the majority of supplier purchases to specific partners – whether this is done under GPAs or under a consortium of satellite industry contractors that's a moot point.

6.4 LTA Benefits

LTAs reduce ordering lead-time significantly by reducing information redundancy and, potentially, provide channel cost savings by reducing the channel transaction costs. The contractor benefits by having ready rates for the cost estimates to the customers and also benefits by being able to source parts at costs lower than the spot market price. Oftentimes, a contractor has to respond to a customer's *request for proposal* sooner than supplier can provide the part price inputs. This increases the risk of contractor using an incorrect price and subsequently, due to incorrect estimate, either loose an order or win it at a loss. Having LTA prices handy avoids such order risks.

For a supplier, the most common benefit of an LTA include a long-term commitment by the contractor, early involvement in product design and development, and being selected as sole source supplier. Another notable benefit derived by these suppliers is that they enjoy cost savings in purchasing raw materials by "piggy-backing" on contractor General Pricing Agreements (GPA) involving large-volume discounts. GPAs are agreements that Lockheed has with some commodity suppliers. Subcontractors need to use Lockheed's GPAs. If some raw material is not part of the GPAs, Lockheed can create a GPA list on suppliers request. This can lower the price. For example, the price of *harness assemblies* can be reduced by five to fifteen percent using GPAs. Practices like these give Lockheed a cost advantage by allowing the suppliers at all levels the benefit of economies of scale. The suppliers can look forward to a long-term relationship and make long-term investments in both process improvement and technological innovation to reduce costs. These contractual practices set into motion a new set of arrangements leading to mutually beneficial relationships throughout the supplier network [17].

7 A Framework for Supply Management in Satellite Systems Industry

7.1 Supply Strategy Matrix

A satellite is a mature product and a commodity. The whole satellite value chain is a bilateral monopoly: a few customers, a few contractors and a few suppliers. It is a market with fierce competition, and high entry barriers across the supply chain. From the contractor's strategic perspective, price is the differentiator to sell to the customers and collaboration is the key to manage the suppliers.

All the subcontract parts that go into a satellite are critical parts. But while parts as such are critical and necessary for a satellite, sometimes, part quantities may not be critical. It may be all right to send a satellite with, say, twenty-five, rather than twenty-seven, *receivers* into the orbit. Price and supply risk to the satellite subcontract parts are a significant threat to stay competitive and to ensure delivery. A contractor has to excel on these parameters to stay viable. And thus, the contractor goal becomes to better manage supply risk and part prices. Technological improvement and quality are other parameters to consider but with the maturity of the satellite product, and the guarantee of quality from all the contractors, these are not differentiators. The technological improvements are driven by the government side of the business and not by the commercial side.

The supply risk comes from factors like higher supplier power, and scarce supply resources. It is a seesaw with supplier and contractor on either side. And thus, a higher supplier power implies lower contractor power. The high supplier power can be because of monopolistic supply landscape or because of technological advantages. Monopolistic supply landscape can be further qualified by redefining it to include scarcity of domestic versus foreign supply sources. A contractor can manage the supply risk by making investments in vertical integration, in developing & qualifying new supplier, or in in-house capacity. The supplier investments can also be made to mitigate technological risks by encouraging the supplier to innovate. In this industry capital is not a source of supplier power because on an average the contractors have more access to capital.

Satellite being a price sensitive product, the overall industry PIE for the contractor and the supplier is fixed. A customer bid award to the contractor fixes a price and total contractor and supplier PIE. Contractor's interest is to divide the PIE favorably. In-house manufacturing – as a cheaper option or as a strategic tool to bargain better supplier prices, spot market, and favorable LTAs are some of the strategies to split the PIE favorably. LTAs should be used to increase margins when the part complexity is medium and supplier power is low. This hinges on the contractor's ability to lock good LTA rates. These rates can be determined using a variety of techniques, section 7.3 offers one guiding framework to evaluate such rates. High part complexity comes with LTA management overhead and LTA risks and thus such parts can be better managed using collaborative spot market. Suppliers with high market power do not prefer to do LTAs. Such suppliers leave spot market as the only engagement option. In terms of sharing the PIE, this is not a favorable situation for the contractors. This market situation also comes with high supply risk. And thus, contractors should take steps to move the suppliers from high power to low power. These steps are primarily investments in the supply. Contractors' ability to invest and supply risk avoidance ensures that the satellite supply market is in a stable state only when the supplier power is low. LTA decisions are affected by the supplier market power and by the inherent LTA risks listed in section 6.3.

The make buy decision for the subcontract parts can be weighed using the supply risk and price strategy laid out above. If the in-house manufacturing provides cheaper parts than the supplier then the contractors should make effort to utilize such manufacturing. The in-house manufacturing capability, cheaper than sourcing or not, can also be used as a lever to bargain better prices with the suppliers. However, any investment in the in-house capacity has to be strategic and not tactical. Such a decision should be made with long-term cost-benefits in mind. Figure 7.1 illustrates this supply management strategy in a matrix. The lower left quadrant is the ideal position to be in for it maximizes the PIE for the contractor. The best contractor strategy – investment in supply, standardizing the parts – is to move the part-supplier combination to this quadrant.

LTAs can be a win-win strategy for both the contractor and the supplier. A supplier benefits even when the supplier is a monopoly, in the following manner: long-term commitment, lower cost of project management, lower raw material costs using the contractor's GPAs, and reduced risk of competition. This frees up both the contractor and the supplier resources for innovation and, consequently, competitive advantage. The reduced risk of competition is especially very attractive to suppliers – this risk can come from a new supplier being developed or contractor establishing an in-house manufacturing capacity.

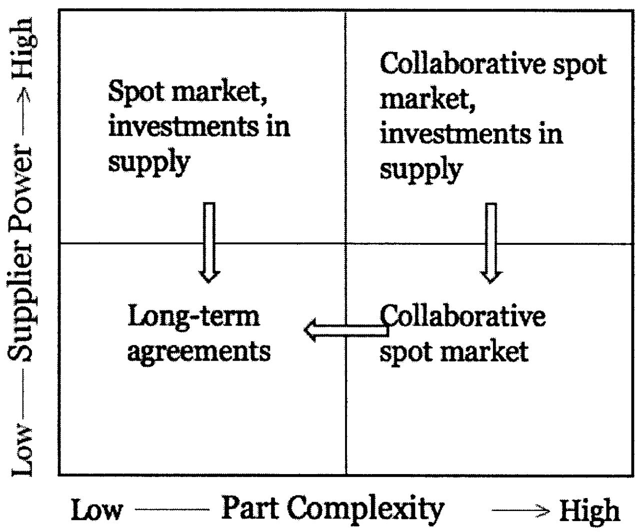

Figure 7.1. Satellite Part Supply Strategy Matrix

Key subcontract part-supplier-contractor elements to consider while using the *Satellite Part Supply Strategy Matrix*:

1. Number of suppliers: single, dual/multiple
2. Availability of accurate demand forecasts
3. Supply risk
4. Supplier cost data: an information advantage like knowing the supplier cost of raw material inputs can be used as a negotiation lever
5. Switching costs from the contractor's and from the supplier's perspective
6. Supplier's dependence on the contractor in terms of the total business volume percentage. The more the dependence the better for the contractor. Higher dependence is equivalent to captive capacity whereby double marginalization can be avoided and at the same time most of the channel profit can be kept by the contractor
7. Part complexity, standardization

8. Supplier technological or innovation position

7.2 An Example Application of Supply Strategy Matrix

Figure 7.2 shows a summary of JCSAT-12 satellite data. JCSAT-12 is part of Lockheed Martin's A2100 telecommunication satellite series that it is designed and built for JCSAT Corporation of Japan.

Supplier Data	Quantity	%
Total	40	
Single source suppliers	7	17.50%
(supplied 14 single source and 16 total parts)		
LTA suppliers	4	10.00%
(supplied 14 LTA and 20 total parts)		
# of only one part suppliers	20	50.00%
# of non-single source one part suppliers	17	42.50%
Subcontract Part Data	**Quantity**	**%**
Total	179	
Total single source	14	7.82%
Parts with change (JSAT11 to JSAT12)	24	13.41%
Domestic parts	131	73.18%
Foreign parts	48	26.82%
Part complexity - High	18	10.06%
Part complexity - Medium	161	89.94%
Not high complexity, not single source	148	82.68%
Not high complexity, no change in design	139	77.65%
LTA Data	**Quantity**	**%**
Total	14	
With domestic suppliers	12	85.71%
With foreign suppliers	2	14.29%
Part complexity - High	12	85.71%
Part complexity - Medium	2	14.29%
LTAs with single source suppliers	0	0.00%
Miscellaneous		
Maximum #parts supplied by one supplier	30	
Minimum #parts supplied by one supplier	1	
Total parts supplied by 2 biggest suppliers	57	
Avg #parts per supplier (excluding 2 biggest)	3.21	
Part quantity requirement range (75 percentile)	1 to 4	
Part delivery lead time range (some key parts)	4 to 12 months	
Part sourcing cost range (some key parts)	$100,000 to a few million	

Figure 7.2. JCSAT12 Sourcing Data

Under *Subcontract Part Data*, we see that majority of the parts are not high complexity, not single source, and fairly standardized designs. Further, we observe that Lockheed has very few LTAs in place, see *LTA data*. And, contrary to the intuition that this research builds that the LTAs should be for less complex items, we see that most of the LTAs are for the high complexity parts. Strategic concerns and the fact that LTAs are a relatively new concept may explain these anomalies. Lockheed started doing LTAs during the mid-90s; compare that with the fifty-year old satellite industry and we can understand why Lockheed's JCSAT12 has low LTA penetration.

7.3 A Decision Framework for LTAs

LTAs discount prices by removing process inefficiencies. LTAs make business easy by removing a lot of repetitive transactions and negotiation requirements. Understandably, this saves money and makes the contractors more competitive. An LTA is a good lean management tool; it removes waste. LTAs thus free up management to engage in more strategic tasks, rather than having to negotiate often on an order-to-order basis. Additionally, and apparently, LTAs provide cost savings as well because the contractor can lock in a subcontract part for lower than spot rates.

However, these benefits are not guaranteed. The ease of business can become a nightmare if there are too many design changes for a subcontract part and, subsequently, the supplier start asking for additional compensation. If the currency exchange rate fluctuates too much, or if the supplier raw material costs swell, the supplier may start asking for money that was not budgeted for this project. The net result may be unexpected project cost overruns and strained business relationship. From execution perspective, an LTA may be altered or abandoned altogether. And thus, our understanding is that LTA price is not the least price that can be negotiated but a price that is less prone to risks listed above.

It may or may not be possible to write or negotiate a perfect LTA that completely eliminates LTA risks listed above. However, it is certainly possible to understand the true LTA costs better and to arrive at an LTA price where such risk is minimized. Historical data analysis and analytical methods can be used to arrive at such an LTA price. Thus there are two tasks at hand – 1) analyze LTA data, and 2) calculate a reference LTA price.

7.3.1 Data Framework and Analysis

The LTA price calculation, laid out in section 7.3.2, is based on the hypothesis that future spot rates, when appropriately transformed, provide the best estimate for LTA price. And thus, this data framework and analysis is to be applied both to the LTA data and to the spot market data. This section provides a framework of data elements that can be used to capture present and historical LTA and spot data. The data thus captured is analyzed to ascertain contractor-supplier strategic position and to arrive at total relevant cost for both spot and LTA.

The framework consists of five components or matrices viz. Part Matrix, Supplier

Matrix, Supplier-Part Matrix, LTA Decision Matrix, and LTA Performance Matrix. If necessary, these matrices can be further extended to capture data at a more comprehensive level. Figure 7.3 below provides the schematic interrelationship between these matrices.

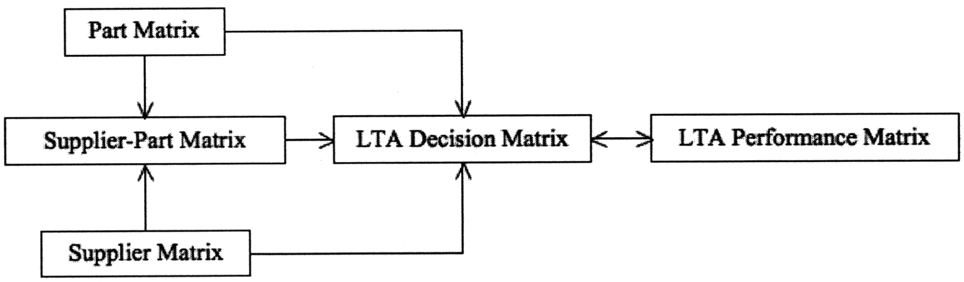

Figure 7.3. LTA Measurement Schematic Diagram

Part Matrix – The Part Matrix, figure 7.4, components captures subcontract part data. The key data includes number of suppliers, make-buy option, part standardization and complexity. The *part risk* is the supply risk to be quantified from a strategic perspective. The supply risk here is a function of number of suppliers and nationality of suppliers (risk from government regulation). Overall the part data provides guidance about the nature of contractor-supplier part relationship and the possibility of LTA. Once qualified with enough historical data, part standardization will provide an answer to the question,

Dimension	Example Input/Values
Number of Suppliers	One, Two, Many
Supplier Dependence	In-house capacity
Part Standardization	High, Medium, Low
Part Complexity	High, Medium, Low
Part Risk	Strategic level

Figure 7.4. Part Matrix

"Whether we should have an LTA at all?" Part complexity refers to technological complexity. This is an important input to make supplier qualification decisions. For example, a contractor can use this data to decide whether to qualify a supplier for this part. If the part complexity is high and the supplier is not known for its engineering know-how then it may be best not to invest qualification money on this supplier, unless the funding is provided by the supplier.

Supplier Matrix – The supplier matrix, figure 7.5, is a comprehensive approach to develop a supplier scorecard for satellite systems supply chain. Supplier profile is the first decision element in this matrix. A supplier has to be eligible to supply parts for the demand over the LTA lead-time. Dependence on contractor, gross margin, company size, network stability, and financial stability determine how aggressive the LTA pricing can be. These elements also provide input to the supply risk assessment. Strategy, management structure, and business suitability are dimensions that provide a deeper qualitative insight into a supplier. For example, two suppliers may have similar risk profile, similar company strengths, but if one is more aggressive in its strategy and the other one is more accommodating then that supplier may be a better choice between the two. Normalization factor has built in probability of a supplier's likelihood of requesting price change due to changes in commodity prices or currency exchange rate.

Dimension	Example Input/Values
Profile	Supplier certification, government approval, national affiliation
Dependence on Contractor	High, Medium, Low
Supplier Gross Margin	Excellent, Good, Average, Poor
Financial Stability	Excellent, Good, Average, Poor
Network Stability	Business with other contractors and tier-II suppliers
Company Size	Net worth
Strategic and Management fit	High, Medium, Low
ITAR Information	Detailed text
On-Orbit History	Percentage rate
Normalization Factor	Variable (price risk, currency risk, other price change requests)
Process Costs	Variable value per order
R&D Investments	Excellent, Good, Average, Poor
Technical & Scientific Expertise	Excellent, Good, Average, Poor
Exclusive Knowledge	High, Medium, Low
IT and Process Competence	High, Medium, Low

Figure 7.5. Supplier Matrix

Normalization factors are determined for spot market and for LTAs, these factors are then used to calculate LTA prices. On an intuitive level this factor when multiplied with the LTA (or spot) price tells the total expected cost of the supplier order. For example, say a supplier quotes a spot price of $100,000 for a subcontract part. During order execution, Lockheed's design team had to visit the supplier to explain design nuances, a cost of $10,000. The supplier requested $3,000 for currency exchange rate fluctuations and another $3,000 to accommodate commodity price increases. All in all, the total relevant cost of this spot order is $116,000. The normalization factor thus will be $116,000 /$100,000 or 1.16. With this normalization factor at hand, we would be able to tell at the beginning the expected total cost of a spot order or of an LTA order.

Understandably, LTA and spot normalization factor values will be different. Normalization factors are not calculated using just one order but are averaged using historical data. A contractor can choose to maintain these factors at one of these levels – supplier, supplier-part, part, or at companywide level.

Total relevant cost LTA, TRC_L = LTA price + currency & commodity price adjustments + design change costs

Total relevant cost spot, TRC_S = spot price + design change costs

Normalization factor LTA, $N_L = \sum TRC_L / \sum$LTA price

Normalization factor spot, $N_S = \sum TRC_S / \sum$spot price

$\sum$ is over the historical data. Note that transactional and administrative costs are ignored in total relevant costs. Since these costs are additive, and not multiplicative, they are kept out of the normalization factor.

The normalization factor is used to convert the LTA price into the total relevant LTA cost. Similarly, normalization factor is also used to convert the spot market price into the total relevant spot cost. The two prices thus become comparable. The last four dimensions of the supplier matrix are based on the use of administrative applications, advanced manufacturing technologies, and manufacturing improvement programs [19].

Supplier-Part Matrix – It is historical data of a supplier's performance vis-à-vis a subcontract part. Figure 7.6 below shows the dimensions maintained and analyzed at supplier and part level. The supply risk is higher for a supplier with higher capacity utilization. Subject to the level of detail that a contractor wants to bring to the data analysis, some of the data in the Supplier Matrix can be also be maintained at the Supplier-Part Matrix level.

Dimension	Example Input/Values
Supplier Cost	Variable
Switching Cost	High, Medium, Low
Supplier Power	High, Medium, Low
Dependence on Contractor	High, Medium, Low
Manufacturing Utilization	A factor of average industry capacity utilization
On-Orbit History	Percentage rate

Figure 7.6. Supplier-Part Matrix

LTA Decision Matrix – The LTA Decision Matrix provides decision values using data from all the matrices listed here. It provides the LTA price range at which a contractor is better off. The upper bound is determined by the spot price and lower bound is determined by how-low-a-supplier-can-go without introducing supply risk into the order. The price calculation framework provided in section 7.3.2 is used to arrive at the normalized LTA cost. It is important to take into account various strategic lever that are provided by the different matrices before a decision about an LTA is made. Figure 7.7 below illustrates the LTA decision matrix.

Decision Variables
Part Matrix
Supplier Matrix
Supplier-Part Matrix
LTA Performance Matrix
Spot Rates

Figure 7.7. LTA Decision Matrix

LTA Performance Matrix – Performance evaluation is a key input to be able to make a more informed decision about LTA and spot. An LTA may not be a good choice when the price stability is low, when the supplier management is not up to the mark or when the supplier is aggressive. Similarly, LTA may not be a good option for a part that's not standardized. This matrix provides empirical, statistical awareness of costs and strategic issues. Figure 7.8 provides an illustration of the LTA performance matrix.

Dimension	Criteria
Price	Number of price change requests - due to design changes, currency risks, commodity price changes, or other reasons
Quality	Number of defects
Delivery	On time delivery percentage
Supplier's Management	Number of issues - escalations, negotiations, supplier price change requests, payment issues
Part Standardization	Number of design change requests

Figure 7.8. LTA Performance Matrix

7.3.2 LTA Price Calculation Model

A contractor's interest in LTAs is to bring certainty to the cost estimates it sends to the customers and to improve its bottomline. LTAs enable this by providing ready cost estimates, and by reducing process inefficiencies. LTAs, however, introduce price and currency risks. These risks either make LTAs expensive or un-implementable. These risks are modeled as normalization factors, discussed in section 7.3.1. The LTA prices can be evaluated as a range whereby the contractor limits the maximum it is ready to pay for a part and the supplier limits the minimum it is ready to sell a part for.

Maximum LTA price is the price at which the contractor is indifferent between spot and LTA price. LTA equivalent of the spot price provides this maximum LTA price. For building this model, we assumed that price is the only criteria to determine indifference curve equivalence between LTA and spot. LTA and spot prices cannot be compared without an appropriate transformation. This is because the cost of executing an

LTA order is not the same as the cost of executing a spot order. For example, an LTA pegged at $100 might have an average $10 additional cost component while a spot price pegged at $100 might come with an additional cost component of $12. This cost of executing a spot and an LTA can be further divided into an additive and a multiplicative component.

The additive part is the order overhead necessary to carry out the business. This part is the process inefficiencies or process cost or transactional and administrative costs. These inefficiencies are reduced by LTAs. The LTA process cost savings for the contractor and the supplier are noted as Δ_1 and Δ_2 respectively. The sum of these process efficiencies, or the spread "$\Delta_1 + \Delta_2$", is negotiating ground for an LTA price.

The multiplicative part is the part dependent on cost risk or order risk (its origin can be LTA risks or other supply related risks.) The multiplicative parts are already introduced as the spot and the LTA normalization factors – N_s and N_L respectively. The total cost of executing an LTA or a spot order is expressed as total landed cost. Thus, the total landed cost for an LTA and spot order can be expressed the following way –

Total landed cost LTA, $TLC_L = P_{LTA} * N_L + \Delta_L$

Total landed cost spot, $TLC_s = P_{Spot} * N_s + \Delta_S$

where P_{LTA} is the LTA rate, P_{Spot} is the spot rate, Δ_L is the LTA process cost and Δ_S is the spot process cost.

A contractor is indifferent between LTA and spot order when

$P_{LTA}* N_L + \Delta_L = P_{Spot}* N_S + \Delta_S$

$P_{LTA}* N_L = P_{Spot}* N_S + \Delta_S - \Delta_L$

$P_{LTA}* N_L = P_{Spot}* N_S + \Delta_l$ (where Δ_l is the contractor process saving introduced above)

$P_{LTA} = (P_{Spot}* N_S + \Delta_l) / N_L$ ---------------------- -(equation 1)

Thus, whenever $P_{LTA} \leq (P_{Spot}* N_S + \Delta_l) / N_L$ contractor is better off doing an LTA. The lower bound for P_{LTA} is defined by supplier's indifference curve, while minimizing LTA risks, between an LTA and spot. This price is simply –

$P_{LTA} = P_{Spot} - \Delta_2$ -------------------------------------- (equation 2)

where Δ_2 is the supplier process saving introduced above) - (equation 2)

The LTA price should always be more than or equal to $P_{Spot} - \Delta_2$. Note that supplier LTA price does not have a multiplicative cost component because there are no cost pressures or risks to the LTA price from the contractor (to the supplier.) The contractor never requests the supplier to lower the contracted price because the contractor is losing money on an order. The model LTA price follows the following range –

$(P_{Spot} - \Delta_2) \leq P_{LTA} \leq ((P_{Spot}* N_S + \Delta_l) / N_L)$

For a P_{LTA} above this price range, the contractor would be better off with a spot market rate. For a P_{LTA} below this price range, either the supplier wont accept the price or the LTA risks are significantly increased so as to make the LTA un-implementable. These risks can lead to LTA termination or supplier price change requests. The LTA price range, along-with strategic considerations, provides a subcontract manager with a significant tool to negotiate LTA price. The sensitivity of the estimated spot price can drive supplier behavior. If the prices are expected to stay stable, the supplier will be comfortable giving up the benefits of the LTA to the contractor. If the prices are expected to go up or lower the supplier may not give up a significant portion of the "$\Delta_1 + \Delta_2$" spread.

Detailed steps to approximate an LTA price range –

1) Forecast future spot rates relevant for the LTA period, P_{Spot} range. Such forecasts are combination of forecasting satellite part demand over LTA length, and pegging prices for that demand. The prices can be affected by micro and macro economic factors. Real options is one method to arrive at spot rates using probabilities and price events.

2) Find normalization factors; N_L for LTA and N_s for spot market. These factors when multiplied to LTA or spot rates provide the expected total relevant cost for that rate.

3) Estimate Δ_1 and Δ_2, the process cost savings for the contractor and the supplier.

4) Use spot rates from step 1, normalization factors from step 2, process cost savings from step 3, equations 1 & 2, and derive LTA rate range (highs and lows) for every spot price.

5) LTA period is a short two-year duration. The LTA price highs and lows (obtained in step 4) can be averaged separately to obtain one LTA range. Alternatively, use *net present value* (NPV) and a suitable *discount rate*, and subsequently equal period payments can be derived from the NPV value range (upper and lower bound for LTA price). The *discount rate* can be, but is not limited to, Lockheed's cost of capital and inflation rate.

Figure 7.9 provides an example illustration of LTA rate range calculation for a single period and it also shows the sensitivity of N_L to N_S. LTA high values are calculated using "(P_{Spot}* $N_S + \Delta_1$) / N_L" and LTA low values calculated using "$P_{Spot} - \Delta_2$" –

Spot price	$100
Contractor process efficiency	$5
Supplier process efficiency	$6

Normalization factor, LTA	**Normalizati on factor, spot**	**LTA high value**	**LTA low value**
0.9	1.1	$128	$94
0.95	1.1	$121	$94
1	1.1	$115	$94
1.05	1.1	$110	$94
1.1	1.1	$105	$94
1.15	1.1	$100	$94
1.2	1.1	$96	$94
1.3	1.1	$88	$94

Figure 7.9. LTA Rate Calculation

For a given pair of N_L and N_S, this figure shows the potential LTA range. An LTA is possible as long as the LTA normalization factor is within the range 0.9 and 1.2. Once the normalization factor takes a value 1.3 (or higher) there are no valid values in the range.

Ability to predict the future spot rates and ability to calculate supplier and contractor process efficiencies, and normalization factors is the main challenge to be able to use this model for LTA evaluations and decision. Real options provides one calculation framework for evaluating spot prices using probabilities and expected prices. The probabilities and associated future prices are used to assess the value of a subcontract part. The assessment includes, among other things, the raw material prices – calculated at Lockheed or supplier GPA estimated prices, administrative cost, production cost, engineering cost and project management costs. The estimated LTA price, along with strategic considerations, can be used as a decision tool to assess supplier LTA price.

8 Key Insights

Bilateral oligopoly, a few contractors and a few suppliers per part, is the stable state for the satellite contractors and suppliers. The contractor landscape hardly changes and whenever the supplier landscape changes such that there are supply risks or dominant suppliers, the contractors make appropriate investments to bring the market back to a stable state. Whenever the suppliers are in the dominant positions it is difficult to get into contract negotiations or write LTA contracts at attractive prices.

Government regulations play an important part in contractor selling and buying decisions. The satellite customer list is restricted by the U.S. regulatory laws; these restrictions can limit the product sale itself or limit the level of technology used in the satellite product. Internationally, governments consider aerospace, including satellites, an industry of strategic importance. These governments fund various satellite projects without necessarily considering profits or losses. Such national interests can lead to a problem of global overcapacity and thus, potentially, can make the commercial satellite industry unprofitable.

A commercial satellite is a mature product and a commodity. The satellite systems are being successfully launched and deployed since late 1950s. In terms of functionality and service that a satellite can provide, satellites are more similar than different. The difference between satellites is largely due to configuration demand and due to technological improvements in the manufacturing process. The market for commercial satellite is very price sensitive. Commercial customers buy satellites using competitive bids and price is the single most important factor for winning such bids.

A satellite is designed and built to specification. Every satellite is a different product; different in terms of how the final product looks, and what all goes into making the product. A satellite can have a range or *receivers*, *sensors*, or *converters* in it. This configuration then requires a different *structure* so as to have a stable product. There are no economies of scale in the industry.

LTAs are flexible contracts that can be used to extract just the supplier surplus and nothing more (than the supplier surplus.) LTAs provide process efficiencies; these process efficiencies and other supplier incentives can be quantified as the supplier surplus available for the contractor. LTA risks are introduced, which either increase the effective contract price or make the contract un-implementable, if the contractor tries to extract more than the supplier surplus.

A disadvantage of LTAs is that these agreements are implementable for standardized parts only. A majority of subcontract parts cannot be even considered for such agreements. Thus, part standardization should be given a high priority. Alternatively, to accommodate parts with less standardization into the contract structure, contractors can explore other form of contracts; for example, fixed price plus an audit system. It should be ascertained if the sum of fixed and audit costs are better than spot rates before such a contract form is adopted.

9 Further Research

This thesis presents a theoretical framework for LTAs. Data can be used to further this research. The expected and actual values for every new LTA or spot prices should be compared and contrasted, so as to ascertain the robustness and applicability of this model. It would be important to statistically calibrate the behavior of the *normalization factor* variable.

This framework relies on ability to estimate future spot prices. The next avenue of research is to build a concrete, and detailed forecasting model for price estimation. This model will have the ability to estimate price events and to assign appropriate probabilities to such events. After such a model is built, it is necessary to put the model through statistical analysis for price sensitivity.

In section 7.2, JCSAT12's sourcing data, we saw that LTAs weren't used as much as we had expected. And the LTAs were done more for higher complexity than for medium complexity parts. This is counterintuitive. While it is possible to guess reasons for such anomalies it is best to research the historical data further to be able to fish out the underlying factors. Focused case studies of part subcontract sourcing can be used to understand LTAs better.

Another area of research would be to explore how firms develop supplier networks. In particular, how firms maintain cost-competitive supplier networks while meeting the demands of both the government and the commercial customers. The LTAs can also be researched for their strategic impact on innovation and collaboration.

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Appendices

Key Definitions

Bilateral Oligopoly: A market situation in which there are a few powerful buyers and a few powerful sellers.

Bilateral Monopoly: A market situation in which there is one buyer and one seller.

Build to Specification: Manufacturing to the design and materials specifications provided by the customer.

Commercial Satellite: a satellite, space system, that is not used by military and, generally, does not have any government regulatory clauses restricting its manufacture or sale.

Commodity: it is a satellite part which does not require a design specification and is generally available in the market to purchase

(Prime) Contractor: satellite manufacturer or the company responsible for assembly and final delivery of satellite to the customer; e.g. Lockheed Martin, Boeing

Customer: a customer is the buyer of a satellite; most often, it is the government, military, and the telecommunication companies

General pricing agreement (GPA): GPAs are used to procure commodities. A GPA is an agreement between a contractor and a supplier whereby the supplier agrees to sell (to contractor) specific quantities and set prices (that are agreed upon by a contractor and a supplier.)

Long-Term Agreement (LTA): LTAs are used to procure subcontract items. An LTA is an agreement between a contractor and a supplier whereby the supplier agrees to build to specification a subcontract item at a set price. These agreements are usually two years in length and may or may not have quantity commitments.

Monopsony: a market situation in which there is one buyer, known as the monopsonist. It is opposite of monopoly which has only one supplier.

Net Present Value: net present value is the present value of all future cash flows. The present value is obtained using a discount rate; this discount rate can be cost of capital of inflation rate.

Offset: offsets are concessions where, in the event of an overseas procurement, the seller compensates the purchasing country, or the buyer, for a perceived loss to the economy. Offsets may require co-production, subcontractor production, investment, and/or technology transfers.

Spot Market: this refers to one-time buy and absence of use of contracts or other agreements for this buy. It is usually a competitive bid sent out to eligible suppliers.

Subcontract Part or Item: an assembly item, or part of a satellite, that a contractor out-sources to a subcontractor (instead of manufacturing it in-house).

Subcontractor: a supplier who supplies or manufactures and delivers subcontract parts to contractors. In this thesis, the term subcontractor is used synonymously with supplier.

Abbreviations

EADS - European Aeronautic, Defense and Space Company

GPA – General Pricing Agreement

ITAR – International Traffic in Arms Regulations

LMSSC – Lockheed Martin Space Systems Company

LTA – Long-Term Agreement

NPV – Net Present Value

PIE – Potential Industry Earnings