International Trade and Finance Association

International Trade and Finance Association Working Papers 2008

Year 2008 *Paper* 25

Economic Characteristics of Aerospace Organizations

Robert A. Goehlich
European Business School, International University Schloss Reichartshausen

Economic Characteristics of Aerospace Organizations

Abstract

This paper provides an overview of the current aerospace sector from an economic point of view, along with possible projections. An aerospace organization shows many different characteristics. These characteristics are selected, which form the basis for the development of follow-up studies about the make-or-buy decision process applied to aerospace organizations. The following characteristics of organizations that operate in the aviation and/or space sector are investigated in this study: market structure, products, contractor classification, industry size, or-ganizational architecture and performance.

This paper was presented May 23, 2008, at the 18th International Conference of the International Trade and Finance Association, meeting at Universidade Nova de Lisboa, Lisbon, Portugal.

Keywords: Aerospace Organization, Aviation, Corporate Governance, Space, Strategy

1 Introduction

The aerospace industry has continued to develop since the first motorized flight of the Wright Brothers in 1903. Today, the importance of aerospace to the world's economy is immense.

One option used to measure the importance of aeronautics to the world's economy is by its contribution to Gross Domestic Product (GDP). For example, direct contribution, such as air transportation, etc. and indirect contribution, such as aircraft manufacturing, tourism, etc. of the US aviation industry to the US GDP has been estimated to be $436 billion per year, or 5% of the US GDP (Anderson, 1999). Another way to consider the importance of aeronautics is the increase in passenger traffic and related aircraft demand. World passenger traffic is expected to increase by around 5% per year according to Airbus' (2008) Global Market Forecast for 2007-2026. Boeing predicts that the total market potential for new commercial airplanes in the course of the next twenty years will be around 29 000 airplanes (Boeing, 2007). Such market share would require an average annual output of over 1000 planes by the world's commercial aircraft manufacturers alone, which is substantially above the current rate of production (Commission on Engineering and Technical Systems, 1999).

The importance of the space sector to the world's economy is lesser than that of aeronautics, but the space sector plays an important role with regard to improvement in a country's quality of life. For example, operating satellites provide weather and natural catastrophe forecasts, help expose environmental offenders, and facilitate communication, education and telemedicine in remote regions. The space sector is also a critical component of a country's technology base for enhancing and maintaining national security (Lorell & Levaux, 1998).

Thus, the increasing importance and potential of the aerospace sector to the world's economy justifies, encourages and necessitates an economic-based investigation of aerospace organizations, such that it is provided in this research.

The paper is structured as follows: In the next section, the characteristics of aerospace organizations are introduced. Section three follows with a discussion that includes the key points. The paper concludes with speculation on the idea that the aerospace sector has many unique characteristics when compared with "normal" businesses.

2 Characteristics

Figure 1 lists the characteristics of organizations that operate in the aviation and space sector, which are investigated in this study. Each characteristic could alone be the subject of a lengthy volume of investigation. However, in order to produce a manageable document, the present study focuses on providing summary information for each characteristic. An exception to these summaries is the larger description of organizational architecture found in this study, which is presented due to its valuable information and complexity. Due to national security concerns that are the nature of aerospace, detailed data availability is very limited. Therefore, the characteristics presented in this section are often based on examples from which I have drawn conclusions and/or insights. This overview of the economic characteristics of aerospace organizations provides only a brief, but not complete introduction to the topic. I selected those characteristics that are most promising to deliver important facts for an effective investigation of the make-or-buy decisions that occur in the case of aerospace organizations.

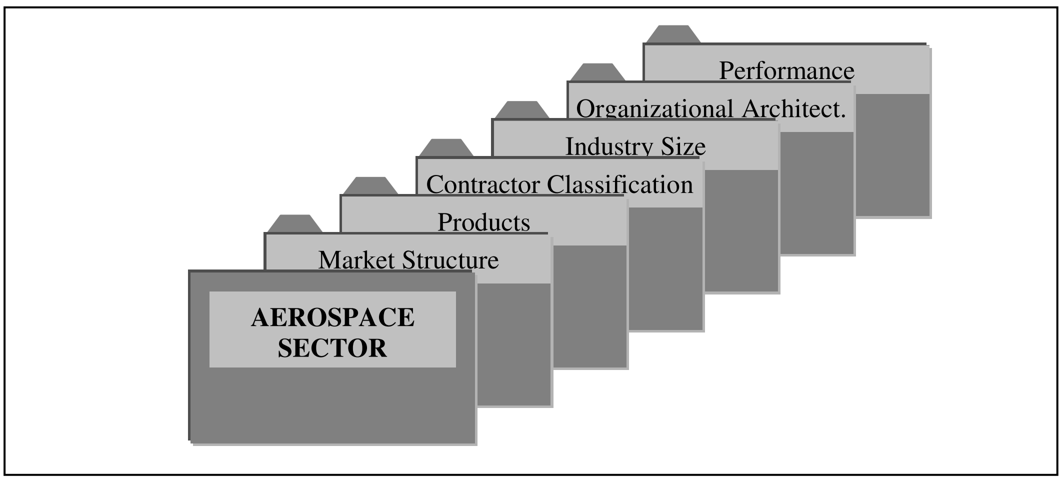

Figure 1: Investigated Characteristics of Aerospace Organizations

2.1 Market Structure

Market demand in the aviation and the space sector is disparate. There is demand for the take-off of an aircraft about every second somewhere in the world, while only approximately one rocket is launched every third day worldwide. Typical market structures, formed by market demand, are shown in gray for the aviation sector in Table 1 and for the space sector in Table 2. Examples are given in parenthesis for each case. Examples in white boxes are only for orientation and do not apply to aerospace. As shown in the tables, market power increases from left to right and from top to bottom. Market power is inversely related to the number of organizations, but is stronger for those organizations that produce differentiated products. In summary, competition among many organizations dominates the aviation market, while the space market is driven by only a few powerful organizations.

Table 1: Typical Aviation Market Structure (marked in gray)

Product	**Number of Organizations**		
	Many	Several	One
Homogeneous	Perfect Competition (e.g., wheat farmers)	Homogeneous Oligopoly (kerosene producers)	Monopoly (e.g., local telephone service)
Differentiated	Monopolistic Competition (airlines)	Differentiated Oligopoly (Airbus and Boeing)	

Table 2: Typical Space Market Structure (marked in gray)

Product	**Number of Organizations**		
	Many	Several	One
Homogeneous	Perfect Competition (e.g., wheat farmers)	Homogeneous Oligopoly (rocket propellant producers)	Monopoly (ISS modules can only be transported by Space Shuttle)
Differentiated	Monopolistic Competition (e.g., restaurants)	Differentiated Oligopoly (launch service operators)	

2.2 Products

This section provides an overview of aerospace products, divided into aviation and space related ones, as shown in Table 3. Examples are given in parenthesis for each case.

There are many different types of aircraft included in this industry, such as airplanes, helicopters, balloons, etc. However, the present study focuses primarily on the production of airplanes since they represent the largest revenue portion of the industry. Major customers of the aircraft industry include commercial airlines, transport companies and the military.

Facilities that produce jet engines and auxiliary parts employ processes that are similar to many other metal casting, fabricating and finishing facilities and processes from a wide range of other industries. Typical products manufactured by these facilities include engines, exhaust systems, motors, brakes, landing gear, wing assemblies, propellers, etc. The main customers for these industries are the enterprises involved in the assembly of aircraft.

The space vehicles and missiles industry includes enterprises that are primarily engaged in research and manufacturing of the following typical products: guided and ballistic missiles, space and military rockets, space vehicles, propulsion units and engines for missiles and space vehicles, and airframe assemblies. The main customer for this industry is the military; however, space vehicles are also used by commercial entities for releasing communication satellites.

Table 3: Primary Aerospace Products

Aviation Sector	Space Sector
• Aircraft w/o Engines (Airbus A380, Boeing B 787, Concorde, etc.)	• Space Vehicles w/o Engines (Ariane 5, Space Shuttle, H2-A rocket, etc.) • Missiles (Patriot, drones, SS9, etc.) • Space Systems (International Space Station, Galileo GPS satellites, Meteosat weather satellite, etc.)
• Jet Engines (Rolls-Royce Trent 900, CFM-56, V2500, etc.)	• Propulsion Units (Space Shuttle Main Engine SSME, Vulcain 2, Solid Rocket Booster SRB, etc.)
• Auxiliary Parts (landing gear, brakes, on-board entertainment system, etc.)	• Auxiliary Parts (landing parachutes, navigation computers, cameras, etc.)
• Infrastructure (Frankfurt airport, SkyChefs catering, Lufthansa Technik maintenance, etc.)	• Infrastructure (Kourou spaceport, Santa Maria ground station, Colibri transport ship, etc.)

2.3 Contractor Classification

Manufacturing and assembly of complete units in the aerospace industry typically involves a prime contractor and several tiers of subcontractors as shown in Table 4 (modified from: US Environmental Protection Agency, 1998). The prime contractor sells complete units to customers, while subcontractors sell to the prime contractor or other subcontractors (US Congress, 1995). The example given in the table is taken from the aviation industry for large aircraft.

While there has not been any foreign content for key aircraft components for early models, such as the Boeing 727 (US companies have produced nose fuselage, front fuselage, center wing box, aft fuselage, wing and empennage), foreign partners have clearly become important for production of current models, such as the Boeing 787 (US companies only produce parts of the nose fuselage, front fuselage and empennage). Also, prime contractors for the B787 model control the selection process of subcontractors, in the same manner as has been done for early models by Boeing (MacPherson & Pritchard, 2007).

Table 4: Classification of Aerospace Contractors

Agents	Tasks	Example
Prime Contractor	Design, develop, assemble and/or manufacture complete units and sell to the customer	Aircraft final assembly and selling to the airline (aircraft)
First-tier Subcontractors	Provide major assembly and/or manufacture of sections of air/spacecraft without design or assembly of complete units	Wing assembly (aircraft parts)
Second-tier Subcontractors	Make various subassemblies and sections	Fuel pump for wing (aircraft parts)
Third-tier Subcontractors	Produce machined components and subassemblies	Electric control unit of fuel pump (variety of industries)
Fourth-tier Subcontractors	Specialize in the production of particular components and processes	Electronic components of electric control unit (variety of industries)
Fifth-tier Subcontractors	Produce basic commodities and/or raw materials	Ceramic for electronic components (variety of industries)

2.4 Industry Size

Figure 2 illustrates the distribution of manufacturing plants and the associated revenues within the US aerospace industry. I choose the US aerospace industry as an example, because the USA has the largest share, e.g., 55% in 1998 (National Science Board, 2002), of the world's aerospace market, with revenue of $161 billion in 2004 (Euromonitor International, 2005). These figures show that while the “aircraft parts” sector of the US aerospace industry is by far the largest in terms of number of manufacturing plants (59%), the “aircraft” sector generates the most revenue (48%). Revenue produced in 2004 was nearly identical for the military sector and the civil sector (Euromonitor International, 2005). In this study, a manufacturing plant is defined as a single physical location where industrial operations are performed. Thus, a company may have one or many manufacturing plants.

Figure 2 indicates that the aircraft-related portion of the US aerospace industry is much larger than the US space vehicle and missile portion. The aircraft portion comprises approximately 90% of the manufacturing plants and about 80% of the revenues for the industry overall. However, considering the small percentage of plants that are engaged in guided missile and space vehicle manufacturing (2%), revenue is relatively high (15%) for this segment of the industry. In general, there are few plants that are responsible for assembling final aerospace products and their production rates are low, but the value of each of their products greatly surpasses that of the supporting industries.

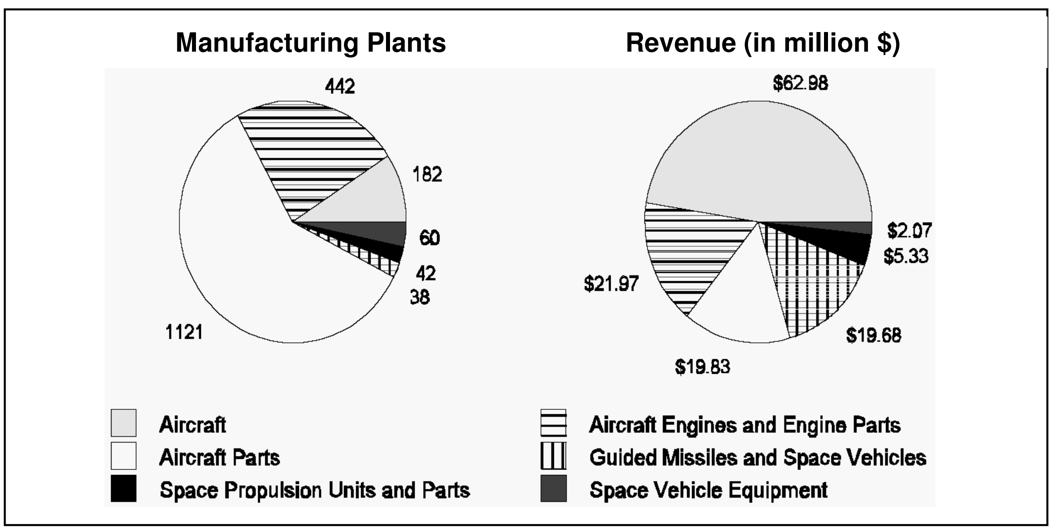

Figure 2: Number of Manufacturing Plants and Associated Revenue for the US Aerospace Industry (US Department of Commerce, 1995)

Table 5 lists the plant size distribution of the aviation sector, while
Table 6 lists the plant size distribution of the space sector. The number of aviation plants is strongly decreasing, while there are an increasing number of employees

per plant. By contrast, the number of space plants is slightly increasing alongside an increasing number of employees per plant. Thus, aircraft, engine and manufacturing of associated parts generally employs fewer people per plant than space vehicle, missile, propulsion and manufacturing of associated parts. This is due to the fact that, for example, a simple glider can be produced by a local team of five persons using a few inexpensive tools, while a complex rocket can only be produced by thousands of employees in a plant equipped with expensive tools. However, the number of employees in the aircraft industry (about 650 000) still exceeds that of the space vehicle industries (about 150 000). Note that the aviation industry (1745 plants) is more than ten times larger than the space industry (140 plants) in terms of number of plants.

Table 5: Plant Size Distribution of US Aviation Industry (modified from: US Department of Commerce, 1995)

Plant Size	**Aircraft Plants**		**Aircraft Engines Plants**		**Associated Parts Plants**		**Total Plants**	
[no. of employees]	**[no.]**	**[%]**	**[no.]**	**[%]**	**[no.]**	**[%]**	**[no.]**	**[%]**
1-9	60	33	112	26	480	43	**652**	**37**
10-49	42	23	130	29	371	33	**543**	**31**
50-249	29	16	129	29	182	16	**340**	**19**
250-2499	32	18	63	14	78	7	**173**	**10**
2500+	19	10	8	2	10	1	**37**	**2**
Total	**182**	**100**	**442**	**100**	**1121**	**100**	**1745**	**100**

Table 6: Plant Size Distribution of US Space Industry (modified from: US Department of Commerce, 1995)

Plant Size	**Space Vehicles Plants**		**Propulsion Units Plants**		**Associated Parts Plants**		**Total Plants**	
[no. of employees]	**[no.]**	**[%]**	**[no.]**	**[%]**	**[no.]**	**[%]**	**[no.]**	**[%]**
1-9	4	10	6	14	16	27	**26**	**19**
10-49	5	13	8	19	14	23	**27**	**19**
50-249	5	13	8	19	18	30	**31**	**22**
250-2499	12	32	15	36	10	1	**37**	**26**
2500+	12	32	5	12	2	3	**19**	**14**
Total	**38**	**100**	**42**	**100**	**60**	**100**	**140**	**100**

2.5 Organizational Architecture

The aerospace sector, particularly the space sector, is well known for its high quality but also for its costly business as compared to other market sectors. In addition to necessary costs, "Business as Usual" costs in the aerospace sector are caused by excessive specifications, high bureaucracy levels, numerous design changes, extended schedules, parallel work on identical topics, poor and mostly belated communication and too many meetings. Koelle (2003), and Goehlich and Ruecker (2005) list strategies to reduce "Business as Usual" costs in the aerospace sector. Their strategies related to organizational issues are discussed in the following paragraph for the development, production and operational phases of the industry.

a.) Development Phase

Success for a buyer (principal) of developing new aerospace systems is strongly related to the type of contract she has with her supplier (agent), the organizational principle of supplier to sub-suppliers and the technique of prototype.

As for the *type of contract*, award fee and fixed price contracts are typically used. Award fee contracts are based on schedule milestones, technical performance and final cost. These contracts provide the contractor with an award when he achieves cost savings. This incentive for the contractor helps to decrease development costs. On the other hand, in a fixed price contract the agent is paid a price for performing a job based on the specifications that are proposed by the principal. Thus, the agent puts in cost-reducing efforts up to the point where the marginal cost of effort equals the marginal benefit. A fixed price contract is more suitable for the production phase, because in the development phase it may cause critical delays in project schedules due to bureaucracy, such as occurs in lengthy negotiations about risk premiums for the agent. Detailed compensation arrangements are investigated by Crocker and Reynolds (1993). In particular in the case of cost uncertainty – typical of the development phase – Jensen and Stonecash (2005) provide a comprehensive overview.

The *organizational principle* for development of a complex program requires a clear-cut prime contractor and subcontractor relationship that includes well-defined responsibilities. Several participating parallel contractors are coordinated by the customer or an additional organization instead of a strong prime contractor, which causes high program costs. For example, reorganization of the responsibility for Space Shuttle operations to only one prime contractor reduced annual costs by 32% compared to the prior practice of awarding five contracts to five different companies working in parallel (Koelle, 2003). Koelle argues that these cost reductions are the result of less manpower, fewer interfaces, fewer planned and unplanned parallel activities and fewer delays.

As for the *technique of prototype*, the so-called "rapid prototyping" and "step-by-step technique" are commonly used. The aviation industry and private investors favor the rapid prototyping technique. Time-consuming and expensive detailed design and theoretical analyses efforts are replaced by early construction in order to verify the design. A physical likeliness of the product is created directly from a three-dimensional model. The prototypes are accurate in physical dimensions and shape, but do not allow for material properties testing (Slay et al., 1999). An example is the American SR-71 aircraft, which took off only 30 months after the contract had been awarded. The step-by-step technique is favored by the space industry and governments (an exemption is Russian space projects, which successfully realize rapid prototyping). A subscale test vehicle is built if the real-size program cannot be fully funded or technological verification by a full-scale flight vehicle seems indispensable. An example is the Delta Clipper DC-X experimental vehicle developed by McDonnell Douglas or the Phoenix flight test demonstrator developed by EADS Astrium.

b.) Production Phase

Different production methods, depending, among other factors, on annual flight or launch rates, respectively, are pursued for economic efficiencies. For a relatively high flight or launch rate, a continuous production activity is maintained, which means scheduled introduction of new vehicles into the program typically occurs in the aviation sector (e.g., daily production of a single aisle aircraft). For a relatively low flight or launch rate, all vehicles plus spares required should be produced in an optimally short time period (in batches) and put into storage until needed, as is typical of the space sector (e.g., batch production of five Space Shuttle orbiters). Production facilities are then converted and used for other projects.

Implementing continuous production in the space sector too, might decrease production costs (including efforts at quality control) tremendously. However, today's market demands do not yet justify producing aerospace systems in high quantity. For example, recent, increasing interest mainly in space tourism, but also in space-based solar power stations, moon or asteroids mining, and very fast delivery services may substantially change current demand-supply interactions (Goehlich, 2005).

In this context, the learning effect on one side and the forgetting effect on the other side are introduced briefly in the next two paragraphs. Despite widely cited examples of learning curves for aircraft production, the marginal costs of producing aircraft represented by direct labor requirements do not always decrease (due to learning effects) and can even increase (due to forgetting effects) slightly over time, as shown in Figure 3.

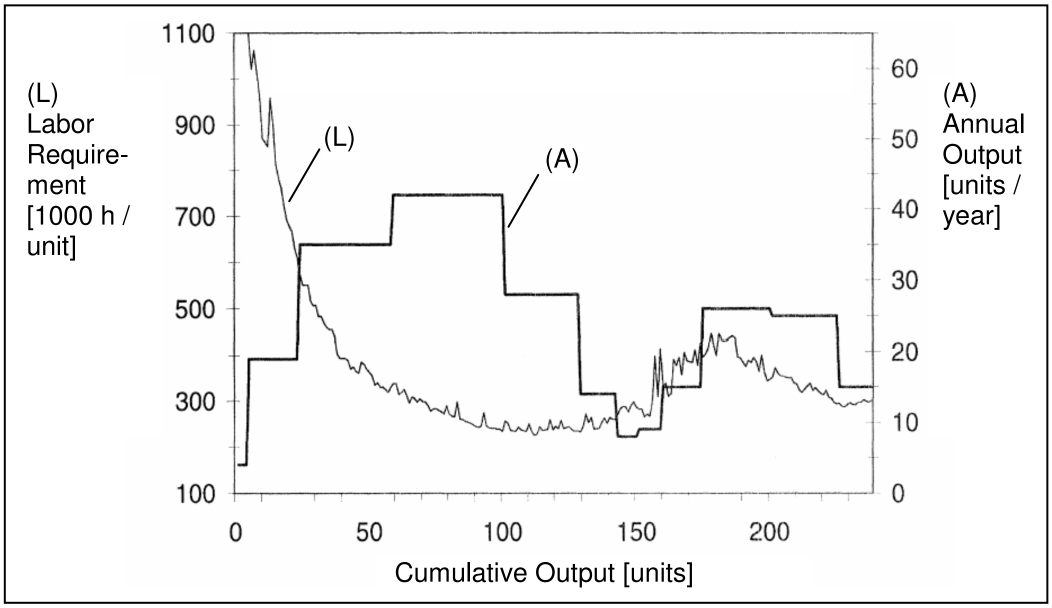

Figure 3: Direct Labor Requirement and Annual Output for Lockheed L1011 Aircraft Production (Benkard, 2000)

Benkard (2004) introduces an empirical dynamic oligopoly model of the commercial aircraft industry that is processed in three steps: (1) define a representative model (learning curves, product differentiation, entry costs, strategic interactions, etc.); (2) estimate primitives of the model (state variables for demand and supply, etc.); and (3) run the model (compute equilibrium, compare model results with existing data, evaluate counterfactual policies, determine accuracy, etc.). This model provides a tool to better understand industry pricing, industry performance and optimal industry policy. The novelty of this model is its capability to endogenously determine major characteristics, such as entry, exit, prices and quantities in

Markov Perfect Equilibrium. A major result of this model is to explain empirically that a company has an incentive to continually price below static marginal costs instead of exiting the market because of an expectation for future success. Once an airline has decided to buy from Producer A, the airline also has an incentive to buy again from the same producer. That is because airlines prefer fleet commonality – also called the “family concept” – as it reduces operational costs, e.g., the same cockpit layout results in no additional costs for training pilots, the same subsystems result in inexpensive maintenance, etc. Therefore, the producer has also a strong incentive to offer a complete family concept to the airlines; even if one aircraft type’s marginal cost is higher than its price.

The organizational *learning effect* takes into account the diminishing effort that is required for manufacture of follow-on units under the same quality standards. In 1936, Wright realized that aircraft production was driven by strong learning effects (Wright, 1936). The learning rate p, an indicator for learning effect, varies across each plane type (Alchian, 1963) and depends on the number n of units built (Arend, 1987). This can be set, in the case of continuous production, if no other data are available, to the following values (Goehlich, 2002): p = 0,90 for n = 2 to 100 units built, p = 0,95 for n = 101 to 1000 units built and p = 1,00 for n > 1000 or n = 1 units built. Thus, p is diminishing with an increase in units built. Learning primarily results from process improvements and same task repetition: economists and engineers analyze the production process and make small changes that result in gradual productivity improvements. The use of new technologies allows processes to require less manpower. Workers become more efficient at the tasks they perform through multiple repetitions. It should be noted that learning comes at high costs too. Same task repetition is the result of process improvements and planning of the company’s organizational structure. New technologies must be studied, verified in experiments and implemented. These activities require manpower resources, expensive labor experiments and acquisitions. This means that a reduction in direct labor requirements is also the result of expenditures (the program improvement budget), which must be taken into account. It can be said that total necessary development costs are divided into non-recurring costs (before the start of production) and into recurring costs (during production). Consequently, as Benkard (2004) claims, is “direct labor requirements” per unit the correct parameter to assess the learning effect? I suggest that the parameter would be better defined as “direct labor requirements plus program improvement budget" per unit in order to correctly model coherences (see Thompson, 2001).

The organizational *forgetting effect* is the hypothesis that a companies' stock of production experience depreciates over time (Argote, Beckman & Epple, 1990). This is caused by the turnover and worker layoffs that embody company experiences. One reason for depreciation of experience occurs in times of falling production rates because those times are accompanied by layoffs. During subsequent increases in production, the company is often unable to acquire the same workers that it formerly released and must retain entirely new workers (Benkard, 2000). In today's aerospace business, whether industry or government, it is common that a substantial number of employees are hired as contract workers in addition to the organization's permanent staff. The motivation for this is to easily dismiss employees in times where fewer laborers are needed. Another incentive is to evade (bureaucratic) requirements. Due to political and organizational reasons that require maintenance of the balance of power allocations, each division is strictly limited in its number of permanent staff, but lesser regulation exists concerning the number of contract workers allowed. Organizational forgetting is also caused by shifting employees to another division or by the normal rates of employee turnover during periods of constant production. It can be assumed that with the increasing size of an organization, the forgetting effect becomes stronger because more requirements exist and the probability that employees are shifted to another division wherein they cannot use their existing knowledge is high. It is very difficult to identify organizational forgetting, however, because data could be consistent, with either a 20% learning rate or a 25% learning rate with 5% forgetting (Benkard, 2000).

c.) Operation Phase

In the case of the Space Shuttle, it is planned to have a simple operation with a high flight rate, as shown in Figure 4 (left). The reality is that doing so requires a complex operation, as shown in Figure 4 (right) for this transportation system with a low flight rate of a few launches per year, and total costs are approximately $0,5 billion per flight. Why do cases like this (the Space Shuttle, for example) occur? Cases such as these can be explained by combining three negative (economic) factors with the (technical) factor that aerospace technology is typically very challenging: a trade-off dilemma exists between development and operation costs, a business proposal dilemma and a budget cut dilemma.

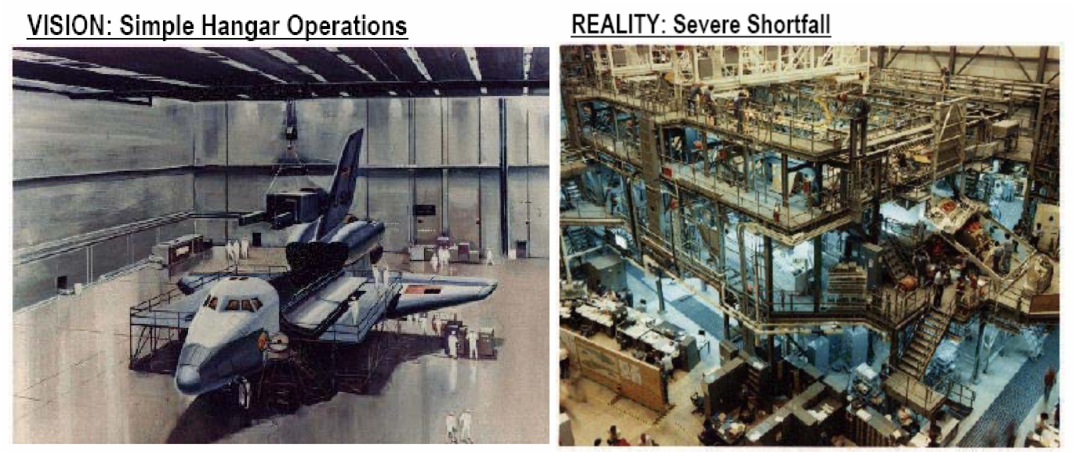

Figure 4: Vision Versus Reality of Space Shuttle Operation (NASA, 2000b)

One of the most controversial topics is the *trade-off dilemma* that exists between development and operation costs: if more effort (in particular in the form of monetary value) is invested in development, operation costs decrease and vice versa. Simplified, decision-makers can select between two program scenarios. Scenario A: low development costs in the short-term (next 10 years) and high operation costs in the long-term (10 to 40 years later). Scenario B: high development costs in the short-term (next 10 years) and low operation costs in the long-term (10 to 40 years later). Rational thinking decision-makers have an incentive to choose Scenario A because the award system (career, salary, bonus, etc.) awards only short-term successes, but not long-term successes.

Next, the *business proposal dilemma* is discussed. To win a business proposal, an incentive exists to estimate "Ideal Cost," which assumes that everything goes as planned (standard industrial proposal) resulting in low cost assumptions: an asset when competing for a contract. However, the history of rocketry teaches differently. In particular, for the space sector, estimated concept life-cycle costs are typically only a fraction of actual, realized space system costs. Technology challenges are more demanding than often assumed and time passes more quickly than planned. For example, the Space Shuttle orbiter development schedule was extended by 20%, which resulted in increased costs of 22%, while the orbiter experienced 25% mass growth during development, which resulted in lower payload performance (NASA, 2000a).

Finally, the *budget cut dilemma* is introduced. During the term of a program, budget cuts commonly occur due to political reorganizations if governmentally funded, or due to market shifting if privately funded. Typically, a large number of aerospace programs are government funded and thus, this topic is of major importance. However, one of the least well-understood sources of instability is the political domain. Overnight, new policies can restrict the launch of vehicles or can revise budgets lower, which can force dramatic change in project scope or even cancellation of aerospace programs. For example, in 1997, 32% of US defense programs experienced budget reductions by Congress, 53% experienced budget increases and only 15% received the budget they requested (Weigel & Hastings, 2004). It can be concluded that the probability that a budget will change is much larger than the probability that it will remain on a nominal path. For an aerospace program to be robust, it must successfully endure any changes that may occur during the course of development and operation. Understanding the effects of political domain instabilities in the form of uncertain future annual budgets on aerospace programs is, therefore, of major importance.

2.6 Performance

Measuring the performance of aerospace organizations is a challenge, because there are often many indicators and various viewpoints. Table 7 shows the world's leading aerospace companies ranked by revenues among their peers; a common performance indicator. As a result of their survey, Woo and Willard (1983) identify 14 distinct indicators to evaluate (strategic) performance: Return on Investment, Return on Sales, Growth in Revenue, Cash Flow/Investment, Market Share, Market Share Gain, Product Quality Relative to Competitors, New Product Activities Relative to Competitors, Direct Cost Relative to Competitors, Product R&D, Process R&D, Variation in ROI, Percentage Point Change in ROI and Percentage Point Change in Cash Flow/Investment.

However, high performance is not always an organization's primary objective. Most aerospace companies' military business comes from government contracts that do not provide incentives for operating efficiently. In addition, most military products are not part of a free market economy due to the government's separation from the private sector. Even if high performance is the primary objective, it may be limited by external factors. Political restrictions can make it impossible to sell businesses that lose money due to unemployment effects. Shareholder restrictions can force companies to maintain duplicative facilities or top management positions, as in the case of EADS (Anselmo, 2005). Low performance can be commonly due to learning effects; aviation companies price their aircraft well below static marginal costs, which is inconsistent with static profit maximization, but consistent with dynamic profit maximization (Benkard, 2004).

Table 7: Aerospace Companies Ranked by Revenue (based on: Anselmo, 2005)

Rank	Name	2003 Revenue [billion $]
1	Boeing	51,5
2	EADS	43,3
3	United Technologies	37,0
4	Lockheed Martin	35,5
5	Northrop Grumman	29,9
6	Honeywell International	25,6
7	Raytheon	20,2
8	General Dynamics	19,2
9	BAE Systems	17,5
10	Bombardier	15,7

3 Discussion

For each characteristic introduced in this study, I choose the key points (shown in the headline), which are, in my opinion, worthy of discussion. I compare these points to other industry sectors, trends taken from the literature and/or my own assessment.

- **Market Structure: Few space organizations have significant market power**

As learned from the characteristic "Market Structure," the space market is dominated by only a few space organizations. Here, market power is defined as the ability of organizations to price above marginal cost.

- **Products: Highly complex systems**

As it can be surmised from the characteristic "Products," aerospace products are highly complex and require significant engineering, manufacturing and supply chain management capabilities, as confirmed by A.T. Kearney (2003). For example, an airplane can comprise up to six million parts, whereas a car may consist of only some 7000 parts. Thus, life-cycle times in aerospace (sometimes more than 25 years) are dramatically longer than for the automotive industry (3-6 years).

- **Contractor Classification: High outsourcing ratio trend**

The characteristic "Contractor Classification" indicates that there is a trend for outsourcing higher ratios and larger units. Larger sub-assemblies or systems come into the final airplane assembly line rather than components and smaller sub-assemblies that require scheduling and inventory management, as has been done in past. This significantly reduces the overall final assembly time and materials management, as stated by Slansky (2005).

- **Industry Size: High national security demands create a large military market share in the aerospace sector**

As shown in the characteristic "Industry Size" section, the military's share of the aerospace industry is about half of the total sector's revenue. Thus, the aerospace business is driven not only by economic aspects, but also strongly by national security demands. Therefore, aerospace is a highly politicized sector (McGuire, 2006). For example, the US government is currently operating under a restrictive launch policy; the American space transportation policy of 1994 requires US government payloads to fly on US-launched vehicles (The White House, 2006). As a result, similar key technologies have been developed individually, wherein each country maintains its own research budget, but with similar objectives. The result is an oversupply of more or less similar national rockets on the one hand and limited demand due to a stagnant satellite market, on the other hand.

- **Organizational Architecture: Highly necessary efforts are partly compensated by strong government financial support**

The characteristic "Organizational Architecture" shows that developing, producing and operating aerospace products is quite tricky. For example, the aerospace sector is marked in the literature by very high fixed costs in the form of plant and research costs (McGuire, 2006), high financial risks (beta values typically reach

1,8 for deregulated commercial airlines (Mullins, 1982)), low profit margins (lower than 5% is the rule (Lynn, 1998)) and very long payback periods (Sherry & Sarsfield, 2002). In the past, governments have played a leading role in the funding of the aerospace sector's research and capital-intensive infrastructure (The White House, 2000). I expect a continuation in government subsidization of the aerospace sector, due to low return on research investments on the one hand, and the government's high interest in aerospace on the other hand.

- **Performance: Challenging assessment of performance**

As mentioned in the characteristic "Performance" section, it is hard to assess performance. Performance should not only be expressed in terms of profitability, because profitability alone, as an indicator for performance, would cause misalignment. An organization must also balance the competing claims of its various stakeholders, in addition to focusing on the welfare of stockholders, to ensure their continuing cooperation, as argued by Barnard (1938). For example, most aerospace product lines are not profitable, i.e., manufacturers rely on one or two hugely successful products to shore up their portfolio (McGuire, 2006). However, without its unprofitable product lines, companies may not be competitive in the market, because, for example, airline customers are typically attracted by a family aircraft concept.

Conclusion

The purpose of this study is to investigate the characteristics of aerospace organizations, focusing primarily on two sectors: aviation and space. The aerospace sector has many unique characteristics when compared with "normal" businesses. Some of the unique characteristics identified in this study are: high market power for some types of organizations, highly complex systems, high outsourcing ratio trends, large military market share, strong governmental financial support and challenging assessment of performance.

Further, this study offers the idea that the aviation and space sectors are, for some features (e.g., high quality standards, massive entry costs, very low production rates, high strategic power and high degree of internationalization) nearly identical, while for other features (e.g., market structure, demand-supply interactions, unit size of production and imperfect competition) different.

Other (extreme) sectors also exist, such as the oil rig sector, the World Wide Web sector, the shipbuilding sector, etc., that have unique and partly similar characteristics to the aerospace sector. An investigation into those sectors is not in the scope of the present study, but may be a fruitful area for future research.

Acknowledgment

This research has been supported by Prof. Dominique Demougin of the European Business School, who is gratefully acknowledged by the author. Valuable comments from Prof. Rose Rubin, University of Memphis, are also acknowledged. Thanks as well to the participants at the 18th International Conference of International Trade & Finance Association (IT&FA) 2008 in Lisbon for their comments and suggestions. The views reported in the paper are those of the author alone, and not those of any institutions. All errors and omissions are the sole responsibility of the author.

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