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## Boeing Is Revolutionizing Airplane Manufacturing

**Lean manufacturing enhances value, promotes environmental goals, and helps rationalize financial risk and reward**

“**B**etting the company” has traditionally seemed to be a fact of life for commercial airplane manufacturers. The financial risk ripples out through the aviation industry. Component suppliers must read the tea leaves of cyclical aircraft markets to match production to demand. And airlines must peer decades into the future to plan fleets for a rapidly globalizing air transport market, while staying competitive today.

Boeing has worked continuously to build flexibility and resiliency into the airplane production process in order to mitigate the economic risk that arises from uncertainty about the health of the global economy, political instability and, most recently, the threat of terrorism and pandemics.

With every generation of new airplanes, Boeing has made great strides in reducing and managing economic risk in the manufacturing process. During the past decade in particular, Boeing has applied developments in information technology, the vastly improved efficiency of the global supply chain, and—most visibly—lean manufacturing principles to develop a revolutionary approach to producing airplanes. The new approach focuses on unprecedented program visibility, transparency, and communication up and down the supply chain to identify risks at their source, where risk management is most effective. Solutions and innovations come from the true experts: design and production engineers, mechanics who build parts and assemble the airplanes, and supplier companies.

Lean manufacturing principles have helped Boeing reduce waste that is embedded in manufacturing process. Continuous vigilance for inefficiencies has helped Boeing improve quality all along the assembly line. It has been possible to eliminate entire work groups dedicated to out-of-sequence activities and rework that traditionally operated on the sidelines of the main production flow. Employees from these workgroups have been reassigned to activities that add value to the product.

Lean principles also deliver significant environmental advantages. Pollution, after all, is a form of waste. By reducing or eliminating sources of contamination and environmental hazards, lean manufacturing processes are helping Boeing cut the costs of managing potentially harmful materials. Active engagement of employees at all levels in development and implementation of lean processes is key to the company’s commitment to certify all manufacturing

*(continued on page 2)*

## The World Is Witnessing the Birth of a Fundamentally New Way to Build Airplanes

By *Walt Skowronski*

When we set out to build a replacement airplane for the 767, we committed to make a generational leap in the design, production and support of airplanes. The extraordinary validation of the 787 in the market testifies to operator and financier confidence that we were right on target on all three counts. The glare of publicity about revolutionary use of composites, open systems architecture and GoldCare



BCC President Walt Skowronski

support have, to a large extent, obscured the equally profound transformation of airplane manufacturing that the 787 program ushers in.

Building large sections of the airplane as single, integrated structures transforms the assembly line. Portable tools move assemblies into place without the need for overhead cranes. With fewer parts coming together in final assembly, there is less scrap and significantly less use of hazardous materials. Lean manufacturing improvements produce a more standard product and will ultimately allow us to assemble a 787 in three days, compared to the several weeks required using conventional techniques.

Reinventing airplane manufacturing is not without risks. In October, we were disappointed to announce a slide in the program’s initial deliveries. Additional time to resolve issues, including supply chain bottlenecks, will help get the new production system up and running.

By the end of December, the production line was fully loaded with airplanes. We are confident that the 787 is the right airplane for the market and that our new global production system is the right way to manufacture airplanes in the 21st century.

The 787 global production system embodies the most complete implementation of lean principles that have proven invaluable on our existing product lines. Standardization is central to these principles. Designing a more standardized airplane streamlines manufacturing processes for us and our suppliers. This in turn allows us to share both the risks and rewards of airplane manufacturing more proportionately among all stakeholders.

This new level of collaboration will reduce assembly time and enhance quality. And, because standard airplanes share standard maintenance and modification procedures, they retain their value in the market and enjoy greater liquidity as assets. ■

**With 817 orders from 53 customers, the 787 Dreamliner enjoys continued market enthusiasm.**

(continued from page 1)

facilities to the International Organization for Standardization ISO 14001 environmental guideline by December 2008.

### A New Way To Build Airplanes

The most visible sign of the revolution in airplane manufacturing is the assembly line itself. The most casual glance at the 737 and 777 assembly lines instantly reveals that airplanes are coming together in a completely different way from just a few years ago.

Airplanes are lined up nose to tail for the 737 assembly line and in a u-shaped moving line for the 777. Airplanes move at a slow but steady pace toward completion and the hangar door. "The airplane is a magnet for the work," said Carolyn Corvi, Vice President/General Manager for Airplane Programs. Parts, tools and people come to the precise point along the line where they are needed, at the time when they are needed. "You don't see the clutter of tool cribs and parts-storage areas that used to ring the static assembly stations," said Corvi.

Thanks to this approach, Boeing has been able to reduce the square footage needed for production of current models while reducing the time needed to build each airplane. On the 737 line, enough space was saved to move the engineers and manufacturing-support personnel into an area adjacent to the production line so they can collaborate more closely with the assembly mechanics. In the Everett factory, more efficient use of space allowed Boeing to set up the assembly line for the new 787 Dreamliner without building a new facility.



The 737 moving line uses less space than conventional assembly stations and helped reduce the time it takes to build each airplane from 22 days to 10 days.

Corvi credits the visual cues built into the new system for much of the improvement. Clearly marked zones along the line indicate where each part and tool should be delivered and staged. It's plainly visible that the necessary items are present. Colored lights that move with the airplane on its way down the line glow green, yellow or purple (the equivalent of a red light, signaling that the line has stopped) to tell everyone on the floor whether an airplane is progressing down the line according to plan. Clearly visible from all points of the production floor, a giant "score board" gives an



The 777 moving line, which will be complete in 2008, includes systems installation, final body join and final assembly. With implementation of the Boeing Production System, Boeing has made significant improvements to 777 manufacturing, including reduction of factory flow time for the airplane, increased inventory turns and improved quality. A continued focus on Lean will create opportunities for further improvements.

overview of how the whole line is functioning.

But the movement of the airplane itself is the most compelling indication of progress, according to Corvi. "If work isn't completed on time, it doesn't get put off until later and pass on to the next station. The line stops until the issue is resolved." Lights flash, warnings sound, and word goes out to responsible teams that include the necessary expertise from manufacturing support, facilities, tooling and engineering.

Delivery of parts directly to the point of use, ready to install, reduces the risk of parts shortages. This in turn reduces the economic risk inherent in holding large inventories.

Provisioning the moving line improves process visibility and facilitates more effective communication with suppliers. This reduces costs that accrue to schedule risk, including the cost of catch-up work that must be completed outside of the normal production order.

### Rooting out risk that arises from variability

Leasing companies and financiers in particular identify variability as a source of economic risk. Variability introduces risk not only during production, but throughout the life cycle of the airplane.

Boeing has forged collaborative relationships with suppliers and customer airlines to reduce the incidence and effects of configuration variability. With the help of customer airlines, we've defined standard packages of options to match the requirements of the various airline business models and operating environments. The engineering for these standard packages has already been done, so no new engineering is required and regulatory certification is simpler.

Standardization of airplane configuration allows us to standardize our processes, which in turn, reduces the risk of parts shortages, error, and out-of-sequence work on the production line. For suppliers, fewer airplane configurations means more predictable parts orders.

Customization is not a one-time cost for airplane owners. Unique configurations must be serviced and maintained. A standard configuration can eliminate unique parts and materials that increase maintenance and training costs and create parts availability risks.

For leasing companies and financiers, a more standard product is a more valuable asset. A standard configuration requires the minimum of modifications to transition to a new market or new operator. And, a standard airplane is easier to convert from a passenger to a freighter configuration to gain extra years of profitable service.

Revolutionizing the way airplanes are manufactured is already delivering valuable results on our existing product lines. The potential for new designs, starting with the 787 Dreamliner, is inspiring. Innovative approaches to manufacturing that are being proven on the Dreamliner production line will help us reduce uncertainties that are a source of financial risk and compress the time between initial investment and return on investment. ■



BCA Vice President/General Manager of Airplane Programs, Carolyn Corvi, surveys the Renton production floor from a vantage point above the 737 moving line. The Renton plant has served as a proving ground for lean manufacturing methods and collocation of multidisciplinary teams.

## A New Age of Aircraft Manufacturing

### 787 Dreamliner production is under way

The game changing 787 Dreamliner is, without question, the airplane the market was waiting for. It has captured the imagination of the traveling public and inspired airlines to develop new ways to operate profitably and offer the most competitive service. With 817 orders from 53 customers as of mid December 2007, the 787 is the most successful jetliner ever launched.

Beyond revolutionizing the materials from which future commercial jets will be built, the 787 ushers in new ways of manufacturing airplanes and of doing business—for suppliers as well as for Boeing.

Building airplanes has always been a global venture, but with the 787, Boeing is raising partnering to greater heights. We are bringing together the best aerospace suppliers from around the world to form a global design-build community that will produce the world's most advanced jetliners.



The 787 production line has come to life as the first three airplanes—Number 1, which is the first flight test airplane, and the two ground test units—undergo final assembly. Many tasks now being performed on the Boeing assembly line will be completed at supplier manufacturing sites when the process is mature.

Launching a new manufacturing system is as challenging as launching a new airplane program. The rewards promise to be at least as great. The new process defines not only how the 787 is built, but how commercial airplanes designed in the 21st century will be built. By integrating the new production technologies with the global supply chain now, Boeing gains a significant head start against other aircraft manufacturers who will have to develop and implement their own versions of the system.

In the monthly program update on December 11, 2007, Pat Shanahan, 787 program vice president and general manager, noted significant progress in resolving supply chain issues and expressed confidence in the advantages of the global 787 production strategy. “We are clearly seeing the benefit of the decision we made this fall to have our structural partners hold on their delivery dates and focus on a required condition of assembly,” said Shanahan.

“We remain focused on three things: driving toward powering up Airplane #1 in preparation for the flight test program; working with our partners to meet the assembly condition and schedule targets; and ensuring that the processes and resources are in place for a rapid transition to full-rate production.”

By December 11, Dreamliner No. 1 had moved forward on the assembly line and two more airplanes had moved in behind it to fill the line. Boeing and the U.S. Federal Aviation Administration had reviewed and agreed to all the technical requirements for type certification. “Component structural testing is 80 percent complete, and safety of flight qualification testing on our airplane systems is 91 percent complete,” Shanahan said.

“Risks remain,” Shanahan cautioned. “We encounter them every day and knock them down every day. While the challenges are significant, the team is committed and engaged, and we are making steady progress across the board.” ■

# Noteworthy Developments

## Boeing Program Update:

### 787:

- Boeing reschedules initial 787 deliveries, first flight
- Pat Shanahan named to lead 787 program

### 777:

- Boeing delivers Air India's first 777-300ER
- Boeing, Qatar celebrate arrival of airline's first 777-300ER
- Boeing completes 90 percent of design work for the new 777 Freighter

### 747:

- Boeing completes 747-8 Intercontinental firm configuration
- Boeing delivers first leased 747-400F to AirBridge Cargo, a Volga-Dnepr subsidiary

### 737:

- Boeing delivers fourth 737-800 to Yemenia Airways
- Ryanair receives 150th next-generation 737-800
- SpiceJet celebrates its first 737-900ER delivery

### CAS:

- Boeing expands landing gear MRO capability, offerings – multiple airlines, gear MROs sign new agreement with landing gear overhaul and exchange program
- Boeing, Thomsonfly.com establish partnership to reduce cost, delivery time for spares – U.K. airline joins component services program (CSP)
- Boeing, Transavia France agree on Maintenance Performance Toolbox for 737 aircraft fleet

## Airplane Orders:

Recent order announcements for Fourth Quarter 2007 include:

- **787s:** LAN (32); Qatar (30) previously unidentified; LCAL (6) previously unidentified ; Royal Jordanian (2); British Airways (24); Vietnam/VALC (12); DAE Capital (15)
- **777s:** LAN (4) 777 freighters (two previously unidentified); Guggenheim Aviation Partners (3) 777 freighters previously unidentified; Emirates (12) 777-300ERs previously unidentified; Cathay Pacific (7) 777-300ERs; Qatar (5) 777 freighters previously unidentified; KLM (2) 777-300ERs previously unidentified; GECAS (2) 777-300ERs previously unidentified; DAE Capital (10) 777-300ERs
- **747s:** Cathay Pacific (10) 747-8 freighters; DAE Capital (5) 747-8 freighters
- **737s:** Jet Airways (20) 737-800s; SAS (2) 737-800s previously unidentified; Transavia (7) 737-800s previously unidentified; KLM (3) 737-700s previously unidentified; Lion Air (22) 737-900ERs previously unidentified; Babcock and Brown Aircraft Management (20) 737-800s previously unidentified; AWAS (31) 737-800s; GECAS (57) 737-800s previously unidentified; Qantas (31) 737-800s; Jeju Air (5); DAE Capital (70); GOL (40)
- **Other:** Boeing Portland receives ISO 14001 environmental certification. Boeing, DAE sign proposal agreement for 100 airplanes. Current Market Outlook airliner needs projections for the next 20 years: Southeast Asia – 1,930 ; Italy – 500 new airplanes; Germany – 930 airplanes



**747-8 Intercontinental Firm Configuration Completed:** In early November, the company announced that it had completed major trade studies to finalize the new airplane's performance and interior features, making way for it and its suppliers to begin detailed design of parts, assemblies and other systems. Delivery of the first airplane is scheduled for late 2010.



### Investors Take Lean Journey:

Leading aircraft-industry investors, guests of Boeing and JPMorgan, got a close-up view of Boeing's Lean manufacturing process on the floor of the 777 factory in Everett, Wash on Dec. 11. Their co-hosted Puget Sound visit also included tours of the company's 787 Dreamliner interior display at the Customer Experience Center and the Alteon customer training facility.

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