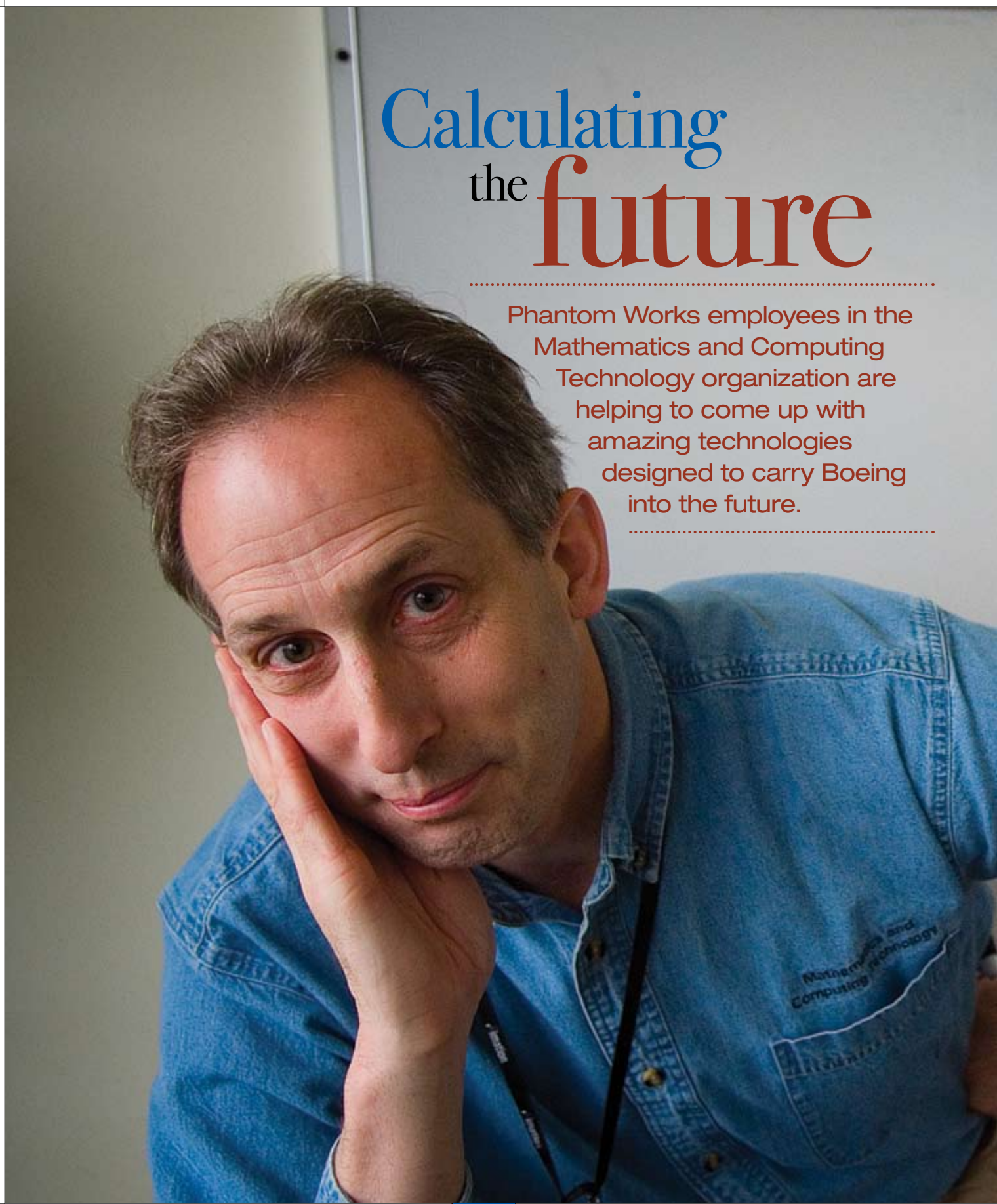

Calculating the future

Phantom Works employees in the Mathematics and Computing Technology organization are helping to come up with amazing technologies designed to carry Boeing into the future.

By Tom Koehler

In a quiet office park in Bellevue, Wash., a group of 250 very smart people are working to develop new technologies for better Boeing products and services.

Comprised of computing experts, mathematicians and engineering analysts, 89 percent of whom hold advanced scientific degrees from many of the world's top-tier universities, the Boeing Phantom Works Mathematics and Computing Technology (M&CT) group has been Boeing's resource for advanced information technology research and development for more than 30 years.

Collaborating closely with the people in Boeing's business units, M&CT is chartered to provide advanced research and

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Left: Tom Grandine, a Boeing Technical Fellow and expert in computer-aided geometric design. Behind him is a basic formula used by Boeing computers about 500,000 times a day. Using special tools, his team was able to achieve a 39 percent weight reduction in a hypersonic vehicle concept.

Above: Martin Meckesheimer and Stephen Jones, pictured in the 787 Dreamliner interior mockup, used applied statistics to make the case for more personal space, bigger windows, enhanced lighting and increased cabin pressure in the 787.

Paul Murray, Charles Erignac and Jim Troy of the Autonomous and Intelligent Systems group with some of the technology demonstration autonomous helicopters they are helping to develop. "The future of aviation is closely tied with increasing levels of autonomy," says Murray.

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development and long-term solutions to address the special requirements of the business units in areas such as multi-disciplinary design optimization, network-centric operations, large-scale data and text mining, mobile network communications, distributed collaborative design, and intelligent decision systems.

"We are about high-tech answers to high-tech problems," says M&CT Director Susan Ying, "and we work with creative people throughout Boeing, as well as at universities, government and private laboratories, and industry partners across the world to make sure Boeing has the right answers at the right time to help keep the company competitive."

In the past, people in M&CT helped produce breakthrough capabilities ranging from digital modeling software that enabled Boeing designers to fly through the 777 airplane before it was built to verify the spatial relationships of objects to emerging processes that include radio frequency identification.

Here's a look at some of what M&CT is working on today:

Computer-aided geometric design optimization

Recently, M&CT helped to solve a problem involving the Hypersonic Space Plane, a futuristic concept involving scramjet propulsion that is intended to produce a vehicle that will take off from a conventional runway and fly at very high speed into low-Earth orbit.

"We needed help in determining the optimum geometric shape or design of the vehicle given the wide range of possible designs," says Kevin Bowcutt, Boeing Senior Technical Fellow in Phantom Works and the lead scientist of hypersonic space plane research within the company. "M&CT developed an innovation that involved very complex modeling of the geometry of hypersonic vehicles and provided a way that the shape could be varied parametrically, like clay or rubber, in search of an optimum shape or design."

"We have been able to develop tools that help engineers quickly and efficiently sort through the entire design space of possible solutions," says Tom Grandine, a Boeing Technical Fellow and expert in M&CT in computer-aided geometric design.

"In the case of the hypersonics vehicle concept, we were able to achieve a 39 percent weight reduction by taking advantage of the synergy possible in the interplay between each of the engineering disciplines," he says.

"Design space exploration is an essential technology for being able to win new business in the future," Grandine adds. "Specifically, the ability to explore design space thoroughly enables Boeing to select candidate designs that best match customer needs and expectations, both in cost and performance. Without these tools, candidate designs must be selected on the basis of educated guesses rather than hard facts."

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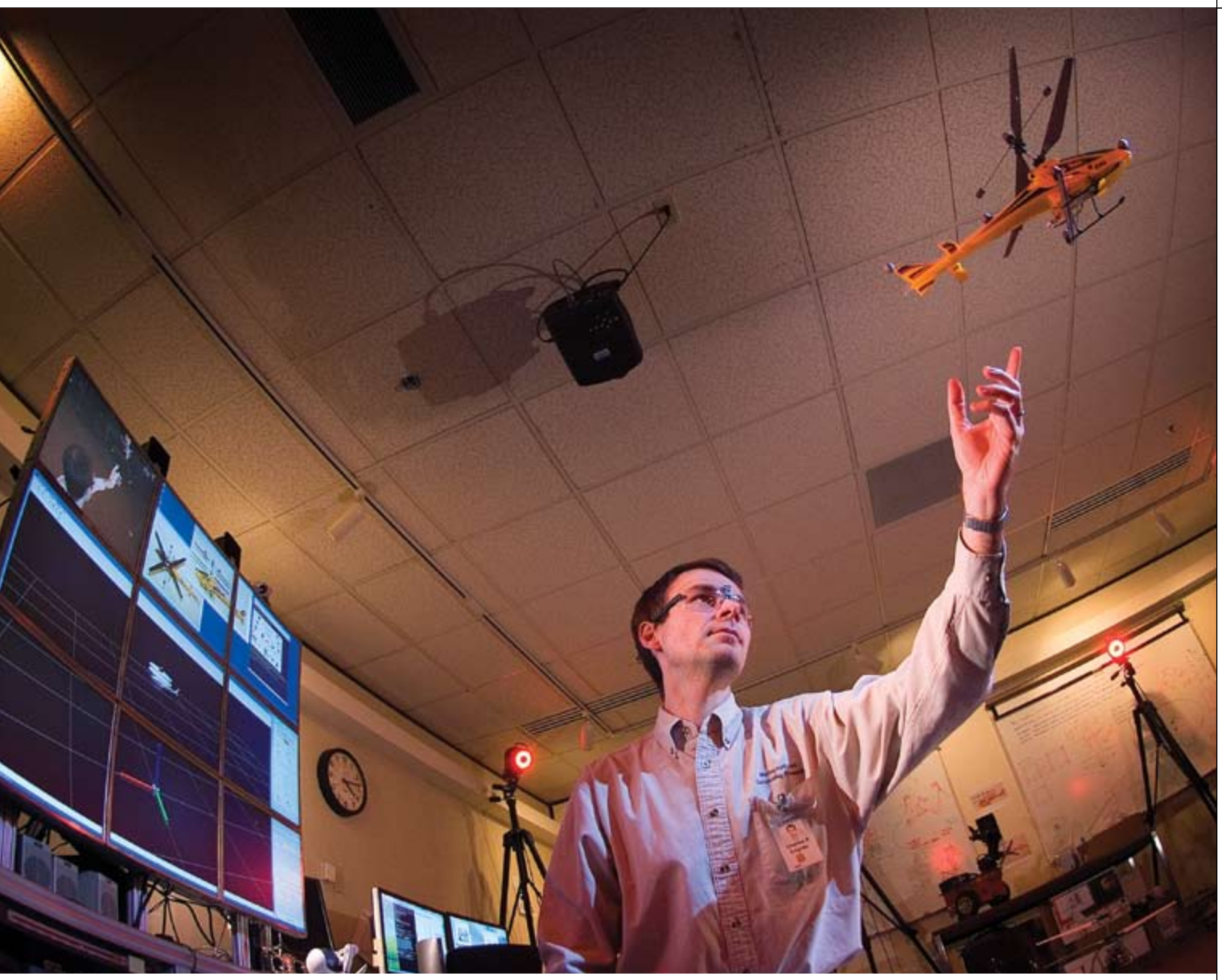
– Susan Ying.

Computer networking

Networks – they are everywhere. People have become dependent on televisions, the Internet, telephones, personal data assistants and many other networked devices. When a network fails, it can be inconvenient or even paralyzing.

M&CT Director Susan Ying: "We are about high-tech answers to high-tech problems."



Charles Erignac, an autonomous systems scientist with the Autonomous and Intelligent Systems group, demonstrates the capabilities of an autonomous mini-helicopter that he and his team are helping to develop.

At Boeing, which supports a very large internal enterprise corporate computing network as well as data services to airplanes in the sky and data services to the edge of the tactical battlefield, network failure or downtime often is not an option.

"Data networks are crucial to many aspects of Boeing's business," says Tom Henderson, a Boeing Associate Technical Fellow. He investigates techniques in M&CT's Network Technology group to adapt, extend, or use Internet-related technologies to solve computer networking problems.

"Many current challenges in networks stem from links that are wireless," Henderson says. "Wireless links are prone to errors and outages, and often the traditional Internet-based technologies don't work as expected in wireless systems.

"In our group, we're working on mobile routers that efficiently route data over these wireless links," he says. "We're working on programs that allow the network devices to configure themselves. And we're also working on modeling techniques that allow us to prototype network concepts with small emulated test networks that run on a single device. The work that our group is doing is being applied to several of Boeing's internal networking projects and we're also working to improve the standards for wireless communications."

Applied statistics

On the Boeing 787 Dreamliner, passengers will be more comfortable than on any jetliner ever made. How do the people at Boeing know for sure? Because they can prove it – thanks in part to the work of M&CT's Applied Statistics group.

"Important decisions are being made all of the time at Boeing," says Stephen Jones, an applied statistician and expert in

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an area of statistics called Design of Experiments. "These decisions are made with imperfect knowledge, and so there is risk associated with them. Statistics, being based on probability theory, provides a suite of methodologies that enable decisions to be made in the face of uncertainty, so that the risks of various decisions are understood and quantified."

Jones, fellow applied statistician Martin Meckesheimer, and others in M&CT's Applied Statistics group helped generate and analyze the statistical data from passenger studies and focus groups that supported the company's decision to produce a breakthrough passenger cabin for the 787.

Olga Walker is part of a team helping to protect Boeing electronic information by using advanced information assurance technology.

"Today, the flying public can hardly tell what kind of airplane it is on, but the 787 will be distinct, featuring more personal space, bigger windows, enhanced lighting and a better overall cabin environment with increased cabin pressure," Meckesheimer says. "We helped provide the statistical evidence that suggests that putting these features into the 787 was the right business decision."

"There's a lot to be said for an informed decision," confirms Blake Emery, Boeing Commercial Airplanes director of Differentiation Strategy. "The kind of research we do with these folks really helps bring forth data that can be a big part of the decision."

"I have no doubt that passengers will know that the 787 offers superior comfort to them and it will encourage them to continue to fly that airplane in the future," Jones adds.

Intelligent systems and robots

While many people dream of finding a robot to handle menial tasks such as taking out the garbage or grabbing the newspaper in the driveway, M&CT is taking the idea much further – believing that robots should almost be able to think for themselves and to act autonomously as individuals or in teams.

"We share a vision of robotics research in which machines are enabled to do complex tasks with little or no human supervision," says Paul Murray, an M&CT autonomous systems engineer.

"Some tasks may be unpleasant or even dangerous for humans," Murray says. The technologies we're developing will enable robots to do these things. Our technology provides unique methods of control between human operators and either individual or teams of robots."

An important example of teaming behavior might be the collaborative search of a building or urban environment looking for threats, Murray says.

Tom Henderson, a Boeing Associate Technical Fellow, investigates techniques in the network technology group to adapt, extend, or use Internet-related technologies to solve computer networking problems.

"It's our strong belief that the robotics technologies that we're building here in M&CT and that we're acquiring from around the world will be used to build the best possible Boeing products. The future of aviation is closely tied with increasing levels of autonomy."

He says that as electronic and mechanical systems continue their downward trend in size and power consumption, an entire new class of intelligent, autonomous devices will become possible, extending human sensory and mechanical capabilities far beyond what is now possible.

Intelligent graphics

There are more than 100 miles of electrical wire on large airplanes. If one of the wires breaks, finding the break and fixing it isn't easy. People in M&CT's Intelligent Graphics group believe the wire itself should tell troubleshooter when and where the problem is.

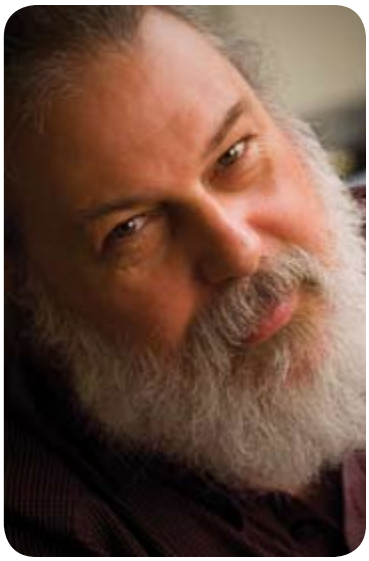
"In addition to making the wiring diagrams easier to use, we're actually hooking them up to hardware on aircraft," says John Boose, a Boeing Senior Technical Fellow who works on advanced computing and intelligent graphics.

"We have a box that sends a signal down a wire and gets an echo back," Boose says. "And the echo contains information about the trouble. We can take that trouble information and put it on a wiring diagram and show exactly where the problem is on that wire."

According to Boose, intelligent graphics help reduce maintenance and operations costs, and improves training and mission readiness for the military; and Boeing's leadership in this technology area has led to cutting-edge products and services, and helped with critical differentiation on government contract wins.

Information assurance

As a large-scale systems integrator, Boeing has a fundamental requirement to distribute, store and process electronic data safely, securely and efficiently. The company's complex systems must meet data and storage requirements, and provide protection from hackers.



Walter Beck has helped to develop technology that provides secure electronic distribution of software to airlines and airplanes.

"Information assurance technology that we've developed is used to build new information assurance systems, as well as to prove that these systems operate correctly," says Scott Lintelman, manager of M&CT's information assurance technology group.

For example, M&CT information assurance expert and Associate Technical Fellow Walter Beck has helped develop technology that provides secure electronic distribution of software to airlines and airplanes. In place of a cumbersome and costly process that today relies on floppy disks, CDs, signed documents and shipping via bonded carriers, the Boeing Electronic Distribution of Software system employs advanced cryptographic techniques to perform electronic functions analogous to the packing, shipping and signing for physical software and documentation.

"A key to the technology is that it incorporates digital signatures that prevent tampering, modifying or forging of the information," Beck says.

"Airline customers are excited to receive the data electronically and avoid the physical media," says Todd Mickelson, senior manager of Information Technology with BCA's Commercial Aviation Services organization.

"Our information assurance technology is applicable throughout the Boeing enterprise – not only to Commercial Airplanes, but also to Integrated Defense Systems," Lintelman says. "One of the important aspects of Phantom Works' mission is to develop a particular technology once, and then transition it to multiple programs throughout the company. The work we're doing for Commercial Airplanes, for example, has already been leveraged in technology demonstrations by the C-17 program. Careful design and formal proof of security properties widens the applicability and ensures transitions to multiple Boeing programs as the system evolves." ■