Analyzing Boeing’s Supply Chain Design for B787 (Dreamliner)

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Abstract

In 2004, Boeing launched the development program of its latest commercial airplane design, Dreamliner (B787), which was made almost entirely from composite materials. The new airplane design became Boeing’s most successful product launch. It received record number of orders from different airlines all around the world. Boeing not only introduced a transformational and extraordinary airplane design, but also revolutionized the way it used to develop a new model. It devised a new supply chain model in which suppliers were responsible to invest their own money to design, manufacture, and integrate major sections of the airplane, based on general specifications provided by Boeing. The program, however, turned into the longest delay in the history of the company. Boeing had to incur huge extra costs to make the program proceed, although with repeated delays. In this paper we seek the root causes which led to all these problems. We present the major supply chain problems which happened in this program, the consequent delays, and how Boeing responded to each of them. We then show how the new supply chain model along with other factors led to these

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problems. More specifically, we show how the adoption of this model weakened company’s position in leveraging its core competency.

**Keywords:** Supplier Management, Boeing, Dreamliner, Core Competency, Product Development

### 1. Introduction

On the 29th of January 2003, the Boeing Company revealed the general specification of its latest airplane design. The new airplane was a fuel efficient jetliner made of almost entirely composite materials – an innovative design which the commercial aviation industry had never seen the like of it. The plane was dubbed Dreamliner or Boeing 787 (B787). Very soon the Dreamliner became Boeing’s bestselling airplane. In fact, it turned to more than just Boeing’s bestselling airplane. In the following years the Dreamliner, with its appealing and unique features, turned to the most successful release in the history of commercial aviation industry with a record number of 500 orders within the first three years of the program’s official launch. Later on Dreamliner’s orders even exceeded 900 at some point. Yet the Dreamliner came to be known as the longest delayed program in the company’s history with more than undesirable consequences, including huge extra costs, lost and delayed revenues, loss of customer’s and investors’ confidence, not to mention a reshuffle of the top management.

When the first signs of the problems were observed in 2007, the company started to pour money and resources to the program. At that time, the top management was under the impression that they could contain the problem to a six month delay (considering some cushion for then unforeseen problems). A six month delay might not look unacceptable for a mega project to develop an extremely complex product. Nevertheless, only the six-month-delay resulted in around $1 billion of extra costs and an estimated reduction of $3.5 billion in revenues for the consecutive year (Gates, 2007a). However, as the subsequent events showed, the roots of the problems were so deep that even now, after almost 30 months of delay, and incurring a lot more extra costs, no airplane has been delivered yet.

The Boeing Company is not only one of the iconic brands of the US, but also one of the few very large companies whose success or failure can have a tangible impact on the US economy.

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2 The number of outstanding orders is a changing figure due to new orders and cancelations.
An eight week halt in the company’s production contributed to the 6.2% decline in the US GDP in the fourth quarter of 2008 (Rothfeder, 2009).

In this research we studied and compared the related published materials and interviewed industry experts as well as those who were directly involved in the program. Through the gathered knowledge we seek to analyze the root causes of this costly and well publicized delay and its impacts. Our analysis is based on the related events which have happened prior to fall 2010. Studying the extensive delay of such a major program in such an influential and generally successful company could be insightful for management practitioners as well as instructive for management students. There have been many news reports and company media releases since the program was first announced in 2003, some supported and some contradicted the many controversial issues that surrounded the program. To the best of our knowledge, however, there has not been any publication which has a comprehensive and analytical look at the delayed program to date. This article could be a first attempt at such a comprehensive and analytic look.

The rest of this article is organized as follows. In section 2, we briefly introduce the background of the company and the Dreamliner program. This section helps us to put discussions and analyses which follow into perspective. Section 3 analyzes the impacts of the delayed program on Boeing. In section 4, we look at the major problems that this program faced, as well as Boeing’s responses to these problems. Section 5 tries to analyze the root causes of the problems. We conclude the article with a summary of the insights and lessons that can be learnt from this case.

2. Background

In this section we provide background information on the Boeing Company, its products, the Dreamliner design, and the Dreamliner program. This background information provides the context for our analyses which proceed.

2.1. Boeing: An Extraordinary Company
The Boeing Company is the nation’s largest exporter (by value) (Reed, 2009). It was founded in 1916 in the Puget Sound area of Washington State. Headquartered in Chicago, it is the world’s largest and most diversified aerospace company as of 2010. Boeing designs, manufactures, and supports commercial jetliners, defense systems, satellites, and launch vehicles. In 1997, the company, in a strategic merger, bought rival airplane manufacturer McDonnell Douglas. As of 2009, the company had customers in 90 countries with total revenues of $68.3 billion. 70% of Boeing’s total sales, historically, are from customers outside the United States. At the end of 2009, $34.1 billion of the company’s sales was from the commercial airplane division, contributing to approximately 50% of Boeing’s annual revenue (The Boeing Company, 2010)

During the mid 90s, Boeing introduced the world’s largest twin jet engine airliner in the form of Boeing 777 (B777). In its quest for combating competition, toward the end of the 90s, the company proposed two more modifications in 747-X series and also the Sonic Cruiser. The 747-X couldn’t withstand competition from the Airbus A380 and faced denunciation from customers. The Sonic Cruiser, though a gas guzzler, was an extraordinary design, and would travel at almost the speed of sound. However, a sharp downturn in the airplane industry after the terrorist attacks in September 2001 dramatically shrank the airplane market, especially for those airplanes with high running costs. Hence, Boeing was left with no choice but to shelve its proposal for the Sonic Cruiser. Shortly afterwards Boeing pulled another extraordinary design out of its magic hat. This new design aimed to address the market need for an airplane with low operating costs. Thus, approximately ten years after the birth of B777, a prospective aircraft design took shape: the fuel efficient Boeing 787 (Dreamliner).

2.2. Dreamliner: An Extraordinary Design

The Boeing 787 is a mid-sized, wide body, twin engine commercial jet airliner. Its seating capacity is, depending on the variant, between 210 and 330 passengers. At the time of launch, the Dreamliner was rated as the most efficient commercial airplane ever made by Boeing and would be 20% more fuel efficient than similar sized airplanes (The Boeing Company). The change from the traditional hydraulic systems to electrical architecture, higher usage of composite materials (derivatives of carbon fiber), use of advanced technologies for a better in-flight
experience, and reduced airplane maintenance costs were some of the very notable features of this plane (The Boeing Company, 2006). Figure 1 compares the composition of the materials used in the Dreamliner and its predecessor the Boeing 777. See also Exhibit 1 for a list of the Dreamliner features.

The usage of composite materials in the Dreamliner’s structure was not Boeing’s first experience with these exotic materials. The company owns a facility dedicated to this purpose called Composite Manufacturing Center (CMC) at Fredrickson, WA. Boeing had used limited composite body parts in its previous models, including B707 and B777. What differentiated the Dreamliner’s design from Boeing’s other models, was the extent to which these materials were used in this model.

The structure of Dreamliner is almost entirely made of composites (See Appendix A). The extensive use of composite materials let Boeing design the structure of the plane from very few, but very large, body parts (sections) which dramatically reduced the assembly time, used much fewer fasteners, and finally made the airplane much lighter. These large sections (see Figure 2) are then assembled together to form the structure of the airplane. By using this new manufacturing method, Boeing can avoid pinning 1,500 aluminum sheets and using 40,000 to 50,000 fewer fasteners than comparable aircrafts (Seattle Post-Intelligencer, n.d.).

![Figure 1: Material Composition of the Boeing 777 and Dreamliner](image-url)
Source: Adapted from the Boeing Company-787 Program fact sheet

The extensive use of composite materials makes the Dreamliner 30,000 to 40,000 pounds lighter than similar aircrafts which, along with other technological advancements enables it to be 20% more fuel efficient and generates 45% more cargo revenue (Walz, 2006).

Dreamliner’s customers, for the first time, can choose the engine of their aircraft from the two available options: General Electric’s GEnX or Rolls-Royce’s Trent 1000. These fuel efficient next generation engines, contribute to 8% of the increase in fuel efficiency (Net Resources International, n.d.)

The new airplane design was received very well by Boeing’s customers. Three months before the roll out (a ceremony in which a new airplane model is first displayed to the public) in July, 2007, the Dreamliner amassed 500 orders, sealing its place as the fastest selling new airplane in the history of commercial aviation (Gates, 2007b).

This is how Walt Gillette3, Boeing’s veteran engineer and aerodynamicist, compares A380, the latest Airbus design, with the Dreamliner:

"The Airbus A380 is the last embodiment of the first century of flight…This (Boeing 787) is the first new airplane for the second century of flight (Wallace, 2007b)."

<table>
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<th>Current Variants</th>
<th>787-8, 787-9</th>
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| Price Tag/unit   | 787-8: US$161.0–171.5 million  
                 | 787-9: US$194.0–205.5 million |
| Estimated Market size | 3,310 units over 20 years (2009-2028)  
                       | $610 billion (List prices in year 2007 dollars) |
| Expectation of sales out of 3,500 units | More than 1750 |
| Firm configuration completed | September 2005 |
| Major assembly began | June 2006 |
| Maiden flight (first flight) | December 2009 |
| Net orders(August,2010) | 847 |
| No. of orders cancelled (as of August,2010)4 | 99 |
| Seat range of airplane | 200-300 |
| Fuel Efficiency | 20% more efficient than similar sized airplanes |

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3 Walt Gillette was the creative force behind the design of 787. He was the vice president of 787 development and production. He retired from the company in 2006.

4 Numbers are calculated from news releases
2.3. Dreamliner: Not Such an Extraordinary Development Program

Boeing not only introduced a revolutionary product, but also revolutionized the way it had developed its other airplanes. The company decided to outsource the manufacturing of the airplane more extensively than any of its earlier models. Moreover, for the first time, it outsourced the engineering and integration of the majority of airplane parts, including different sections of the fuselage, the horizontal tail, and the wings. Although Boeing had the proper capability and expertise within its own engineering team, the company offloaded the engineering phase to suppliers to contain development costs. In this way, Boeing limited its role in the Dreamliner program mainly to the provider of the general design and the assembler of the sections delivered by the suppliers. The detailed design and the manufacturing of the majority of the airplane are left for the suppliers. We will discuss the reasons behind such an unprecedented move in section 5.

Through this new approach, Boeing outsourced more 90% of the engineering, manufacturing and integration of the Dreamliner to outside suppliers5. The vertical fin remained the only major part which was designed and manufactured directly by Boeing. The rest of the major parts and systems, including all the composite sections, were outsourced to various supply chain partners across the globe6.

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5 Boeing, originally, outsourced more than 70% of the design and manufacturing of the Dreamliner to suppliers. Later on, the company sold of its Wichita and Tulsa plants, increasing outsourcing, according to industry experts, to more than 90%.

6 Personal Interview with Dominic Gates, summer 2010. He is an industry expert and an aerospace reporter with The Seattle Times.
Boeing named its major suppliers the *global supply partners*. This was because suppliers’ role in the program was more than just the manufacturers of the outsourced parts according to the Boeing’s blueprints. If a supplier wanted to participate in the program, it must invest its own money and perform the engineering development and integration of the outsourced parts (based on the general specifications provided by Boeing). The major partners chosen by Boeing were Spirit AeroSystems- USA (nose and a portion of forward fuselage), Alenia Aeronautica- Italy (center fuselage), Kawasaki Heavy Industries- Japan (a portion of forward fuselage), Vought Aircraft Industries- USA (aft fuselage), and Fuji Heavy Industries- Japan (center wing box) and Mitsubishi Heavy Industries, Japan (wings) (Lott, 2010). See figure 2 for more details. Each of these companies had to invest heavily in the design and development of their parts. In addition to suppliers’ direct investment, there were some government helps. The Government of Japan helped the Japanese companies $1.5 billion and the Government of Italy helped Alenia Aeronautica $600 million in subsidies (Pritchard & MacPherson, 2004). The major supply
partners were also called *risk sharing partners* since they agreed to receive part of the revenue of selling each airplane as their payment (Drew, 2009a). So, they shared Boeing’s risk in success or failure of the program.

This business and supply chain model was received very well by the industry experts, analysts, and even investors. By convincing the suppliers to invest their own money in this program, Boeing managed to cut the development costs to around 55% of the originally estimated $10 billion budget for the program (Lunsford & Micheals, 2004). Due to his successful implementation of the new global supply partners model, Steven Schaffer, vice president and general manager of the global supply partners at Boeing Commercial Airplanes, was named the supply chain manager of the year (2007) by the Purchasing Magazine. All in all, everyone seemed to be excited about the brilliance of the program design.

The events that followed this initial hype, however, proved that neither the business and supply chain design, nor its implementation was free of major flaws. Starting in 2007, Boeing faced a series of problems in its Dreamliner program, which led to a series of delay announcements. As of fall 2010, the first delivery is delayed by two and half years and many experts believe it can extend to a 3 year delay. Figure 3 shows the timeline of these delays and the related announcements.

As we can see in Figure 3, Boeing managed to display the first materialized Dreamliner in its roll out ceremony, as it was scheduled, in July 2007. Boeing insisted on having the roll out on July 8th 2007 since the digits of this date symbolize the airplane name (07/08/07 787). The 787 which was displayed to the public in this ceremony was not as complete as it looked. Most of the parts delivered to Boeing’s assembly facility were incomplete. Engineers and technicians at Boeing had to use temporary fasteners to pull the parts together for the show. In fact, Boeing rushed the suppliers to deliver the parts even if they were not complete so that it could keep its promise for the symbolic roll out date.
The maiden flight, i.e. the first time a new airplane model takes off the ground, was originally planned for September 2007. The first delay announcement came shortly after the rollout which postponed the maiden flight to November/December 2007. At this stage, Boeing was under the impression that it could easily resolve the problem. So, it did not postpone the first delivery date. The reason for this delay was announced to be a shortage of fasteners and problems with flight control software.

On October 10th 2007, a second delay due to supply chain problems shifted the first flight to March 2008 and the first delivery was delayed by 6 months. It was followed by a third delay announcement on January 16th, 2008. The reason was announced to be delays by unnamed suppliers and insufficient progress on the shop floor because of the travelled work, i.e. suppliers’ unfinished parts which then had to be fixed by Boeing’s more experienced technicians. First flight was then shifted to the end of June 2008 and first delivery to early 2009. Continued problems due to unfinished work from suppliers made Boeing announce, on April 9th 2008, a fourth delay, postponing the first flight to the fourth quarter of 2008 and the first delivery to the third quarter of 2009.

On June 20th 2008, Boeing managed to meet (although late) an important milestone in bringing the Dreamliner to life: the power-on. The power-on is the event of turning on the electrical systems of a new airplane model for the first time.
Contract disputes between Boeing and the labor union led the Boeing workers to go on a strike for 58 days beginning September 7th, 2008. Shortly after the strike, on November 4th 2008, the program was delayed for the fifth time. This time, the delay was announced to be due to incorrect fastener installation and the labor union strike. It was confirmed on December 11th 2008 that the first flight would be rescheduled to the second quarter of 2009 and the first delivery to the first quarter of 2010. One week after the Paris Air Show, on June 23rd, 2009, the company announced a sixth delay – citing the need to repair the body of the aircraft as the reason. The first flight was then postponed to the end of 2009 and the first delivery to the end of 2010. Finally, the first Dreamliner took off the ground in December 2009. The latest Boeing’s announcement, as of fall 2010, predicts that the first delivery will not happen until the middle of the first quarter of 2011.

3. The impact of delays on the company’s performance

In this section we try to investigate how the delays in the Dreamliner program impacted Boeing. We look at these impacts from two perspectives: the stock market performance and the number of order cancellations.

3.1. Stock market performance

As one of the measures for tracking the impact of delays on the company, we look at the Boeing’s stock performance. The stock performance of a company is affected by internal performance of the company as well as the general macroeconomic conditions of its industry. Since we are only interested in the impact of internal performance on the stock price, we look at the Boeing’s stock price relative to its industry average (Aerospace and Defense). We assume that the general macroeconomic factors affect all the companies of the industry almost equally. So, when we look at Boeing’s stock price relative to its industry average, these external factors should mostly cancel out. To make this comparison possible, we normalize both the Boeing’s stock price and the average of the industry stock prices to an index of 100 at the beginning of 2004. We then track the stock performance of both Boeing and the Industry average with respect
to this normalized index (See appendix B for more details). Figure 4 shows this comparison from 2004 (launch of the program) till fall 2010. This figure also shows the dates of the important events of the program.

![Figure 4: Being’s stock performance compared with the Aerospace/Defense industry average](image)

As we can see in figure 4, Boeing’s stock increasingly performed better than the industry average since the launch of the program till the roll out date. This is the period of time which the program was mostly praised and it received a record number of orders. Shortly after the roll out, the delay announcements started. We can see that the superiority of the Boeing stock started to decline after the first delay announcement. This decline continued and in mid 2008 Boeing stock started to actually perform weaker than the industry average. This weaker performance continued until late 2009 when the maiden flight happened and Boeing stock managed to gain part of its old strength. Although the Boeing’s stock price could be affected by internal factors other than
the Dreamliner program, we can see from figure 4 that there is a strong correlation between the success and failure of this program and Boeing’s stock price.

3.2. Order Cancellations

Figure 5 compares Boeing’s total number of order cancellations, Dreamliner’s number of order cancellations, and the total number of order cancellations at Airbus (Boeing’s major competitor). It is interesting to note that during the height of the recession years, Airbus had the highest number of order cancellations, while Boeing lost very few orders. The opposite happened in 2009, when the number order cancellations at Airbus dropped considerably while Boeing’s cancellations increased dramatically, mostly because of customers cancelling their Dreamliner orders. This jump in the number of order cancellation can be a consequence of continued delays and the uncertainties surrounding the fate of the program.

Figure 5: Order Cancellations of Boeing and Airbus
Source: Adapted from the Boeing Company website and Airbus’s Annual reports
4. Program’s major problems and Boeing’s response to them

Following its roll out ceremony in July 2007, the Dreamliner’s maiden flight (the first takeoff) was expected to be in August or September of the same year, with its first delivery scheduled for May 2008 to All Nippon Airways, Japan (The Boeing Company, 2007). Things did not go as planned. During the months that followed, supply chain problems started to surface. In this section we introduce highlights of these problems and Boeing’s responses to them. For brevity’s sake, we do not discuss all the documented problems.

4.1. Fasteners problems

4.1.1. Shortage of fasteners

One of the first supply chain problems that surfaced in this program was a shortage of fasteners. After the terrorist attacks in September 2001, the airline industry faced a very severe crisis. The crisis led airplane manufacturers such as Boeing and Airbus to downsize their workforce. Boeing alone laid off 35,000 of its employees. Consequently, suppliers such as Alcoa (fastener division) also had to lay off 41% of its workforce. Many mid and small suppliers were driven out of business. Therefore, the industry experienced an overall decrease in the capacity of fastener production. After the demand picked up in the following years, the capacity could not keep up with demand, which led to a general shortage of fasteners in the industry (Glader & Lunsford, 2007).

This problem was even worse for the Dreamliner program. The new composite design needed much fewer fasteners (about 80% fewer). In addition, the airplane was in the development phase, so the orders were for very few numbers of airplanes. The relatively small volume of fastener orders from the Dreamliner program did not stir an enthusiastic response from the suppliers who preferred to exploit their limited capacity in larger orders to benefit from economy of scale in their production batches. Consequently, suppliers couldn’t consider small orders with lower priorities. This situation posed serious threats to the Dreamliner (Wallace, 2007a)
Visits by Boeing’s executives to Alcoa Inc., fasteners facility, followed after the fastener delay. Boeing and Alcoa planned to develop ways to speed up production. Alcoa’s plan was to add up to its existing capacity at Mexico and Hungary and also to open up a new plant in China (Glader & Lunsford, 2007).

4.1.2. Incorrectly installed fasteners

The problems with fasteners continued to haunt the Dreamliner program. If it was the shortage of fasteners which caused a delay earlier in the program in 2007, on a second occasion, a year later, the delay was caused due to improper installation of the fasteners. Close to 3% of the fasteners installed at Everett and suppliers’ locations had to be removed and reinstalled again. The procedure to install these fasteners was new and Boeing claimed that unclear specifications on how to install these fasteners caused the problem. To ascertain that in future they don’t face such problems, Boeing emphasized that they would improve their quality management systems, training of workforce on fastener installation and also help their suppliers with training on fastener installation (Gates, 2008b).

4.2. Travelled work

Suppliers who could not complete their parts according to the specified requirements passed on incomplete sections of the airplane to Boeing’s final assembly facility at Everett, WA. Workers at Everett had to incorporate additional effort to finish the incomplete work. They named this type of extra work as travelled work. This was compounded by the problem of mechanics at Everett having to encounter parts for assemblies sometimes without proper paperwork or even assembly instructions in another language which required translation (Lunsford, 2007).

Boeing had to include travelled work into its already tight production schedule which resulted in further delays. For example, flaws in manufacturing of the mid fuselage structures by Alenia Aeronautica, the Italian supplier, made Boeing to issue a “stop work” order to the supplier. Although Alenia Aeronautica had a lot of experience in dealing with composite materials, it failed to live up to Boeing’s standards. Analysts even termed the problem caused by Alenia Aeronautica as negligence rather than lack of experience in handling composite materials. Boeing realized the problem after Alenia had manufactured 23 mid fuselage sections. After
issuing the “stop work” order, Boeing planned to apply patches to the defective areas. The delay arose at the same time when another technical snag happened due to a problem at the wing-fuselage joint (Drew, 2009b).

4.3. Problematic sub-suppliers

When Boeing for the first time, outsourced the engineering, manufacturing, and integration of major sections of the airplane to its supply chain partners, these partners in turn outsourced different tasks of their contracts to sub-suppliers. As a result, Boeing faced a supply chain with more sub-suppliers (and more layers of sub-suppliers) than it had ever experienced before. The subsequent events showed that Boeing was not ready to deal with such a complicated supply chain, nor these sub-suppliers were all able to meet Boeing’s high standards.

Vought Aircraft Industries, a supply chain partner, was in charge of building the rear fuselage of the Dreamliner. Vought offloaded the production of floor grids to IAI (Israel Aircraft Industries). However, the Israeli company failed to deliver the integrated floor grid of the first Dreamliner on time. Due to pressures from Boeing to deliver the rear fuselage on time for the roll out in July 2007, Vought was left with no option but to ship the first rear fuselage to Everett which had only 16% of its structure completed and none of the systems installed. Joint efforts by Boeing and Vought to resolve sub-supplier problems paved the way for adjustments in the supply chain. IAI was directed to supply unassembled floor grid pieces, so that Vought could join them to one single piece at its Charleston facility, before dispatching the fuselage assembly to Everett. With such changes, after about one year, the fuselages from the Charleston plant were 98% complete by structure and had 87% of the systems installed, before being delivered to Everett for final assembly (Gates, 2008a).

Another instance of problems with the sub-suppliers rose when Boeing outsourced the Brake Control Monitoring System (BCMS) to General Electric. General Electric, in turn, subcontracted the design of the software to Crane Co. The software which was delivered to Boeing caused serious feedback problems at Everett. The improper test and verification of the software by HCL, an Indian subcontractor of Crane, was found to be the source of the problem. Crane accepted the responsibility and spent around ten times its initial budget to rework the job. The misfortune of Boeing in this regard did not end there. After the problem was resolved by Crane, during the taxi
testing of the first Dreamliner, Boeing realized that the temperature generated in the brakes was higher than expected. So, they needed to relocate the Remote Data Concentrator (RDC) and the BCMS needed to be redesigned. This required an additional investment by Crane to redesign the software. This time, however, Crane was not willing to pour more money into this project. In a legal battle, on who should pay the costs of redesign, Boeing was directed to pay $18.9 million for the redesign cost. It was then decided that Boeing would work directly with Crane rather than with General Electric as intermediary (Ostrower, 2009; Shwiff, 2009).

4.4. Labor union strike

A 58-day strike by 27,000 agitated workers caused further delays into the already delayed Dreamliner program. One of the major issues in this dispute (the second time in three years) was the employees’ concern about their job security, which had been intensified by the extensive outsourcing in the Dreamliner program. What made the unhappy workers even more aggravated was all the travelled work (supplier’s unfinished parts), which they were asked to fix. While Boeing’s employees felt that they were losing their jobs to outside suppliers, at the same time, they were asked to use their considerable experience and expertise to fix all the unfinished works which the inexperienced suppliers failed to complete.

The strike, which was the longest in 13 years, cost Boeing $100 million per day in deferred revenue. The strike ended when the machinist union secured a four year contract in which Boeing offered a 15% pay rise over the four year period of the contract. Boeing included this extra pay as an incentive in the contract to gain flexibility and prevent further obstruction by the workers to its future outsourcing plans (Lunsford, 2008; Patalon III, 2008)

After the two month strike, Boeing decided to open a second assembly line at North Charleston in South Carolina. Boeing needed a new assembly facility to ramp up production for its delayed Dreamliner program. The company decided to open the new facility in South Carolina to isolate the program from potential disruptions by its unionized workforce in Washington State. South Carolina did not have the problem of labor union and the labor cost was relatively lower. In addition, the new assembly facility would be close to two other Dreamliner production facilities in South Carolina. These facilities originally belonged to Vought Aircraft
Industries and Global Aeronautica\(^7\). At Vought, aft fuselages were manufactured and various systems were installed in them. On the other hand, the next door facility, Global Aeronautica, joined fuselage sections from Italy and Japan and installed various systems in them to ship a single unit to Everett. To resolve the supply chain problems and increase the production capacity, these facilities needed additional investments. However, Vought and Global Aeronautica, who had already invested heavily in the program and did not receive any income due to the extended delays, were hesitant to pour more money into these facilities. Therefore, Boeing was left with no choice but to buy the facilities\(^8\).

By building the new assembly facility in South Carolina, Boeing wants to ensure Dreamliner production remains continuous without any labor disruption to meet the production goal of manufacturing 10 airplanes per month by the end of 2013 (Ostrower, 2010). This decision was made in spite of the diseconomy of scale of building an assembly facility parallel to the existing facility in Everett.

5. **Root causes of the problems**

There have been many factors which played influential roles in turning the Dreamliner program into an operational and financial nightmare. These factors were not independent and in many cases they amplified each other. In other words, the delays have been the result of a network of interconnected factors (see figure 6). Moreover, many of these factors are specifically more problematic in aerospace industry which has its own distinct features. This is how Stan Sorscher enumerates some of the features which characterize this industry\(^9\):

- Complex and heavily engineered products
- Very dramatic learning curves where productivity improves very rapidly
- Unit costs are very high
- Expectations of public and customers are very high

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\(^7\) Global Aeronautica was a 50%-50% joint venture between Alenia Aeronautica and Vought Aircraft Industries.  
\(^8\) Personal Interview with Dominic Gates, summer 2010.  
\(^9\) Personal interview with Stan Sorscher, summer 2010. He is an industry expert and a former Boeing Engineer. After his retirement he is with the SPEEA (Society of Professional Engineering Employees in Aerospace).
- Consequences of mistakes are very damaging
- New products come once every decade or so
- Requires high intellectual capital
- High rewards for success and severe penalties for failure
- Requires a lot of coordination

Keeping these features in perspective, in this section, we try to identify the main factors which led to the problems of the Dreamliner program.

5.1. Global Supply Partners approach

Among all the factors which caused this costly delay, the new “Global Supply Partners” model seems to play a central role. All other factors were either consequences of implementing this model, or reinforced by it. Through this supply approach, suppliers were responsible for the engineering, development, and manufacturing of the parts which were outsourced to them. Therefore, to participate in this program, they had to make considerable investments. On the other hand, through this approach, Boeing managed to achieve two goals: (1) considerably reducing the initial investment needed for developing the Dreamliner, (2) moving toward a system integrator company as the top management envisioned for the future of the company. By reducing the initial investment (fixed cost) of the program, Boeing could reduce the financial risk associated with the success or failure of the program. This feature could especially be appealing to investors, whose demands usually have great influence on the strategies set by the top management. On the other hand, being a system integrator rather than a manufacturing company, among other reasons, could give them the ability to be more flexible and responsive to changes in the market condition.

The new product design with its many unique features, along with a new supply chain model with its appealing promises, worked very well for Boeing – at least for the first three years after the launch of the program in 2004. Very strong stock performance and record number of orders, for an airplane which existed only on paper, were signs of Boeing’s good fortune in this program.
The good promises of the new supply chain model, however, came with a few inevitable downsides: (1) loss of core competency, (2) weaker future innovation capability, (3) more challenging troubleshooting and future modifications, (4) higher uncertainty in Boeing’s ability to deliver Dreamliner’s promised features, and (5) suboptimal supplier selection. Below, we will have short discussions about each of these downsides which come along with the implementation of the new supply chain approach.

5.1.1. Loss of core competency

The old debate of what functions should be outsourced in a company and what functions should be kept in-house as the source of core competency applies to Boeing too. Here, we want to argue that, by implementing the new Global Supply Partners, Boeing has weakened its ability to safeguard its core competency. We can observe four reasons:

i. Historically, Boeing has shown great ability in managing mega-projects of developing new airplanes. In the Dreamliner program, Boeing kept this project management role, as well as the assembly of the final product, in-house and outsourced pretty much everything else (with the exception of the vertical fin which remained the only major section of the airplane manufactured in-house).

The Dreamliner development project, however, was not exactly similar to the projects that Boeing had experienced beforehand. There were many features of the Dreamliner program which made it quite distinct from its predecessors: (a) the supply chain structure was multilayered and more complex, (b) suppliers were responsible for the integrations of the major sections of the airplane, (c) and above all, the detailed design of the airplane sections was done by the suppliers. Many of the supply chain problems which delayed the program were clear evidences that Boeing was not specifically experienced in managing such a project, which means the project management in this program could hardly be Boeing’s core competency.

ii. When Boeing outsourced the detailed design of the airplane sections, it had to share with suppliers some of the unique design knowledge and techniques which had been accumulated in Boeing through designing and developing airplanes for almost a century.
For example, a proprietary manual, “How to Build a Commercial Airplane”, which was developed by Boeing engineers for over five decades, was shared in large part with Tier-1 suppliers developing the Dreamliner (Nolan, 2009).

iii. When a part of a product becomes a commodity, it turns into a low value-added part of the product. Outsourcing the manufacturing of this part might then be a good strategy for the company, so that it can focus on high value-added parts of the product. The ownership of the design and manufacturing of high value-added parts, as well as the related processes, can be considered as the source of core competency for a company.

Aerospace industry, and in particular commercial aviation, has a very steep learning curve. That is, the first airplane of a new model costs many times more than the tenth airplane, for instance. The reason is that, for the first few airplanes, after each airplane is made, the processes can be improved dramatically by learning how to do things properly. The steep learning curve of this industry is due the extreme complexity of the products. So, it is very unlikely that everything can be done in its best way the first time. This is true for an airplane, as a whole, as well as for each of the major airplane sections. Therefore, there is high value-added in the development and manufacturing of the first units.

By outsourcing the engineering, manufacturing, and integration of the major sections of the Dreamliner to outside suppliers, Boeing let this learning curve, and the corresponding high value-added functions, transfer to those suppliers.

5.1.2. Weaker future innovation capability

In this program Boeing introduced possibly the next generation of airplanes in which the structure is made almost entirely from composite materials. Through its Global Supply Partners approach, Boeing empowered its partners with the ability of designing and manufacturing airplane sections from composite, while excluding (or at least limiting) itself from such capabilities, which could be the key to the future of commercial airplane industry. Pisano and Shih (2009) argue that the ability to innovate products depends on the ability to innovate the related processes. In other words, when a company deals with the manufacturing processes of a
product, the ability to innovate related new processes lies within that company. These new processes, in turn, could enable the company to manufacture the next generation of that product (Pisano & Shih, 2009). A good example could be Boeing’s ability to introduce the Dreamliner as a composite airplane. This could be due to Boeing’s past experience with the composite materials. So, when Boeing outsourced almost all the manufacturing of the airplane structure to outside suppliers, the ability of future innovations in making airframe structures from composite materials was also transferred to these suppliers. This can limit Boeing’s competitiveness in introducing future generations of composite airplanes.

5.1.3. More challenging troubleshooting and future modifications,
While Boeing reduced its development cost by outsourcing the design and engineering of the airplane section, at the same time, it limited its access to the detailed design of these sections. Since the suppliers spent their own money to design and develop the parts, they naturally retain details of these designs as their own property. “That means Boeing will have to depend on suppliers for any changes or modifications in future, for the parts that will go onto the 787. Boeing has no idea what went into the design, because they don’t own the design. It is on their (suppliers’) computers, the design principles and the calculations are all with them (suppliers) and they own it legally and intellectually,” explains Stan Sorscher10.

This feature has made any trouble shooting a more complicated task, especially if the problem involves two or more sections developed by different suppliers. As an example, in July 2009 Boeing announced that the joint between the center wing box and the wing faced a stress related problem. Japanese supplier- Mitsubishi Heavy Industries (MHI) had developed the wing. Another Japanese supplier Fuji Heavy Industries (FHI) had developed the center wing box and Boeing had developed the interface. Since neither of the suppliers owned the interface and nor did Boeing have access to the design of the parts, Boeing had to re-test the already completed Dreamliners again and bear the cost of over runs (Gates, 2009a).

10 Personal Interview
Similar problems might happen if Boeing wants to make any modification or extends the features of the airplane. It would not be surprising if the suppliers ask for compensation to let Boeing access the detailed designs on these occasions.

5.1.4. Higher uncertainty in Boeing’s ability to deliver Dreamliner’s promised features,
Boeing’s lack of full access to the detailed designs and the complexity of the supply chain, as well as a problematic development program have created some doubts about Boeing’s ability to deliver all the promised features of the Dreamliner. Due major modifications in the first three Dreamliners, Boeing is not going to these airplanes, which is against company’s initial plan to refurbish the first airplanes and sell them. (Cohan, 2009). Although Boeing still insists that the Dreamliners which are going to be delivered to the customers will live up to the promises, not all industry experts are certain about it.

5.1.5. Suboptimal supplier selection.
In the Global Supply Partners approach, only those suppliers could participate who had the financial capability of investing their money up front in the program and willing to wait until Boeing sells the airplane before they receive any payment. This was a strong and limiting prerequisite. Therefore, the technical capability of suppliers had to come second after the financial capability of the supplier. This could result in suboptimal selection of supplier from a product development point of view. This does not necessarily mean that all suppliers were poor choices. However, the existence of a few very problematic supply partners in this program suggests such suboptimal supplier selection process.

5.2. Financial Risk vs. Operational Risk
“Back in 2003, the odds were against the program … As a result, the only way you get this thing (the Dreamliner program) going is if you promise to limit the development costs to a tiny
fraction of what they should have been. The only way to do that was to develop an extremely unrealistic supplier model.” says Richard Aboulafia\textsuperscript{11}, an industry expert.

In 2003, Allan Mullaly (then CEO of Boeing Commercial Airplanes) managed to get the project through, against some opposition from the Board of Directors. To do so, Mullaly had to reduce the financial risk of the project by reducing the required upfront investment and spreading the risk among various supply chain partners. What the company overlooked was the fact that the new Global Supply Partners approach devised a much more complicated supply chain and engaged the company in a program plan which it had not experienced before. In addition to implementing an unprecedented complex supply chain, Boeing was developing a new breed of airplane which had its own design and manufacturing surprises (much more than developing a new airplane from traditional materials and technologies). This meant the program had to endure a much higher level of operational risks. The history of the program suggests that Boeing had not considered this high level of operational risks and uncertainties in the program schedule and resources. On the other hand, the operational risks and financial risks are not independent of each other. When the company faced all the realized operational risks, they brought back all the financial risks along with them. The industry experts estimated that Boeing managed to reduce the initial investments into nearly half. At the end, the extra costs are estimated to be twice the savings in the initial investment, not to mention all other tangible and intangible losses due to delays.

5.3. What Boeing knew and what it did not

Although Boeing had enough experience on how to outsource manufacturing, it did not know very well how to outsource the design of an airplane. Boeing gave its supply partners the general technical specification of the airplane sections and expected the suppliers to come up with the detailed designs. One of the shortcomings of Boeing was its failure to realize the design and development practices that its engineers knew only too well but its supply partners did not know

\textsuperscript{11} Personal Interview with Richard Aboulafia, summer 2010. He is an industry expert and a senior aerospace analyst with the Teal Group.
them at all. After decades of designing airplanes, Boeing had developed practices which were key in being a successful airplane designer and developer. Boeing was so used to knowing and implementing these practices that it failed to understand that these are not common knowledge among its suppliers. As Lynn Lunsford puts it, these practices have become part of Boeing’s DNA. For instance, it has been a common practice in Boeing that all parts of detailed design being approved by a designated engineering reviewer (DER) to guarantee the consistency of different parts of the detailed design. Boeing did not articulate this practice to its suppliers and it was surprising for Boeing that some of the suppliers had failed to have their designs approved by a DER. Since Boeing expected its supply partners to perform this task, many of Boeing’s DER had already been either retired or laid off. So, Boeing was not able to address the problem very quickly.

Another Boeing’s shortcoming in outsourcing the design of the Dreamliner sections (highly related to the one mentioned above) was the insufficient level of monitoring and communication it set up with its supply partners. Outsourcing the design of the different sections of an extremely complicated product to multiple parties need a whole new level of monitoring and communication which is not comparable with what Boeing used to set up for outsourcing the manufacturing of the airplane parts. This fact was reminded to Boeing by a senior advisory group which consists of retired Boeing’s managers whom the company invited back in 2010 to analyze Boeing’s challenges. This is how Joseph Sutter, the unofficial leader of the advisory group, addresses the problem of improper monitoring and communication with suppliers in the Dreamliner program: “You better damn well have a high percentage of Boeing guys there looking over their shoulders” (Sanders, 2010).

5.4. Supply partners’ incentives

One inherent problem within this supply chain model is that when the program starts to deviate from its schedule, it can deteriorate the participants’ incentives in doing their best. Assume a

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12 Personal Interview with Lynn J Lunsford, summer 2010. He is an industry expert and a senior aerospace reporter at the Wall Street Journal.

13 Joseph Sutter is the most renowned living veteran of Boeing and is considered as a legendary figure in the aerospace world. He was the head of the design team of the world’s first Jumbo-Jet B747 (Sanders, 2010).
scenario in which the program is delayed because of problems at one supplier. Now if another
supplier spends a lot of money and effort to deliver on time, it will not gain anything. In fact, in
this case, it would be in supplier’s best interest to spend as little as possible and be just slightly
better than the worst supplier. Of course no one wants to be the worst supplier since it should
then endure all the blames and bad publicities. If there was perfect information, that is, every
supplier knows the progress of all other suppliers, this behavior would not hurt the program.
However, since suppliers lack such perfect information, each one of them decides about its effort
level based on guessing the progress level of the others. This behavior can seriously hurt the
program. Not all suppliers necessarily behave in this way, however, the general setup works
against suppliers’ incentive to do their best. What intensified this problem in the Dreamliner
program was that the supply partners owned the design of the outsourced section. So, they had
strong bargaining powers and could not be replaced easily.

5.5. Poor problem solving
In many of the reported supply chain delays, it seems that the problems surfaced at a very late
stage, when it was very difficult to deal with them. The fastener shortages as well as the defects
in the mid fuselage are both examples of the problems which could have been detected and
resolved much sooner and much cheaper. However, they surfaced when there were no other
choices but to delay the program and spend a lot more money than it was really needed. The
reason could be either the lack of proper monitoring system, or the lack of a proper problem
solving culture which reacts to the signals of trouble in a timely manner. In our studies we found
evidences showing that there has not been a close relationship between the top management and
the body of the company. The most obvious evidence could be two labor union strikes in three
years (in 2005 and in 2008).

Lack of trust and a good relationship between top management and the body of the company
can work like a barrier that prevents a smooth and timely flow of information from those who
detect the problems to those who need to make the decisions to resolve the problems.

Another reason for poor problem solving could be lack of a mechanism which encourages the
supply partner to share, as soon as possible, the information about any trouble or possible delay.
If such a mechanism does not exist, then the suppliers usually tend to postpone sharing of bad news. “Many of the delays on the 787 program have come strictly because suppliers, who were supposed to raise their hand for help, were reluctant to do so. They had to deal with their egos and legal reasons” says Lynn Lunsford\textsuperscript{14}.

5.6. Experienced, skillful, but unhappy employees

The successful development of an airplane depends heavily on having experienced and skillful workers, technicians, and engineers. As we mentioned earlier, airplane development programs have a very steep learning curve. So, it is not just a good design which leads to a successful product, it is also the learning process which happens throughout the development program. This learning process is feasible when the workers, technicians, and engineers involved in the program possess the proper skills and understand this culture.

Boeing has been in this business for almost a century. The company has nurtured generations of skillful employees, who developed and manufactured many successful airplane models. Stan Sorscher relates the great success of Boeing in its previous models to the company’s understanding that it needed to leverage its employees’ skills and experiences to steer the program\textsuperscript{15}. In this sense, one can argue that Boeing’s workforce and the accumulated knowledge which resides with them is the company’s real core competency.

In the Dreamliner program, however, Boeing weakened the role of its experienced employees by relying mostly on its global supply partners who helped the program with the initial investment. This approach not only put this valuable source on the side, but also created a sense of job insecurity among the employees. Boeing’s employees not only felt unappreciated but also were worried about their job security. As we discussed earlier, this issue was one of the major concerns in the machinists strike in 2008. “One of the biggest issues of the strike was the

\textsuperscript{14} Personal interview with Lynn Lunsford, summer 2010.
\textsuperscript{15} Personal interview with Stan Sorscher, summer 2010.
continued outsourcing of the company and it remains an issue that it is our work (which is going out to suppliers)” says Connie Kelliher16, IAM17 spokesperson.

Boeing workforce proved their competency again, in the Dreamliner program, by fixing all the unfinished travelled work which suppliers failed to complete during the early stages of the program. As another piece of evidence, among the very few sections of the Dreamliner which was delivered on time and on budget was the vertical fin which was designed and manufactured by Boeing’s employees at the Fredrickson facility.

Even after the realization of so many problems in the new supply chain model, Boeing insisted on its intention of not relying on its existing experienced workforce by building a second assembly line in South Carolina. The main purpose was to isolate the Dreamliner program from any future labor disruption. “With a second supplier for every part, Boeing potentially could continue with the production of the 787 in South Carolina even if the Machinists went on strike here (Washington). Repeated labor disruptions have affected our performance in our customers' eyes.” said Boeing spokesman Jim Proulx (Gates, 2009b).

6. Conclusion

While the Dreamliner program started as a great success for Boeing, it turned into the company’s longest delayed program with extra costs almost twice the initial program budget. The delays resulted in (a) poor stock performance (see figure 4), (b) deferred revenue, (c) penalty payments to customers for late delivery, (d) unscheduled (direct or indirect) payments to suppliers who delivered their sections on time (e) order cancellations (see figure 5), and (f) a drop in Boeing’s Boeing’s credit worthiness by credit rating agencies (Dunlop, 2009). Analysts estimate that the extra costs of the program (including extra R&D costs, rework, and penalties) could reach up to $10 billion.

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16 Personal Interview with Connie Kelliher, summer 2010. She is a spokeswoman for the IAM.
17 IAM is the International Association for Machinists and Aerospace workers representing active and retired aerospace workers at Boeing Industries in Washington State.
In this study we tried to show the root causes of the problems in this program. Figure 6 shows the relationship between the factors which resulted in delays and extra costs. We can see that, among all other factors which contributed to the problems, the adoption of the new “Global Supply Partners” model played a central role. There are systematic consequences which resulted directly from implementing this approach as well as problems which were intensified by other
factors. There are also factors which when combined with the delays became problematic. For instance, we can see that the delays were a consequence of incompetent suppliers. On the other hand, delays caused the program to enter the recession period, which in turn become a problem for suppliers who invested heavily in the program and did not receive any payments. So, the suppliers’ financial problems become another source of trouble for the supply chain. When Boeing found two of its suppliers, Vought and Global Aeronautica, in this situation, it was left with no choice but to buy their whole Dreamliner operations in South Carolina just to ensure the continuity of the program.

We believe that Boeing could have avoided many of these problems by keeping the detailed design and engineering phase of the program in-house. The real core competency of the company is its unique know-how which resides with its skilled and experienced employees. Therefore, if Boeing leverages these elements, the Dreamliner along with many other programs could be much more successful.

There are signs that Boeing might revise its “Global Supply Partners” approach for its future programs. "We outsourced too much. ... We didn't consider the extent of the risk we'd take on by going outside," said Jim Albaugh, CEO-Boeing Commercial Airplanes (Gates, 2010). "We will make sure the voice of the engineers is much more involved in the decision making as we go forward."

**Acknowledgement**

We would like to thank all the industry experts who shared their valuable knowledge and thoughts on the Dreamliner program with the authors. We specifically want to thank Dominic Gates, Seattle Times; Lynn J Lunsford , Wall Street Journal; Richard Aboulafia, Teal Group; Connie Kelliher, Spokeswoman-IAM (International Association of Machinists and Aerospace Workers) and specially Stan Sorscher, Former Boeing Engineer currently with SPEEA (Society of Professional Engineering Employees in Aerospace).
References


Appendix A

Figure B1: Composites on B 787’s body
Source: Seattle Post-Intelligencer
Appendix B

The normalized stock index of Boeing (NYSE:BA) is compared with the average of the normalized stock indexes of 16 other companies listed on various stock indexes. These 16 companies are chosen as the most relevant ones for comparison from Yahoo Finance Website. Yahoo finance (http://biz.yahoo.com/ic/610.html) categorizes Boeing and the 16 companies as Aerospace/Defense-Major Diversified. The table below lists the companies chosen for comparison and the stock exchange on which they are listed:

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<tr>
<th>#</th>
<th>Company</th>
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<td>1</td>
<td>Babcock Intl.Group (BAB.L)</td>
<td>LSE</td>
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<td>2</td>
<td>Cobham (COB.L)</td>
<td>LSE</td>
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<td>3</td>
<td>General Dynamics Corp. (GD)</td>
<td>NYSE</td>
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<td>4</td>
<td>Raytheon Co. (RTN)</td>
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<td>5</td>
<td>BAE Systems (BA.L)</td>
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<td>6</td>
<td>Dassault Aviation(AM.PA)</td>
<td>Euronext (Paris)</td>
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<td>7</td>
<td>Kaman Corporation (KAMN)</td>
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<td>8</td>
<td>SAAB –B (SAAB-B.ST)</td>
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<td>9</td>
<td>Bombardier (BBD.B)</td>
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<td>DigitalGlobe, Inc. (DGI)</td>
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<td>11</td>
<td>Lockheed Martin Corporation (LMT)</td>
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<td>12</td>
<td>THALES (HO.PA)</td>
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<td>16</td>
<td>Textron Inc. (TXT)</td>
<td>NYSE</td>
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