



Flying machines of the **future**

Boeing's Phantom Works looks into the future to come up with some 'pretty cool stuff'

by **Marc Sklar**

GRAPHICS: (Above) The Phantom Ray unmanned flying test bed, shown in an artist's concept, is 36 feet (11 meters) long with a wingspan of 50 feet (15 meters). It is scheduled for systems, ground and flight tests this year. **MICK MONAHAN/BOEING**

(Right) Phantom Works and SkyHook International are developing this neutrally buoyant hybrid aircraft for heavy-lift operations into remote areas. It will be capable of lifting up to 40 tons (36 metric tons). **JOE NAUJOKAS/BOEING**

As a massive hybrid neutrally buoyant aircraft delivers oversized pipeline equipment north of the Arctic Circle, a homeowner uses the Internet to check the cheapest time to run a load of laundry.

At 65,000 feet (19,800 meters) over a battlefield, a liquid-hydrogen-powered aircraft keeps tabs on troop movements and helps control unmanned attack aircraft flying from carriers 500 miles (800 kilometers) offshore.

Officials in a major city monitor massive security operations for a global sports event, while hundreds of miles above, nanosatellites—each the size of a toaster oven—collect data on crop conditions, flood threats, the health of the planet and more.

The stuff of science fiction? No. Just a glimpse at some of the capabilities and applications of projects in various stages of development by employees of Phantom Works, the division of Boeing Defense, Space & Security charged with advanced development. With a team of only about 2,000 employees, Phantom Works has numerous programs and initiatives going at any one time in fields as varied as aviation, space, energy management, and military and intelligence operations.

"What we do is look into the future and work with our customers to determine where capability gaps may exist," said Darryl Davis, Phantom Works president. "That can mean anything from advanced aircraft to spacecraft to network systems to energy management to hovercraft to

hybrid airships to unmanned vehicles to security systems, as well as all the components that go into those. It's pretty cool stuff!"

Stuff with intriguing names such as Phantom Ray, Phantom Eye, SkyHook and WaveRider.

"It's really cool to work in an environment where leadership provides whatever is needed to nurture creativity," said Krishna Badrinath, a manager with Advanced Modeling & Simulation. "We get to work on projects that leverage smart ideas and best-in-class technologies. Ultimately, that helps Boeing be far more competitive."

Ann Meyer is also a manager with Advanced Modeling & Simulation. Last summer, her 16-member team executed 16 modeling and simulation demonstra-

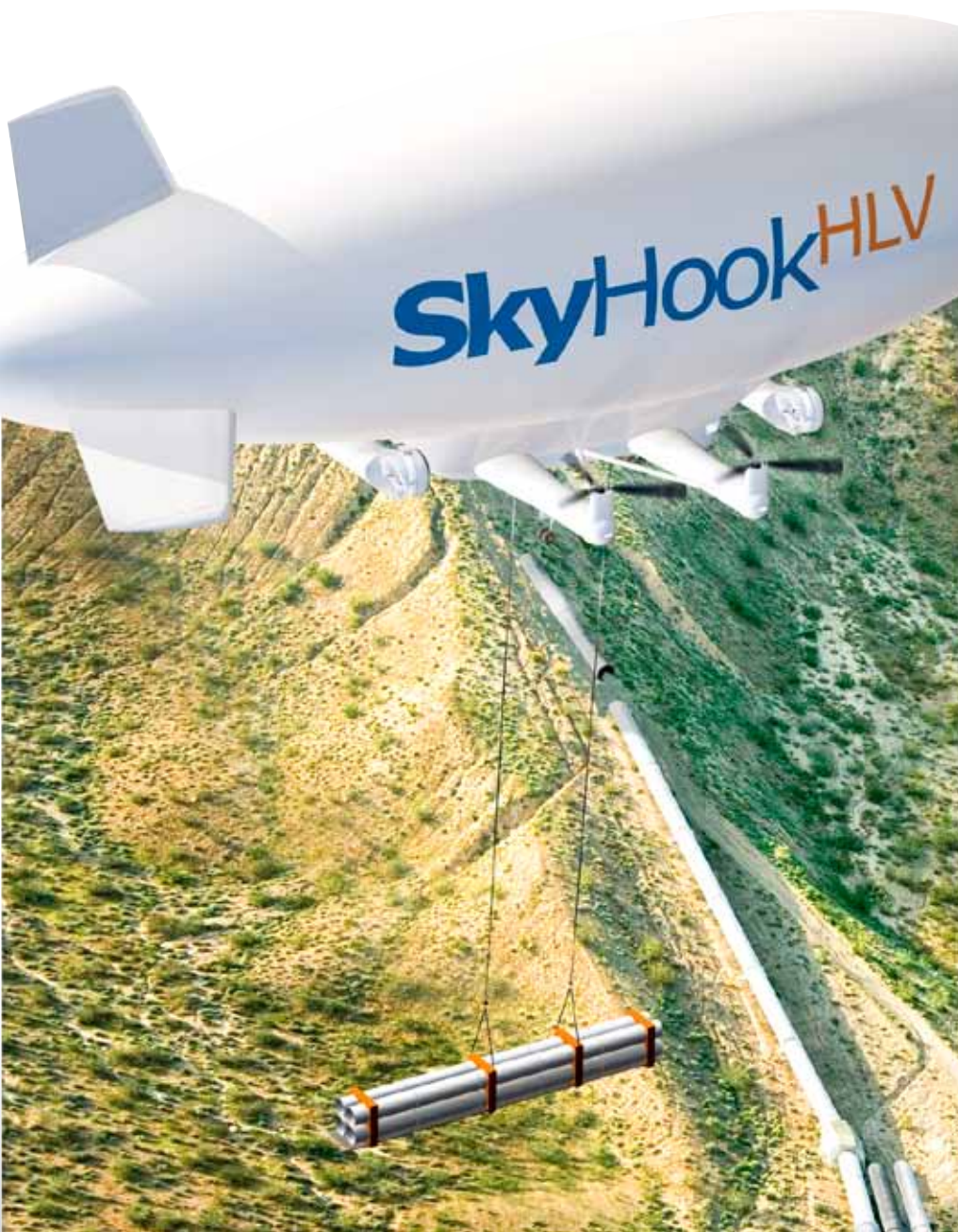
tions for multiple BDS businesses in only four hours. "We were told that the success of the event was influential toward enhancing Boeing's work with the customers," Meyer said. "I'm thrilled that our small team can significantly impact things like sales or Boeing's presence around the world."

Phantom Works and BDS focus resources on what's known as rapid prototyping. This is the process of rapidly and affordably developing a model, vehicle or system. Phantom Works typically focuses on "technology demonstrators" to prove a new technology or set of technologies. These usually are built using minimal tooling.

One result of this prototyping effort is Phantom Ray, announced in early 2009.

Phantom Ray builds on Boeing's successes with the X-45A and X-45B Unmanned Combat Air Systems, and the development work done on the X-45C. In 2010, Phantom Ray will undergo ground and systems tests, leading to first flight later in the year. Flying and testing Phantom Ray will demonstrate Boeing's commitment to be a leader in the unmanned aircraft business.

Another Boeing-funded prototype is the Phantom Eye High Altitude Long Endurance (HALE) unmanned aircraft program. Tests of a liquid-hydrogen-powered propulsion system are under way while the prototype aircraft is being built. The HALE prototype would be able to remain on station for more than four days at an altitude of about 65,000 feet (19,800 meters). It would



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PHOTO: FRED TROILO/BOEING



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PHOTO: MICHAEL GAIL/BOEING



GRAPHIC: The Phantom Eye High Altitude Long Endurance prototype is being built to stay aloft for up to 10 days and carry up to 2,000 pounds (910 kilograms) of payload. Potential applications for the liquid-hydrogen-powered aircraft include battlefield and border observation, port security and telecommunications.

MICK MONAHAN/BOEING

carry out intelligence, surveillance and reconnaissance missions. A full-production aircraft would likely be able to stay on station for up to 10 days.

While Phantom Eye would be stationed over one area for long periods of time, the X-51A WaveRider will streak across the sky at more than a mile per second (1.6 kilometers per second). A program of the Air Force Research Laboratory and Defense Advanced Research Projects Agency, WaveRider is a scramjet demonstration aircraft for hypersonic flight testing.

“The X-51A will set the foundation for several hypersonic applications including access to space, reconnaissance, strike, global reach and commercial transportation,” said Joseph Vogel, Boeing X-51

program manager. “This is a true flying vehicle, not just the engine demonstrator the program was initially established to be. It has all the systems of an aircraft.”

Four flight tests are scheduled this year. The demonstrator will launch over the Point Mugu Pacific Test Range in California from a U.S. Air Force Boeing B-52H carrier aircraft. After release, an onboard booster will accelerate the X-51A to about Mach 4.5 (or 4.5 times the speed of sound) before its air-breathing engine takes over and hurls WaveRider to speeds in excess of Mach 6.

In December, the WaveRider took to the skies in a “captive carry” test under the wing of a B-52H. “That test was the culmination of many months of hard work by the X-51A team to verify that hardware,

electrical and software integration was complete,” said Vogel. “It was a key step on the way to our upcoming flights.”

On the other end of the speed range is the SkyHook Heavy Lift Vehicle. (See story on Page 22 of the August 2009 issue of *Frontiers*.) Currently being designed by Boeing for its Canadian partner SkyHook International, the neutrally buoyant vehicle will measure 410 feet (137 meters) long, 205 feet (62 meters) wide and 141 feet (43 meters) high. SkyHook combines a helium-filled envelope that carries the weight of the vehicle itself with four helicopter rotors that generate the power to lift payloads of up to 40 tons (36 metric tons). Ducted propellers are used for maneuvering and can propel the aircraft horizontally, at maximum payload, up to 200 nautical

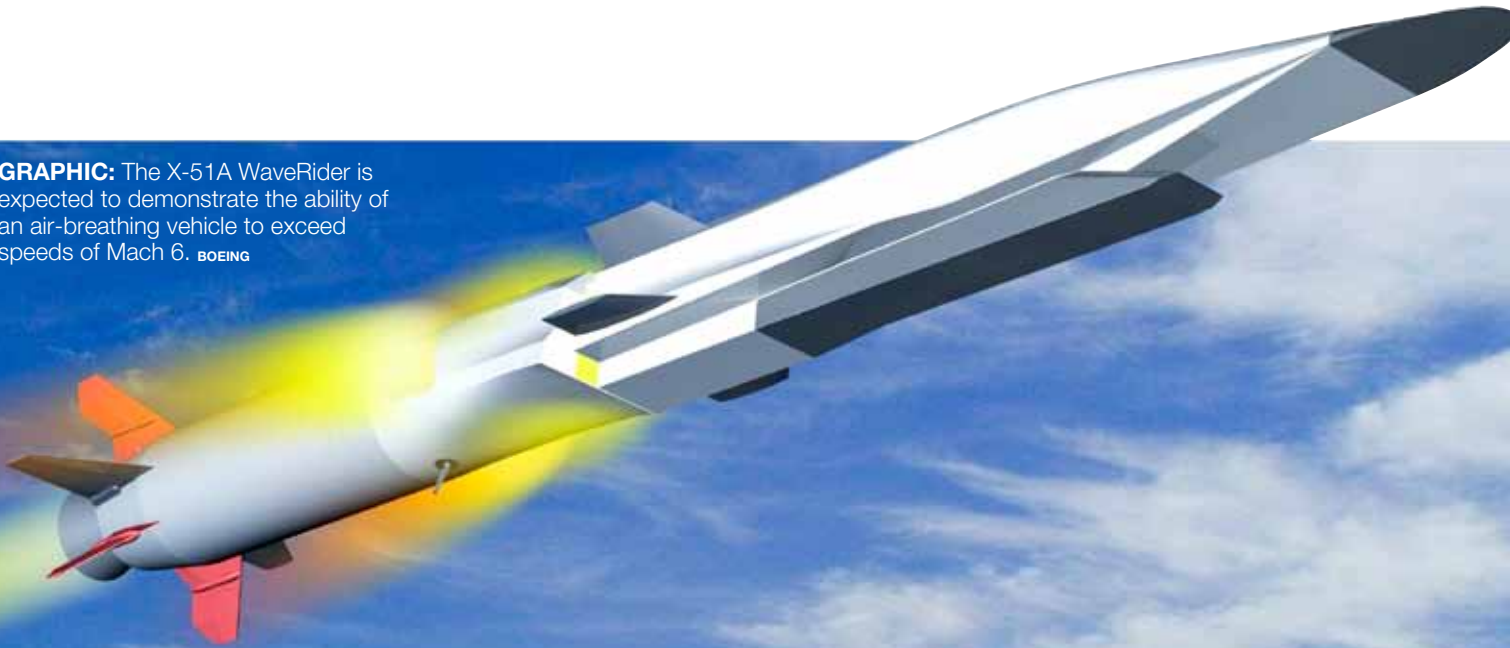


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– Phil Stranahan, integrated software product team lead with Advanced Network & Space Systems

PHOTO: MICHAEL GAIL/BOEING

GRAPHIC: The X-51A WaveRider is expected to demonstrate the ability of an air-breathing vehicle to exceed speeds of Mach 6. **BOEING**



miles (230 miles, or 370 kilometers) without refueling. The SkyHook can be used for hauling heavy equipment to remote sites for uses such as power-line installation, or for extractive industries, such as mines, when roads do not exist.

At much higher altitudes, a Phantom Works–led team is successfully demonstrating an enhancement to the Global Positioning System that helps warfighters obtain vital positioning information even when enemies are jamming the signals. The High Integrity GPS program will make access to the positioning information more reliable.

“What’s unique about the program is that the requirements for the system are developed as the technology matures; so we’ve had to build software that can

incorporate changes along the way,” said Phil Stranahan, who leads an integrated software product team with Advanced Network & Space Systems. “It’s very challenging, but I’m confident our work will result in a deployed system that will be a huge benefit to the warfighters.”

In mid-2009, the U.S. Defense Advanced Research Projects Agency awarded a Phantom Works–led industry team a \$15.5 million contract for phase 2 of the Fast Access Spacecraft Testbed. The program is an effort to develop a new ultra-lightweight High Power Generation System that can generate up to 175 kilowatts of power for spacecraft. That’s more power than is currently available to the International Space Station.

Boeing also continues research in

nanosatellites and picosatellites. These tiny spacecraft (nanosatellites are spacecraft weighing less than 22 pounds, or 10 kilograms; picosatellites weigh less than about 3 pounds, or 1 kilogram) are demonstrating both what small satellites and smaller components can do to boost the capability of larger satellites. Boeing’s CubeSat TestBed 1 nanosatellite has completed more than 10,000 Earth orbits and successfully demonstrated numerous advanced technologies.

Also on the drawing board are ideas for advanced fighter aircraft for the U.S. Navy, known as F/A-XX, and a next-generation U.S. Air Force bomber.

Wendy Teare, an operations analyst with Advanced Boeing Military Aircraft, is conducting virtual experiments with Navy



engineers and operators in the Virtual Warfare Center. “Through these events, our customer has become a seamless member of our team and, accordingly, has helped us anticipate what the Navy needs in the future in terms of fighter aircraft,” she said.

Phantom Works also is focused on moving into adjacent markets to support BDS growth plans. Leveraging networking and systems-of-systems expertise, BDS started its Energy Solutions group last year. The organization has already won, along with energy industry partners, U.S. Energy Department grants to work on Smart Grid technology. Smart Grid covers all aspects of the electrical grid, from production and transmission to consumption and efficiency as well as security. It includes new technology and networking of information to

allow everyone from power companies to customers to make smarter decisions on use and generation of energy.

“I come to work each day knowing I am part of something big and new,” said Ken Stoltman, with Energy Solutions. “Being in business development, I get to be one of the first to interface with companies who want to work with us in the rapidly growing energy market. I love watching their faces light up when I tell them of our energy competencies, such as being the record holder for the world’s most efficient solar cell, or that we’ve been creating energy solutions for 35 years. I get to tell them about an unmanned aerial vehicle that can monitor thousands of miles of transmission lines, or a communications system that integrates a utility’s massive

logistics command and control network.”

What’s next? That is the question that drives the Phantom Works team. “We constantly invest in people, technology, processes and ideas,” said Dave Whelan, vice president, strategic innovation for Phantom Works, and BDS chief scientist. “We see innovation as a core competency of Boeing, and especially Phantom Works, that spans our business planning horizons from today’s products to tomorrow’s advanced systems and on to the technology enablers for our ‘systems after next.’” ■

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PHOTO: RICHARD RAU/BOEING



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From ideas to **profits**

While maintaining a strong customer focus, the end goal for Phantom Works is to turn its development programs, prototypes and concepts into profitable programs for Boeing Defense, Space & Security business units.

“Our goal is to invest in research and development projects in market growth areas that will allow us to bring great products to customers quickly,” said Daryl Pelc, Phantom Works vice president, Engineering and Technology. Projects that have made the transition to the business units include:

- The A160T Hummingbird unmanned rotorcraft—an endurance record holder,

it has demonstrated cargo hauling for the U.S. Marine Corps

- Ship-to-Shore connector—a proposed replacement for the U.S. Navy’s Landing Craft Air Cushion, a hovercraft used for transporting forces and equipment for coastal landings
- ScanEagle UAS—a small tactical unmanned aircraft system now providing U.S. and allied military forces with high-quality imagery for intelligence, surveillance and reconnaissance

– Marc Sklar

GRAPHIC: Phantom Works is providing technology assessments to help the U.S. Navy analyze its options for a future manned or unmanned aircraft known as F/A-XX. **CHUCK SCHROEDER/BOEING**



Scores of projects in
the works

The leader of Phantom Works talks about the challenges and the future



“The type of projects we get to work on ... keeps the innovation juices flowing.”

— Darryl Davis, president of Phantom Works

PHOTO: BOB FERGUSON/BOEING

As president of Boeing's Phantom Works, Darryl Davis is at the center of an organization that by definition takes risks. He's responsible for developing advanced concepts and technologies and executing new programs before they reach the System Design and Development phase. *Frontiers* recently spoke with Davis about the challenges of being on the “front end” of the business.

Where does your interest in flight originate?

I come from a small town in Indiana. On Sunday afternoons, my dad would pack us up in the station wagon and we would go out to this little county airport, and we'd sit there and watch these little airplanes buzz around the airport. Because of my dad's fascination with aviation, I naturally took an interest and read anything I could get my hands on about airplanes. Next thing you know, I was in college studying to be an aeronautical engineer. Did I know then exactly what I wanted to do? No, I just knew I was extremely interested in things that flew and simply followed that passion. I can tell you I did the right thing because this is a lot of fun.

What is Phantom Works?

Fundamentally, we're all about the future. What we do is look at all the things Boeing Defense, Space & Security is doing and determine where we can open new markets for Boeing. We interface with the three other BDS businesses (Boeing Military Aircraft, Global Services & Support, and Network & Space Systems) to help them develop advanced concepts and technologies that address potential

markets and meet the evolving needs of customers. Our job is to take the risks and deliver the future for BDS.

What are some of the challenges?

The big challenge is deciding what to work on first. To do that, we have to anticipate where significant revenue streams are going to be in the future and align our capabilities accordingly. There has to be alignment between our internal investment and where we think customers will focus their resources. In a perfect world we'd do everything at once, but of course we can't because we're limited in people, dollars and facilities. So, the challenge is to pursue projects that will have the highest payoff.

Of course, defense spending cutbacks are also a challenge, but we're focused on quickly bringing programs online that can offset portfolios that may change in the next five to 10 years due to changes in defense spending priorities.

What can we anticipate from Phantom Works in 2010?

We're continuing our move toward rapid prototyping—showing customers we can field programs without a major design and development effort. Phantom Ray, an unmanned flying test bed to develop advanced air system technologies, is scheduled to make its first flight in late 2010. Tests of the High Altitude Long Endurance aircraft are under way. The unmanned aircraft would carry out intelligence, surveillance and reconnaissance missions. Flight tests for the X-51A are scheduled for the first part of this year. Flying at speeds in excess of Mach 6, the

vehicle will set the foundation for several hypersonic applications.

Those are just the big milestones for 2010. But there are numerous Phantom Works programs at various stages of development.

What is Phantom Works' competitive advantage?

It's got to be our people! We don't have large manufacturing facilities, but we do have a small team of employees who do amazing things. They're not only bright and creative; they're flexible. You have to be since projects can be dropped very quickly, or new opportunities can pop up just as quickly. Also, our programs ultimately transition from development to one of the three BDS business units, so our people have to be pliable enough to come into this environment, work a program, then take that program and what they've learned to the businesses.

What do you like best about your job?

We are on the front end of the business, and that is fun! We get to experiment, prototype and flight-test. Successfully transitioning a program to one of the business units is what it's all about. But, no sooner do we do that, we're on to the next project. The type of projects we get to work on and the tempo of the work keeps the innovation juices flowing. It's a great challenge. ■

PHOTO: The Phantom Ray unmanned flying test bed is being built by Phantom Works to develop advanced air system technologies. First flight is planned for late 2010. **BOEING**