December 2006

Challenge

A Boeing Engineering, Operations & Technology magazine for Boeing employees

XTREME Engineering

How Boeing employees cope with arctic temperatures in Fort Greely, Alaska. See story beginning on Page 14.

INSIDE:

- Promises kept: Who's helping Boeing keep its word to customers?
- Standards pay: What Information Technology is doing to make Boeing more efficient
- Where the rubber meets the ramp: The thrill of flight-test engineering

Enterprise perspective

Welcome to another issue of *Challenge* magazine, a publication designed specifically for the engineering, operations and technical work force of Boeing.

While this is the seventh edition of *Challenge*, it is the first issue to be produced as part of the Engineering, Operations & Technology organization, formed in July this year to improve the efficiency and effectiveness of Boeing's engineering, operations and technology functions, which also include the program management, quality assurance and supplier management functions

As a result, *Challenge* has expanded its coverage beyond its former focus on engineering to include the wide variety of people and projects across the enterprise that make up all these functions.

That's why you will find articles in this issue about how the operations and engineering functions are working together to streamline their processes, and how various development programs across Boeing are working to become more efficient and effective in their performance.

You will also see in many of the articles how various Boeing initiatives are influencing improvements across the enterprise. One good example is how the Development Process Excellence initiative led to an improvement in how Boeing will develop its enterprise R&D investment strategy.

Other interesting articles will inform you about the status of Boeing's common processes and systems initiative, how flight-test and ground-test teams operate, and how some Boeing employees are meeting special engineering challenges during the frigid winters of Alaska.

And of course we will introduce you to many of the engineers, technologists and manufacturing people across the enterprise who are dedicated to meeting our commitments to our customers and making Boeing the leading aerospace company in the world.

I pointed out above that this issue of *Challenge* is the first to be produced as part of EO&T. I might also point out it is the first issue to be published since I have taken the leadership position at EO&T. So I sincerely hope you enjoy these stories and learn something from them. I also hope you will provide us with feedback and suggestions for future issues. This is your magazine, after all.

Thanks and keep up the great work!

John Tracy

Boeing Senior Vice President
Engineering, Operations & Technology

Challenge has expanded its coverage beyond its former focus on engineering to include the wide variety of people and projects across the enterprise that make up all these functions.

Challenge magazine, focusing on engineering, operations and technology, is published twice a year for all Boeing employees.

Challenge

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Promises kept
Kathy Erlick, helping to streamline 10 engineering functions: "Building a winning team means drawing out the best in people. It's about involvement. Everybody wants to feel that they are contributing to the solution."
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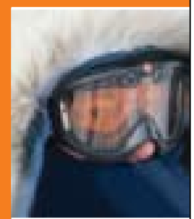
ON THE COVER:
Extreme weather conditions present special challenges for employees at Fort Greely, Alaska, where the team, including Jon Brumbach, Interceptor Production Operations site manager, recently placed missiles for the U.S. Missile Defense Agency's Ground-based Midcourse Defense program into silos. (See story on page 14)



Where the rubber meets the ramp
David Milanes, A160 flight test engineer: "You have to make very quick decisions, and they have to be right."
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Getting it right at the beginning
Ed Petkus, leader of the 787 airplane development team: "Defining a new aircraft is difficult because each time one design parameter changes so do all the rest, which requires recalculation and reevaluation."
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Flight engineer Ralph Chaffin on the flight deck of a 737 at Boeing Field in Seattle. The airplane will be thoroughly tested before it is delivered to the customer. Chaffin has worked in flight test with a variety of commercial aircraft, tankers, trainers and transports.

Flight test teams shake out Boeing aircraft performance to make sure that the vehicles operate perfectly under any conditions.

Where the Rubber Meets the Ramp

By William Cole

They are the calm voices who let military test pilots know when they are reaching the edge of the envelope. They are the technical experts on the flight decks of commercial jetliner test flights who continuously operate and test the aircraft's critical systems. They are the crew members who don flight suits to fly with transport test pilots practicing assault landings. They are the "pilots" who control autonomous helicopters from a ground-based station in the Mojave Desert.

Meet some of the flight test engineers who shake out Boeing aircraft performance to make sure that the vehicles operate perfectly under any condition.

Drama in the mission control room

It was a tense moment for the 50 engineers concentrating on a bank of monitors in the mission control room at Edwards Air Force Base in Southern California.

Signals from Boeing's X-32B concept demonstration aircraft for the Joint Strike Fighter program were indicating that all three critical navigation systems, which help to stabilize the aircraft, were "red," or not responding.

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"That could be bad news, or very bad news," says Bill "Jaco" Jaconetti, then flight test conductor for the experimental aircraft. "It could mean that the aircraft simply had reduced stability. Or it could mean it was out of control."

Jaconetti and his team had to find some answers quickly. They immediately broke out their emergency procedures to get to the root cause of the problem. But soon they were relieved to hear from the test pilot that the aircraft appeared to be flying normally. Not taking any chances, the team aborted the mission and brought the aircraft in early.

Mercifully, such incidents are so rare that they stand out in a flight test engineer's memory. On the ground and in the air, Boeing military and commercial engineering teams put their products through a punishing array of tests. From the time the engines start to the time they shut down, a stream of data from the aircraft and the pilot is used to monitor the aircraft, says Jaconetti. During a flight test, his team has five focus areas: the overall health of the aircraft, its engine parameters, its avionics systems, the state of its fuel and its instrumentation.

"Our goal is to shake out new systems and parts, to put every aircraft through every situation that the end user could possibly experience," says Jaconetti, one of a select group of engineers who have traveled the world to make sure that Boeing aircraft deliver as promised. "We push the aircraft to its limits; we take it to the edge of the envelope. I serve as a filter between the team and test pilot, providing only necessary information. Our challenge is to make real-time calls. We have to think quickly and accurately enough to recognize a system's limit, to knock it off at exactly the right time. One misjudgment and you could break something."

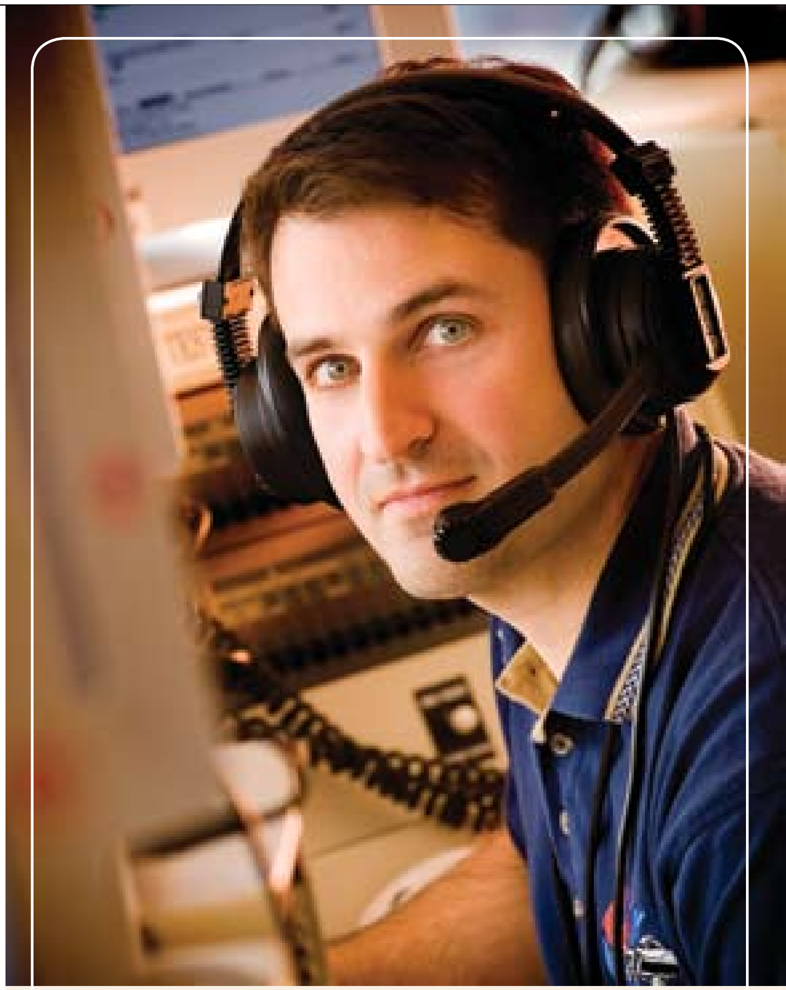
"Our goal is to shake out new systems and parts, to put every aircraft through every situation that the end user could possibly experience." – Bill Jaconetti.

Now on a special assignment as the integrator for the Integrated Defense Systems Test and Evaluation function, Jaconetti was previously flight test technical lead on the F-15SG (Singapore) development program, flight test conductor for the F-15 and F/A-18E/F development programs as well as for the X-32. He and his team of 30 engineers, aircrew, and maintenance people successfully execute dozens of flight-test missions each year.

Jaconetti grew up near O'Hare airport in Chicago. An airplane flew over his house every 45 seconds every day of his boyhood. Far from being annoyed by it, Jaconetti developed a fascination for the aircraft. He decided that engineering was his destiny. After earning a bachelor's degree in aeronautical engineering, he began a search for his dream career.

He remembers every word of the voicemail offering him a job interview at Boeing: "We have an F/A-18 Super Hornet. You are going to be responsible for everything that happens to that aircraft. Call if you are interested."

He did, naturally. "I wound up with one of the best jobs at Boeing," he says.



Bill Jaconetti is described by F-15 chief test pilot Joe Felock as a "flight-test engineer extraordinaire." From the control room on the flight ramp in St. Louis, Jaconetti and his team routinely pushed aircraft to their limits.

Madelene Vega: Flight-testing the big bird

Edwards Air Force Base sits in the baking Mojave Desert in Southern California.

However, it is paradise for pilots and flight test engineers.

Named after Capt. Glen Edwards, a young U.S. Air Force pilot who died aboard the YB-49 jet-powered flying wing in 1948, Edwards occupies 44 square miles and contains two powdery lake beds, ideal for emergency landings.

It was at Edwards that Chuck Yeager broke the sound barrier in the X-1, and where every Air Force test vehicle from the SR-71 Blackbird to the F-22 Raptor is put through its paces.

"I knew when I was five years old in Puerto Rico that I wanted to fly," says Madelene Vega, a flight engineer on the C-17 program at Edwards Air Force Base in Southern California. "I knew how to fly a plane before I knew how to drive a car."

Today it's where the space shuttle sometimes lands and where stealth aircraft climb into the sky. It's also where F-15s can be seen doing hairy "tail slides" – climbing vertically until running out of airspeed then dropping backwards, momentarily out of control.

And it's where Boeing flight test engineer and test conductor Madelene Vega dons her Boeing-blue flight suit several times a week to board a C-17 Globemaster III transport. She, a three-person flight crew (two pilots and a loadmaster) and sometimes a few supporting engineers, then take off for four-hour missions that usually take them over Edwards air space, Long Beach, Calif., and the Pacific Ocean.

"Every flight is different," says Vega. An accomplished engineer fluent in Italian, Spanish, and Portuguese, she has worked on flight-test projects in Italy, Germany and Brazil for three aerospace companies. Sometimes she flies on the C-17 to Charleston Air Force Base, S.C., where the team practices assault landings. "We are in effect pioneers, testing an aircraft for the first time," she says. "It's very exciting."

But it's also hard work, and there's not much time to enjoy the ride. Vega's responsibilities include monitoring test parameters, acting as cockpit safety monitor, communicating necessary information to the flight crew and, most important, documenting the test results.

"My job is to keep the flow of the mission going," she says. "I make decisions about the order of each test. The C-17 is an amazing, very complex airplane with constantly changing flight control laws. You have to remain focused all the time. It's challenging." Nevertheless, there is camaraderie among the onboard team. "I learn so much from my crews and supporting fliers," says Vega.

Edwards is where Madelene Vega dons her Boeing-blue flight suit several times a week to board a C-17 for exhaustive flight tests.

Before each flight, she plans the mission, drawing up test-profile sequencing that will take the aircraft to its limits. She creates the flight cards, which detail the parameters of each test and serve as a guide to the flight crew. She conducts aircrew briefings and debriefings. She also has to interpret and define test requirements according to military air vehicle specifications.

"I knew when I was five years old in Puerto Rico that I wanted to fly," she says. "Science fiction in general and particularly the movie 'Star Wars' had a strong effect on me. I used to pretend that I could fly to the moon when I was a kid. My dad was an engineer. I was always asking him questions like, 'Why is a fire truck red?' (Answer: In the 1930s, when most cars were black, red stood out.) I was hooked when my parents gave me flying lessons for my 16th birthday. I learned how to fly an airplane before I learned how to drive a car."

Since then, Vega has developed a pedigree career history. She was an engineer at McDonnell Douglas in Long Beach for more than 10 years, working her way through every commercial airplane program at the company. Then, after three years overseas, she returned to Boeing and the C-17.

"You have to love airplanes to do this job," she says. "I never take this for granted. I want to continue expanding my knowledge of aircraft systems and testing. I'm doing something that not many people get to do. It's my life."

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Ralph Chaffin sometimes flies twice a day. No two airplanes are the same, he says. Each customer requires a slightly different configuration.

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Ralph Chaffin: One of Boeing Field's best

As he walks across the crowded tarmac at Boeing Field, Seattle, veteran flight engineer Ralph Chaffin almost always gets a wave and a smile from pilots, air crews, production engineers, maintenance folks, mechanics – and, most importantly, from Boeing's airline customers.

Today, he'll be doing an exhaustive preflight check on a 737. Then he'll join the crew to fly out over the Pacific Ocean, back over Washington, do a touch-and-go at Moses Lake, Wash., and head back to Boeing Field.

The vehicle could just as easily be a widebody, or in a couple of years, a 787 Dreamliner. He's qualified to coordinate flying quality tests for all new-production 737 Next Generation (-600/-700/-800/-900ER) models, 747-400, 767 and 777 airplanes. When he disembarks from a test flight, he receives the same warm reception.

"When you've been doing this for a while, you develop a bond with the people you work with," says Chaffin, flight engineer and systems operator for Production Flight Test at Boeing Commercial Airplanes. "We work closely together as a team. Over time, you develop trust." But trust, he cautions, is something you have to earn.

A strong aircraft systems background is clearly essential for a flight test professional, he says. And Chaffin certainly knows his airplanes. He has flown in every conceivable variation of commercial jets, tankers, trainers and transports since the 1970s for Boeing, other aerospace companies, and the U.S. Navy. He supported the E-3/AWACS aircraft flight testing and accumulated more than 6,000 hours as a C-130 flight engineer and TA-4J/US-2B military flight crew member in the navy. He not only has a degree in professional aeronautics; he's a licensed FAA turbojet flight engineer and an FAA airframe and powerplant mechanic.

He says that communication, flexibility and stamina are perhaps the essential qualities for a person in his job.

"You have to be absolutely precise and clear when you are describing a condition to a pilot or another team member," he says. "You have to be able to adapt to rapidly developing situations. You must be prepared to fly at any time. During a flight test, you must be able to perform what we call 'crew resource management.' That means that you have to know exactly what to tell the crew and when. It calls for some swift decisions. What do the wrong numbers for the engine or the pressure controller mean? And do I need to tell the crew about them?"

The captain, he says, will almost always be concerned with the flying qualities of the airplane. The first officer concentrates on communications and navigation. The systems officer monitors the electrical, hydraulic and pneumatic systems.

"There's so much going on during a flight test that to the casual observer it might look like chaos," he says. "I prefer to think of it as a choreographed dance, with each move having a purpose. But as the coordinator, you have to see through the clutter and establish some priorities."

He and other system operators/flight engineers at BCA actually have a dual role. On the ground, they conduct detailed first-flight preflight tests. They do start, taxi and post-flight evaluation of all aircraft. But they also do in-flight checks on all production aircraft, sitting upfront in the observer seat between the pilot and co-pilot. That sometimes means flying twice a day. They are in essence serving as flight systems officers. Flight engineers regularly flew as members of regular flight deck crews before the computerized systems of modern airplanes reduced the number of people needed in the cockpit from three to two.

"We probably flight-test 35 planes a month," says Chaffin. "Every one of them is slightly different from the other. Each customer has a different configuration."

No matter what the challenges, Chaffin considers himself blessed. "I look forward to every single day at work," he says. "It's fantastic, and I never get tired of it. How many people get to do the job they dreamed of doing as children?"

David Milanes: Piloting from the ground

There's quite a gale blowing at the Southern California Logistics Airport, a former U.S. Air Force base in Victorville, Calif., which is home of the A160 Hummingbird UAV flight test program. Located in the Mojave Desert, 2,875 feet above sea level and 95 miles north of Los Angeles, Victorville is often buffeted by blustery weather. The prevailing winds, blowing in from the Pacific Ocean to the south, normally keep the air free of smog.

Today, the wind is gusting to 30 mph, not enough to cause a ground test cancellation. But it's enough to make the A160 flight test team slightly relieved that A160 aircraft A001RB is not scheduled to go up. The aircraft is tethered to the flight ramp, where it will undergo only ground tests.

Dave Milanes, lead aircraft test engineer and ground-based pilot for the autonomous helicopter, is inside the ground control station. He and two members of his ground-test team, Andrew Abramson, an electrical engineer, and Matt Theis, an aerospace engineer, are busy looking at incoming data from the A160, which has its engine running. Abramson is checking voltage levels of the electrical system and vibration data. Theis is monitoring the overall health of the aircraft and comparing trends with previous tests.

"We were essentially making sure that it was safe to fly," says Milanes. "But we were also testing a new engine controller that we had been working on."

"When things arise you have to make very quick decisions and they have to be right."
– David Milanes.

Boeing Advanced Systems is developing the A160 under a contract with the Defense Advanced Research Projects Agency (DARPA). Development, manufacturing and assembly of the A160 takes place at the Boeing Concept Exploration facility in Irvine, Calif. The aircraft is designed to fly with endurance up to 20 hours, longer than any other unmanned helicopter. It can fly at an estimated top speed of 140 knots at ceilings up to 30,000 feet, with a high hover capability up to 15,000 feet. Intended missions for A160 include reconnaissance, surveillance, target acquisition, communications relay, and precision resupply.

The computer control stations on the ground are where a pilot and a co-pilot monitor the aircraft's autonomous flight and can step in to give certain directions to the vehicle's onboard computer. In fact, the first flight of A001RB – the 5th A160 built to date – will probably be flown by Mary Jayne Adriaans, the A160 test director, who is responsible for all A160s in test. During the actual flight, a video camera mounted on the front of the aircraft will give the team a pilot's-eye view from the helicopter.

"It's not like flying a radio-controlled model airplane," Milanes explains. "The A160 is piloted by its computer, which we program in advance. When we use the stick, we are telling the flight computer how fast to make the aircraft fly, how fast to spin the rotor, and other such commands. It would be a little like a passenger aboard a regular helicopter instructing the pilot to fly at 80 knots, say, or to slow down to 20 knots. But in an emergency, there are actions we can take to bring the aircraft safely to ground."

What kind of engineer does it take to manage the testing of such a vehicle?

"You have to know the system inside and out," says Milanes, an MIT graduate with a degree in aeronautics and astronautics. He took the job straight from college in August 2003.

A160 flight-test engineer David Milanes conducts a ground test for A001RB – the 5th A160 built to date – from a control station in Victorville, Calif., home of the A160 flight-test program.

"When things arise, you have to make very quick decisions, and they have to be right. If you make the wrong decision, it can have dire consequences. This is not like driving a car that you can just stop in the middle of the road. You have to be able to think ahead, anticipate what can go wrong, and be ready to take the appropriate action."

Milanes always knew he wanted to be in aerospace. But it was an MIT recruiting flier for a job opening at Frontier Systems Inc., the original developers of the A160, that caught his eye.

"This is a special class of aerospace," he says. "I wouldn't have been here if I hadn't seen the flyer and applied for the job. It's exciting. You are on the cutting edge of a technology that one day will be operating in the field. This is not your everyday job. It's enjoyable; it's very easy to be highly motivated. It's fun working on the ship, and it's fun being surrounded by great co-workers." ■

Ed Petkus leads the development team on the 787 Dreamliner program. The 787 is seen as a good example of a well-managed development program that has taken advantage of a host of improved processes, capabilities and computational tools.

How do we avoid problems in the development of crucial Boeing programs that will one day be the lifeblood of the company? Today's focus on development process excellence provides an answer.

Getting it Right at the BEGINNING

By Jay Spenser

When does any aerospace product face the greatest opportunity for success and risk of failure? Boeing engineers know that it's during the product's creation.

Today, Boeing is fundamentally reinventing how it plans, measures and executes its product developments. Still at an early stage, this transition to better business practices is changing how development program engineers do their work and interact with their Boeing, customer and supplier teammates.

"Development programs are by definition difficult and we know we'll run into problems," says John Tracy, Boeing Senior Vice President of Engineering, Operations & Technology. "That's why we're defining and implementing business processes that let us do things more quickly, give us greater visibility earlier and enhance our ability to respond to unexpected challenges as they arise."

At the heart of this transformative activity is the Development Process Excellence Initiative, which is designed to maximize the yield of Boeing's R&D investments and improve the efficiency and effectiveness of its development program processes. One of the other four enterprise initiatives, Lean+, applies to everything Boeing does, including development programs, and provides powerful tools for reducing cycle time and eliminating rework.

Today's focus on development process excellence dovetails with engineering and manufacturing activities that are leveraging Boeing's experience on current and past programs to benefit new ones across the enterprise. The aim of these activities is to integrate identified management best practices into Boeing development programs, provide optimized tools and processes for companywide use, set in place a skilled and a motivated team, and ensure that new technology is ready when needed by the programs.

"We're making excellent progress," states Jim Morris, vice president of Engineering and Manufacturing for Boeing Commercial Airplanes, who is also a leader of the enterprise Program Management, Engineering and Manufacturing functions within EO&T. "If we simply keep on improving in all four of these areas, we'll be in great shape for the future."

Nan Bouchard, Boeing Integrated Defense Systems vice president of Engineering and Mission Assurance, describes development excellence as a continuing journey because processes

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Corky Townsend, chief project engineer on the 747-8 development program, says lean product development "means doing the right things and in the right order as quickly as possible."

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can always be further improved. "It takes time to see results when you change processes and tools," says Bouchard, who is also aligned with EO&T as a leader of the enterprise Engineering function. "But we're already seeing how our efforts are helping us give customers the capabilities they need, on time and at the promised cost."

By way of example, Bouchard – who until recently led the Development Process Excellence initiative – points to development programs across Boeing. A few are presented below.

A new development paradigm

When the Boeing 747-8 enters service in late 2009, it will be the first Boeing airplane developed at the program level using a Boeing-invented tool called *process-based program planning*. An alternative to standard milestone-driven schedules, process based program planning has no fixed milestones beyond the hard-and-fast dates that can't be moved.

This program planning tool employs a dynamic database of rigorously integrated requirements to shine light on the entire value stream and identify solutions. It leverages Boeing's knowledge about which tasks are the most critical and what information is needed by whom in what sequence to achieve program goals.

Tasks dependent on other tasks are linked so downstream impacts can be understood and managed. Critical events that drive the program are identified so priorities can be set and needless work avoided. Constraints are also identified up front so that they can be effectively managed.

"Lean product development means doing the right things and in the right order as quickly as possible," says 747-8 Chief Project Engineer Corky Townsend. "Conventional planning leads people to rush their work and hand things off that aren't complete just to meet a deadline. Under process-based program planning, the idea is to do it right the first time even if it takes a little longer. The schedule adapts dynamically to highlight where help is needed."

"This represents a major paradigm shift," states Steve Holt, lean product development implementation manager for Boeing Commercial Airplanes. "In the past, program managers would set milestones for their integrated product teams, and then keep asking them whether their parts would be ready on time. Now we instead ask them, 'how much time will you need to create your part?' This alternative approach shines light on constraints from the very start. That's an enormous advantage because you can make plans to recover when you're two years out, whereas your recovery options are limited if you only find out late in the game."

Defining the future

The Boeing 787 Dreamliner program is creating an ultra-efficient jet transport that will redefine air travel. Development excellence and Lean+ processes and tools are central to this ambitious program and have been from the beginning.

"Defining a new aircraft is difficult because each time one design parameter changes so do all the rest, which requires recalculation and reevaluation," says Ed Petkus, leader of the 787 airplane development team. "It's a critical phase at the outset of development programs that we call lines, loads, and laws."

Fortunately, significant Boeing investment over the past 15 years gave Petkus and his engineering team a host of improved processes, capabilities and computational tools. They combined these with process-based planning to complete the 787's lines, loads, and laws definition in record time, shaving three full months off an 18 month time flow across two loads cycles.

"We did it by taking these new processes and tools and blending them into a seamless system based on process-based management principles," says Petkus. "It was a learning experience and an incredible performance by the team."

Rewarding the messenger

In St. Louis, the Boeing EA-18G Growler program also illustrates how Boeing is today developing its products more efficiently. Derived from the F/A-18F Super Hornet, the Growler airborne electronic attack airplane brings new capabilities to the Navy, including the ability to keep up with strike aircraft and communicate while actively jamming to suppress enemy air defenses.

Functional discipline and best practices are hallmarks of the Growler program, which surmounted technological and schedule challenges to deliver the first EA-18G to the Navy ahead of time and under budget. Effective development, supplier management and lean processes played starring roles in this success.

The Growler program brings customers and suppliers into the fold. Weekly program management meetings link all participants by phone and Internet-based collaborative tools so that everyone can see and discuss the same data charts. Because Boeing, supplier, and Navy personnel are all developing parts for the EA-18G, they are fully integrated into these meetings.

"Morale on the EA-18G program is excellent because we focus on the data," says Bob Feldmann, vice president for F/A-18

Functional discipline and best practices are the hallmarks of the EA-18G airborne electronic attack aircraft development program. Here key engineers John LaFiore, Roy Saffold and John Keaveny are pictured with the antenna test model of the aircraft in St. Charles, Mo.

programs, Boeing Integrated Defense Systems. "When you do that, it removes personalities and politics from situational reviews so that intellectually honest discussions take place."

Growler program engineers look forward to these meetings because they can talk of what they and their teams have accomplished each week. They know that any issues they raise will be dealt with.

"Today, our improved development processes have removed the 'shoot the messenger' threat,'" says Feldmann. "In fact, it's 'reward the messenger' these days because everybody knows that not raising concerns or identifying trends early enough is what can bite us."

"I don't think I've ever seen as much openness and honesty," agrees EA-18G Avionics Engineer John LaFiore. "We invite our customers to every meeting and we don't try to hide anything. In fact, we also trained Northrop Grumman – our prime subcontractor – in our business processes, and they in turn trained their suppliers, so we're all working within a consistent set of metrics."

This sharing of best practices benefits the Navy by lifting the EA-18G program to new heights of efficiency. "We now have the same visibility with our key suppliers that we have monitoring our own performance," adds LaFiore. "Our subcontractors like this new way of doing business because it helps them measure and improve their own performance."

The P-8A Poseidon: Out front

Development excellence takes many shapes. Just ask Brandon Ray, a structural design engineer on the P-8A Poseidon program in Renton, Wash. Now being developed for the U.S. Navy, the P-8A multi-mission maritime aircraft is based on the 737-800, a member of today's Next-Generation 737 twinjet family.

"As a Lean+ initiative, my P-8A integrated product team pioneered the use of data package visibility boards that display, prioritized and in one place, all the work packages we designers are responsible for," Brandon says. "All the Poseidon IPTs are using these visibility boards now because they show information at a glance that we used to have to go around and collect from different sources."

For all the benefits of standardization on optimized tools and processes, of course, a one-size-fits-all approach doesn't serve the best interests of every development program. Consequently, Boeing strives to give its engineering leaders the flexibility they need to tailor these standard best practices to the specific needs of their programs.

P-8A's Brandon Ray and team pioneered new work package visibility boards.

"After all these years and all this experience, we have a pretty good idea of what works best on the development front," says Steve Goo, vice president for Program Management and Business Excellence, at Integrated Defense Systems. Goo is also aligned with EO&T as a leader of the enterprise Program Management function. "We've also identified the things that set past developments up for failure or limited their success, so we can avoid repeating those mistakes in the future." ■

Northern XPOSURE

By Amy Reagan

Temperatures that can go from below zero to above freezing in one day . . . long hours of darkness . . . severe spring storms that produce dangerous lightning.

All this can sometimes make for difficult living and working conditions for residents of the northern-most U.S. state.

But Boeing employees and subcontractors have adapted to Alaska's sometimes harsh environment to maintain a vital piece of the United States' missile defense.

Fort Greely, Alaska, is home to about 250 Boeing employees and subcontractors as well as about a dozen interceptor missiles emplaced in silos as part of the Ground-based Midcourse Defense (GMD) program. The missiles will serve as a line of defense should the country come under an intercontinental ballistic missile attack. Fort Greely is on the eastern side of Alaska and is about 350 miles from Anchorage in the south and 105 miles from Fairbanks to the northwest.

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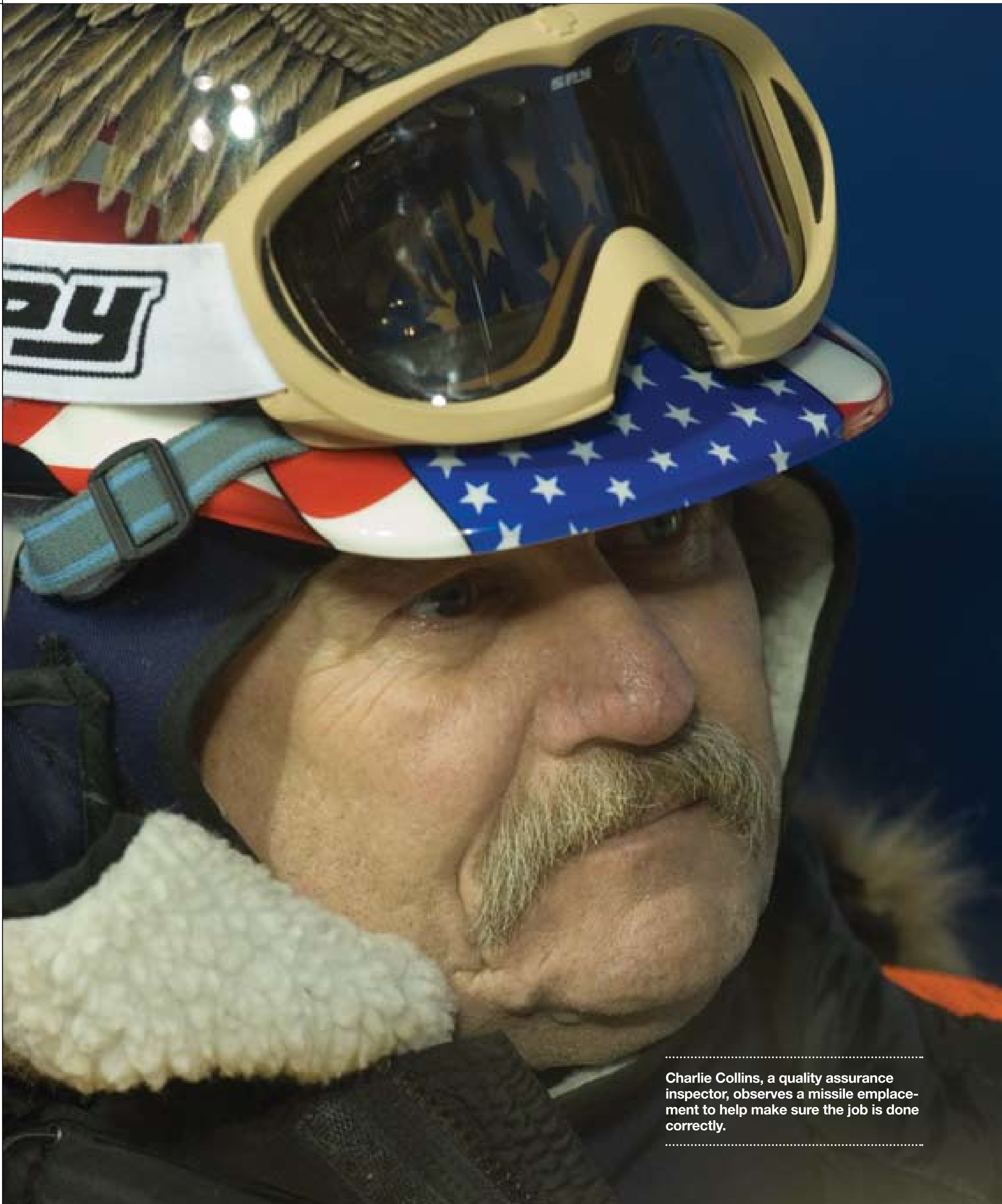
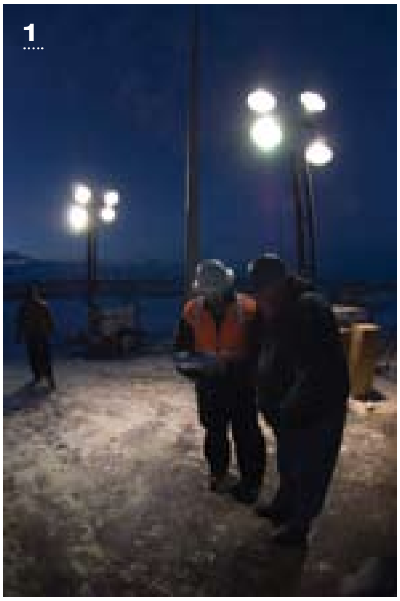
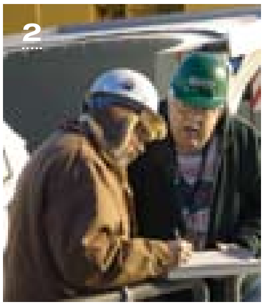
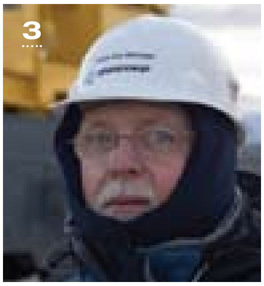
Alaska's winter cold presents special challenges for Boeing employees working on America's front line in missile defense.



Charlie Collins, a quality assurance inspector, observes a missile emplacement to help make sure the job is done correctly.







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Missile Defense Systems Director of Engineering Dan Olberding says some of the most demanding engineering environments anywhere in the world are found in the interior of Alaska. "These cold regions offer unusual challenges. Design engineers must take into account the behavior of materials, the performance of mechanisms, and numerous human factors in the extreme cold and extended periods of darkness. And Boeing's systems engineers must understand, properly specify and adequately test each element of the system for these environments."

The practical difficulties of working in Fort Greely begin with simply trying to get there. Visitors must fly first to Fairbanks, then brave the elements in a two-hour drive to get to Fort Greely. Depending on the season, travelers may encounter frigid temperatures, washed out roads, or have to negotiate moose and other large animals that cross the road.

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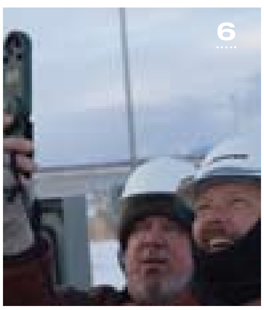

1. **Safety engineer John Lewis, and a colleague, provide emplacement support for one of the missiles.**

2. **Don Day, mechanic task leader, and John Lewis confer on top of one of the missile silos.**

3. **"Employees are very aware of safety concerns and issues," says Fort Greely site manager Scott Campbell.**

4. **Equipment being delivered by a U.S. Air Force C-17 Globemaster III transport to Allen Airfield at Fort Greely.**

5. **One of the missiles being placed.**

6. **Marshall Coyle, manufacturing manager, and John Christensen, quality engineer, check wind speed during one of the missile emplacements.**

7. **Don Day observes the operation.**

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Working at Fort Greely in temperatures that can feel like -80 degrees Fahrenheit when the wind is high is a huge switch for staff analyst Misty Merschat, who grew up in balmy Florida. "Wearing the right clothing is the key," says Merschat, who moved to Alaska with her U.S. Army husband three years ago. "And in the winter when there are up to 22 hours of darkness, you simply have to make the effort to get out and keep busy. But you soon adapt. Alaska is so beautiful, and I am so proud of our Boeing team."

Once at the base, she and other employees and guests live in comfortable, warm conditions. Outside they face almost constant hard winds with extreme temperatures in winter and sometimes strong storms and forest fires in summer. The wind often blows so hard that the portable restrooms, for example, must be tied down with steel cables over the tops and anchored with heavy, solid concrete blocks. In the winter months, employees with responsibilities outdoors sometimes can work only for 20 minutes at a time before getting back into their trucks to warm up.

"Because of the conditions at Fort Greely, employees are very aware of safety concerns and issues," says Fort Greely site manager Scott Campbell. Staying outside too long could result in frostbite or hypothermia, and the harsh conditions create great stress on structures and hardware. "Our employees know that their decisions and actions could have life-or-death consequences for themselves, their families and, in fact, the country."

Because the work at Fort Greely is of international importance, the team makes sure that the facilities and hardware all work properly in the subzero temperatures. For example, the buildings have roofs with ventilation designed to prevent blowing snow from entering the vents and to prevent ice dams from forming. Plumbing systems in the buildings must be installed underground below the frost line to avoid freezing pipes. The missile silos are temperature-controlled to protect the missiles, and special lubricating oils must be used for metal on the buildings as well as for hardware associated with the missiles.

"Necessity is the mother of invention, and the conditions at Fort Greely have forced us to come up with some creative solutions for many common engineering and maintenance problems," Campbell says. "But we all recognize the importance of this facility to the nation's defense, and we are all committed to ensuring that it will perform as required should the need arise."

Above: The 800-mile-long Trans Alaska Pipeline System stretches past Fort Greely from Prudhoe Bay on Alaska's North Slope to Valdez, the northernmost ice-free port in North America.

Left: Caribou and other wildlife, including moose and bears, are a common sight around Fort Greely.

Below: For all its extremes, Alaska offers stunning landscapes, balmy summers and outdoor adventure, making it one of America's most attractive destinations.

Mike Hoskowicz, a logistics engineer from Huntsville, Ala., travels on equipment delivery flights to and from Fort Greely.

Chief Technology Officer to lead development of integrated R&D strategies for the enterprise

New Step in R&D

As part of its long-term growth and productivity initiatives, Boeing has recently formalized a strategic process to maximize the yield of its enterprise R&D investments and ensure they are properly balanced to meet the near- and long-term needs of the company.

This step was based on a recommendation by the Development Process Excellence initiative to formally establish an enterprise-wide technology community led by Boeing's Chief Technology Officer to ensure that a well integrated, well focused, multi-year technology investment strategy is created for Boeing.

This recommendation, which was reviewed and approved by the Executive Council in October, was itself based on a review of how the business units and Phantom Works have been working together to plan and implement Boeing's R&D investment strategy each year, as well as a review of best practices and policies inside and outside the company.

The result is a more formal process in which Boeing CTO Bob Krieger will lead an Enterprise R&D Board in the review of the business units' R&D plans and the integration of them into an enterprise R&D investment strategy. To ensure that all business unit and company objectives are met, Integrated Defense Systems President and Chief Executive Officer Jim Albaugh and Boeing Commercial Airplanes President and CEO Scott Carson will review and approve the Board's enterprise strategy along with the CTO.

The Enterprise R&D Board will consist of representatives from the business unit R&D communities, Phantom Works, Business Development and Strategy, and the Development Process Excellence initiative. The charter of this board is to collaborate on producing an integrated, multi-year R&D strategy that will:

- *Allow the business units to better focus their investments on meeting the specific near-term needs of their current programs and near-to-mid-term needs of their development programs – such as those in the IDS Advanced Systems and BCA Technology and New Product Development organizations.*

- *Allow Phantom Works, as a centrally managed R&D organization, to better focus its investments on common and enabling technologies needed to meet the mid- and long-term needs of the business units, while actively assessing next-square and white-space business opportunities for the company.*

"This will be a truly collaborative process through which Boeing can attain a stronger competitive advantage and increase the yield of its enterprise R&D investments," says Krieger. "In my new corporate role as CTO, I am looking forward to working with everyone to develop better integrated R&D investment strategies for the enterprise."

The process will start with identifying core technologies that are needed to keep Boeing competitive in the future. The Board will then review current enterprise plans for maturing these technologies, identify funding or timing shortfalls, and propose approaches to overcoming these shortfalls. These approaches will become part of a strategic plan for each key technology.

This plan will also identify which sources of technology development are most appropriate to leverage, including the business units, Phantom Works, contract R&D, global partners, non-aerospace sources, acquisitions, universities, technical affiliations and the Boeing Technical Fellowship.

This strategic approach to enterprise R&D planning is being further reinforced by the functional discipline, common processes and systems, and intellectual property protection initiatives of the Engineering, Operations & Technology organization, as well as by the Lean+, Internal Services Productivity and Global Sourcing initiatives.

"As we introduce new technologies, processes and systems that can improve the cycle time, cost, quality and performance of our products, we need to share them across functions and protect them from the competition," says John Tracy, senior vice president of EO&T. "And we must leverage our global suppliers and partners to ensure we are both finding and delivering the best the world has to offer."

"All this will allow Boeing to more efficiently and effectively execute current programs and successfully compete for, and create, new ones," says Boeing Chairman, President and CEO Jim McNerney. "And these are key objectives of our productivity and growth initiatives." ■

Getting the best yield from R&D

In addition to balancing the near and long-term focus of Boeing's R&D investments, this integrated approach to strategy development will help maximize the yield of Boeing's R&D investments by:

- **Eliminating duplication of effort**
- **Replicating R&D results across the enterprise**
- **Better leveraging contract R&D and global research**
- **Ensuring the right technologies are in the right place at the right time**

Current members of the Enterprise R&D Board

Bob Krieger – Boeing Chief Technology Officer

Amy Buhrig – Boeing Commercial Airplanes Director of Technology

Ron Johnson – Integrated Defense Systems Advanced Systems Vice President of Engineering & Technology Transition

Frank Doerner – Phantom Works Vice President of Aerostructures, Manufacturing & Support Technologies

Shep Hill – Boeing Senior Vice President of Business Development and Strategy

John Pricco – Vice President and Leader of the Development Process Excellence Initiative

Through a Looking Glass Clearly

A policy of transparency and openness at Boeing Operations is leading to speedy problem-solving, greater efficiency – and millions of dollars worth of savings.

From left, mechanics Wayne Coleman and Jeff Bond work on the C-17 ramp toe rigging at the C-17 plant in Long Beach, Calif. The C-17 program has one of the best operations records at Boeing.

By Daryl Stephenson

When something is transparent, you can see through it clearly and easily – with nothing obstructing the view.

The word "transparency" comes up frequently in discussions throughout Boeing Operations about how to bring new efficiencies to the shop floor. An open sharing of data – through such things as common processes, standard work, Employee Involvement, process action teams, online systems, and joint programs between Integrated Defense Systems and Commercial Airplanes – is providing a clear window into the true status of programs.

That's seen as a vital tool in the disciplined management of programs – and the successful implementation of initiatives such as Lean+ that yield significant improvements in cost, quality and cycle time. More and more, problems are raised widely and early, which leads to help and solutions being provided just as quickly. That results in significantly lower costs for implementing change.

Flap mechanic Steve Averill, left, who installs 737 wing flaps and flap track fairings, is shown with Chip Bonner, lead aircraft readiness log inspector, who verifies part and serial numbers on the 737 final assembly floor in Renton, Wash.

"One of the strategies for functional discipline is to create a culture of transparency and openness so everyone can make decisions using the facts and data," says Steve Goo, IDS vice president of Program Management and Business Excellence, who is

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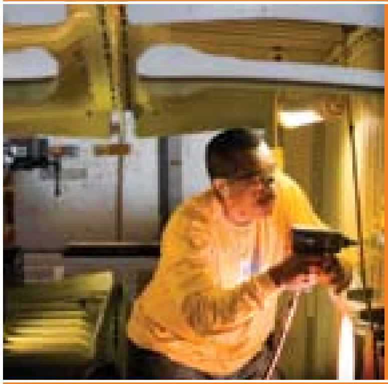
Streamlining the C-17

At the C-17 program in Long Beach, Calif., engineers and manufacturing employees are working side-by-side on the factory floor to produce an efficiency record that is the envy of the industry.



Mechanic Rube Smith works on a C-17 wing half join.

"We have true employee ownership in the assembly build process," says Bob Stanger, director of C-17 Operations. "Lean techniques have been built into every step of the process – and the employees are fully involved in leading the effort." So far, 161 C-17s have been delivered to the U.S. Air Force and the Royal Air Force of the United Kingdom.

"Seven years ago we located everyone involved in the build process here in the shop," says Eusebio Gomez, director of Technology Integration and Lean Manufacturing, as he walks through the various work positions. "That way, we have a totally integrated team – engineers and manufacturing employees working together permanently, solving problems immediately."

Through employee involvement and "design for manufacture," the team is constantly identifying areas where savings can be made and re-engineering parts of the airplane to make them easier to build. Now, major assemblies use fewer parts, and several of them arrive already completed from St. Louis.

Engineers are continuously working to reduce weight: the metal tail has been replaced by a lighter composite tail, and the aircraft is now equipped with new landing gear doors that are stronger and more durable than the existing doors, and easier and cheaper to produce.

Factory floor space is expensive to maintain, and efforts have been under way to better utilize it. In the final assembly frontline area, for example, the team managed to save 168,000 square feet of assembly area – a 44 percent reduction – through lean efforts that reduced cycle time and the need for two parallel positions. Through what are called "ergonomic blitzes" and the use of technology in the workplace, the team is saving time and effort as well as reducing on-the-job injuries simply by making work easier and more efficient for assemblers.

Continuously updated electronic progress charts have replaced traditional paper at each of the positions. Lighter and more efficient tools – drills, rivet guns and hoses, for example – have speeded up assembly time and given the machinists better access to assemblies.

"We are a process-driven organization, and it is paying off for our team and the customer," says Stanger.

Sealer Barbara Rogers applies anticorrosion sealant to the 737 wheel well. 737 engineers have adapted a technique used on the F/A-18 to make installation of the wheel-well hydraulics more efficient.

Wheel-well hydraulics assembly techniques shared across programs

Installation of hydraulic tubing and associated parts in the main landing-gear wheel wells of the Boeing 737 traditionally has been a difficult, costly and time-consuming job.

Four mechanics, working in a confined space, install more than 2,000 parts, including about 350 tubes. They perform more than 750 torque operations in roughly two shifts. Currently installed piece by piece, many of these tubes are layered with other systems and interlaced with electrical wire bundles.

After the installation is completed, the hydraulic system undergoes what's known as the "Oil On" functional test to check for leaks. Because the installations are complex and the access to fittings is limited, leaks (as many as two or three) are common during this test. Usually, a tube connection only requires additional torque to correct the leak. Considerable effort is then required to clean the affected area of the wheel well.

Now, the 737 Hydraulics Value Stream team in Renton, Wash., believes there is a better way – transform the piece-by-piece installation of the hydraulic tubing and components into modules assembled off line. This moves most of the effort off the airplane and out of the critical path of Final Assembly.

The goal for this new process is to reduce installation time for the 737 wheel well hydraulic tubing by as much as 80 percent, says Edward White, 737 project manager for the modular installation development. And the inspiration for this concept, he points out, came from the Boeing Integrated Defense Systems F/A-18 Super Hornet production team in St. Louis.

White's team was formed within 737 Final Assembly to pursue the idea of a modular approach for installation of the wheel well hydraulics. About a year ago, during a Metals Assembly Technology Exchange, White and another member of his team saw a presentation about a nose landing gear wheel well hydraulics pre-assembly project on the F/A-18 program. "It acted as a nice catalyst, and we shared what we learned with our Hydraulics Value Stream Team in Renton," White recalls.

Then in April this year, several members of the Hydraulics Value Stream team visited St. Louis to observe pre-assembly work and installation of hydraulics in the F/A-18 nose-gear wheel well. They also noted that the F/A-18 team was using special fittings, less likely to leak because they eliminate the torquing operation that can be difficult in restricted areas. They also have a visual indicator that ensures proper installation before functional test.

Armed with first-hand knowledge from the F/A-18 program, the 737 wheel well team is designing new assembly processes for the hydraulic tubing, parts and equipment. These processes call for pre-assembling the hydraulic tubes, parts and equipment into modules away from the main 737 line, a sequenced installation of these modules, and the use of the axially swaged fittings.

The new process is expected to make it easier to access and install hydraulics system components in the wheel well, to significantly reduce the amount of touch labor and improve the quality of the installation.

Working with the Rapid Prototyping Centers in St. Louis and Seattle, the team constructed a full-scale mockup of the main-landing-gear wheel wells, stuffed with tubes, components and equipment. They are using this mockup to develop and integrate the various pre-assembly modules to work out issues before the new process is implemented in production of the 737. The team hopes to be able to do that early next year.

"It's been a real team approach," says White. "Engineering, manufacturing, mockup, Material and Process Technology, Lean support personnel, and customer support engineers – all these functions and more are working together to apply new ideas and drive improvements. This allows us to design and integrate a dramatic improvement such as this that otherwise would not have happened."

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also a leader of the enterprise Program Management function within Engineering, Operations & Technology. "Get it out there in the open, so we all know what is going on."

Then, he says, if a program is in trouble, "we can see where the struggles are and we can get the team the help it needs. We encourage that kind of culture. If you're a program manager and you need help, we must know about it. Programs are hard, and we know there will be problems."

An example of transparent data-sharing of program status is an online tool called Track Plan, which provides up-to-date metrics on all production programs in St. Louis. Developed about four years ago by St. Louis industrial engineers when the C-17 pylon team implemented a pulse moving line, Track Plan electronically displays color-coded, easy-to-read charts to indicate how far along work is in regard to parts and assemblies. The system is updated every hour.

"It's like a scorecard that gives you a complete picture," says Chandler Varma, an IDS manager in Industrial Engineering. "It shows cost, compliance to planned work sequencing, quality, and things that need immediate attention. If there are problems, you can see where they are quickly – in real time – and then the problems can be addressed immediately."

Shop floor employees, engineers, business operations people – anyone with a stake in a production program – are able to access Track Plan, which replaces paper status boards that used to be displayed in work areas. Efforts are under way by Varma's team to share Track Plan with other Boeing sites.

The sharing of information, processes, innovations and best practices across Boeing is the basis for Process Action Teams, or PATs, that have played a major role in saving money for Operations since 1998.

"The job of these Process Action Teams is to look across the enterprise, find the best technology, the best processes, and the best practices so that we can all get better at it every day," says

Brian Kuntz, a sheet metal assembler and riveter trims and fits a fairing on an F/A-18E/F in St. Louis.

Jim Morris, Boeing Commercial Airplanes vice president of Engineering, Manufacturing and Operations. Morris is also a leader of the enterprise Program Management, Engineering and Manufacturing functions within EO&T. "We've used them frequently as we've developed the 787 in a search for the best ideas."

Richard Van Gels, C-17 production operations specialist, left, and Tom Guenther, final install mechanic, standing above the C-17 engine and pylon in the final assembly area, discuss details of an operation.

Boeing Operations has nine PATs that include representatives from both BCA and IDS. The PATs share best practices and lean principles "by the commodities we manufacture," says John Van Gels, Integrated Defense Systems vice president of Operations and Supplier Management. "For example, we have a structures team, a field and ramp team, and others." And in the eight years they've been functioning, the PATs have saved Boeing almost $1 billion, Van Gels asserts.

The PATs also have played a major role in standardizing the Boeing quality management system across the business units and with suppliers, says Barbara O'Dell, BCA vice president of Manufacturing. Thanks to the PATs, the international quality standard AS9100 (which applies specifically to the aerospace industry) has been adopted across Boeing.

Now, there's a common understanding of processes and a much more streamlined set of procedures to follow," says O'Dell.

The PATs are just one area in which Morris, Van Gels and their respective Operations teams work together. "We go over succession plans so that we can move the best people to the right

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Mark Weiler, aircraft production mechanic, installs a left-hand main landing gear assembly at F/A-18E/F final assembly in St. Louis. The F/A-18 Super Hornet program, always ahead of schedule, underweight and within budget, has long been considered a model acquisition program.

Flight-line operations have been making a major contribution to efficiency efforts at Boeing. Jack Jones, director of Everett Field Operations and Deliveries and leader of the Field/Ramp Process Action Team in Washington, stands in the rain behind a Boeing 777 bound for delivery. His PAT, one of nine at Boeing, has focused on the sharing of best practices with the emphasis on lean throughout the enterprise flight-line operations. The team has helped place work at locations that offer the best cost and schedules, and provide skills and support where needed.

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jobs," says Van Gels. "We look at people at IDS and BCA who can be moved back and forth. There are more than 500 IDS engineers working on the 787 program, for example. And we have some Technical Fellows from BCA helping us in IDS with special projects."

The exchange of information and ideas between IDS and BCA can lead to novel solutions to long-standing problems.

Morris describes the cooperation between IDS and BCA Operations as "a great working-together relationship," which is enabling Boeing "to provide products and services to our customers that no one else in the world can provide." He cites the P-8A Poseidon Multi-mission Maritime Aircraft program as another example of that relationship. "Here we have a 737 airplane modified to support a U.S. Navy mission, and IDS and BCA have worked closely with the Navy to define the requirements to figure out what we have to do. The same kind of synergy is starting to emerge on the military tanker program, where we will use a commercial platform."

Sometimes, the exchange of information and ideas between IDS and BCA can lead to novel solutions to long-standing problems. BCA's 737 production team in Renton, Wash., for example, is implementing a new process adapted from the IDS F/A-18 Super Hornet line in St. Louis to reduce the time and cost of installing about 350 hydraulic tubes and more than 1,000 associated parts in the wheel well of the 737 main landing gear (See page 24). The solution is to convert the assembly, traditionally a labor-intensive operation, into a modular preassembly away from the main line. It's hoped that final assembly installation time for 737 wheel well hydraulic components will be reduced by 80 percent.

"Think about what could happen if we could replicate that kind of example throughout the company," says Morris. "How much more competitive would we be and what great products would we be able to produce?"

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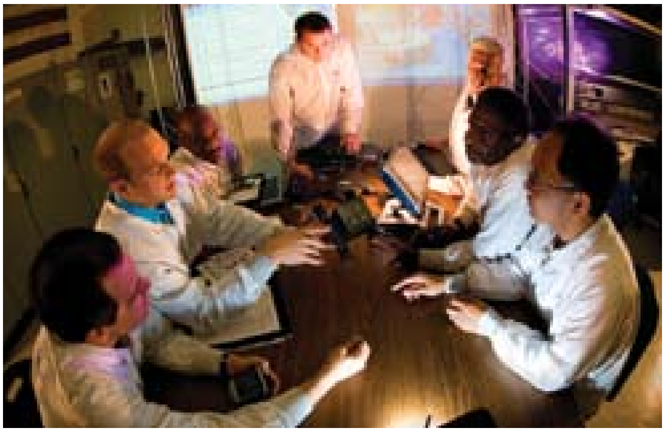
A major contributor to improving efficiency at Boeing Commercial Airplanes Operations is the use of moving production lines.

"The best example we have of that is the 737 moving line, which is a great example of lean," says Morris. "The 737 moving line has reduced our cycle time by 50 percent and our inventory by more than 60 percent."

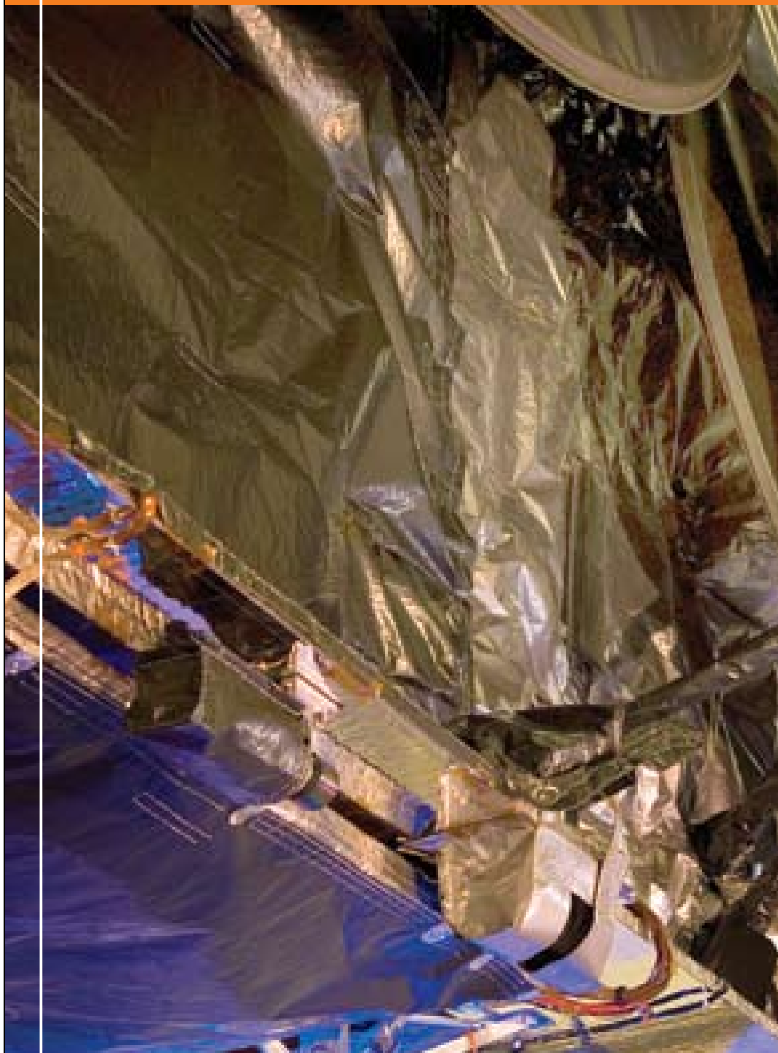
The 737 main production line became fully operational as a moving line in 2002. Because the moving line has been so successful, BCA Manufacturing has been working to apply the moving line concept to other lines as well. The 777 line became a moving line in early November 2006 and, down the road, the 787 production line also will be a moving line, says Morris. "The moving line has really been the best tool that we know of to eliminate waste in the production system," he says.

Today, teams throughout Boeing are "exporting all these great tools and processes around the company and to our suppliers around the world so that they can just get better all the time and be able to better support us," says Morris. "And the payoff is that we're having a very healthy business that allows us to reinvest in our future. Our productivity is enabling our growth. And we are producing the best set of products and services to satisfy our customers around the world."

Boeing Operations is becoming an organization that is dedicated to "developing people that have the expertise of building, managing suppliers and understanding quality requirements for new programs," says Van Gels, who is also a leader of the enterprise Operations Supplier Management functions within EO&T. "We're moving in the direction of becoming a multi-talented organization, in which people have experience with different programs. The more experience you have, the better off you are. It's all about continuous learning. There's no holding people back when they have all this great experience." ■



Shop floor technicians and support personnel performing a tabletop review of a new manufacturing task using 3D visualization in an advanced collaborative environment at the Satellite Development Center in El Segundo. From left are: Bill Baldwin, Travis Brown, Ted Lumpkin, Chris Walker, Paul Claussen, Ron Ward and Mario Ponce.



Inspector Sandy Santiel, left, and Integration Manager James Garrett check out a DIRECTV satellite being assembled at the Satellite Development Center in El Segundo, Calif.

The El Segundo satellite operation: A model of efficiency

Lean initiatives have become a way of life at the IDS Satellite Development Center (SDC) in El Segundo, Calif., where at any given time more than a dozen powerful satellite spacecraft – including some for DIRECTV – are in varying stages of production.

"We are in a very competitive industry," says Tim Miller, Employee Involvement and Lean Operations director. "Quality and cost are critical to every program and customer, so we are aggressively implementing an integrated improvement strategy comprised of lean, employee involvement, theory of constraints, and six sigma throughout the SDC."

For example, lean efforts have reduced cycle time in the final assembly area for the DIRECTV satellite program that will beam programs from space into millions of homes. The program's lean team ran a "reverse planning" workshop where members started with the desired end result and worked backwards. This produced a true network-planning document that determined the optimal sequence for many complex operations. With this, the program was able to identify the desired planning path for DIRECTV spacecraft antenna integration and deployment operations, thereby maintaining a correct sense of which task should take priority.

Through a Looking Glass Clearly

But it's not just the major programs that can claim the greatest improvements. A small team of Electronic Manufacturing technicians who build electronics systems for a number of different satellite programs were voted best-in-class by outside lean experts. They have reduced their work area by 50 percent and improved efficiency by 30 percent.

Much effort goes into making things simpler during the design and build process at the SDC. The Manufacturing Assembly & Test Proof of Concept lab center is working on a variety of high-tech ways to help people

Electronic assembler Irene Gomez is a member of a team was voted best-in-class by industry lean experts The team builds electronics systems for a number of different satellite programs.

do their jobs more efficiently. They educate and train the employees at Satellite Development Center as well as suppliers, contractors and customers.

The devices they have come up with include wearable computers, a four-screen monitor system that allows technicians to save time by looking at multiple sets of data at the same time, and in 3-D illustrated work instructions that enable manufacturing technicians and engineers to "walk through" an assembly operation before they start doing it for real.

In satellite electronics every component, slice and unit is photographed using digital photography. This photographic documentation is used for anomaly resolution as well as a training aid. SDC builds extremely reliable hardware, but should an anomaly occur, one of the first items of documentation that is used in the investigation is the digital photograph. As the saying goes, "a picture is worth a thousand words."

One recent improvement is the collocation of the photographic equipment and photographers inside the factory. The hardware no longer has to be repackaged and expedited to the photo services room. This significantly cuts down on cycle time, reduces costs and eliminates many of the opportunities for damaging the hardware due to mishandling.

Kathy Erlick

Kathy Erlick has what some might consider a daunting goal – to keep a Boeing promise to make engineering more efficient within Global Mobility Systems at Integrated Defense Systems in Long Beach, Calif. To help streamline processes and tools within the 10 engineering functions, she needs every ounce of her education and training in systems engineering and project management – not to mention a doctorate in organizational leadership. She inherited her dad's engineering spirit. "It was born in me," she says. But she discovered her most important talent as a child – relating to people who have differing views. "Building a winning team means drawing out the best in people," she says. "It's about involvement. Everybody wants to feel that they are contributing to the solution."

Across Boeing, engineers, technologists and manufacturing people are helping the company to meet its commitments to customers.

Promises Kept

By William Cole

When Boeing promised airlines a next-generation jetliner that would reduce fuel costs by 20 percent, its design engineers came up with the 787 Dreamliner. When the company promised the U.S. Navy a new electronic aircraft that could suppress enemy defenses, designers created the EA-18G Growler. When Boeing promised the U.S. Air Force increased communications and bandwidth capabilities, engineers created the Wideband Gapfiller Satellites program.

"Delivering results shows that promises made are promises kept," says John Tracy, senior vice president of Boeing Engineering, Operations & Technology. "Who stands behind us when we make a commitment to our customers in the Pentagon, to the airlines or to our space agencies? It's our employees – people of every background, experience, talent and skill – who work in our factories, our labs and our offices. They have set high expectations for themselves. They're proud of their work. They care about Boeing and its customers. They get the job done. They keep their word."

Meet a few of Boeing's 156,000 teammates who explain how proud they are about helping Boeing to meet its commitments to customers and beating the competition.

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Alex Velicki

How does Boeing produce advanced structures that can better withstand battle damage in, say, a C-17? Or create a lighter, less-expensive commercial airframe for the future? It calls on advanced structures experts like Phantom Works' Alex Velicki in Huntington Beach, Calif., who is working on second-generation composite designs. "We borrowed an approach from the recreation industry, which builds tents and boats," says Velicki. "Using similar techniques, we developed a one-piece composite panel design with highly efficient load paths and stitched interfaces to arrest damage. We can infuse it with resin and cure in an oven, all without the use of interior moldline tooling. We took some existing ideas, applied them to aerospace-grade materials, and then moved it forward."

Olga Sevostianova

She was once a stress analyst for the renowned Russian Tupolev Design Bureau in Moscow. Now Olga Sevostianova is among the 1,200 Moscow-based Boeing Design Center engineers helping the company to deliver on its commitments to Commercial Airplane customers across the world. She was named Engineer of the Year at the center in 2005. A Boeing employee for six years, Sevostianova sometimes travels to Puget Sound in connection with her job as stress lead engineer working with the assembly team on the 787. She enjoys teaching, and learning in Russia and the United States. “We have so many young engineers so eager to learn,” she says. “The range of talent at Boeing is extraordinary. I’m learning new things every day. This is an exciting company to work for. We have a great future.”

Amy Helvey

Mention metallic processes to Amy Helvey and her eyes light up. “It’s at the heart of our aircraft and other products,” she says. A consistent winner of her grade school math competitions, Helvey knew that engineering was for her at an early age. “I watched airplanes take off and land when I was a child,” she says. “Being fascinated by flight led to my being fascinated by the complexity of the internal structures of aircraft.” Now, as manager of the metallics additive process at Phantom Works’ advanced manufacturing facility in St. Louis she is helping the business units by figuring out better ways to produce metal parts. “New ways of building up titanium is the big push in our industry now,” she says. “I love R&D work, and R&D people. This is a great place.”

Candice Smith

As a key member of the Combat Systems team at IDS, Candice Smith is helping to keep a Boeing promise to provide the world's best capabilities to the U.S. Army. After high school, she was planning to join the U.S. Air Force. Then she received help from a guidance counselor who introduced her to a minority engineering program at Southern Illinois University. She joined the Army National Guard as a military policeman, won a scholarship from SIU, and now is working in St. Louis as a systems engineer. "I'm so glad that I took that opportunity," she says. "I'm the first college student in my family. My parents were so proud and happy for me." Now, she's trying to help other youngsters."I want to help them achieve their dreams just as others have helped me."

Eusebio Gomez

By leading a major efficiency effort on the C-17, Eusebio Gomez is helping to keep a Boeing pledge to the U.S. Air Force to bring down costs. Gomez thrives on the challenge. But Boeing's drive for diversity – in products and people – has also played a big role in his enthusiasm for the job as director of Technology Integration and Lean Manufacturing at the C-17 plant in Long Beach, Calif. "There is an immense variety in our products, and they are being created and produced by a remarkable blend of people," says Gomez who began working on the program 17 years ago as an industrial engineer. "It all starts and ends with our employees," he says. "Without them we can do nothing. Working with the people on the shop floor to affect change offers the greatest reward. I am proud of them and proud to work on this program."

Gary Wright

Boeing customers look to Gary Wright to make sure that the wing structures for the 747-8 intercontinental and freighter aircraft can be built to meet performance goals. “This is somewhat similar to building a home. I have to let the customer know what’s possible, in engineering terms,” says Wright, chief wing structures design architect for the 747-8 in Everett, Wash. “And that sometimes means inventing new processes and building new tools, materials and facilities to get the work done. There are many different things we are doing inside the wings and in the way we build them to make them more efficient.” Wright grew up in an airplane family – “my dad was a mechanic and pilot” – and was intrigued by aerospace at an early age. “This is more than a job,” he says. “It’s a passion.”

Melissa Lorenzen

Boeing promises to provide space satellites of the highest quality to government and commercial customers. Melissa Lorenzen, an electromagnetic compatibility engineer in El Segundo, Calif., is in a pivotal position to help. She supports the design teams who create the “brains” of the satellites – radio frequency, digital and processor units. “I work closely with the designers to make sure the unit will pass EMC testing in the lab once it is built,” she says. Her love for mathematics and physics led her to major in engineering at the University of Southern California and to her Boeing career. But she’d like to take a leadership role working with people. “You can learn far more from the people around you than from reading a book,” she says. “People, not theories, provide solutions.”

Gary and Mike Renieri

They've led parallel lives and careers, and it's hard to tell them apart. But identical twins Gary (left) and Mike Renieri of St. Louis are making individual efforts to help Boeing keep its pledge to customers. Gary works on systems design reviews for Combat Systems at IDS; Mike works on structural composites development for Phantom Works. They joined Boeing in 1976 and each became Technical Fellows. "We didn't plan it this way," says Gary. "We grew up interested in the same things." Mike says, "When we're working on technical issues we can help each other fill in the gaps through the strong synergy between us." Both are proud to be helping Boeing "give customers the best products they can lay their hands on."

Terra firma testing

By Chas. Dowd

The fledgling 787 Integration Test Vehicle, or ITV, just beginning to spread its wings in Seattle, is the latest member of a flock of "Iron Birds" – land-based test fixtures – first hatched by Boeing in the 1960s. A 75-ton hybrid test rig made up of actual components of the flight control and hydraulic systems linked to three test benches of system software, the ITV makes sure all parts of these crucial systems work together seamlessly.

Len Inderhees, program lead for the 787 Integrated Test Vehicle, at the flight deck in Seattle. In the background is the high bay where actuation and hydraulic components are located.

Many of the new ITV features support the shortest development time in Boeing history, explains Jim Draxler, ITV Integrated Product Team leader. "The 777 Flight Control Test Rig could only run one test at a time," Draxler says. "There are three test benches in the 787 ITV, so we can run three tests simultaneously. It's the only way we could meet the 787's compressed schedule."

The schedule also made it necessary to design the tests and the ITV concurrently with the aircraft design. The goal is to keep the ITV about eight months ahead of the airplane. "Sometimes we had to guess where development was going to have the testing ready when the test article arrived," says Len Inderhees, technical lead for ITV Design and Operation. "Sometimes we guessed right. When we didn't, it meant we had to work to catch up." Inderhees also says that the kind of test being run has changed a lot. Today the majority of the testing involves software, a change from earlier iron birds that concentrated on hardware.

New control techniques change the ITV

In the control-by-cable era, when there was a direct connection between the controls and the assemblies they controlled, the test vehicles were laid out like the aircraft. In today's fly-by-wire environment, they don't have to be. "I remember going through the 767 electro-mechanical test vehicle," Draxler says. "It was in the corner of the factory up in Everett. You had to crawl over and under structures and a lot of things were hard to access. Here everything's out where it's convenient. It has a much smaller footprint than even the 777 Flight Controls Test Rig."

The 787 ITV components were designed together by both the suppliers and Boeing and then built by the suppliers. At the same time, suppliers built a duplicate rig for their facility so problems uncovered in Everett tests could be replicated in the supplier's factory.

"The rigs were a challenge," says Inderhees. "Every company and country has its own engineering customs – their own ways of mounting test articles, making connections and safety precautions.

Dave Roberts, lead for the ITV simulation test systems, at an ITV test conductor workstation.

The first thing we had to do was establish a set of common interfaces so the rigs from different suppliers worked together."

ITV testing is aimed at finding any integration problems before they're built into the aircraft, giving suppliers a chance to correct them. "We're engineering correct operation into the plane from the very beginning," Inderhees says. "It's a lot cheaper than going back and fixing things during or after construction." He also points out that once it's been tested in the ITV, there's less need to test on the airplane and verify it in flight to satisfy the FAA.

Testing the untestable

Like the wind tunnels, the ITV lets engineers test things they wouldn't dare test on an aircraft in flight. "All of our vital systems feature triple redundancy," explains Inderhees. "You don't want to go up in an airplane and disable every combination of the two layers of redundancy to make sure the third one works. We can also make sure that the second level of one system can work with the third level of another."

Inderhees pointed out that the ITV is one of the concepts that underlie the Boeing core competency in large-scale integration.

Brian Cohen, engineer for the hydraulic, landing gear and actuation rigs, in the ITV high bay.

"The 787 ITV represents a very different kind of integration test facility from even the one we built for the 777," he says. "The lessons we learn on this one will be applied to the next testing rig for the next generation of aircraft. It's a constant evolution." ■

Experience meets the next generation

The Integrated Test Vehicle team is as unusual as the ITV itself. Because of the boom-and-bust cycle of the aircraft business, the 10- and 12-year engineers were gone, so the ITV was created by a team of 20- to 25-year veterans and new engineers just out of college or grad school. With the compressed schedule, the younger engineers weren't eased into the job: they were handed major responsibilities the minute they walked in the door.

"In college they taught us engineering fundamentals. We learned how to learn about engineering. But we had to learn practical applications here," explains Rowena Beaudry, an engineer of only a year who works with newcomer Brian Cohen on hydraulic systems.

"We knew we'd have to do some training," says Jim Ouderkirk, a Boeing electrical engineer for 25 years. "No college curriculum teaches how to build this kind of simulator. Plus we're really trying to reverse engineer an aircraft that hasn't been completely designed yet."

"They needed very little hand-holding and learned our processes and airplane systems very quickly," says Ron Sanders, a 20-year veteran. "They brought tremendous energy and enthusiasm, and cranked out a tremendous amount of work."

"Sometimes they made us rethink the way we did things," says John O'Brien, who has 26 years of Boeing experience. "We've written specs for drive stands before, for instance. We gave Brian some previous specs, and he expanded them, writing in things we'd missed before. And they're the computer generation. They taught us a lot about e-mail and instant messaging," he says with a grin.

Both newcomers and veterans agreed that the mix was a bonus. "We need these young people – and lots more of them," jokes Ouderkirk. "Otherwise we'll never be able to retire."

Boeing is becoming more nimble, global and efficient through the deployment of standard processes and systems.

Standards PAY

In Everett, Wash., from left, Garry Herzberg , an Associate Technical Fellow with Boeing Commercial Airplanes, Renée Marley, a Boeing IT project manager, and Paul Dodd, an Associate Technical Fellow with Boeing IT, discuss how to adapt a wireless system used in 777 production for use on the 787 Dreamliner. It's one example of how Boeing IT is working with Boeing business units to develop standard processes and systems.

By Tom Koehler

After the mergers of Boeing, McDonnell Douglas, Rockwell, Hughes Space and Communications and others, the company's many Information Technology organizations took inventory of all of the IT systems in the new Boeing. The objective: to determine how many systems there were, understand system overlaps and gaps, and agree on the right systems to carry the company into the next decade.

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What they discovered was a complex collection of business processes and systems that varied by business unit, program and site.

Employees in the predecessor companies created similar products and services, but the business processes used to perform the work were developed by different people at different times. Consequently, the IT systems in place to support the business processes also were different. For example, McDonnell Douglas engineers used different computer-aided design systems from Boeing engineers, and Rockwell supplier management employees used different purchasing systems from Hughes procurement agents.

Complicating matters further, programs within the various companies often performed similar work differently. Employees who built fighter jets in St. Louis, for instance, used different processes and systems from those used in Seattle for commercial airplanes, or those used in Southern California for cargo airplanes. Employees who worked on defense programs in most cases used completely different processes and systems from those of their counterparts on the commercial or space sides of the enterprise.

There was even variation between sites. Employees in Renton, Wash., put together single-aisle 737s and 757s using different processes and systems from those used by employees in Everett, Wash., who put together 747, 767 and 777 twin-aisle airplanes, or employees in Long Beach, Calif., who assembled 717s. In Wichita, Kan., where major airplane components were assembled, people used different processes and systems from those used anywhere else.

"We learned that we had more than 8,000 different systems across the enterprise, and every one of those unique systems supported a unique business process," says Scott Griffin, Boeing chief information officer and leader of the company's Information Technology organization. "As Boeing looked to the future, we knew we needed to be more nimble, global and efficient in order to compete effectively. We knew that we could not make that transition with our current collection of complex and redundant processes and systems."

Boeing IT: an enabler of change

Boeing is becoming more global and collaborative, working more closely with suppliers around the globe. On the high-profile Boeing 787 Dreamliner program, for example, suppliers in the United States, Asia and Europe are active, risk-sharing partners in the design, fabrication and assembly of the airplane. They collaborate real-time on design across geographical and company boundaries.

Boeing must also become more nimble, allowing it to react more quickly to changes in market conditions. "One key requirement is the ability to quickly move experts to new programs," Griffin says, adding that "we can't do that in today's complex environment of unique processes and systems."

Enterprisewide standard processes and systems allow workers to be immediately effective when they move from one part of the company to another because they do not have to learn new processes and systems.

Boeing IT has several roles in the new Boeing, says Griffin, whose IT organization is part of Engineering, Operations & Technology (EO&T).

"Job one is to support the production requirements of the global enterprise – seven days a week, 24 hours a day, 365 days

IT support of the Boeing initiatives

Scott Griffin, chief information officer and leader of Boeing's Information Technology organization, says that IT standardization efforts support all four of the company's growth and productivity initiatives in the following way:

- **Internal Services Productivity**
  Reduce IT costs year over year, regardless of the company's growth or the growth in IT statement of work.
- **Lean+**
  Define a small, standard set of business processes and systems.
- **Global Sourcing**
  Drive down the cost of purchased IT services, currently more than $1 billion per year, regardless of IT statement of work growth.
- **Development Process Excellence**
  Deploy Boeing program management best practices to manage enterprise IT development projects.

a year," he says. "We maintain the systems and IT infrastructure that keep the company's programs running around the globe. We also protect the company's information resources by making them secure. Equally important are our efforts alongside the enterprise functions – Engineering, Operations, Supplier Management, Human Resources, Finance and other organizations – to move the company to standard processes and systems.

"Boeing IT is helping the company transform itself into a lean, global and collaborative enterprise."

In 2000, under Scott Griffin's direction, the many IT organizations of Boeing began work on a five-year initiative to deploy a standard IT infrastructure and to reduce the company's systems complexity by 25 percent. By 2005, the company had been able to reduce computing cost as a percentage of sales by 25 percent.

"Today our IT infrastructure is common across the enterprise, and we have reduced our applications by one-third," Griffin says. "This progress is the result of good working-together relationships between Boeing IT, the enterprise functions and

Don Imholz, Boeing IT vice president of Systems: "We have a target of 1,500 systems by 2010, down from the 5,000 systems we have today."

the business units. But we still have a lot more work to do toward standardizing our business processes and reducing the complexity of our IT solutions."

The 'forward-looking' architecture

In 2006, EO&T broadened its focus, and Boeing IT stepped up to an aspirational target. Griffin and his Boeing IT team were challenged to develop a "forward-looking IT architecture." The assignment was to start with a clean slate and define the IT architecture of a more global, nimble and collaborative Boeing. The result was a radically different "go forward" plan for both business processes and systems

"The 'forward-looking architecture' is now part of our vernacular at Boeing," says Barb Claitman, former IT director of Enterprise Architecture and Integration, who is now leader of IT for Commercial Airplanes. "We talked with people throughout the company, as well as our suppliers and consultants, and we asked a lot of questions. What should be our standard process for releasing three-dimensional engineering models to our suppliers? How do we want to collect and re-use that data ourselves at Boeing?

"Developing our IT architecture is a lot like putting together a master plan for a community," Claitman says. "We're not designing a single house – we're designing what we want the whole community to be. Where do the roads need to go? What utilities do we need? How do we want people interacting?"

"The 'forward-looking architecture' is now part of our vernacular at Boeing," says Barb Claitman, vice president of IT for Commercial Airplanes.

"This forward-looking approach resulted in a target of 1,500 systems by 2010, down from the 5,000 systems we have today," says Don Imholz, Boeing IT vice president of Systems. "For example, we took a hard look at the number of purchasing systems and asked, 'Do we really need 12 different processes and systems for purchasing?' "

"We would like to get to one or two purchasing systems that support the purchasing needs of both the commercial and defense sides of our business," Imholz says.

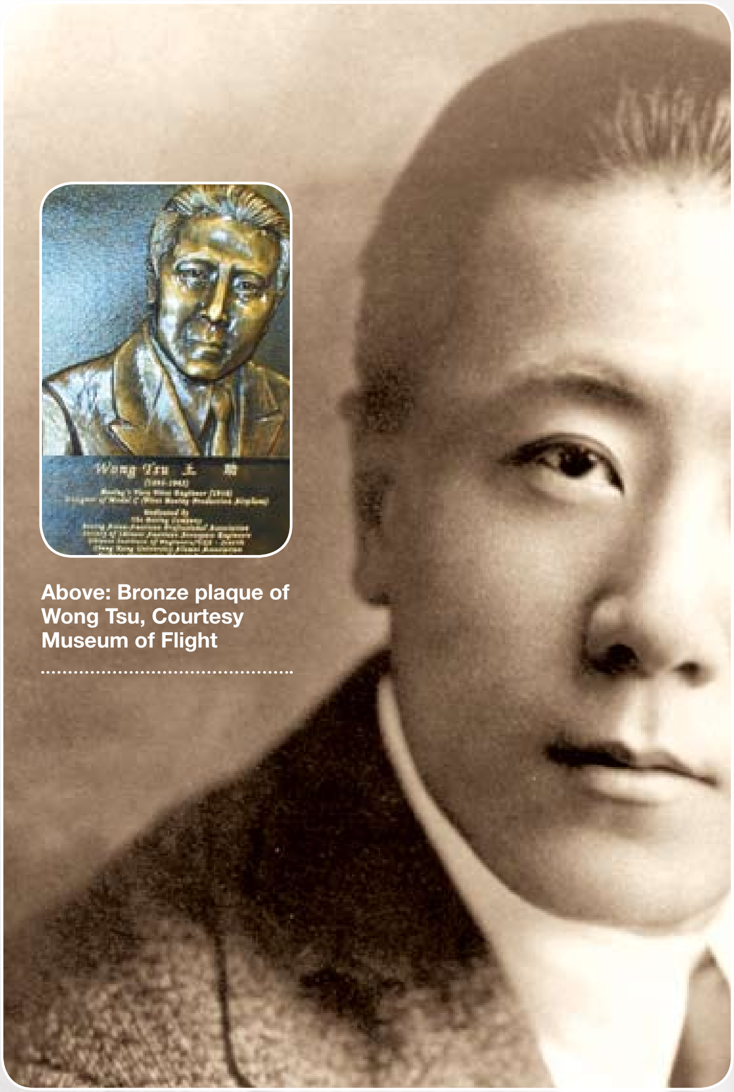
When a forward-looking system is selected, the goal is to replicate its use and eliminate redundant systems. Boeing program and project management professionals and financial analysts throughout the enterprise will be using a standard software toolset for integrated scheduling and earned value management activities.

The Cost Schedule Planning Reporting (CSPR) system was adopted in September as a standard by Commercial Airplanes, and had already been in use in Integrated Defense Systems. The new CSPR standard replaces several other scheduling and earned value management software tools – and its adoption is in line with Boeing's Internal Services Productivity initiative, which is driving the elimination of redundancy and capture of internal cost savings.

One of the key roles of EO&T is to "accelerate the deployment of standard processes and systems," says John Tracy, senior vice president of EO&T. Tracy is responsible for Boeing IT, Phantom Works and Intellectual Property Management, and also leads the enterprise Engineering, Operations, Supplier Management, Quality Assurance, and Program Management functions.

"Our goal is to promote 'functional excellence' within the company's major functional areas, and to deploy a lean set of standard processes and systems across the enterprise," Tracy says.

"We are committed to enabling a more nimble, global and efficient Boeing," Griffin emphasizes. "Our vision is to deliver integrated IT solutions that support revenue growth and improve the productivity of the enterprise. We will give people the information they need to do their jobs, replicate IT best practices, and help launch new programs with tried-and-true processes and systems. And we will work hard to capitalize on the best IT people wherever they are in the world." ■



Above: Bronze plaque of Wong Tsu, Courtesy Museum of Flight

Chinese-born Wong Tsu was The Boeing Company's first engineer and helped put the company on a sound footing.

The 1ST ...and the Best

By Eve Dumovich

A fledgling Boeing Airplane Company got an industry footing in the early 1900s, due largely to the creative talents of its first engineer – a Chinese graduate of the Massachusetts Institute of Technology.

Wong Tsu, born in Beijing, in 1893, designed Boeing's first mass-produced product – the Model C training seaplane. The airplane went on to become Boeing's first financial success. He also introduced aviation innovations on two continents, and set the stage for Boeing China today. Wong was dedicated to advancing aeronautical science as both an inventor and as an ambassador.

Wong was only 12 years old when he was selected for the Manchu government's Yang-Tai naval academy. Four years later he was one of the first Chinese naval cadets sent to England, where he earned a bachelor's degree in naval architecture and mechanical engineering from Armstrong Technical College. The Chinese government then sent him to the United States and the Massachusetts Institute of Technology to study the new science of aviation.

The MIT aeronautical engineering program was the first in the country, started in 1914 by Jerome Hunsaker, helped by graduate student Donald Douglas. Its first students also included Navy engineer George Conrad Westervelt, who in 1915 was in Seattle with William Boeing designing the first Boeing plane – the B & W.

Westervelt was stationed back east before it was finished and Boeing formed Pacific Aero Products. He asked Hunsaker to recommend a skilled aviation engineer, and Hunsaker recommended Wong.

"[Wong] is a good man," Hunsaker wrote. "Intends to spend two more years working in this country and wants a chance on aeroplane design and construction."

Wong meets Westervelt

Wong graduated from MIT in June 1916 and had learned to fly at the Flying Boat School of the Curtiss Co., Buffalo, N.Y. He talked to Westervelt, now aboard the USS *Wyoming* in New York harbor, and then headed to Seattle to work on the Model C, using data from the MIT wind tunnel and research from Gustav Eiffel.

Wong was able to test his theories in the air. According to a Seattle newspaper of the time, William Boeing allowed his employees to fly the planes they were building.

"Among the most enthusiastic members in the newly established aviation school now being conducted by the Pacific Aero Products Company at the Lake Union testing and trial grounds is a young Chinese, T. Wong ... who in addition to cherishing the ambition to become a proficient birdman, is a mechanical engineer and draughtsman," the reporter wrote.

The Model C first flew on Nov. 5, 1916. It was the second airplane designed by the new company but was designated the C-4 because it was the fourth airplane owned by William Boeing. An improved Model C, with a bigger rudder, made its first flight April 9, 1917. Two weeks later, Boeing changed the name of Pacific Aero Products to Boeing Airplane Company.

On May 22, 1917, a month after President Woodrow Wilson declared war on Germany, Boeing issued Wong a check for $50.77 for "payment in full for services rendered." Wong went back to China where he started the first Chinese airplane factory in an old engineering works at Foo Chow.

Conrad Westervelt wrote: "When he [Wong] returns to China ... he will of course be one of the few men in that country fluent in aviation matters and I would look forward to the possibilities of some business in that country through him."

By 1918, Wong was building the first Chinese floatplanes at a shipyard in Mah-Wei, including the Sea Eagle and the River Bird. During the next decade, Wong produced dozens of aircraft there, helping to establish China's aircraft manufacturing business.

BOEING HISTORICAL ARCHIVES PHOTO

Boeing and Eddie Hubbard in front of the C-700 with a mail sack.

The story of the Model C

The Model C seaplane trainer launched Boeing as an airplane manufacturer. It was the first military plane Boeing built and also was the first Boeing plane used to carry the mail. It led to development of the Model 40A mail and passenger biplane, and future success building commercial air transports.

By 1917, World War I was going strong and Josephus Daniels, secretary of the Navy, urged Boeing to hurry production of the Model C. In addition, the Navy needed proof that the Model C planes were as good as Boeing claimed they were.

If they passed tests at the Pensacola, Fla., Naval Base, the Boeing Airplane Company would be in business.

Because the biplanes could not fly that far, two Model Cs were taken apart, packed into crates and shipped by train – accompanied by Claude Berlin, Boeing factory superintendent, and pilot Herb Munter.

They reassembled the little seaplanes at the Navy base where despite 35-mph winds and 4-foot waves, the Model C proved better than anything the Navy fliers had seen. Three months later, Boeing Airplane Company seamstresses and carpenters were rushing to fill an order for 50 Model Cs for a total price of $575,000.

Boeing began final assembly of the airplane in a shipyard on the Duwamish River he had bought in 1910. By 1918, Model Cs were being manufactured in the timber structure known today as "The Red Barn," later moved to the Museum of Flight in Seattle.

The Army bought two experimental EA models, essentially landplane versions of the C. The Navy ordered one to be modified with a single main pontoon and small auxiliary floats, known as the C-1F. Boeing built another Model C for himself as the C-700. On March 3, 1919, Boeing and Eddie Hubbard made the first international airmail delivery to the United States when they used the C-700 to carry 60 letters from Vancouver, British Columbia, to Seattle. All 56 Model C-type aircraft were built between 1916 and 1918.

Building Sino-American relationships

Westervelt's words proved prophetic.

In 1928, Westervelt went to Shanghai as a representative of the Curtiss Wright Corporation, working with the Chinese government to found the China National Aviation Corporation (CNAC), and inaugurate commercial air service in China. He selected Wong to be chief engineer in charge of CNAC services and maintenance operations.

By 1934, Wong, now a Lieutenant Colonel, became the first general manager of the Central Hang Zhou Aircraft Company, building Curtiss Hawk pursuit planes and Douglas observation planes.

In that capacity, Wong visited the Boeing Company in Seattle, the Douglas Aircraft Company in California, and the Boeing School of Aeronautics in Oakland, Calif. There is also a record of him visiting the Stearman Aircraft Company in Wichita, Kan. Wellwood Beall, Boeing sales representative to China in 1935, recorded friendly meetings with Colonel Wong Tsu.

Innovations during wartime

In 1938, when the Japanese invaded the Chinese coastline, Wong's factory moved inland – first to Wuhan and then to Kunming. In 1940, Wong established the Chinese Bureau of Aeronautical Research (later the Aviation Industry Development Center).

During World War II, it was hard to get materials to Chinese airplanes built inland, so Wong designed and built a unique troop-carrying glider made out of bamboo. By the war's end in 1945, Wong headed the Aviation Research Academy in China. He spent his last decade teaching aviation engineering at the National Cheng-Kung University. He died on March 4, 1965 in Tainan, Taiwan.

His legacy lives on around the world. Wong's accomplishments are documented in a display at The Museum of Flight in Seattle and at the Boeing Historical Archives.

His bronze portrait at the Museum of Flight was sponsored by The Boeing Company, the Boeing Asian American Professional Association, the Society of Chinese American Aerospace Engineers, the Chinese Institute of Engineers /USA-Seattle, the Cheng Kung University Alumni Association and the Beihang University Alumni Association. ■

Brad Cornell, senior engineer 787 Flight Crew Operations, foreground, in the 787 rapid prototyping flight deck simulator in Seattle. Behind him, from left, are Graham Whitehouse from flight deck and Gordon Sandell from avionics simulating a tailored arrival that helps to validate design requirements.

Touchdown

Commercial Airplanes and Phantom Works engineers are developing a technology for smooth – and tailored – airplane landings at congested airports that promises considerable cost savings for the airlines.

By Daryl Stephenson

It doesn't take a pilot or an air traffic controller to know that moving arriving aircraft efficiently through busy terminal airspace can be difficult.

As traffic builds, controllers must often direct aircraft away from an airport and place them in holding patterns until they are ready to bring them in for landing. As a result, these aircraft burn more fuel, flights get behind schedule and noise increases.

In this setting, aircraft come in without any advance planning of their arrival paths. Their approaches fit a vectored, step-down pattern, as pilots and controllers engage in back-and-forth voice communication to make course corrections and ensure proper descent. The aircrews are unable to take advantage of built-in technologies onboard their aircraft that are designed to provide for an automated, smooth approach.

Boeing engineers from Phantom Works and Commercial Airplanes, working with government agencies, airlines, air navigation service providers and other aerospace companies, have come up with a better way through an innovative advanced Air Traffic Management concept called Tailored Arrivals.

The Tailored Arrivals concept combines new automation technologies in air traffic control facilities on the ground with data link technologies in aircraft to effectively plan approaches in advance and provide a more efficient routing of the aircraft to touchdown. Recent trials of Tailored Arrivals have involved the use of the Federal Aviation Administration's Ocean 21 automation system developed by Lockheed Martin and Boeing aircraft equipped with the FANS-1/A air/ground integrated data-link system. The concept also can work with Airbus aircraft equipped with FANS-1/A.

The FANS-1/A data link establishes a four-dimensional flight profile (three spatial dimensions plus time) between an air traffic control facility and the flight deck of an approaching aircraft when it's ready to begin its descent, about 140 miles away from final destination.

The flight crew uses the auto-load function to transfer the profile into the aircraft's flight management computer (FMS) for review. Once the crew accepts the profile and confirms that it will be flown, the FMS flies the given trajectory to touchdown with considerable accuracy. Rather than the vectored, step-down approach, the profile is an efficient, predictable, continuous descent – with the aircraft's engines operating at near idle from cruise altitude to near touchdown.

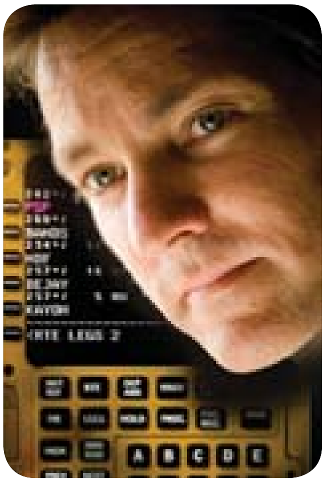
There's little need for voice communication between the aircrew and controllers as the data link system transmits information such as aircraft position, intent and weather to the ground air traffic control facility. The approach reduces fuel consumption, emissions and noise as it eases the workloads of pilots and controllers.

"One of the main themes of the Tailored Arrivals project is to get more value out of the existing capability in the airplane and the new emerging capabilities in ground systems," says Rob Mead, Phantom Works lead engineer for advanced ATM air/ground communications. "We're trying to get to a point in which the airplane can fly the way it was designed to be flown (with full use of built-in automation), with a data link to ground tools that now have the capability to run the Tailored Arrivals procedure. We think this can improve the efficiency of flight operations without a lot of new investment by airlines or airports."

Trials of Tailored Arrivals (in Australia, The Netherlands and most recently at San Francisco International Airport) are indicating that the concept can help aircraft save significant amounts of fuel as they approach an airport for landing. The fuel savings range from about 400 pounds or 60 gallons to about 800 pounds or 120 gallons per flight.

"When fully implemented, Tailored Arrivals could save airlines $100,000 per year in fuel costs per aircraft for flights into major airports," says Mead. "The real benefits would be in congested airspace operations, which would depend on the characteristics of each air space."

The Tailored Arrivals trials, which have been going on for more than two years, are also showing that the concept can increase airspace capacity and maintain airline schedule integrity. The trials have taken place in three parts of the world to ensure "that we have a global package that is flexible enough to meet regional needs," Mead says. The first set of trials was in 2004 at airports in Sydney and Melbourne, Australia.



Engineer Kevin Elmer, a member of the Tailored Arrivals team in Huntington Beach, Calif.

The most recent set of trials at San Francisco included 17 flights with United Airlines 777-200 airplanes in mid-2006. Boeing conducted the trials under a joint program with the National Aeronautics and Space Administration's Ames Research Center at Moffet Field in California.

The trials' diverse set of environments, technologies and partners is bringing the Tailored Arrivals concept closer to reality, says Brad Cornell, BCA senior engineer, 787 Flight Crew Operations, who led the 2004 trials in Australia. "We're adding complexity, we're adding robustness, and we're adding to our portfolio of partners who can understand and advance the technology," he says. "We're trying to accelerate fundamental change to open the market for future growth of commercial aviation. And we'll reach out to anyone who will help us in that mission."

Mead says that demonstrating how Tailored Arrivals work in a congested environment is the next step as part of a follow-up program with NASA. "What we would like to do is to get into a more congested area, preferably a landlocked area, so that we can exercise more of the domestic data link and upgrade the ground automation to handle congested operations," he says.

"From a technology readiness standpoint, the technology is ready," Mead says. "The savings get very big very quickly for the airlines." ■

The ultimate engineering reward:

Industry recognition

By Doug Kinneard

Boeing employees and retirees are not only recognized by their colleagues as experts in their fields, but by industry peers around the globe. Many are honored by national and international associations and organizations for their outstanding technical work, for their contributions to the community, and for their efforts to mentor and educate students and young engineers. Here's a list of some of the leading culturally diverse organizations and the Boeing employees they recognized in 2006:

Frederick "Yaw" Davis, engineering manager for Phantom Works Engineering & Information Technology's Integrated Electronics Subsystems Technology team in Huntington Beach, Calif., received the Pioneer of the Year Award from the National Society of Black Engineers.

PHOTO BY JACK BYERS

Asian American Engineer of the Year
Dev Banerjee – AAEOY Engineer of the Year, St. Louis
Susan Ying – AAEOY Engineer of the Year, Northwest
Jay Yoshinaga – AAEOY Engineer of the Year, Southwest

American Helicopter Society
Leo Dadone – Gruppo Agusta Award
Peter Hartman – Gruppo Agusta Award
Robert Narducci – Gruppo Agusta Award
Andrew Peterson – Gruppo Agusta Award

American Institute of Aeronautics and Astronautics
Edward Gerry – Pioneer Award
Alan Mulally – Honorary Fellow
Phillippe Spalart – Fluid Dynamics Award
John Tracy – Fellow
Robert Van Allen – Pioneer Award

ASEI-American Society of Engineers of Indian Origin
Kumar Bhatia – Engineering Excellence Award
Dinesh Keskar – Outstanding Achievement Award

BEYA-Black Engineer of the Year
David Blanding – Career Achievement Award
James Bell – Listed Among the Top 100 Blacks in Technology
Norma Clayton – Listed Among the Top 100 Blacks in Technology
Jim Wigfall – Listed Among the Top 100 Blacks in Technology

Government Electronics and Information Technology Association
Larry Bauer – Technical Fellow, Configuration Management
Karen Chandler – Associate Technical Fellow, Configuration Management
Dan McCurry – Technical Fellow, Configuration Management
Jim Vandyke – Associate Technical Fellow, Data Management

Hispanic Engineer National Achievement Awards Conference
Michael Cave – Top 100 Most Important Hispanics in Technology
Roberto Duffy – Top 100 Most Important Hispanics in Technology
Rudy deLeon – Top 100 Most Important Hispanics in Technology
Rigoberto Perez – HENAAC Role Model (of the week, March 13)
Art Rosales – Top 100 Most Important Hispanics in Technology
Philip de St Aubin – Top 100 Most Important Hispanics in Technology
John Tracy – HENAAC Engineer of the Year, Executive Excellence
John Tracy – Top 100 Most Important Hispanics in Technology
Yvonne Vargas – Luminary Award

Industrial Research Institute
David Swain (retired) – Medal of Technology Award

Institute of Industrial Engineers
Rick Bennett – Innovation Award
Hong Chen – Innovation Award
Dale Flinn – Innovation Award
Diane Godfrey – Innovation Award
Steven Guyot – Innovation Award
Rich Hawn – Innovation Award
Dino MacRis – Innovation Award
David Miller – Innovation Award
Steven Souza – Innovation Award
Yolanda Strickland – Innovation Award
Cindy Williamson – Innovation Award

International Council for the Aeronautical Sciences
Robert Liebeck – ICAS Award for Innovation in Aeronautics

National Society of Black Engineers
Frederick "Yaw" Davis – NSBE Pioneer of the Year

Organization of Chinese Americans
Charlotte Lin – Asian Corporate Achievement Award

Royal Aeronautical Society
Paco Escarti – Fellow
Jim Jamieson – Fellow
Ron Johnson – Fellow
Jim Morris – Fellow
Dennis Muilenburg – Fellow
Vladimir Titov – Fellow

SAE-Society of Automotive Engineers, International
Kirby Keller – Power Systems Conference Oral Award
Robert Spitzer – International Medal of Honor

SHPE-Society of Hispanic Professional Engineers
Carlos Galvan – Most Promising Engineer Award

SME-Society of Manufacturing Engineers
Carolyn Corvi – Eli Whitney Productivity Award

Society of Experimental Test Pilots
Rudy Haug – Awarded the position of Fellow
Norm Howell – Iven C. Kincheloe Award

Society of Women Engineers
Frances Ferris – SWE Fellow
Susan Moore – SWE Fellow

Standards of Engineering Society
Laura Hitchcock – Leo B. Moore Medal

Women of Color in Technology
Elaine Banks – Technology All Star
Daneisha Brazzle – Rising Star
Elaine Clemens – Technology All Star
Cecille Herrera – Rising Star
Nia Jetter – Rising Star
Anne Kao – Research Leadership Award
Eileen Loh – Rising Star
Carolyn Nichols – Career Achievement Award
Rachel Tuilesu – Rising Star
Christelle Watkins – Technology All Star
Barbara Wilson – Professional Achievement Award
Shanying Zeng – Technology All Star

Chief Technology Officer Bob Krieger:

Boeing inventors are among aerospace pioneers

By Doug Kinneard

Today's Boeing inventors rank among those "who have taken us from low-flying biplanes to powerful rockets," said Bob Krieger, Boeing chief technology officer and president of Phantom Works, when he presented Special Invention Awards to honorees in St. Louis. They were among 107 Boeing employees honored at three separate ceremonies across the United States for their 33 inventions in 2006.

"You join those who have transported astronauts to the moon and landing vehicles to the outer reaches of space," said Krieger. "And you are among those who have moved us from the operation of individual aircraft to a vast network of integrated systems that will connect and protect people around the world."

Jim Morris, vice president of Engineering and Manufacturing at Boeing Commercial Airplanes, and Nan Bouchard, vice president of Integrated Defense Systems' Engineering and Mission Assurance, were also keynote speakers at events in Seattle and Long Beach, Calif., respectively.

"In the spirit of Bill Boeing, our inventors think through what is said to be impossible – and instead they find a way to succeed," says Intellectual Property Management Vice President Rob Gullette, who sponsors the awards.

Midwest Region

Method and Apparatus for Automatically Collecting Terrain Source Data for Display during Flight Simulation
Robert Lechner

Landing Gear High Performance Shock Strut (HPSS) Valve
Akif Bolukbasi

Sustaining a Fleet of Configuration-Controlled Assets
Alan Bacon
Robert Beggs
Kim Bonin
Randolf Bradley
Terence Burke
Barry Fox
Peter Gould
Dean Hooks
Stephen King
Janet Oakes
Christian Stoughton
Jenny Thompson
Robert White
Chandler Wilson

Gaze Tracking, Eye-Tracking Assembly and an Associated Method of Calibration
John Aughey
Carl Vorst

Computational Air Data System Using Angle-of-Attack and Angle-of-Sideslip
Kevin Wise

Systems and Methods for Production Planning by Visualizing Products and Resources in a Manufacturing Process
Joseph Anelle
Carl Bouffiou
Steven Franzen
William Kehner
Robert Schreiber
Mark VanHorne

Method for Coordinated Command and Control of Autonomous Vehicles
William Bond
Roderick Leitch
Jackie McNeese Jr.
Eric Muehle
James Riddle

Wireless CASS Interface Device Electromagnetic Railgun Projectile
James Cook
Randall Marion
William Rootz
Steven Wegener

Electromagnetic Railgun Projectile
Douglas Elder

Standoff Land Attack-Expanded Response Device Computer
Aaron Eggemeyer
James Leonard
Robert Menzel
Richard Meyer

System and Method for Detecting a Leak in a Hydraulic Fluid System
Allan Beiderman
Patrick Rexing

System Anechoic Test Chamber and Method of Determining a Loss Characteristic of a Material Specimen
Leland Hemming
Charles Leonard

Boeing 767 Tanker In-flight Refueling Capability (multiple inventions and inventors):

Truss Mounted, Directional Loading, Fluid Carrying Apparatus Redundant Seal Fitting – Fluid Carrying Apparatus

Surge Pressure Reducing Hose Assembly

Manifold Mounting – Load Carrying Apparatus, Infinitely Adjustable

Shrouded Valve Body – Conducting Apparatus, Shutoff Valve Assembly

Shrouded Body – Fluid-Conducting Apparatus, Flow Meter Assembly

Aerial Refueling System

Shrouded Fluid-Conducting Apparatus
James Carns
Theron Cutler
Mark Shelly

Mass on Model
Bruce Shimel
Scott Stevenson

System, Method and Computer-Program Product for Structured Data Capture
Scott Greene
David Hester

(James Milstead, Renee Pankrast recognized at Southwest event, for this same invention, which appears in the list twice for this reason.)

Northwest Region

Technology/Invention: Method, Apparatus and Computer Program Products for Information Retrieval and Document Classification Utilizing a Multidimensional Subspace
Inventor(s)
Anne Kao
Jason Wu
Robert Cranfill
Stephen Poteet
William Ferng
Andrew Booker

Methods for Fabricating Electromagnetic Meta-Materials
Minas Tanielian

Formed Structural Assembly and Associated Preform and Method
Garry Booker
Luis Leon
David Foutch
Gregory Ramsey
Daniel Sanders
Jeff Will

Phased Array Antenna Choke Plate Apparatus and Method
Stanley Ferguson
David Rasmussen
Michael Taylor

Airline Traffic Modeling and Allocation System
Roger Parker
Richard Lonsdale

Method for Restoring Software Applications on Desktop Computers
Dustin Coe
Jeffery Flenoy
Eric Brehm
Kirk Wong
Michael Reese

Superplastic Forming of Titanium Assemblies
Thomas Connelly
Kent Dunstan
William Williams III
Peter Comley
Larry Hefti

Near-Hermetic Packaging of Gallium-Arsenide Semiconductor Devices and Manufacturing Method Therefor
Fong Shi

Fastener Installation Apparatus and Associated Method
Daniel Hippe

Single Fiber Links for Full Duplex Aircraft Data Network
Tuong Truong

Integrated System-of-Systems Modeling Environment and Related Methods
Don O'Connell
Phillip Denby
Ali Bahrami

Southwest Region

Phased-Array Antenna Architecture Having Digitally-Controlled Centralized Beam Forming
William Davis
Robert Hladek

System, Method and Computer-Program Product for Structured Data Capture
James Milstead

Renee Pankrast (Scott Greene, David Hester recognized at Midwest event)

Probabilistic Risk Evaluation of Debris Impact Capability and Tolerance, PREDICT
Ian Fialho
Winston Wang

Reflector Deployment Error Estimation
Richard Fowell
Arunkumar Nayak
Hanching Wang

Phase Recovery Filtering Techniques for SCP Throughput Shortage
Richard Chiang

Molding Process and Apparatus for Producing Unified Composite Structures
Roger Burgess
Coleman Standish
Patrick Thrash
Alexander Velicki

System, Method and Computer Program Product for Signal Processing of Array Data
Richard Nielsen
Sandra Nielsen

Modular Inter-modal Platform (MIP)
Anibal Garcia
Thomas Reiner
Myles Rohrlick
John Simmons
James Wells

PORTRAIT

The Phantom Works' Automated Aerial Refueling Program team

We believe in discipline and innovation – working inside the rules but outside the box. That's because we are involved in a fast-moving, competitive technology that is important to the United States military capability – automated aerial refueling. Here in St. Louis we're serving one of Boeing's most important customers, the U.S. Air Force Research Laboratories. The key technologies that we and our four subcontractors have just demonstrated allow an unmanned aircraft to fly safely behind a tanker. Ultimately, the autonomous vehicle will be able to maneuver behind the tanker, receive fuel, perform a break away and, with more refuelings, remain in the air for days on end. The capability will also augment the operation of manned aircraft by improving safety and reducing pilot workload. We're proud of our success in putting together the software and flight control hardware quickly and efficiently, using Boeing's best talent, rapid prototyping and some new validation tools. We had no hardware or software problems in flight. The end result: We're helping to make the world a little safer.

From left to right

Brad Swearingen
Real Time Software Engineer

Jason Lahr
Flight Controls Engineer

Clint Sigler
Avionics Engineer

Lance Portell
Real Time Software Engineer

Zach Nielsen
Flight Controls Engineer