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Boeing: The Fight for Fasteners

For want of a nail the shoe was lost.
For want of a shoe the horse was lost.
For want of a horse the rider was lost.
For want of a rider the battle was lost.
And all for the want of a horseshoe nail.
Old English proverb

The Boeing Company ended 2008 on rough footing. For the fourth quarter, the company reported a loss of $85 million. Quarterly revenues of $12.7 billion were off by 27% year-over-year, primarily due to the impact of a machinists strike, which reduced commercial deliveries by approximately 70 airplanes.[1] The company also announced a lower-than-expected earnings forecast for 2009. "The global economy continues to weaken and is adversely affecting air traffic growth and financing," said Jim McNerney, Boeing's chairman, president, and chief executive officer.[2]

Indeed, 2009 started off just as difficultly. By the beginning of February, 31 orders for the 787 Dreamliner aircraft had been cancelled by LCAL, a Dubai-based leasing company, and S7 Group, Russia's second-largest airline.[3] More cancellations and deferrals were likely for the 787, which had been the fastest-selling aircraft in the history of commercial aviation. By the end of 2006, before Boeing had originally scheduled to test and deliver the 787, Boeing had firm orders for approximately 500 aircraft.

Boeing originally was scheduled to deliver the Dreamliner to airline customers in mid-2008. However, after five announced delays over two years, the company was forced to postpone the first test flight. As of August 2009, the exact flight test schedule was still pending. Deliveries to customers were expected to be delayed until at least the second quarter of 2010. A delay of this magnitude was unparalleled in the history of Boeing commercial airplane development.

One driver for the delay was an industry-wide shortage of aerospace fasteners, the hardware that held the aircraft together. Engineers at Boeing never could have imagined that fasteners, which comprise approximately 3% of the total cost of an aircraft, would become such an issue. "It's amazing what it comes down to at the end of the program," said Mike Bair, the Boeing vice president who was initially in charge of the 787 Dreamliner program (until October 2007). "We're getting down to the point that every part, even a bolt, is important."[4]

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Boeing's senior leadership tasked John Byrne, Director of Supplier Management Common Commodities, and Valerie Feliberti, Senior Manager for Structural Standards, with developing and executing a strategy to address the fastener shortage. To solve the problem, Byrne and Feliberti quickly realized that they could not just use a band-aid solution; rather, they had to drive sweeping changes to the way the industry and supply chain functioned.

"To ensure that Boeing had enough fasteners to meet future production goals for the fastest-selling aircraft in history, we knew that we had to fundamentally change the structure of the industry's supply chain," said Byrne. "This, of course, would be no easy task."

Against a bleak economic backdrop that had an indefinite end, it was all the more important for Boeing to resolve the fastener shortage with aircraft part suppliers and fastener manufacturers. This meant addressing the near-term problem of not having enough fasteners while developing and implementing a fastener procurement system that would ensure enough fasteners to meet deliveries — in a timely way and efficiently — for the long run.

The Boeing Company

The Boeing Company was founded in 1916 in Seattle, Washington, by timber baron Bill Boeing to manufacture seaplanes. Boeing made its first sale of two B&W seaplanes to the New Zealand Flying School in 1918, and later that year delivered the first of 50 seaplane trainers to the United States Navy.

In the 1950s, Boeing helped usher in the jet age with the popular 707 airliner, which was selected as the first Air Force One jet. In the 1950s and 1960s, worldwide large commercial aircraft production was dominated by American manufacturers; Boeing became a market leader in each significant aircraft segment.

In the mid-1960s, Boeing was approached by Juan Trippe, President Pan American World Airways, to build a massive jet to meet increased demand for long-distance airline travel. The plane, called the 747, was developed by Boeing in a "bet the company strategy." The project was highly risky both financially and technically. However, the strategy paid off. In April 1966, Pan Am ordered twenty-five 747 airplanes for $525 million, and the first jumbo was delivered to Pan Am in December 1969. Boeing achieved a monopoly in the very large aircraft segment (~ 400 seating capacity) and changed the way the world traveled. The segment continued to boom, and the 747 became a key product in sales and profitability. Boeing's aircraft strategy helped it achieve a 62% market share by the 1990s.[5]

In 1997, Boeing merged with aircraft manufacturer McDonnell Douglas, making Boeing the largest aerospace company in the world with customers in 145 countries, a business backlog of more than $100 billion, and more than 220,000 employees worldwide. Boeing also became a major part of the American economy, with 67% of Boeing aircraft by value made in the United States.[6]

(See **Appendix 1** for a list of Boeing in-production commercial aircraft.)

The 787

In the 1990s, Airbus, a European-based aircraft manufacturer, emerged as a formidable competitor to Boeing. With its aggressive marketing, risk taking, and engineering expertise, Airbus quickly became a manufacturer of choice.

In 1994, Airbus held a 28% share of total aircraft deliveries, compared to Boeing/McDonnell Douglas' 72% share. Airbus' popular small aircraft, however, helped change the tide. The A320, Airbus' single-aisle aircraft launched in the late 1980s, won 59% percent of all orders in its category in 2002. By 2003, Airbus surpassed Boeing in total deliveries for the first time with a 53% market share.

In response to the shift in the marketplace, Boeing began exploring the development of a new aircraft in the late 1990s. The most significant of these explorations began in 1999 for an aircraft called the Sonic Cruiser, which would have been unlike any commercial jet available in the marketplace. The near supersonic speed (approximately 647 mph, 15–20% faster than current commercial jets) of the radical 250-seat, delta-wing design meant the Sonic Cruiser would cut travel times by approximately 20%, or one hour for every 3,000 miles traveled.[7]

However, after holding lengthy discussions with airlines, Boeing shelved the project in December 2002.[8] Sensing that airlines were less interested in speed and more interested in improved fuel economy, Boeing switched its strategy from the super-fast Sonic Cruiser to a super-efficient, midsized aircraft that would make considerable use of advanced composite materials instead of traditional aluminum and other metals. Initially referred to as the 7E7 (for "Efficient"), the airplane was christened the "Dreamliner" in the summer of 2003, the name being chosen by popular vote in the "Name Your Plane" online promotion.

The 787 was developed in response to market analyses, which predicted that air traffic growth would come in the form of increased frequencies in a point-to-point network, rather than a hub-and-spoke system. (In contrast, Airbus believed growth would come in traffic through hub airports.) The 787 was designed to be a midsized commercial airplane for point-to-point travel carrying 210 to 330 passengers at a cruising speed of Mach 0.85 (same speed as a 747 and 777), while using 20% less fuel than any other airplane of its size.[9]

The 787 would be one of the first commercial aircraft to take full advantage of composite material technology, with as much as 50% of the airplane made up of composites, including the fuselage and wings. By comparison, a 777 was only 12% composite.[10] The use of composites would allow Boeing to increase the humidity levels in the 787 cabin, increasing passenger comfort. Additionally, composites were lighter and stronger than aluminum, more resilient to damage, and less susceptible to fatigue — all of which would help lower maintenance costs for airlines. In April 2004, the program was officially launched with a 50-aircraft order from All-Nippon Airways.[11]

Boeing officially unveiled the Dreamliner to the public in Everett, Washington, on July 8, 2007, at a large event attended by employees, airline customers, partners, and government officials. "Our journey began some six years ago when we knew we were on the cusp of delivering valuable technologies that would make an economic difference to our airline customers," said Bair, the vice president in charge of the 787 program. "In our business, that happens every 15 or so years, so we have to get it right."[12] These words would come back to haunt Boeing.

The Commercial Aircraft Industry (1990s–2000s)

Post September 11th

In the late 1990s, with global air traffic soaring, commercial aircraft production reached an all-time high. In 1998 and 1999, Boeing delivered 564 and 620 aircraft, respectively, to customers. During this same timeframe, the company reported record revenues of $56 billion (1998) and $58 billion (1999).[13, 14]

However, after the terrorist attacks on September 11, 2001, global air traffic growth slowed to a crawl — and aircraft deliveries and orders dropped significantly. From 2003 to 2005, Boeing averaged 285 deliveries, a drop of more than 50% from the level of deliveries reached in 1999. Aircraft orders also fell dramatically. From 2002 to 2004, annual orders for Boeing's aircraft averaged approximately 260, down from the 589 level reached in 2000 (see **Figure 1**).

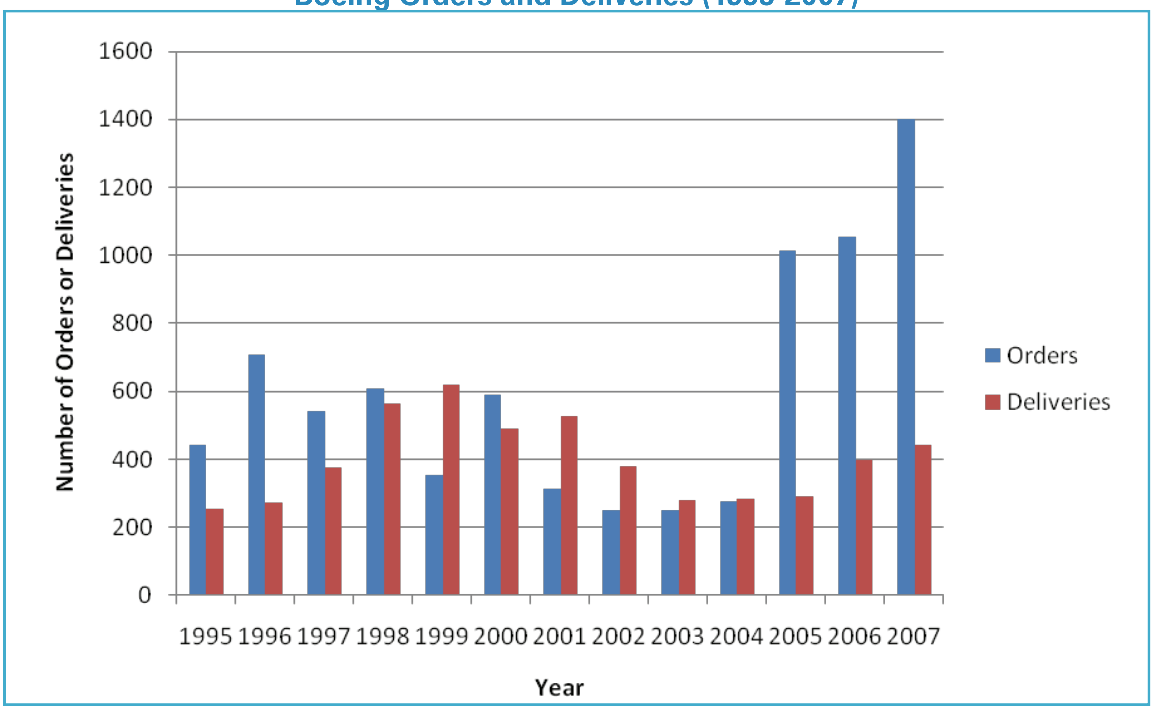
A Turnaround

Toward the end of 2004, global air traffic growth improved considerably, and with it orders for new commercial airplanes. From 2004 to 2005, orders for Boeing airplanes soared by 267%. Customer demand continued to remain high, and orders exceeded 1,000 annually for an unprecedented three consecutive years, as shown in **Figure 1**. In 2007, Boeing set a record for total orders in a single year with 1,413 net commercial airplane orders.[15] These orders were for the legacy commercial jetliners (i.e. aircraft already in production, such as the 737, 747, 767, and 777) and for the new aircraft in development, the 787 Dreamliner.

By the end of 2007, the Dreamliner had become the world's fastest-selling commercial airplane in history with 817 orders since its launch, valued at over $136 billion.[16]

Figure 1

Boeing Orders and Deliveries (1995-2007)



Source: Boeing Company

Boeing's Paradigm Shift

The 787 Dreamliner was indeed a huge technological advancement and a milestone for both Boeing and the entire aircraft industry. On the day of the Dreamliner's unveiling, Airbus co-CEO Louis Gallois commented, "Today is a great day in aviation history. Whenever such a milestone is reached in our industry it is always a reflection of hard work by dedicated people inspired by the wonder of flight."[17]

The Dreamliner also marked a major change in the way aircraft were manufactured. The two major manufacturing shifts that defined the 787 Dreamliner program were the following:

1. **Product Design: The Role of Composites**

   With their focus on building a fuel-efficient aircraft, Boeing's designers saw the opportunity to leverage advanced composite materials for the 787. This allowed for the manufacture of "single piece sections" for the aircraft — a design that was not possible with aluminum. In comparison, the fuselage of an aluminum plane was composed of many metal parts: stringers, skins, frames, clips, and thousands of fasteners. In the 787, the fuselage was formed into one single part, a full barrel section. Fewer parts meant fewer integration points, lower weight, less overhead, and increased simplicity in the supply chain. (See **Appendix 2** for a diagram of the different fuselage designs.) In fact, as much as 50% of the primary structure, including the fuselage and wing on the 787, was made of composite materials.[18]

2. **Supply Chain Design: The Role of Partners**

   In Boeing's legacy aircraft programs, most aircraft assembly took place at Boeing's facilities in Washington state near Seattle. As the company transitioned to the 787 program, however, Boeing's management planned to move toward a systems integration supply chain model of aircraft development. This meant the supply chain for the 787 would expand risk-sharing among suppliers to levels never before witnessed. Systems integration would benefit Boeing by assigning a Tier-1 production partner, who was a supplier that manufactured parts directly for Boeing, the responsibility for major subassemblies, and hence, any development or production cost overruns[19] (See **Appendix 3** for an assembly diagram showing Boeing's partners' roles.)

Longtime Boeing partner Alenia Aeronautica, an Italian-based company, committed $590 million to the 787, while the Japanese Heavies — Fuji Heavy Industries (FHI), Kawasaki Heavy Industries (KHI), and Mitsubishi Heavy Industries (MHI) — were expected together to contribute approximately $1.6 billion to the project. In return, Boeing agreed to award an initial order of components for 150 aircraft to Alenia and share design and development work with the Japanese companies.[20, 21] Boeing contributed $4.2 billion to the 787 as the large-scale systems integrator. Additionally, three other Tier-1 US-based companies — Global Aeronautica, Spirit AeroSystems, and Vought — provided $3.1 billion in development support. Boeing had close ties to all these firms. Global Aeronautica was originally a joint venture between Alenia Aeronautica and Vought (Boeing later purchased Vought's equity stake in the JV in March 2008). Spirit AeroSystems was the former Boeing Commercial Airplanes site that was divested from Boeing in 2005. Finally, Boeing purchased Vought's 787 facility in South Carolina in July 2009.

The Fastener Industry

What Are Fasteners?

Fasteners were an integral part of the aircraft assembly process. Though they were only a fraction of the total cost and material that went into manufacturing an aircraft, fasteners had the important role of holding together the entire structure of an aircraft (see **Appendix 4**).

Aerospace fasteners included items such as bolts, nuts, rivets, washers, and spacers. Most were made of aluminum, titanium, or stainless steel alloys.[22] These raw materials made up 35% to 40% of the total cost of a fastener.

Aircraft production required hundreds of millions of fasteners each year. The range of fasteners required to assemble one airplane extended from 440,000 (for a 737) to 2.7 million (for a 777).[23] The fasteners were consumed by Boeing and more than 500 suppliers in countries around the globe.[24] With several hundred airplanes being delivered each year, as shown in **Figure 1** earlier, Boeing and its suppliers consumed over 700 million fasteners annually.[25]

Fastener Industry Supply Chain

There were many entities involved in the fastener supply chain. The two primary consumers of fasteners during aircraft production were the aircraft manufacturer and its major Tier-1 partners.

Original equipment manufacturer (OEM) aircraft builders generally sourced fasteners directly from fastener manufacturers or through third party aerospace distributors, such as Wesco, B/E Aerospace, or Anixter. Tier-1 partners procured from a number of sources, such as fastener manufacturers, aerospace distributors, and brokerage houses (i.e. third party logistics handlers that negotiated purchase order contracts with fastener manufacturers).

During the downturn of the aircraft industry in the early 2000s, post September 11th, the fastener industry quickly consolidated. Prior to September 11th, the fastener industry had six primary manufacturers. Afterward, there were three: Alcoa Fastening System (AFS), Precision Castparts Corp. (PCC), and Lisi Aerospace. AFS was formed from the consolidation of Huck, Fairchild, Kaynar, and Republic Fasteners. PCC combined manufacturers SPS Technologies, Air Industries, Shur-Lok, and Cherry Aerospace. LISI Aerospace acquired HiShear and Monadnock. During this industry consolidation, manufacturers significantly reduced capacity and their workforce. Consequently, many plants were idled or permanently closed. Approximately 80% of fasteners used to produce Boeing airplanes came from these three manufacturers.

A Stressed Supply Chain

As the aircraft industry started to ramp up production during the mid-2000s, analysts estimated that fastener usage would grow by a 13% compound annual growth rate (CAGR) between 2003 and 2010.[26] At Boeing, management forecasted accelerating growth in demand for fasteners into the end of the decade. During this same time, the Asian manufacturing economies experienced significant growth, and raw material prices started to climb higher, increasing the lead time for raw material orders to one to two years. (See **Appendix 5** for trends in the prices of titanium and nickel.)

Many aerospace distributors, speculating on a huge increase in demand, began placing large orders for fasteners with manufacturers, in many cases double to triple normal order sizes. Speculators hoped to charge high premiums for potential spot purchases from manufacturers.

However, with the uncertainties about what capital and training investments were required for new part types, and a lack of assurance on orders, manufacturers held off from adding capacity. They wanted to wait until new contracts could be signed with aircraft manufacturers. Also, an 18-month delay in the delivery of the Airbus A380 — and its enormous fastener requirements — created slack capacity in the industry, which made it less urgent for fastener manufacturers to increase capacity.[27]

As true demand continued to grow and reluctance from fastener manufacturers to add capacity persisted, the fastener industry started running at 80–90% capacity by the end of 2006. In addition, due to the worker reduction by manufacturers in the early 2000s, many manufacturers started facing labor shortages.

Boeing's Fastener Procurement Process

A Look Back

Prior to 1995, Boeing signed no long-term contracts with fastener manufacturers. Orders were individually placed and often with a single manufacturer. However, in 1995, due to the rising costs of fasteners, Boeing signed its first long-term five-year contract with a select group of fastener manufacturers.

To help manufacturers with production planning, Boeing provided a forecast of the number of aircraft it expected to produce, but no forecast of fasteners. The reason for this was that actual consumption of fasteners varied widely, even within a given aircraft model. Customer-specific airplane configurations and normal variances in the manufacture of airplanes created an uncertain demand pattern; the best information that Boeing had was how many fasteners had been used from inventory.

In 1998, in the effort to better control the quality of fasteners, Boeing switched from using National Aerospace Standards (NAS) to Boeing Aircraft Company (BAC) specifications for approximately 80% to 90% of its fasteners. BAC standards were approved for use only on Boeing aircraft (both commercial and military) and required a higher quality of materials and greater inspection controls. For instance, the new standard required manufacturers to perform qualifications by facility and by part. Many of the qualifications were extremely complex and could take 12–18 months to approve — even when adding one part family.[28] As a result of this more stringent standard, the number of qualified fastener manufacturers that Boeing could source from declined.

In that same year, to mitigate raw material risk for aircraft parts, Boeing developed the Raw Material Strategy. Under this new strategy, Boeing contracted TMX Aerospace as the third party logistics provider to manage the ordering and distribution of aluminum and titanium within the supply chain (see **Appendix 6**). TMX Aerospace was a part of ThyssenKrupp AG, a global industrial group headquartered in Düsseldorf, Germany, with $69 billion in annual sales.[29]

In the late 1990s, in other efforts to improve the supply chain for aircraft parts, Boeing developed a consumption based ordering (CBO) system called Min/Max (minimum/maximum) to stabilize the supply chain for 737 floor beam production at its Wichita, Kansas, factory. The Min/Max system provided current information each day over the Internet to floor beam sub-tier suppliers. The information consisted of current inventory levels, average monthly usage, and the minimum/maximum inventory levels to be maintained for each 737 floor beam part within the Boeing factory.

The Min/Max system was deemed a success at Boeing. With daily information, manufacturers were better able to optimize their production runs and parts delivery. Use of Min/Max allowed Boeing in a single year to reduce inventory by more than $300 million,[30] and delivery performance for parts improved by up to 98%.[31] In 2001, the two Boeing inventors from Wichita applied for a US patent for this system.

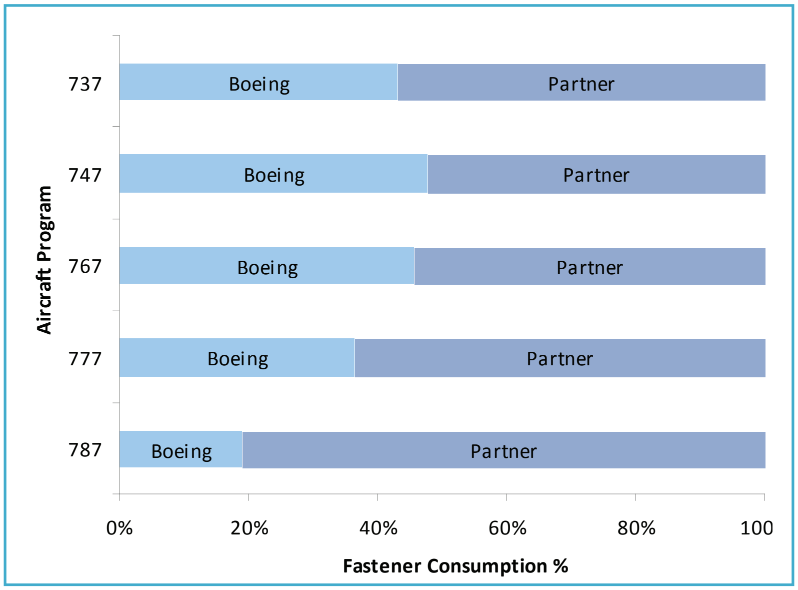
With the success in 737 floor beam production, the Min/Max system was implemented for fasteners at multiple Boeing sites in 2000. Administrative changes to fastener purchase orders were reduced from four times to once per year. This saved $900 million in administrative labor costs annually per part.

The Beginning of a Problem

In its legacy programs, Boeing procured about half of all fasteners required to build aircraft. However, under the proposed 787 supply chain, the proportion would change drastically — partners would procure roughly 80% of the fasteners. **Table 1** shows the increase in the percentage of fasteners consumed by partners in the 787 program compared to Boeing's legacy programs.

Table 1

Direct vs. Indirect Consumption of Fasteners by Program



Source: Boeing Company

The shift in the control over the procurement process away from Boeing and toward partners started to exacerbate an already complicated fastener supply chain. Additionally, due to the 787's composite material, the 787 required many new types of fasteners with a different coating and a higher proportion of titanium. To produce these new fasteners, manufacturers needed to change over their plants and source a greater amount of titanium. "As a result of this, under the 787 program, both fastener spend and operational risk increased dramatically," said director Byrne.

The first signs of an industry shortage came when Boeing's partners started calling Boeing for fasteners. "Our partners were calling us on the phone telling us that they couldn't get fasteners. We would try to help out as we could from our own inventory, but more and more partners started calling with the same request," said senior manager Feliberti. "At this point, we knew there was something wrong."

In the summer of 2006, it became evident to Byrne and other Boeing senior leaders that the organization had a fastener crisis that needed immediate attention. During a regularly scheduled 787 supplier council meeting, which was attended by Boeing's senior leadership and key suppliers in order to update each other on the status of the 787 program, Byrne was asked to give a report on the state of fasteners at Boeing.

"I told the council that the lead time for fasteners was growing, primarily because of supply and demand issues and the fact that the supply chain was infinitely more complex than we had imagined. After sharing this information with the senior leaders, the room fell silent. There were a lot of worried and blank faces," said Byrne.

Boeing's senior leaders did not want anything to constrain the organization's ability to produce and sell more Dreamliner aircraft. "Fasteners had suddenly become a huge nightmare for Boeing," said Byrne.

As a stopgap, Byrne and Feliberti devised a strategy to use fasteners from current inventory as temporary fasteners. The temporary fastenings were adequate for the number of takeoffs and landings involved in flight tests, but had to be replaced before any Dreamliners could go into service with airlines.[32] They also developed a makeshift database to prioritize the use of fasteners across all partners. "This was only a temporary tool to create more visibility in the supply chain," said Feliberti.

Boeing CEO McNerney, reflecting on the fastener shortage, commented, "The worst thing we can do for our customers is to over-promise and under-deliver."[33]

Investigating the Problem

In February 2007, Byrne and Feliberti commissioned a Boeing team to investigate the issues causing the industry-wide fastener shortage. They also hired McKinsey & Company, a prominent consulting firm, to help analyze the fastener industry, map out the supply chain, and make recommendations for solving the fastener supply chain issues.

The analysis showed that the industry was highly convoluted and lacked transparency. "What we initially thought was a small fire turned out to be a huge blaze," said Byrne. "The data proved that there were fundamental ordering and scheduling problems in the industry."

An industry mapping revealed that fastener manufacturers were dealing with very complex information flows. (See **Appendix 7** for flow chart.) For example, Boeing's Tier-1 partners each used different ordering methodologies, making it hard for manufacturers to develop accurate production forecasts to match demand (see **Table 2**).

Table 2

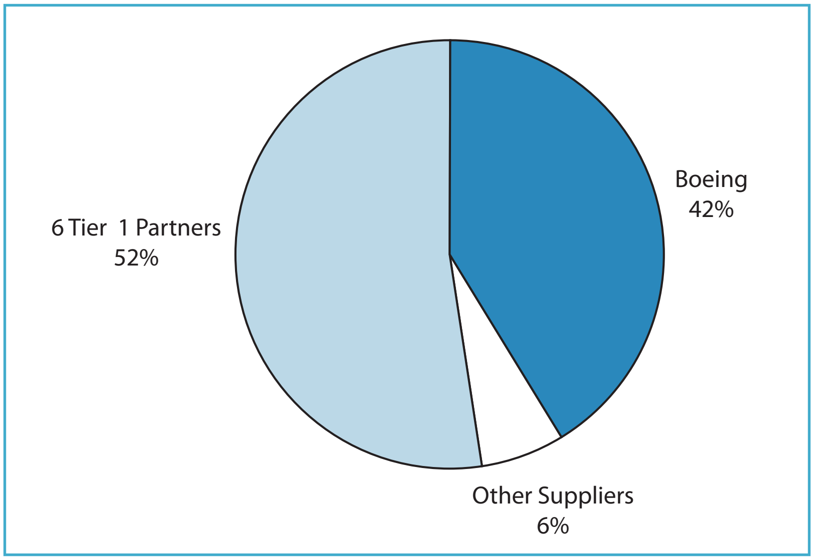
Boeing's Tier-1 Partner Ordering Methodologies

	Current Ordering Methodology
Partner A	Min/Max and AMU data to signal demand to manufacturers Different Min/Max systems at different sites One site may order from manufacturers while others utilize distributors
Partner B	Outsources fastener procurement and ordering to third party distributors
Partner C	Orders through brokerage houses for logistics and currency exchange risk Purchases at market rates with 1-2 large orders a year
Partner D	Uses distributors and manufacturers Places quarterly aggregated orders

The varying ordering methodologies created differing pricing structures. A close look at pricing uncovered that, in some cases, Boeing's partners paid a significant premium for fasteners; some of Boeing's partners paid a weighted average 178% markup on fasteners compared to Boeing.[34]

The mapping also showed that fasteners were consumed by Boeing and more than 500 suppliers worldwide. As shown in **Figure 2**, however, six Tier-1 partners — Alenia Aeronautica, FHI, KHI, MHI, Spirit AeroSystems, and Vought — combined with Boeing accounted for 94% of the total requirements for BAC-standards fasteners for all airplane models.

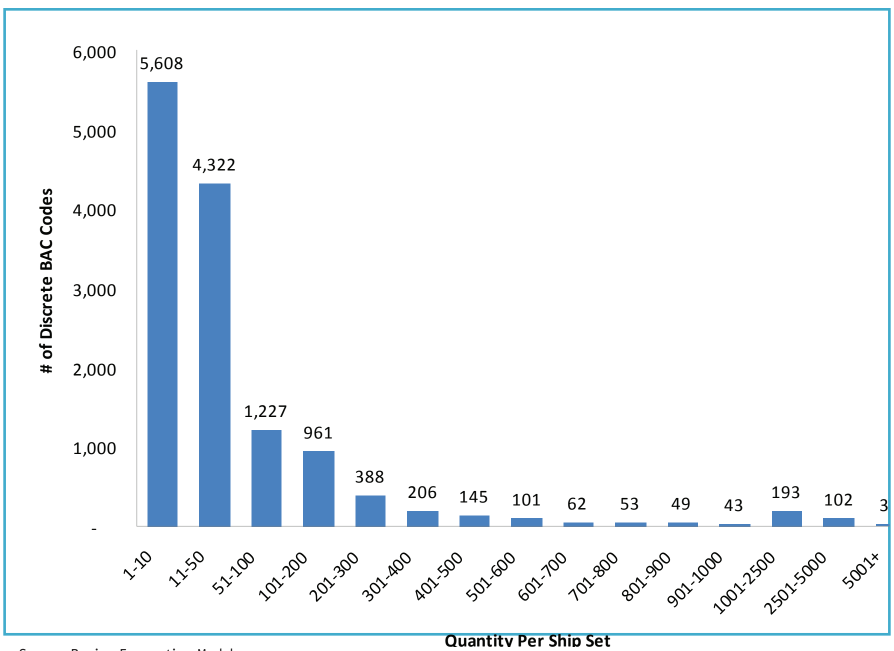
Figure 2
BAC Fastener Usage for All Airplane Models



Source: Boeing Company

The team also analyzed the number of unique Boeing's fastener types by production volume. **Figure 3** shows the high number of discrete fasteners considered low-volume/small-batch per ship set (i.e. per aircraft). For most manufacturers, an efficient batch size was around 35,000 units.

Figure 3
Discrete Fastener Types by Volume



Source: Boeing Forecasting Model

Additional analysis of total industry capacity confirmed management's suspicion that the industry did not have enough aggregate capacity to meet the total demand of the supply chain, leading to stock-outs. Globally, there was a shortage of approximately 110 million hi-lock fasteners, a key component of aircraft assembly. A forecast pointed to the shortage continuing into 2012, even if manufacturers executed all planned capacity increases. (See **Appendix 8** for the industry analysis.)

After four months of analysis, McKinsey & Company provided Byrne and Feliberti with six tactics for solving the fastener supply chain issues, and worked with them to develop a model to implement these tactics. In June 2007, Byrne and Feliberti presented the results to the Boeing Commercial Airplane Programs Leadership Team (APLT), clearly outlining the challenges in the fastener supply chain. A subsequent discussion with the APLT centered on the six tactics to improve performance of the supply chain. The most important of these tactics were addressing the need for 1) better demand signaling and 2) aggregating fastener demand for Boeing and the six partners.

"The decision point was whether to try and solve this problem under the framework of the original legacy system or try to shake up and change the entire industry dynamic," said Byrne. "It came down to an all-or-nothing decision. Everything in the industry was so interconnected. A huge structural change was necessary."

With a mandate from the APLT to improve the fastener supply chain and a clear understanding of the problems, Byrne and Feliberti moved forward with a new model, which they named the Fastener Procurement Model or FPM.

The Fastener Procurement Model

FPM Design

The FPM was centered on a buy/re-sell philosophy. Under this philosophy, Boeing would use a central purchasing entity as an aggregation point to manage purchase orders and inventory. Inventory management would entail using a central warehouse to receive and distribute fasteners to the entire Boeing supply chain. Prices for fasteners would be negotiated by a Boeing contracts team. This would alleviate a partner's responsibility for issuing direct purchase orders with fastener manufacturers.

Since the FPM aggregated demand volumes, Boeing planned to negotiate contracts directly with fastener manufacturers, ensuring favorable pricing. The contracts would strategically source work among select manufacturers to minimize lead times and maximize efficiency. The benefit of Boeing negotiating contracts instead of partners would be getting Boeing's preferential pricing. Historically, Boeing's prices had been one to five times lower than its partners' prices. This low fastener price would be a key incentive for partners to implement the FPM.

To create a pull in the supply chain, the FPM adopted a Consumption Based Ordering (CBO) methodology, under which Boeing and its partners would upload daily fastener inventory levels into a central Boeing web portal, called Boeing Partners Network (BPN). The BPN would use this information to aggregate demand. The result would be greater understanding of demand, increased inventory turns, and stabilized production within the supply chain. Under the CBO methodology, when Boeing's warehouse inventory levels fell below a specified minimum level, manufacturers would be responsible for replenishing inventory above the minimum, but not exceeding the specified maximum level. (See **Appendix 9** for more information about the CBO methodology.)

The use of demand-aggregated contracting and CBO would increase visibility within the supply chain by giving manufacturers a clear picture of true demand. However, in order to be successful, the supply chain would also require a consistent and effective demand forecast. Under the proposed FPM, Boeing would create a forecasting algorithm, which would take into account partners' average monthly usage (AMU) of fasteners, and historic and future aircraft production rates. This algorithm would be used to forecast demand for Boeing and the partners.

To ensure smooth operation of the FPM, a dedicated internal organization within Boeing would need to monitor partner compliance and provide operational and implementation support. Tier-1 partners would be allowed to use BAC fasteners only on Boeing aircraft, including those in the aftermarket. Additionally, third party distributors would be able to purchase BAC fasteners only in the quantities that were needed for Boeing aircraft.

To ensure compliance by partners, the FPM would require that each participant sign a contract entitled the Standards Participation Agreement. Its purpose would be to clearly define the roles and responsibilities for each party and the actions that would take place in the event that their responsibilities were not fulfilled. The agreement would also define the criteria necessary for implementing a CBO system and address each party's right to opt out of the model.

The FPM was designed with the idea that the whole fastener supply chain would benefit by implementing the model. Fastener manufacturers would experience a decrease in demand distortions and fluctuations, resulting in better production schedules. Tier-1 partners would benefit from greater fastener availability and lower prices. Boeing would experience timely delivery of fasteners and sub-assemblies. All parties involved would benefit from decreased costs.

Implementing the FPM

Carrying forward with the APLT mandate, the Boeing and McKinsey teams visited the six Tier-1 partners in July and August 2007 to introduce the FPM. This involved travel to partner sites in the United States, Italy, and Japan. The partners were given a detailed presentation on the FPM, along with options for aggregating demand and an opportunity to jointly solve the fastener issues. "A key challenge for us was how to navigate through the industry complexities and run current operations while trying to fundamentally change the industry with the FPM," said Byrne.

After the visits, the FPM team expanded. Jill Christenson was added as program manager, and Mark Cantu joined the team as the senior supply chain analyst. In November, Adam Martin, an alumnus of the Tauber Institute of Global Operations at the University of Michigan, was recruited as the full-time manager. McKinsey & Company continued to provide consultation to the Boeing team until March 2008.

Stakeholder Perspectives

Tier-1 Partners

In early 2008, the FPM team further built out its staff, adding a second manager, Eric Salenski (another Tauber Institute alumnus), four procurement agents, and four CBO experts (see **Appendix 10**). The FPM team also strived to better engage its Tier-1 partners. To better understand Tier-1 partners' readiness for the FPM, the FPM team developed a specialized survey to evaluate the maturity of their inventory management system. The survey assessed certain inventory management aspects based on a scale of 1 to 5, with 5 being the most matured.

The following describes the incremental criteria for each of the five maturity levels:

- **Level 1:** Organized warehouse stocking with planned locations, with some kind of IT system in place to track real-time inventory level upon receipt or pull.
- **Level 2:** Production floor inventory setup in planned locations, with formal replenishment processes in place.
- **Level 3:** Warehouse inventory managed using the min/max ordering method, with the capability to calculate AMU. Production floor inventory managed via a two-bag system, where bag sizes reflect fastener usage and value.
- **Level 4:** IT systems with the ability to automate data collection and track and report key performance metrics such as AMU accuracy, bill of material (BOM) accuracy, etc.
- **Level 5:** Demonstrated high performance on daily inventory reporting, AMU accuracy, inventory record accuracy, and BOM accuracy for a minimum period of six months.

The results of the survey revealed that only one of Boeing's Tier-1 suppliers had reached a maturity higher than 2. In some cases, partners ordered several years' worth of fasteners and stored them all in large bins; this ordering system did not take historic usage levels into consideration.

"Under the FPM, Boeing's partners were all responsible for figuring out their own procurement process. The assumption by Boeing on the 787 program was the partners had good capabilities. But this turned out only to be an assumption," said Byrne.

To better educate its partners on the FPM, in May 2008, the FPM team organized a series of two-day workshops to break down FPM requirements to specific and measurable tasks. Some of the specific tasks included modifying the BPN to accept consumption and inventory data from Tier-1 partners, adopting procedural and organizational changes, and implementing CBO systems and performance metrics. These performance metrics include AMU accuracy, BOM accuracy, daily updates to the BPN, as well as general compliance with the FPM.

Despite the great promise of the FPM, partners had many concerns about the model. The first was having only one specific manufacturer make a certain type of fastener. (For Boeing, this option was based on a low cost provider strategy.) The FPM team tried to address this by having partners create a list of preferred manufacturers for specific fasteners; however, it was not guaranteed that the partners' requests could be met when sourcing decisions were ultimately made.

Many Tier-1 partners felt that they did not have enough information to make a decision about whether or not to participate in the FPM. For instance, some partners did not understand how Boeing planned to share value across the supply chain (i.e. how would fastener manufacturers, Tier-1 partners, and distributors share the benefits?)

In the early development of the model, Boeing believed that it would be able to share in the cost reduction that its Tier-1 partners would experience by purchasing through the FPM. However, a difficult situation arose in which fastener prices — which were largely driven by volume — could not be determined with certainty until the number of participating partners was known. Partners, on the other hand, could not indicate their willingness to participate without knowing fastener pricing.

Identifying the sources of value to share between Boeing and its partners appeared to be more difficult than initially imagined. The FPM team had a catch-22 situation.

Fastener Manufacturers

Manufacturers were an important part of the supply chain, and their understanding and support of the FPM was crucial to its success. Prior to the introduction of FPM, many of Boeing's fastener manufacturers had successfully implemented Boeing's CBO program. Manufacturers faced significant variability in order patterns and welcomed CBO because it increased visibility in demand. For instance, Allfast, one of Boeing's fastener manufacturers, received orders that ranged from 32 pounds to 15,000 pounds with multiple releases for its solid skin rivets. "Looking at the distribution of order quantities (over 200 shipments), only two quantities were ordered more than once," said Jim Randall, CEO of Allfast. The CBO system allowed Allfast to smooth out the manufacturing process and reduce the overall cost of fasteners for Boeing. Randall stated, "The CBO provides visibility of what to make and helps us know how to plan. The cost is well worth it given the visibility." Ensuring accuracy of data was perceived as a major challenge in implementing a CBO system.

Because of the success of CBO, many fastener manufacturers urged its distributors to adopt the program. However, there was significant resistance. "We've been trying to get distributors to use CBO, but they would rather not share their information with us," said Randall.

To roll-out FPM to fastener manufacturers, in early 2008 Boeing sent out a Request for Proposal (RFP) in order to get preliminary pricing data. The RFP asked manufacturers to bid on part families at several volume levels. These levels represented Boeing demand, partner demand, and Boeing and partner demand. Definitions of the levels were not clearly communicated to the manufacturers, and most chose not to bid on the partner demand. The reasons stated were that the volume of demand seemed unreasonably high or that the manufacturer was already under contract with a specific Tier-1 partner for a part family.

Randall commented, "We didn't understand why the RFP had stuff on there that other manufacturers already had under contract. Also, the numbers were high beyond conception! To us, this RFP went too far, too fast."

Many simply did not understand how the RFP was constructed and were confused about how to best respond to it. Another hurdle was on the issue of pricing. "In the current industry structure, manufacturers could charge different prices to different suppliers. Under the FPM, this would probably go away. So why would manufacturers want to adopt a program that would drive down prices?" said Byrne.

Boeing's lack of engagement with the manufacturers continued the derailment of the FPM. Many of the manufacturers stated that they knew nothing about the FPM and would not work with it. At the end of July 2008, the FPM team went to southern California, the vicinity near the majority of fastener manufacturers, to present the model to the manufacturers and to try to mitigate the concerns.

Fastener Distributors

Upon further analysis, the FPM team realized the use of distributors and third-party distributors within the Tier-1 suppliers was more widespread than originally thought. Some of the Tier-1 suppliers were heavily invested in their distributors and did not want to disrupt these business relationships. To move forward, the FPM needed to better address the role of distributors.

Tension within Boeing

In summer of 2008, Byrne and Feliberti recruited a team of three students from the Tauber Institute of Global Operations at the University of Michigan[35] for a faculty-supervised internship project to critique the FPM model designed for Tier-1 partners and help develop a new FPM model for Tier-2 partners. Byrne and Feliberti brought the students in because they wanted to start getting ready for the next phase of the FPM.

However, implementing the first phase of the FPM started to hit more roadblocks. Internally, the FPM was also getting pushback. Though Boeing's executive management supported the FPM in principle, many middle managers were skeptical. "There were some in Boeing who were unwilling to move the FPM forward. They wanted to know how this would improve their bottom line before starting anything. Senior management could have helped the situation by clearly communicating their commitment to the FPM to others within Boeing," said Feliberti. "What started out at as an effort to ensure the availability of fasteners turned into something completely different."

In particular, Boeing's Structures contracts group was skeptical of the benefits of the FPM. The Structures team was responsible for managing Boeing's contractual relationships with fuselage partners. For the 787, contracts were signed based on entire aircraft structures and priced according to the market. In other words, partners were obligated to deliver entire aircraft structures based on an agreed-upon price, not a bill of materials.

The Structures group's main concern with FPM was in opening up a partner's contract to include the FPM. The group thought this would lead to the partners asking for other contractual changes. "The Structures group feared that partners would demand changes to the original contracts that would not be beneficial to Boeing," said Byrne.

Another group that was apprehensive about the FPM was the Materials Management Organization (MMO). MMO handled all the logistics for ordering, scheduling, and issuing of fasteners out to final assembly internally within Boeing. Similar material flow functionality would be a key piece to the overall design of the FPM. Yet, this part of the FPM was not yet fleshed out in detail.

Going Forward

Though the FPM created numerous theoretical benefits, these benefits were much harder to quantify than the costs, which explained some of the resistance encountered with manufacturers. The risk for Boeing was that the manufacturers and Tier-1 partners would write off the FPM business case because the benefits were so difficult to estimate.

There were also a number of key questions Boeing's management needed to wrestle with related to value-sharing: How should value-sharing between Boeing and the partners be managed? Could Boeing construct a supply chain and governance model that would consider the concerns of all of the parties involved (e.g. Boeing, manufacturers, Tier-1 suppliers)?

The FPM team leaders knew that they had to address the concerns and questions of the FPM soon, as Boeing could not afford to have any more production delays due to fasteners.

Byrne commented, "The fear right now is that because of this economic downturn, fastener manufacturers will take capacity offline. However, once production picks up again, we'll have the same problem that we had before. That's why it's all the more important that we get the FPM running."

Appendices

Appendix 1

Boeing In-Production Commercial Aircraft

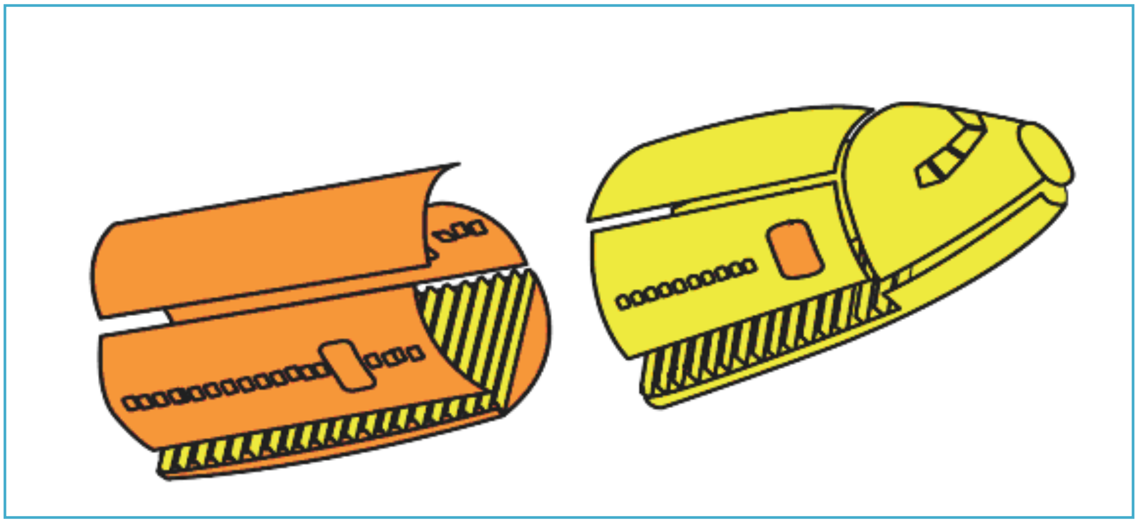
Model	Data	Image
737	**737-700** Passengers: 126-149 Range: 3,365 miles; 6,230 km Length: 110 ft; 33.6 m Maximum Takeoff Weight: 154,500 lb; 70,080 kg	
747	**747-8** Passengers: 467 Range: 8,000 miles; 14,815 km Length: 250 ft; 76.3 m Maximum Takeoff Weight: 975,000 lb; 442,250 kg	
767	**767-400ER** Passengers: 245-375 Range: 5,625 miles; 10,415 km Length: 201 ft; 61.3 m Maximum Takeoff Weight: 450,000 lb; 204,120 kg	
777	**777-300ER** Passengers: 365 Range: 7,930 miles; 14,685 km Length: 242 ft; 73.9 m Maximum Takeoff Weight: 775,000 lb; 351,534 kg	
787	**787-8** Passengers: 210-250 Range: 8,200 miles; 15,200 km Length: 186 ft; 57 m Maximum Takeoff Weight: 484,000 lb; 219,540 kg	

Source: The Boeing Company

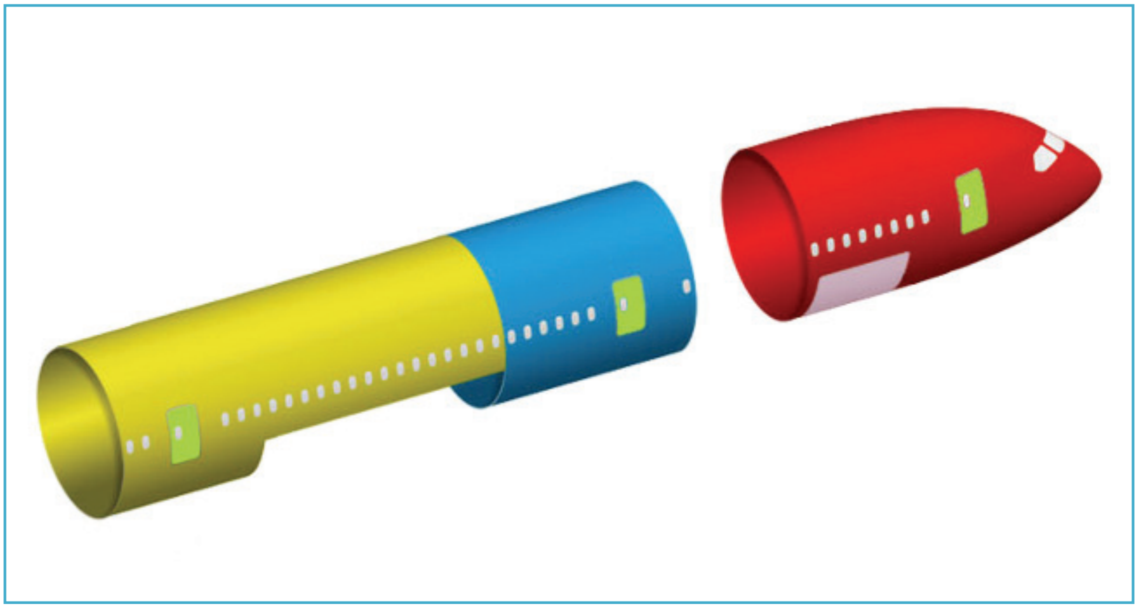
Appendix 2

Comparison of Fuselage Assembly

Boeing's 767 Program



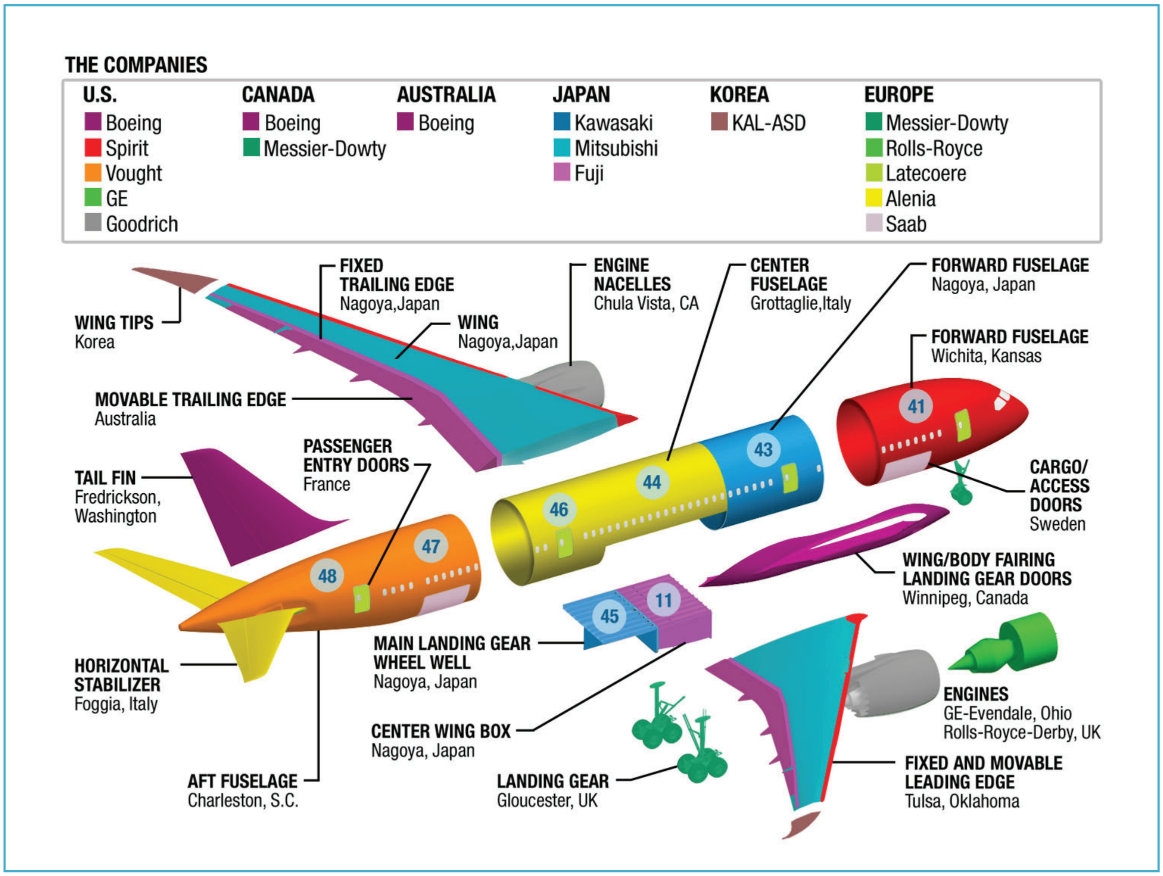
Boeing's 787 Program



Source: The Boeing Company

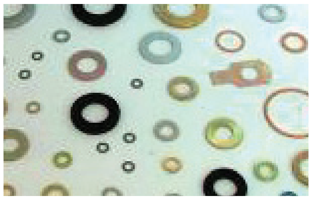
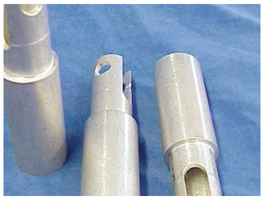
Appendix 3

Partners Involved in Boeing's 787 Program



Source: The Boeing Company

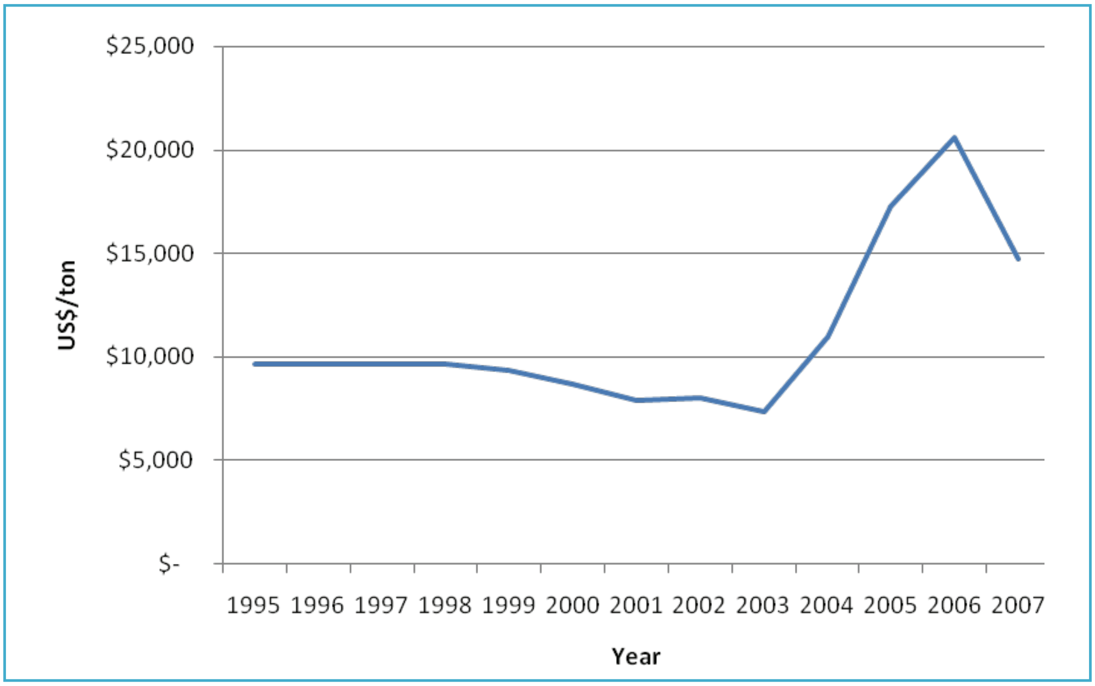
Appendix 4
Types of Fasteners

Fastener Type	Description	Picture
Hi-locks	Hi-locks are used as permanent fasteners in primary and secondary structures where hole-filling characteristics are important and where their tension and/or shear properties are desirable.	
Pins	Pins are used in hinges or other single pin shear joints.	
Nuts	Nuts are used primarily on bolts that are designed to be removable.	
Collars	Collars are designed to be used on hi-locks in permanent applications. The frangible nut element on the collar ensures that the proper preload is applied to the joint during installation. Collars may not be reused.	
Washers	Washers are used to protect the head-to-shank fillet radius of bolts, to provide a surface on which to apply torque against, and to ensure that nuts do not "bottom out" on bolt shanks during installation.	
Rivets	Rivets are used in permanent shear applications as a lightweight fastener where the lower shear strength of a rivet is acceptable.	
Spacers	Spacers are typically used with fasteners to avoid clamping two lugs of a clevis together (and the resulting bending stress), or to provide reach to attach internal wiring to a structure.	

Source: The Boeing Company

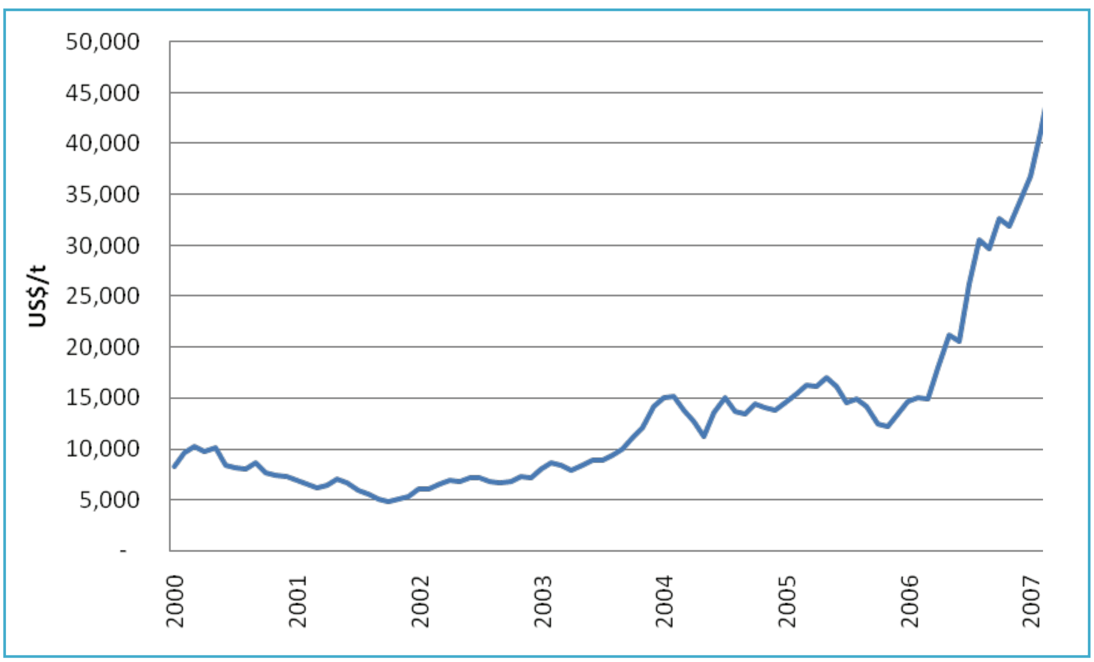
Appendix 5

Titanium Price Trend (1995-2007)



Source: D.A. Buckingham and J.Gambogi (U.S. Geological Survey)

Nickel Price Trend (2000-2007)



Source: London Metals Exchange

Appendix 6
TMX Aerospace

TMX Aerospace was a third-party logistics provider of aluminum and titanium for Boeing's entire supply chain. Approximately 10,000 raw material types flowed through TMX Aerospace to nearly 500 Boeing suppliers. The value of these raw materials was approximately $1.2 billion, which included flows to both Boeing and the rest of the supply chain.

Before the development of Boeing's Raw Material Strategy (RMS) in 1998, Boeing and its suppliers individually purchased aluminum and titanium from more than 50 raw material distributors and mills around the world.[36]

Under RMS, Boeing planned to aggregate demand across its supply chain and sign long-term contracts with a limited number of aluminum and titanium mills. To coordinate this, TMX Aerospace would place purchase orders with the aluminum and titanium mills as an agent for Boeing. TMX Aerospace would then sell the raw materials to suppliers at stable, set prices. The results would be 1) beneficial pricing for Boeing and its suppliers, 2) no need for raw material escalation clauses in supplier contacts with Boeing, and 3) a stable supply of metal in the supply chain.

To implement the TMX Aerospace platform, Boeing first signed contracts with aluminum and titanium mills for the aggregate demand in the Boeing supply chain. Up to this point, none of the mills had contracts with Boeing or its suppliers. Because Boeing was willing to make a firm commitment to directly purchase 100% of the demand of its supply chain, it garnered the attention of the entire raw materials industry; most mill owners felt that if they did not bid on the Boeing proposals, they would not get any part of the work.

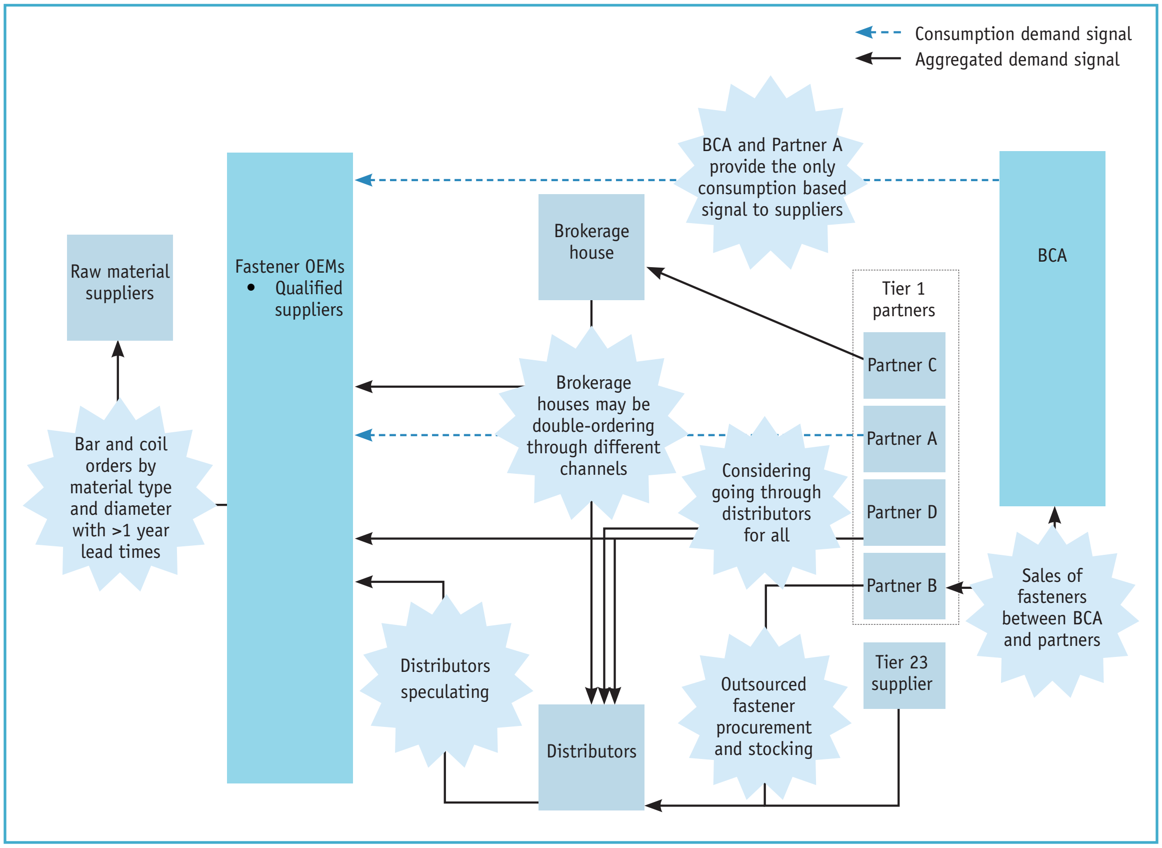
Though Boeing was able to easily get support for the supply chain initiative from the mills, it faced challenges in rolling out the TMX Aerospace program to its suppliers. Initially, suppliers committed to sourcing less than half of what Boeing was under contract to purchase from the mills. Nonparticipants believed that they could source aluminum and titanium cheaper elsewhere – and, in many cases, they were able to do so. For example, during the aircraft industry downturn post-September 11th, an oversupply of raw materials forced many aluminum and titanium mills to undercut TMX Aerospace's fixed prices. As a result, many of Boeing's suppliers chose to use their old distribution network rather than source through TMX Aerospace.

"We misjudged the market's reaction to the TMX Aerospace program," said Jeff Hanley, a Boeing manager in the raw materials group at the time. "Not getting our suppliers to buy into TMX Aerospace early on was one of our biggest mistakes."

To increase supplier adoption of TMX Aerospace, Boeing used its market position to force suppliers to use the program or risk losing all work with Boeing once their contracts expired. Consequently, over time, 100% of Boeing's suppliers adopted TMX Aerospace.

In the mid-2000s, as the aircraft industry started to heat up, and with it the price of aluminum and titanium, TMX Aerospace was able to effectively stabilize prices for Boeing's suppliers and allow Boeing to manage production without delay. Prior to TMX Aerospace, during challenging times, Boeing and many of its suppliers were forced into costly delays. Though many suppliers were initially hesitant about using TMX Aerospace, by the late 2000s all suppliers were supportive of it.

Appendix 7
Fastener Industry Supply Chain



Source: The Boeing Company

Appendix 8
Global Supply and Demand for Fasteners

			Projected		2012 Industry Shortage/Surplus		
(in millions of units)	2007 Supply	2007 Consumption	2012 Supply	2012 Consumption	Worst Case – No Added Capacity	Best Case – All Planned Capacity Addition	2007 Boeing Spend
Hi-locks	265	375	375	510	-245	-135	$28
Straight Fittings	9.1	8.4	11.8	11	-1.9	0.8	$13
Pins	510	470	720	615	-105	105	$55
Shaped Fittings	1.4	1	1.9	1.4	0	0.5	$10
Nuts	365	285	520	365	0	155	$18
Nut Plates	65	40	90	50	15	40	$5
Collars	340	205	505	300	40	205	$9
Washers	535	230	620	290	245	330	$4

Source: The Boeing Company

Appendix 9

Boeing's Consumption Based Ordering (CBO)

The main features of Boeing's CBO system were the following:

1. System

The Boeing Partners Network (BPN) was the central IT system used by Boeing to track current on-hand inventory levels and to make forecasts. Within the Fastener Procurement Model (FPM), Tier-1 partners were required to have a similarly capable IT system to upload data to the BPN.

The BPN calculated a numeric value for each part based on average monthly usage (AMU) and the manufacturer cost data. Specifically, the process for determining the annual demand was as follows:

- Determine AMU
- Multiply AMU times 12 (months)
- Multiply by cost of part

A stratification code was then derived based on this numeric value. There were four possible values for the stratification code: A, B, C, or D. Each implied different inventory min/max levels. For example, stratification code A denoted a much lower maximum level than stratification codes B and C, since it was assigned to high volume or high cost parts. The reason for this was that the more expensive and more frequently used parts would be delivered more often to avoid high holding costs.

2. Demand Visibility and Forecasting

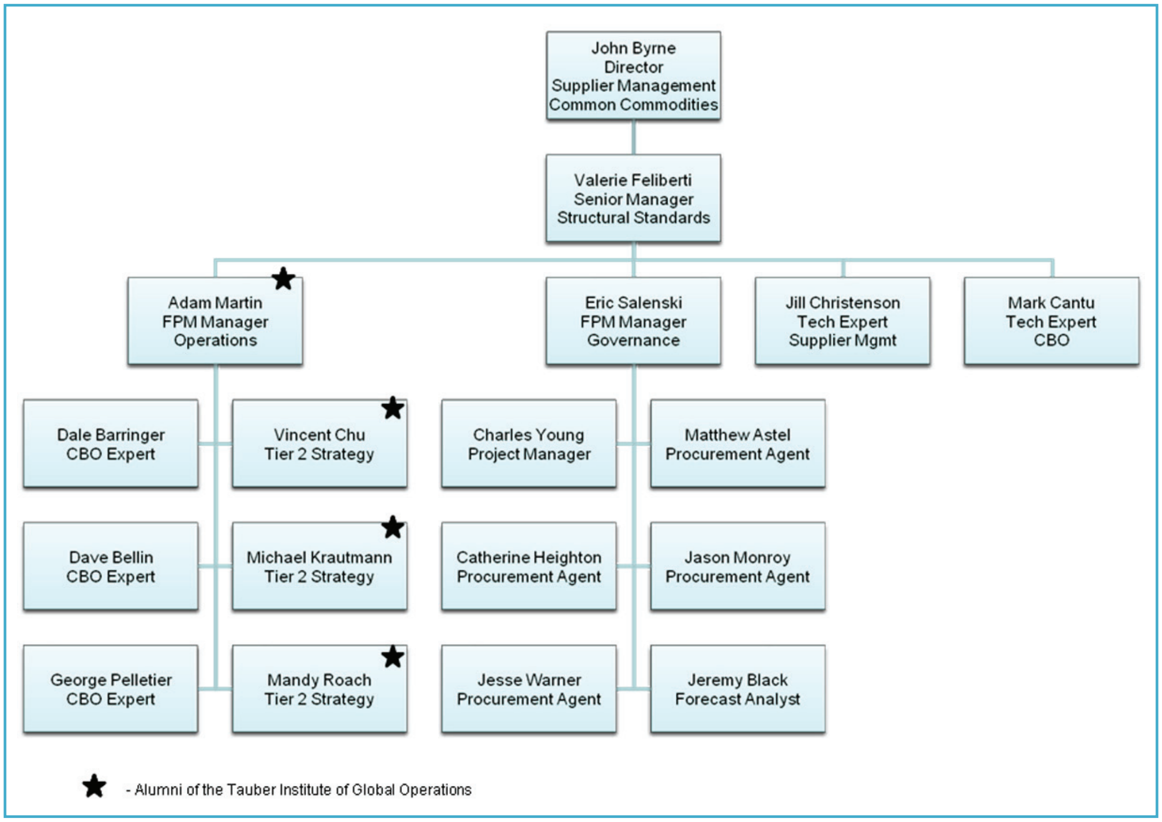
To provide greater visibility to true demand to manufacturers, Boeing and its Tier-1 partners would be required to update a minimum/maximum worksheet daily with information such as current inventory on-hand. The worksheets would then be uploaded to the BPN, where demand would be aggregated and forecasted for the manufacturers. With this information, manufacturers would be able to more accurately plan production. Additionally, Boeing and manufacturers would be better able to negotiate long-term contracts.

Within the FPM, participants would be restricted from procuring from outside manufacturers, thus ensuring demand within the supply chain for manufacturers. Additionally, key metrics would be defined and monitored (i.e. AMUs, bill of materials, etc.) regularly to ensure accuracy.

3. Replenishment

Fastener replenishment was driven by two main trigger points: delivery and production. The delivery trigger point was an inventory level (above minimum) which signaled to fastener manufacturers the need to replenish on-hand inventory. The production trigger point was related to the level of manufacturers' raw materials and the sourcing lead times. The goal was to ensure timely production to replenish partners' inventory.

Appendix 10
FPM Team Organizational Chart
Summer 2008



Source: The Boeing Company

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