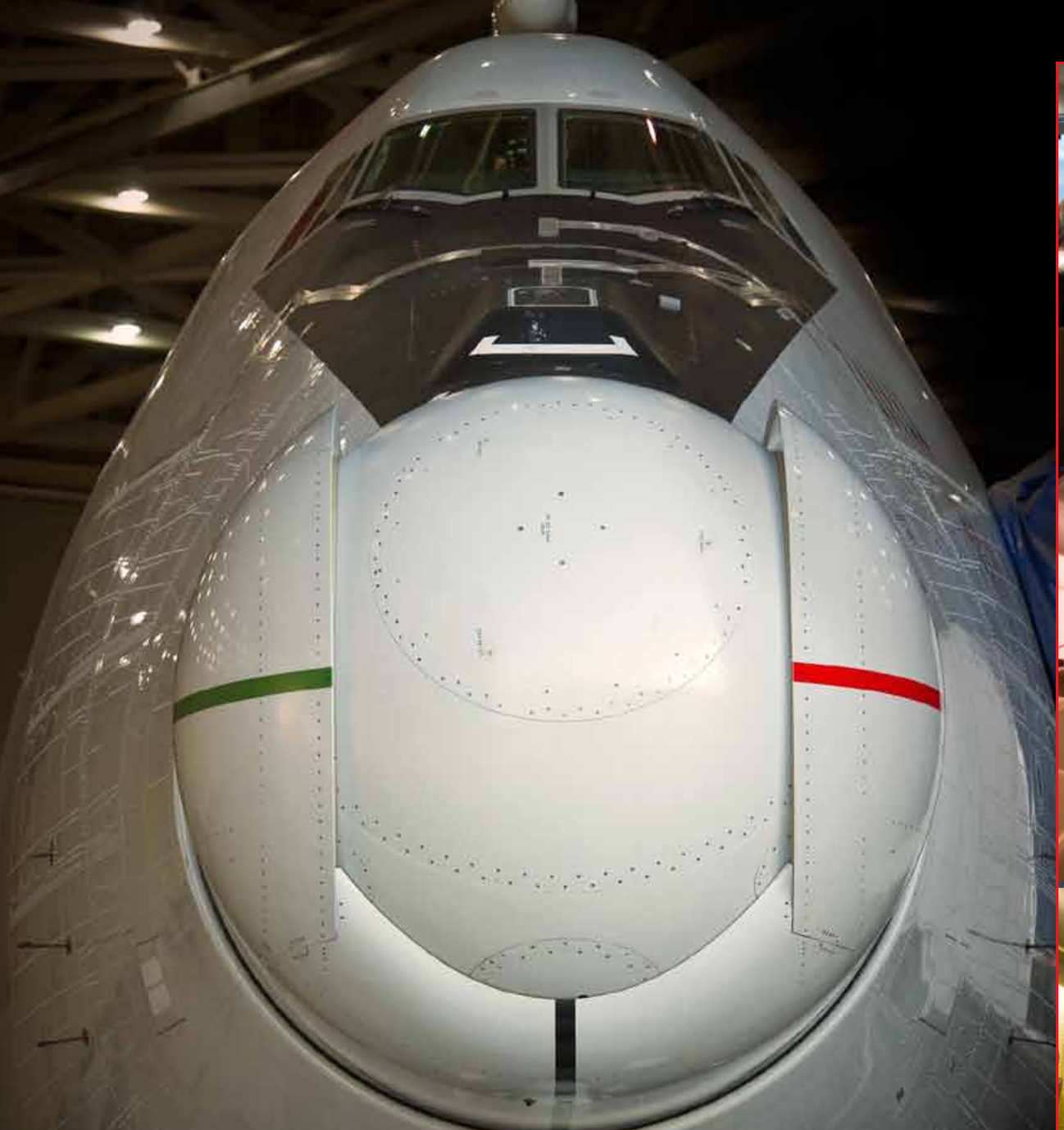

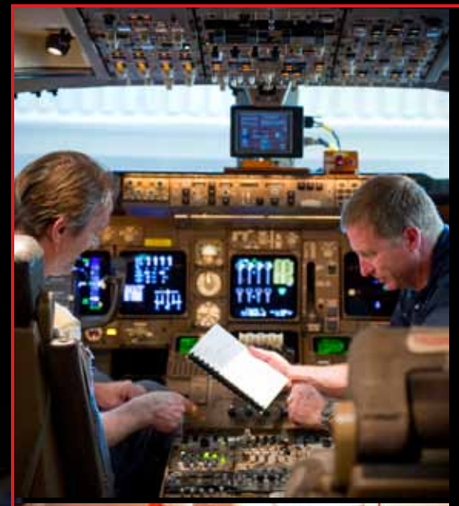

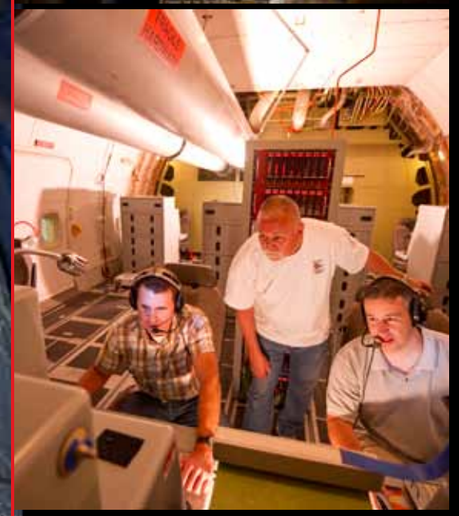

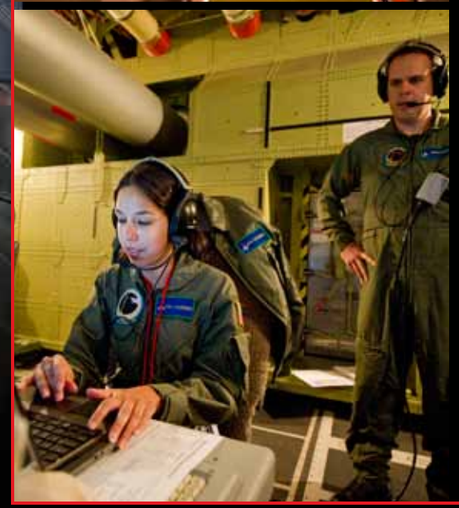

PHOTOS: (Above) The nose turret of the modified 747 known as the Airborne Laser Test Bed contains a large telescope that is used to focus and direct the high-energy laser beam to its target. **(Insets, from top)** Boeing aircraft maintenance, launch and recovery flight technicians David Porr, left, and Dave Delazari conduct pre-flight checks for an Airborne Laser Test Bed mission; George Rodriguez, standing, Boeing Operations manager, works with Northrop Grumman Airborne Laser Test Bed teammates Bob Birkitt, left, and John Rendler, who monitor laser fluids loading for a mission; Lockheed Martin teammates Lisa Saguibo, left, and Chris Cirves verify laser functions prior to a flight. BOB FERGUSON/BOEING

Field of beams

The use of laser weapons has reached a tipping point and Boeing is rapidly advancing this speed-of-light technology By Eric Fetters-Walp

A century's worth of imaginings about using focused beams of light as weapons has moved from science fiction to reality.

Laser-guided and directed-energy weapons—the next evolution from successful precision-guided munitions introduced in the 1970s—are revolutionizing warfare. And The Boeing Company, through its Strategic Missile & Defense Systems, is among those making significant advancements in the power, range and precision of laser technology.

Boeing's customers, meanwhile, are defining how to incorporate this new capability into current and future missions.

Even with recent revisions in the U.S. Defense Department's spending priorities, laser weapons continue to capture the Pentagon's attention. The U.S. Air Force's chief scientist, Werner J.A. Dahm, told the *Los Angeles Times* he considers lasers to be "potentially game-changing" to the warfighter.

"Watching the Airborne Laser Test Bed shoot down a missile in midflight or the Advanced Tactical Laser cause a vehicle to burst into flames for no apparent reason because an infrared laser did its job—it's science fiction brought to life," said Mike Rinn, vice president and program director for Boeing Directed Energy Systems, a unit of Strategic Missile & Defense Systems.

Prototypes being developed, in some cases solely with company funding, help Boeing make the case that it is the right choice for effective and safe laser systems, Rinn added.

"We are working on rapid prototypes, which are meant to shape the market and demonstrate the capability of these systems for the warfighter. They also give us data to prove and improve how these systems work," Rinn said.

A historic first was achieved in laser capability last year when the Airborne Laser Test Bed destroyed an in-flight ballistic missile with a directed-energy weapon.

Consisting of a huge chemical-powered laser mounted on a modified 747-400 Freighter, the Airborne Laser is being co-developed by Boeing, Lockheed Martin and Northrop Grumman for the U.S. Missile Defense Agency. Originally contracted by the U.S. military in 1996, it is designed to shoot at tactical-range missiles while they are in the boost phase—between the missile's launch and when it leaves the atmosphere. By heating and weakening the missile's skin, the megawatt-class Chemical Oxygen Iodine Laser causes the missile to break up in flight.

Although lasers have been tested for decades, the challenge has been to combine the powerful beam with the right cutting-edge optics, beam control and targeting technology, according to Rinn.

"Nobody in the world is flying with this large a laser and this precise a pointing system,"

he said of the Airborne Laser Test Bed. “That’s what makes this program so unique.”

Last year’s experiment was the first of its kind. Despite some technical issues, the Airborne Laser has successfully engaged a total of nine missiles to date. With each experiment, the team continues to make breakthroughs in the application of laser technologies—such as advanced optics, beam control and pointing, Rinn said, noting these breakthroughs are critically important to the future capabilities of U.S. warfighters and their allies.

But the challenges are not just technical.

In 2009, the Pentagon shifted the Airborne Laser from a potential weapons system program to a research and development program, meaning leaner budgets in the future. Even so, the program’s partners hope to continue proving the system’s worth. Rinn said the program has accomplished much, and he believes it still could produce a future viable weapons system.

The Airborne Laser may be the most high-profile directed-energy weapons program under development by Boeing, but it is hardly the only one. The U.S. Defense Department has multiple contracts with the company to research lasers for a number of military missions, from destroying improvised explosive devices to defending naval ships.

Larry Pinkel, program management specialist for Boeing Laser Technical Services, said the technology is gaining trust among warfighters, who are used to lasers as sights, pointers, designators and dazzlers on the battlefield.

“There’s no doubt that we’re approaching the tipping point, or we may already be there, when it comes to the use of directed energy in a battlefield,” Pinkel said. “We’ve demonstrated that these weapons systems can do things that no other weapon can do, and that they can save lives.”

An example of that is the Boeing Acquisition Tracking and Pointing System, a laser weapon system that can be integrated on a number of military platforms. To keep the Boeing Avenger air defense weapon system up to date against the latest potential threats, Boeing has funded its own initiative to fully integrate this laser tracking weapon into the Avenger vehicle. The prototype, called Laser Avenger, has been demonstrating its capabilities over the past three years.

“It allows the warfighter to flip a switch and shoot a Stinger missile, flip a switch and fire a gun, or toggle another switch and fire the laser,” said Phil Hillman, Avenger Program manager for Boeing Defense, Space & Security. “You don’t see the laser. All you see are the results.”

With advanced targeting systems, the laser has demonstrated its ability to destroy the type of improvised explosive devices that pose a growing threat to warfighters, said Dave DeYoung. He’s a Directed Energy Systems program manager responsible for many of Boeing’s independent research and development laser efforts. These systems have shown

“We’ve demonstrated that these weapons systems can do things that no other weapon can do, and that they can save lives.”

– Larry Pinkel, program management specialist for Boeing Laser Technical Services

PHOTO: Drew Riedle, left, a Systems Engineering manager in Albuquerque, N.M., and engineer Barry Crow ready a beam control system for disassembly from its Avenger platform. **BOB FERGUSON/BOEING**

they can destroy unexploded ordnance and unmanned aerial vehicles. Work continues with the U.S. Army and Navy to apply the technology to several different platforms.

The Army is working with Boeing on the High Energy Laser Technology Demonstrator program, which will defend tactical vehicles and troops against incoming rocket, artillery and mortar projectiles. After the prototype system is installed on an Oshkosh Heavy Expanded Mobility Tactical Truck, initial firing tests will take place at the White Sands Missile Range in New Mexico.

Boeing also is advancing a Free Electron Laser weapon and Tactical Relay Mirror System. The latter is designed to extend a laser beam's range. The Free Electron Laser is being developed for the U.S. Navy and will pass a beam of high-energy electrons through a series of powerful magnetic fields to create an intense laser. This electric-powered laser, just out of the preliminary design phase, could defend naval ships against cruise missiles and other potential threats. The Office of Naval Research recently awarded Boeing a contract to complete the critical design of the electric-powered Free Electron Laser.

Boeing also has invested in development and testing of a surveillance detection system that incorporates laser technology and is capable of near-real-time, 360-degree detection of optical threats. (See story on Page 52). The system is designed to identify when friendly forces are being monitored or targeted through the use of cameras, binoculars, sniper scopes or other optical means.

All of the weapons applications under development by Directed Energy Systems are well-suited to maximize the advantages of lasers, including precision targeting to avoid collateral damage or casualties. Challenges still exist, however, including dissipating the heat generated by laser units and managing the size of laser units that can generate powerful beams. The Airborne Laser Test Bed's weapon, for example, fills much of a 747. Pinkel said Boeing is working with the military to make lasers more rugged and suitable for battlefield conditions.

Greg Hyslop, vice president and general manager for Strategic Missile & Defense Systems, said Boeing and its partners will continue to refine laser capabilities to fulfill the missions proposed by the Pentagon.

"I'm constantly amazed by the men and women of Strategic Missile & Defense Systems who help design technological innovations that save lives and deliver game-changing weaponry to the warfighter," Hyslop said. "Our successes are a direct reflection of the challenging work they perform, their understanding of our customers and their continued commitment to excellence." ■

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"You don't see the laser. All you see are the results."

– Phil Hillman, Avenger Program manager for Boeing Defense, Space & Security

PHOTO: In the Rapid Prototyping & Modeling Lab in Seattle, Greg Leggett, left, manager of Test Services, looks on as Siyani McFall, Boeing Test & Evaluation lab technician, uses a laser to create a timesaving drill jig—a key component used to locate and drill holes through the leading edge of an airplane's wing. **JIM ANDERSON/BOEING**

Bright ideas

Laser technology has far-reaching applications at Boeing, from jetliner production to making wind-tunnel models

Directed-energy weapons are still emerging as a practical technology, but lasers are used every day by Boeing employees for airplane production, tooling and research tasks.

On the 777 production line in Everett, Wash., lasers help align sections during final body join. Similarly, they assist in aligning wings on the Next-Generation 737 final assembly line.

After jetliners leave the Everett factory for the paint shop, the Laser Exterior Marking System uses lasers to display livery patterns on an airplane's exterior for better accuracy during painting.

One of the more innovative uses of lasers takes place in the Rapid Prototyping & Modeling Lab in Seattle. This Boeing Test & Evaluation facility often is called upon to make airplane conceptual and wind-tunnel models, prototype parts and unique tools. Components of both the 787 Dreamliner and the 747-8 have been produced by the lab's lasers.

Greg Leggett, manager of Test Services, said the laser tools his lab uses perform "additive manufacturing," also called fused deposition, using resins, powdered nylon and even metal powders to build 3-D parts and tools from scratch.

To do this, a high-powered laser melts the powder together to form a solid layer. Each layer is then built upon the next to form the desired shape. In stereo-lithography, an infrared laser bonds layers of photopolymer liquid resin to produce detailed models and tools to tolerances within 1/5,000th of an inch.

Boeing also has pioneered the use of a process called selective laser sintering to manufacture certified, flight-worthy aircraft parts. This process similarly uses a laser to produce parts from powdered nylon. It creates parts and tools with less fine detail than stereolithography, but with more durability.

Because the laser tools can create models and parts directly from computer-drawn plans, there is no need for molds to be created, Leggett said.

"I've had an aircraft in flight test call us at 3 p.m. for a part," he said, "and by 7 a.m. the next morning, we have it ready and delivered there." ■

– Eric Fetters-Walp

Beam me up

At age 50, the laser has boldly gone where no technology has gone before—except in science fiction

By Christina Kelly

In 1953, many moviegoers were treated to their first glimpse of a "laser" in the science fiction thriller *The War of the Worlds*, where Martians fired beams of red lights to vaporize humankind.

Seven years later, in May 1960, the world's first functional laser was developed up the road from Hollywood in Malibu, Calif., at HRL Laboratories, formerly known as Hughes Research Laboratory.

A number of laboratories were attempting to demonstrate the laser concept, but it was Theodore Maiman, a young physicist at HRL, owned by Boeing and General Motors, who won the technological race.

Laser is an acronym for light amplification by stimulated emission of radiation—an optical device that produces an intense monochromatic beam of coherent light. Now 50 years old, it has led to significant advances in science, communications, manufacturing, medicine, defense and countless other fields. It has been singled out by the National Academy of Engineering as one of the 10 greatest developments in a century chock-full of notable inventions.

"The idea was postulated nearly 100 years ago, by Albert Einstein, and then proved at HRL in 1960," said David Whelan, chief scientist for Boeing Defense, Space & Security and an admitted fan of old science fiction movies.

"Boeing and its legacy companies were a part of laser innovation then, and continue today pursuing advanced technologies to improve laser weaponry, better pointing and tracking systems, and laser communications for satellites," Whelan said. "It is one of the world's most prolific technologies, and it plays a big part in our everyday life, from supermarket scanners to medical instruments."

Laser applications continue to grow. Surgeons use lasers to perform cataract surgery; groceries are scanned at checkout via lasers; printers churn out crisp copy thanks to lasers; laser gyroscopes guide commercial airliners to their destinations and control their landing approaches; lasers are revolutionizing biomedicine and chemistry; and lasers ensure precise alignment of parts in the assembly of the newest Boeing jetliners.

Whelan noted that the U.S. Energy Department is experimenting in Livermore, Calif., with the world's biggest laser in hopes of producing laser-driven nuclear fusion.

Boeing, meanwhile, is developing a wide range of laser systems to address multiple defense needs. The Airborne Laser Test Bed made history last year by shooting down a ballistic missile in its boost phase. But that laser, the highest energy beam ever fired from an aircraft, fills much of a 747—a far cry from the small laser weapons fired by TV characters Flash Gordon, Buck Rogers and Captain Kirk.

But hand-held lasers could eventually move from science fiction to reality. Just as electronic systems have gotten smaller, lasers also are shrinking, according to Anthony Galasso, a laser physicist and director of Advanced Integration Capabilities in Boeing's Phantom Works organization.

"We could see even more powerful and compact solid-state lasers that could fit on combat aircraft," Galasso said. "This technology offers game-changing abilities. We are boldly going where no one has gone before." ■

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PHOTO: Bryan Morris, an electro-optical physicist working in Directed Energy Systems in Albuquerque, N.M., examines a 3-D camera he developed for military and commercial applications. The laser-assisted system is designed to map the ground in three dimensions. **BOB FERGUSON/BOEING**

Engineering at the speed of light

Directed Energy Systems, part of Boeing Strategic Missile & Defense Systems, is researching and developing laser weapon systems to meet a number of customer requirements. The major programs:

AIRBORNE LASER TEST BED

The Airborne Laser Test Bed is designed to destroy ballistic missiles in their early stages of flight using a high-energy chemical laser, along with battle management equipment and a beam control system, integrated on a modified 747-400 Freighter. Along with Boeing, Northrop Grumman and Lockheed Martin are part of the program for the U.S. Missile Defense Agency.

FREE ELECTRON LASER

Boeing has a contract with the Office of Naval Research to complete critical design of the electric-powered Free Electron Laser, which provides an ultra-precise, speed-of-light capability to defend ships against emerging threats. The megawatt-class laser will counter hyper-velocity cruise missiles, ballistic missiles or low-cost, low-tech threats.

HIGH ENERGY LASER TECHNOLOGY DEMONSTRATOR

Under this $23 million U.S. Army contract, Boeing is developing a truck-mounted solid-state beam control system that can destroy incoming rocket, artillery and mortar projectiles. Field testing is scheduled to begin this year.

BOEING ACQUISITION TRACKING AND POINTING SYSTEM

Developed by Boeing, this system destroyed 50 improvised explosive devices during a test in September 2009. The solid-state laser, mounted on a combat vehicle called Laser Avenger, also has destroyed small unmanned aerial vehicles in tests. The laser system is designed to be integrated into other platforms as well.

TACTICAL RELAY MIRROR SYSTEM

Working with the U.S. Air Force under a $40 million contract, Boeing is helping develop a relay mirror system that can be carried on unmanned aerial vehicles or other airborne vehicles. The system would relay ground or airborne laser beams to allow them to provide intelligence, surveillance and reconnaissance, or “shoot over the hill,” without having direct line of sight. ■

PHOTO: Control systems engineer Tony Lazzaro, left, and optomechanical engineers Matt Edwards, center, and Bryan Crespin work on the telescope of the Tactical Relay Mirror System in Albuquerque, N.M. BOB FERGUSON/BOEING