

# Dream High – Development of Aerospace Fasteners in End User's Perspective

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The global systems of aerospace manufacturing are classified in (1) manufacturers of large aircrafts and aviation systems, (2) manufacturers of sub-systems (fuselages, engines, aviation electronics), (3) suppliers of aerospace components (components, fasteners). According to Boeing company, a Boeing 747 consists of 6 million components, over half of which are fasteners. Due to short supply of titanium and aluminum fasteners worldwide in year 2008 along with labor shortage with suppliers, the company had delays in many of their aircraft deliveries, and the company experienced damages of business reputation as the result. With the recovery of global economy, the global market of aerospace fasteners is expected to be up to 6.8 billion US dollars of value in year 2018. This article will focus on interpreting programs for the supply and demand of aerospace fasteners by the perspective of aircraft manufacturers.

## Fasteners as Key to On-time Delivery for Aircraft Manufacturers with Booming Sales

The Farnborough International Airshow that rivals with Paris Air Show and German ILA Berlin Air Show as the major three aerospace shows in the world was just held last month in July. At this UK show, the sense of rivalry was high between the two giants of aircraft manufacturing- The Boeing Company and Airbus SAS who recently expanded its manufacturing bases to the US. The competition can be seen by the manifests of orders and deliveries between years from 2012 to 2014, as shown in **Table 1**. Regarding sales performance by the numbers of orders, as indicated in Table 1, Airbus seems to take the lead in 2013 and during the first half of 2014, and yet by the numbers of deliveries, Boeing appears to outperform Airbus by having obviously driven off the nightmare of delayed deliveries that had afflicted the company's sales for five years between 2007 and 2012, and having just won over an order of 40 aircrafts placed by All Nippon Airways (ANA) at the end of this past July, making the number of net orders accumulated up to 823 aircrafts for the first half of this year, allowing Boeing to outperform their tough rival Airbus in the same period by a margin of 17%. Both aircraft manufacturers anticipate a production value of new aircrafts as reaching 5 trillion US dollars by the year 2035.

**Table 1. Orders and Deliveries During Years 2012-1st Half 2014 as Reported by Boeing and Airbus**

Unit: per aircraft	Boeing	Airbus	Remarks
Total Orders 2012	1,203	900	Boeing's sales came mainly from the new 737 MAX model, which is expected to be in service in 2016.
Total Orders 2013	1,531	1,619	
Net Orders 2013	1,355	1,503	Airbus A320neo as a hit model in the market
Deliveries 2013	648	625	
Total Orders 2014 (Jan.- Jul.)	837	980	
Net Orders 2014 (Jan. – Jul.)	823	705	The debut scheduled for A320neo in September prompts customers to cancel orders for 44 A320 models
Deliveries 2014 (Jan. – Jul.)	342	352	
Total Deliveries Estimated 2014	725	626	

Source: News release by The Boeing Company and Airbus / compiled by MIRDC in August 2014

## Aerospace Fasteners Are High Priced Products Required to Be Flawless

Aerospace fasteners are roughly categorized as the following: bolts, nuts, rivets, washers and spacers, as detailed in **Table 2**, with the materials for most aerospace fasteners remaining to be aluminum, titanium or stainless steel. Due to material price soaring high in recent years, the ratio of material cost against overall cost of fasteners has increased from 30 to 40 in percentage.

**Table 2. Categories of Aerospace Fasteners**

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 fastener 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

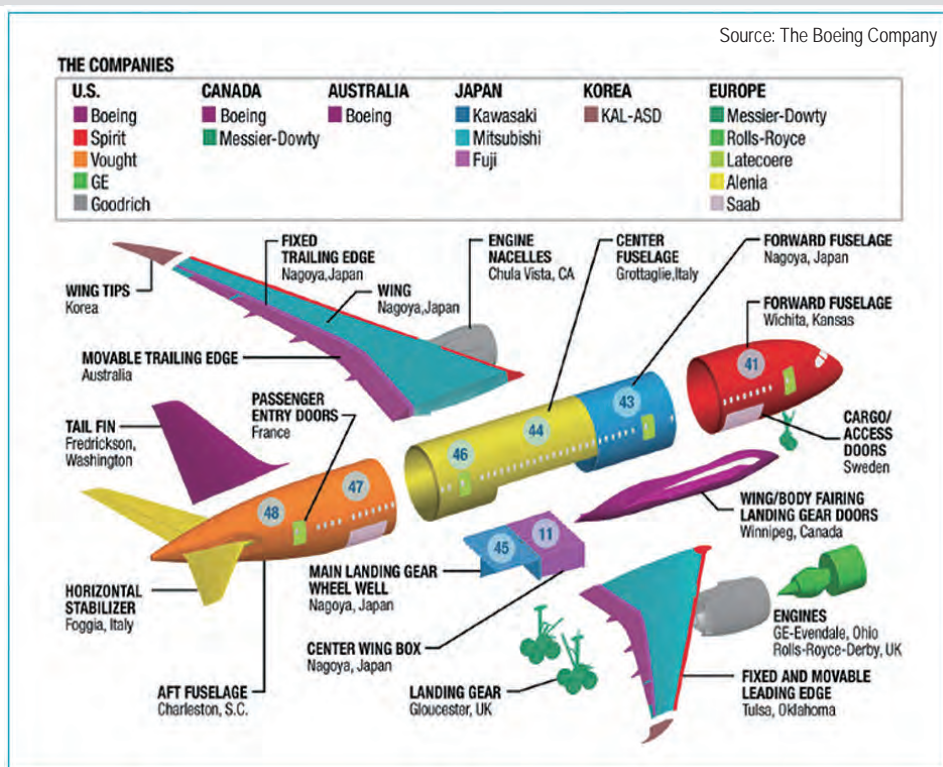
Aerospace fasteners are primarily used in applications of aviation electronic systems, engines, structural bodies, etc. and sale orders of such products normally include the sale of products along with after-sale maintenance and repairs. For this reason, programs for the sales and marketing of aerospace fasteners can be very comprehensive. In the real world of aircraft manufacturing and maintenance, the purpose of fasteners is not merely holding parts of all different sections of primary and secondary structures of an aircraft together, because the production and maintenance of aircrafts are processed through application procedures of pressuring and non-pressuring. When an aircraft design engineer is at work, numerous factors should be taken into consideration. For instance, fasteners with fastening as primary function are required to have shear and tension properties under normal flight operation and extraordinary conditions when stressed under gusts of wind. They even have to take into account situations where motors are in operation or where the aircraft is landing, considering whether the substances of the fasteners can sustain its original structure to allow the fasteners sound and fine operation. Apart from the diameter and number of fasteners, the list of considerations goes on including weight, self-checking ability, molding applicability, air hydraulic applicability, corrosion protection, and certainly cost analysis.

Given the relatively long service life cycle, manufacturing procedures of aerospace products are required to be meticulous and sophisticated, particularly the engine and fasteners that are used in conjunction with it so that they conform to the highest safety standard, and for this reason, aerospace products must undergo strict procedures of qualifications and inspections before becoming qualified suppliers in the global supply chain of aerospace products. In addition to good grasp of technology and capability of quality control, fastener manufacturers allowed to enter the supply chain of aerospace products still need to be capable of managing the production while controlling the lead time from the time of order-taking to that of delivery. Because fastener manufacturers must be equipped with certain amount of competence in order to be included in the aerospace product supply chain, the profit margin for aerospace fasteners can be much higher than that of ordinary fastener products; for instance, the unit price of bolts as general hardware is around NT\$20 (equivalent to US\$0.60) per kg, that of fasteners for automobile maintenance is priced at NT\$120 (equivalent to US\$3.63) per kg, but that of fasteners for aerospace applications can be priced up to NT\$900 (equivalent to US\$27.30) per kg. Furthermore, due to the high entry barrier, the number of competitors is kept relatively small. Taking Taiwan as example, with around 600 manufacturers of general hardware & fasteners and 400 automobile fastener manufacturers, there are less than 10 aerospace fastener manufacturers.

### The Environment is Tense Along Supply Chain but it is the Key to Success in On-time Delivery

Figure 1 shows partners for production plan of Boeing 787 aircrafts, with fasteners suppliers located throughout the world, while the number totaled up to 500 manufacturers. Affected by factors of raw material price increase and higher cost of human resource, the production plan of B787 has seen sourcing for the supply of components in Asia, hoping to lower production costs, given the advantages of export regulations in Asian countries being relatively better-developed, cheaper human resource and easily accessible raw materials. The compound annual growth rate of aerospace fasteners in Asian market is estimated to be over 9% by year 2018.

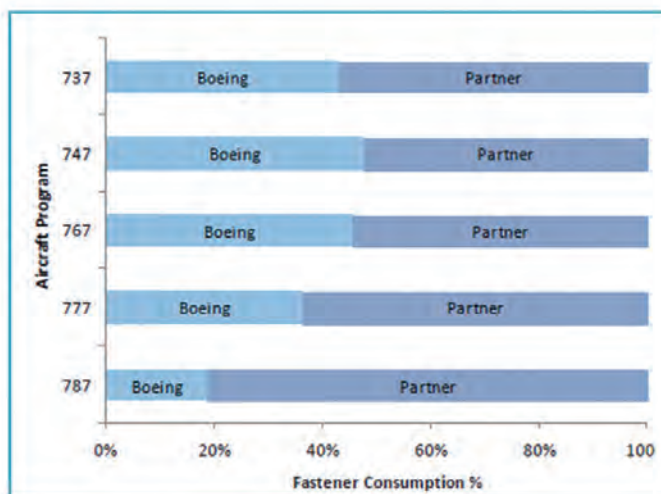
Figure 1. Partners for the Production Plan of Boeing 787 Aircraft



Source: The Boeing Company

For suppliers of aerospace fasteners, their major consumers/customers are aircraft manufacturers plus the Tier 1 suppliers of aircraft manufacturers. For example, the Boeing company has six Tier 1 suppliers, which are Alenia Aeronautica, FHI, KHI, MHI, Spirit AeroSystems, and Vought. The consumption of fasteners by these T1 suppliers together with those by Boeing accounts for 94% of all fasteners consumed by all suppliers in Boeing's aircraft production programs. The major three suppliers of fasteners for the Boeing company, namely, Alcoa Fastening System(AFS), Precision Castparts Corp. (PCC) and Lisi Aerospace, altogether supply over 80% of all the fasteners required for Boeing's production programs of aircrafts. As shown in **Figure 2**, the ratio of fastener consumption by the Boeing Company varies by production programs for different aircraft models. By the production program of Boeing 787, the fastener consumption by Tier 1 suppliers accounts for over 80% of all fasteners consumed by all suppliers and Boeing, in contrast with only 20% of consumption by Boeing itself, indicating a shift with regard to who the major consumers are, with aircraft manufacturers no longer the ones but their Tier 1 suppliers.

Figure 2. Direct vs. Indirect Consumption of Fasteners by Production Programs of Boeing Aircrafts

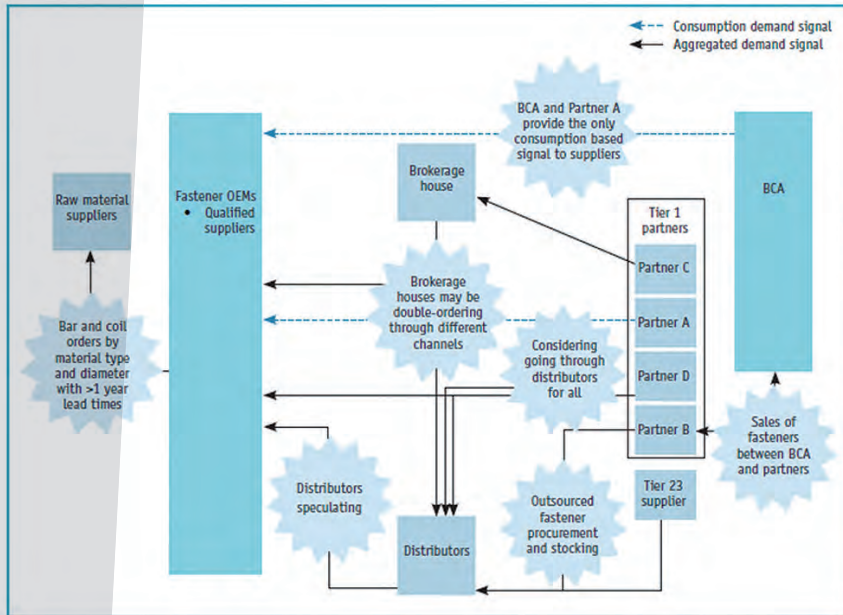


**Figure 3** illustrates the strategy that the Boeing company has developed for tackling with potential crisis of supply chain breakage, working with Tier 1 suppliers on fastener procurement and even double-ordering fasteners as countermeasures against supply shortage. In order to improve the supply chain of aircraft components in the late 90s, Boeing developed a consumption-based ordering (CBO) system to deal with ordering and stocking problems, using minimum/maximum consumption systems which are connected through the Internet, updating the suppliers on daily reading of stocking level, average monthly consumption, as well as the min/max amount of stocking, so as to facilitate the suppliers to estimate their own production capacity, allowing the filling of back orders in effective manner and not having to worry about stocking level dipping low. The improvement brought by this ordering and stocking controlling system not merely helped reduce the cost of stocking for B737 production programs by a worth of nearly 3 million US dollars and prompted the suppliers to improve their deliveries, the network helped establish the data for inventory systems, saving for the company 0.9 billion US dollars on the expenses of administrative and personnel operation.

With the advancement of aviation technology, the fastener supply chain held stabilized by the min/max systems became no longer adequate to meet new demands for problem solving.

On one hand, with B787 aircraft adopting a large amount of compound materials, the fasteners used in conjunction with these new materials are required to be processed with different types of surface treatments while using titanium metals as base substance. The adoption of new types of fasteners in Boeing's production programs prompted some manufacturers of aircraft components to realize potential risk of not using newly developed fasteners. They turned to Boeing and asked Boeing to provide them with these new fasteners for production and assembly applications of new model aircrafts. In response to such request, Boeing initially shared some of their inventory with their component suppliers, allowing new fasteners to be available for their component suppliers, but Boeing eventually found itself unable to cope with incessant request of this kind and decided to leave it to the mechanism of the market. The

**Figure 3. Current Ordering Strategy for T1 Suppliers to Place Orders with Boeing**



result is that some component suppliers ended up having to pay twice as much to acquire newly developed fasteners.

Boeing obviously has encountered crisis with fastener supply, knowing that two problems need to be addressed immediately; that is, how to design a better demand signal, for one, and how to compile fasteners demands of the Boeing company and

its Tier 1 suppliers; the Fastener Procurement Model (FPM) is the result of this problem-solving effort. Based on the concepts of procurement and resale, the FPM demand signal system utilizes a central procurement entity for the management of procurement orders and stocking. This system of stocking management requires the use of a central warehouse for receiving and distributing of fasteners, while the pricing of fasteners is left for negotiation by a team of the Boeing company and the fastener suppliers. This allows for the elimination of liability and risks for partners in the joint venture. By directly placing orders to fasteners manufacturers, Boeing stands in a favorable position for pricing negotiation, while securing the upper hand in choosing the manufacturers who could offer shorter lead time.

The FPM system also adopts Consumption-Based Ordering (CBO), with Boeing and its Tier 1 suppliers uploading their fastener stocking levels to the central system, referred to as Boeing Partners Network (BPN) located internally at the Boeing company. This partners network system then gathers the demands of the company and its suppliers, with an ultimate result of knowing more about the demands and stabilizing the supply chain for production

### 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

Source: The Boeing Company

through improved inventory turnabout rate. By CBO, when the inventory level at the Boeing company dips below the designated minimum level, fastener manufacturers will take charge in getting the inventory replenished back up to the minimum level, but, in the meantime, not exceeding the designated maximum level.

To ensure the operation of FPM, internal task forces are set up to monitor the network partners for the practice of conforming to regulations, which may require the types of fasteners allowed for after-sales maintenance and repair to be those having been installed in Boeing aircrafts; besides, the quantity of fasteners in a procurement is also regulated; only the quantity actually needed can be put forth on the procurement, thus eradicating the possibility of unnecessary stocking. To ensure network partners abiding by regulations, FPM system requires each of the suppliers (including the buyer and the seller, fastener manufacturers and Boeing's Tier 1 component suppliers) to sign off an agreement. The whole concept of FPM is for both of aircraft manufacturers and their suppliers to benefit from being able to see their production plans becoming realized and do so with ease and in timely manner.

## Future Development of Aerospace Fasteners

In terms of company scale, aerospace fastener suppliers are generally not as large as aircraft manufacturers. With suppliers forming alliance after the launch of FPM system, fastener suppliers may see the prices they can offer are not as favorable as those in a free market, while their role in the production supply chain for aircraft manufacturers is merely an associated partner. Yet, in another perspective, FPM system, by ensuring logistics of orders, prevents from excessive production and oversupply, helping fasteners suppliers with the processing of production plans.

be even higher, making the entry barrier in the market even higher. Furthermore, with prosperity of the aviation industry in recent years and the market demand going high, the prospect for manufacturers dedicated to development of aerospace fasteners should be quite promising. ■

In addition, given the unique environment of aviation industry, the specifications required for aerospace fasteners can never be standard. With such thinking, viewing the innovation of technology is the way out, we will be able to see that the market of aerospace fasteners is not necessarily for the buyers, or against the sellers. It can be anticipated that fasteners made of compound materials will be in the trend for the future, while demand for quality verification will