March 2015

AEROSPACE AMERICA

NEXT-GEN SATELLITES

through robotics and additive manufacturing

A PUBLICATION OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

AEROSPACE AMERICA

March 2015

DEPARTMENTS

FEATURES

BULLETIN

ON THE COVER
Laser metal deposition, a 3-D printing process, is used to produce aerospace components. Credit: TWI Ltd.

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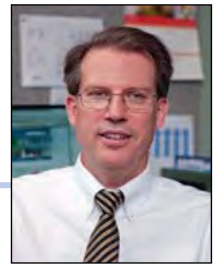
AIAA
Shaping the Future of Aerospace

Editor's Notebook



Keeping audience analytics in perspective

As the Aerospace America team charts the magazine's future, I've been thinking a lot about analytics, the digital tools that the media use to track which online articles are the most widely read.

Analytics are powerful tools for editors and the business side of the house, but like all powerful tools, they can be dangerous if used incorrectly. Aerospace America will use analytics as one of many pieces of evidence to gauge how well we are doing at engaging you, our audience. We won't substitute analytics for editorial judgment or use the data to pressure our contributors.

As important as analytics are, they don't tell the full story. They are inherently rooted in the past, which can lead a contributor or editor to make next month's story a lot like last month's. I call this the content view of journalism. Cranking out content works for a while, but eventually the readers' eyes glaze over and the audience erodes. It's not a sustainable strategy.

Impactful publications do things differently. They focus on mission rather than content, even if they use the term content as a convenient shorthand — like "copy" in the old days. These publications are always on the lookout for fresh insights, anecdotes and great storytelling. They are oriented toward the future more than the past.

Publications succeed in the long run because readers trust them. Readers might not love every word they read, but they sense that the words come from an independently minded group of people.

Analytics can help editors sense whether they are engaging readers in this way. But analytics can never fully measure a publication's impact. That's because no one can predict how a piece of information might be used weeks, months or even years from now.

Let's say Aerospace America runs a small article about a new recipe of aluminum alloy, and the analytics show that 100 people viewed it. Another article tells the inside story of an exciting robotic landing. It gets 10,000 views.

Does this mean the robotic landing story was more successful?

Maybe in the short term, but what if someone reads the aluminum story, acquires the alloy and uses it to create an aircraft engine that is vastly more fuel efficient than today's engines? There is no algorithm or data that could have predicted that. We have to run the article and see what happens.

In my mind, Aerospace America's mission is a fairly simple one: To be valuable and impactful to its readership. That value can't be measured by page views alone.

Ben Iannotta
Editor-in-Chief

Data the 'crown jewel' in no fault found

The no fault found incidents examined in Debra Werner's article, "A Maddening, Costly Problem" [February], present a component- and system-level challenge. Effective troubleshooting of these incidents requires access to a broad set of engineering data sets. Telemetry and onboard housekeeping data will play an important role in bringing predictive maintenance, but without other key data sets, it has the potential to deliver those NFF false positives.

In many cases, time to resolution can be accelerated if engineers have the ability to readily refer back to a serialized piece of equipment's original schematics, design specifications, configuration data and original testing data. Given that most equipment in this industry is designed for decades of service, engineering teams often struggle to readily locate associated files created during earlier stages of the product's life-cycle. These precious data assets have often gone "dark" due to loss of tribal knowledge, while every three to five years IT hardware refresh cycles further disrupt tracking of data assets by moving them from an old system to a new one. All of this makes rediscovery years later a difficult proposition. Product life-cycle tools have been modestly successful in managing this issue, but they frequently cover only a small portion of the engineering data assets — design, test and simulation data — created over decades.

Werner's piece does a fine job of illustrating one of the industry's most vexing challenges, and it lays the groundwork for a discussion between engineering and IT about prioritizing access to these crown jewel engineering data sets to help with reliability issues such as NFF.

Manuel Terranova
President and CEO, Peaxy Inc.
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Tom Swift's air travel foresight

When reading the "Revolutionizing Air Travel" article by Philip Butterworth-Hayes [January], I had an astonishing sense of deja vu. As a boy of 10 or 12, I ran across a treasure trove of old science fiction books in a small-town library. These books went back years before I was born, back to the 1910s and 1930s. Included in the library's collection were several books in the "Tom Swift" series.

Now these were not the 1950s-70s era "Tom Swift, Jr." books, such as "Tom Swift, Jr. and His Outpost in Space." These were the predecessors, which included "Tom Swift and His Airship," published in 1910.

However, one of the books I recall from that collection was "Tom Swift and His Sky Train, or Overland Through the Clouds," published in 1931. The "Sky Train" was a string of commercial, passenger-carrying gliders, towed by one powered airplane. At intermediate terminals, some gliders would be released and land, while others would be towed aloft and linked into the string as it cruised along.

The Aerospace America article, of course, describes a much more sophisticated and well-thought-out operations concept than does the children's book. Still, I wanted to call it to your attention in hopes that you might bring it to the attention of the researchers looking into the passenger-exchange vehicles. I know that if I were working on some revolutionary aerospace concept and I were to find a distant ancestor of the concept showing up in an 83-year-old children's book, I would be delighted and tickled.

Daniel D. Villani
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At last, recognition for no fault found

I very much appreciated seeing Debra Werner's article, "A Maddening, Costly Problem [February]." With less money and fewer program starts, sustainment will need more attention. The no fault found problem is just one of many that weapon system sustainers must tackle each day.

Retiring after four decades in this field, I am often confronted with, "Er... what is weapon system sustainment anyway?" So I have created a blog — weaponsystemsustainment.blogspot.com — where sustainment solutions are posted and discussed. In intercontinental ballistic missiles, for instance, NFF is particularly vexing given the need to avoid costly maintenance trips to silos and mission-killing downtime. Over the decades, we found better ways to incentivize good data from repair techs, track the convoluted remove-and-replace bowl of spaghetti, and generally implement FRACAS [failure reporting analysis and corrective action system] in a repair depot.

Col. Charles Vono
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All letters addressed to the editor are considered to be submitted for possible publication, unless it is expressly stated otherwise. All letters are subject to editing for length and to author response. Letters should be sent to: Correspondence, Aerospace America, 1801 Alexander Bell Drive, Suite 500, Reston, VA 20191-4344, or by email to: beni@aiaa.org.

Researchers want to put commuters behind the wheel of a helicopter

"Where's my flying car?"

That question has become a joking acknowledgment that the technological wonders predicted decades ago often fail to materialize. But researchers in Europe now say they might have an answer.

One reason personal aircraft have failed to catch on is that operating a plane or helicopter requires much more training than does driving a car. But a flight control system that integrates manual operation and automation in a new way could reduce training requirements and make flying a small aircraft nearly as simple as driving a car, say researchers at the Max Planck Institutes and the German Aerospace Center, DLR.

They have designed what they say is an intuitive steeering-wheel-based system for operating a small helicopter called myCopter. At the heart of the design is a new way of combining manual and automated flight control systems that the researchers call "haptic shared control."

Under this concept, the human pilot and an automatic control system continuously share control authority. As long as an optimal trajectory is flown, the pilot needs to apply only minimal force to the steering wheel. But as the pilot moves farther away from the agreed flight path, the force needed to steer the aircraft grows, encouraging the pilot to move back to the most direct and safest route. The pilot can always choose to overrule the haptic control system in case of an emergency.

myCopter

The myCopter would have car-like controls, including a steering wheel and foot pedals to increase or decrease speed.

"Such a system would allow the human to interact with automation directly and overrule it if necessary. In this way, the human retains ultimate control authority," said Frank Nieuwenhuizen, a research scientist at the Max Planck Institute for Biological Cybernetics, in an email. "It has been shown that such systems can result in increased performance in vehicular control tasks."

Flying a conventional helicopter can be complicated. The pilot uses a cyclic stick to adjust pitch and roll; a collective stick to change altitude and, in combination with the cyclic, to develop thrust; and two anti-torque pedals that adjust yaw by changing the pitch of the tail rotor. The myCopter would replace the cyclic with a steering wheel.

"The pilot simply turns the steering wheel as required to fly the helicopter in the intended direction," said Bianca Schuchardt from the DLR Institute of Flight Systems, in a press release The collective stick would remain, to control altitude. Instead of controlling yaw, the floor pedals would operate like the accelerator and brake pedals in a car, allowing the pilot to speed up, slow down and hover. An eight-way thumb switch on the myCopter steering wheel controls reverse and lateral flight.

The myCopter flight control concept has been tested in the Air Vehicle Simulator operated by DLR in Braunschweig, Germany.

The myCopter is envisioned as a single-seat personal air vehicle that could take off and land vertically with a range of 100 kilometers. The cruising speed would be between 150 and 200 kilometers per hour and the vehicle would be available to fly in most weather conditions.

The researchers are also exploring how personal air vehicles would operate within airspace systems and their impact on society. Technologies being investigated include automation for obstacle avoidance, path planning and formation flying.

The myCopter project has received €4.3 million ($4.9 million) — €3.4 million from the European Union and the remainder from the research agencies involved. In addition to the Max Planck Institutes and DLR, the project consortium includes the University of Liverpool, the Swiss Federal Institute of Technology Zurich, the École Polytechnique Fédérale de Lausanne in Switzerland and the Karlsruhe Institute of Technology.

In the myCopter personal aircraft, shown in an artist's rendering, a pilot would share control with an automated system.

myCopter

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Australia's aerospace industry poised for growth

From the introduction of a new turboprop utility plane to work on the latest military jet, signs are that Australia's aerospace industry is about to take off.

Proximity to fast-growing civil aviation markets in the Asia-Pacific region, recent government investment in aerospace research and development facilities, and a growing share of component production and support for the F-35 Joint Strike Fighter are fueling the growth of the Australian aerospace industry, experts say.

GippsAero's 10-passenger utility plane made its first flight in 2012, and deliveries to customers are expected to begin this year.

Mahindra Aerospace

The industry currently generates revenues of about AUS $4 billion (US $3 billion) a year, according to the Australian Trade Commission, the government agency known as Austrade. Commercial aircraft and parts account for 33 percent of that; military aircraft, parts and guided missiles, 30.5 percent; maintenance, repair and overhaul another 29.8 percent; and light aircraft and parts, 6.7 percent. The industry comprises 830 companies employing 14,000 people, according to Austrade.

The commercial sector includes companies such as GippsAero, which later this year expects to make the first customer deliveries of its Airvan 10, a 10-seat, single-turboprop utility plane, marketing manager Shanti Lakhan said in an email. GippsAero, a subsidiary of India's Mahindra Aerospace, also has plans for larger and more ambitious projects, including a twin-engine 18-seat commuter aircraft. Details will be released once certification of the Airvan 10 is complete, Lakhan said.

In the defense sector, the Lockheed Martin F-35 program is likely to contribute to industry growth. Australia has ordered 72 of the fighters, and every F-35 will have Australian parts, according to Lockheed Martin. Nearly 30 Australian companies have been awarded F-35 contracts with a total value of AUS $432 million, the Australian Defence Ministry said in December. The F-35 could be worth up to AUS $8 billion to Australian industry over the life of the program, according to information on Lockheed's F-35 website.

In addition, the U.S. Defense Department said in December that Australia would host the facilities responsible for maintenance and upgrade of F-35s in the southern Pacific region.

The region is also expected to see a boom in civil aviation. Boeing, in its latest Current Market Outlook, says the Asia-Pacific region will lead the world in demand for new airplanes through 2033, with sales of 13,460 aircraft valued at US $2 trillion anticipated.

For several years the Australian government has invested heavily in its aerospace sector, especially in the establishment of advanced materials research and development facilities. Over the last four years, research and technology investments totaling AUS $4.08 billion have resulted in the development of aerospace research centers, including the Australian Advanced Manufacturing Research Centre, the Defence Materials Technology Centre, and the Materials Science and Technology division of the Commonwealth Scientific and Industrial Research Organisation, or CSIRO. In May 2012 Boeing and CSIRO announced a five-year AUS $25 million research program in space sciences, advanced materials, energy and direct manufacturing.

In August, a group of Australian aerospace metal production companies, research agencies and the Aviation/Aerospace Australia trade association launched the Manufacturing Excellence Taskforce of Australia National Commercial Aerospace Hub to help companies gain access to a greater share of the market. The global aviation industry's procurement of metal components is estimated to be worth AUS $50 billion, but Australian manufacturers garner just AUS $200 million of the market, according to a META news release.

Unmanned aircraft are another growing segment of the Australian aerospace industry. In December, Northrop Grumman Australia was created to consolidate Northrop Grumman's various defense businesses along the east coast into a single company, with capabilities that include unmanned systems, aircraft support and sustainment, and intelligence, surveillance and reconnaissance systems.

One of the company's efforts will be to support Australia's planned purchase of the MQ-4C Triton high-altitude, long-endurance unmanned maritime patrol aircraft.

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Crowdfunding for firefighting planes

Dale Head was tired of waiting for the U.S. Forest Service to reconstitute its fleet of air tankers. On Jan. 15 he launched a crowdfunding campaign on Indiegogo to raise $4.95 million to buy two P-3 Orion turboprops parked at the former McClellan Air Force Base in Sacramento and use them to fight fires.

A P-3 Orion operated by Aero Union drops retardant on a fire in California's Mendocino National Forest in 2006.

U.S. Forestry Service

“At a certain point, someone has to pick up a flag and run with it,” said Head, a former P-3 air tanker pilot.

While the campaign has gotten off to a slow start, raising less than $5,000 in its first two weeks, Head hopes support for the effort will spread among people concerned about prospects for the ferocious fire season anticipated in the western United States due to a severe drought in California, Nevada and southern Oregon.

With proper maintenance, P-3s are dependable air tankers, said Hart Drobish, another former P-3 air tanker pilot who supports the Indiegogo campaign. The four-engine turboprop, used by the U.S. Navy since the 1960s to hunt submarines, has a bay designed to hold bombs but that can also accommodate retardant tanks. Plus, since the aircraft was built to carry a load of weapons, “it's a very powerful plane,” Drobish says.

Head is among those worried about the size of the U.S. Forest Service's air tanker fleet. In 2014 the agency had contracts for the exclusive use of 17 commercial air tankers — mostly turboprops and jet airliners converted into firefighters — and eight U.S. military C-130s equipped with firefighting tanks. That's well short of the fleet of 40 air tankers in 2001, before two fatal accidents sidelined the oldest of the planes. The Forest Service has been restoring its fleet under an initiative called Next Generation Air Tanker that seeks privately flown air tankers capable of flying faster, carrying more fire retardant and requiring less maintenance than older aircraft.

For the 2015 western fire season, the Forest Service plans to add six more next-generation aircraft to its fleet, for a total of 21 air tankers under exclusive-use contracts. Seven military C-130s also will be standing by, Forest Service spokeswoman Jennifer Jones said by email. Jones declined to specify which new aircraft the agency plans to bring into its fleet this year and said she cannot speculate about whether the agency would use P-3s if they were available. The Forest Service relied on P-3s to combat fires until 2011, when the agency canceled its contracts with Aero Union, an aircraft operations and maintenance company based in Chico, Calif., due to safety concerns.

The Forest Service, however, is not the only agency that hires air tankers. States also contract aerial firefighters, and California, with 50 aircraft under contract, has the largest fleet, says Daniel Berlant, spokesman for the California Department of Forestry and Fire Protection. “There is not an outstanding need” for the P-3s, Berlant said by email. “However, any airtanker vendor who meets FAA airworthiness requirements and our own contracting criteria can sign up for our ‘Call When Needed’ vendor list.”

Head is banking that the P-3s would be in high demand once they were compliant with government regulations and waiting on a ramp. If the $5 million campaign is successful, Head plans to hire mechanics and crew chiefs, rent a hangar and prepare two P-3s to fight fires in 2016.

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Dust-busting technology for moon, Mars exploration

NASA researchers test an Electrodynamic Dust Shield in a vacuum chamber during reduced-gravity flights on a NASA aircraft.

NASA

The Apollo astronauts who walked on the moon in the late 1960s and early 1970s faced a dusty dilemma. Lunar dust clung to their spacesuits, earning them the moniker "the dusty dozen."

The dust gummed up gauges, sun shades and tools that the moonwalkers carried.

As Apollo 17 commander Eugene Cernan put it during a debriefing back on Earth: "I think one of the most aggravating, restricting facets of lunar surface exploration is the dust," he said, according to a transcript. The biggest problem, he said, was "its restrictive, friction-like action."

Fast forward four decades, and technologists at the Kennedy Space Center's Swamp Works facility are reporting good progress on the KSC Electrodynamic Dust Shield, an electric system they hope will tame the dust the next time astronauts walk on the moon or when they venture to Mars.

If all goes as planned, conductive threads would be added to the surface layers of astronaut spacesuits. Low-power AC current would course through these electrodes to produce electromagnetic fields — traveling electronic waves that would repel dust. If it turns out that shielding the entire suit is not feasible, another option would be to focus on keeping dust off critical components, such as the quick disconnects to gloves and boots. Transparent film versions are also in the works for solar arrays and spacecraft windows.

Developers are working on a version of the technology that will be made available to the companies participating in NASA's Lunar Cargo Transportation and Landing by Soft Touchdown, or Lunar Catalyst, program, which aims to develop commercial robotic lunar landers. If a Lunar Catalyst spacecraft goes to the moon, a dust shield on a landing pad will attempt to repel the dust that arises as the craft lands.

The technology is based on an "electric curtain" concept developed by NASA in 1967 and further developed in the 1970s at the University of Tokyo. Prototypes of the shield are under study at KSC's Electrostatics and Surface Physics Laboratory and have been evaluated on low gravity research planes.

"So far, our testing has shown the electrodes can remove most of the dust," said Carlos Calle, founder and manager of the lab. "Thin wires are embedded in surfaces such as fabrics and can be made transparent on clear surfaces for optical devices, windows, visors, thermal radiators or solar panels."

KSC's dust shield was originally developed to remove dust from the solar panels of Mars rovers and landers, but the technology has yet to be flown in space.

Karen Thompson, KSC's chief, said the technology can be applied to habitat windows to ensure a non-dusty view.

Once the dust removal system circuitry is switched on "it just throws off dust and particles off the surfaces," Thompson said at the NASA Innovative Advanced Concepts 2015 symposium in January.

Thompson described how the dust hampered the Apollo moonwalkers by sticking to their quick-disconnects. "They couldn't connect them more than three times before they couldn't make a seal anymore," she said.

The dust shield technology might be applied to the whole spacesuit or on the locations of the quick-disconnects, Thompson said. It could keep dust and particles from being brought into habitation units.

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Criminal case draws attention to aerospace hacking

There's a term for the practice of buying data from mercenaries who hack into companies, including aerospace firms: espionage as a service. Cybersecurity experts are warning of a growing threat from this kind of espionage, with mercenaries infiltrating computer networks in search of documents they can sell to the highest bidder, often earning $100,000 to $500,000 for valuable data.

"They live inside as many corporate networks as possible and do not leave," said Jeffrey Carr, president and chief executive of cybersecurity firm Taia Global Inc. of Seattle. "Even if they are discovered, they find a way back in."

In the espionage-as-a-service model, hackers often market corporate secrets to Russian and Chinese business executives, Carr said. He points to the case of Su Bin, a Chinese businessman who owned Beijing Lode Technology Co. Ltd., a firm with offices in China and Hong Kong that provided cable harnesses for aviation and space companies. From 2009 to 2013, Su allegedly worked with two hackers to infiltrate Boeing's networks and steal plans for the company's C-17 military cargo jet. Su and his accomplices also allegedly obtained documents related to Lockheed Martin's F-22 and F-35 stealth fighters. The allegations are described in the U.S. Justice Department's June 27 criminal complaint. Su was indicted in August on five counts, including stealing trade secrets and illegally exporting defense articles and technical data.

U.S. Justice Department

An image from an FBI criminal complaint shows an F-35 flight test plan that businessman Su Bin allegedly obtained from a U.S. company and then translated into Chinese.

Carr isn't the only one warning of mercenary hackers. Symantec Corp. of Mountain View, California, sounded the alarm in 2013 when it identified a group it dubbed Hidden Lynx that allegedly waged sophisticated attacks on hundreds of organizations around the world.

"Mercenary hackers can be professional, shrewd and cyber invisible," said Sam Adhikari, chair of the AIAA Cybersecurity Working Group and vice president of operations and research for Sysoft, a software company based in New Jersey. To counter the threat, Adhikari suggests firms confuse hackers by revealing incorrect designs for new technology and observing how the hackers steal the designs and transfer them to outside computers. Companies also can employ data mining techniques to identify patterns that precede attacks.

"Mercenary hackers will observe and 'poke' a network for a long time before attacking it," Adhikari said by email. "It is possible to find the statistical patterns they create."

Carr said hacking has become so pervasive companies should accept the fact that their data networks have been compromised and focus on protecting their most valuable information.

"Recognize what's of value, what a competitor would want, then encrypt and isolate it so it cannot be exfiltrated without your knowledge," he said.

Taia Global published a report on the topic in January, "The TRIES Framework, Counter-Reconnaissance Against Espionage as a Service Threat Actors." TRIES stands for target, reconnoiter, infiltrate, exfiltrate, sale — the primary actions taken by mercenary hackers.

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Hoppin' and tumblin' on other worlds

For scientists who want to explore the surfaces of asteroids or comets, traditional wheeled rovers aren't the right fit because they're designed for high-gravity bodies like Mars.

Robotics experts at Stanford University have devised an alternative concept for maneuvering across diminutive, low-gravity bodies.

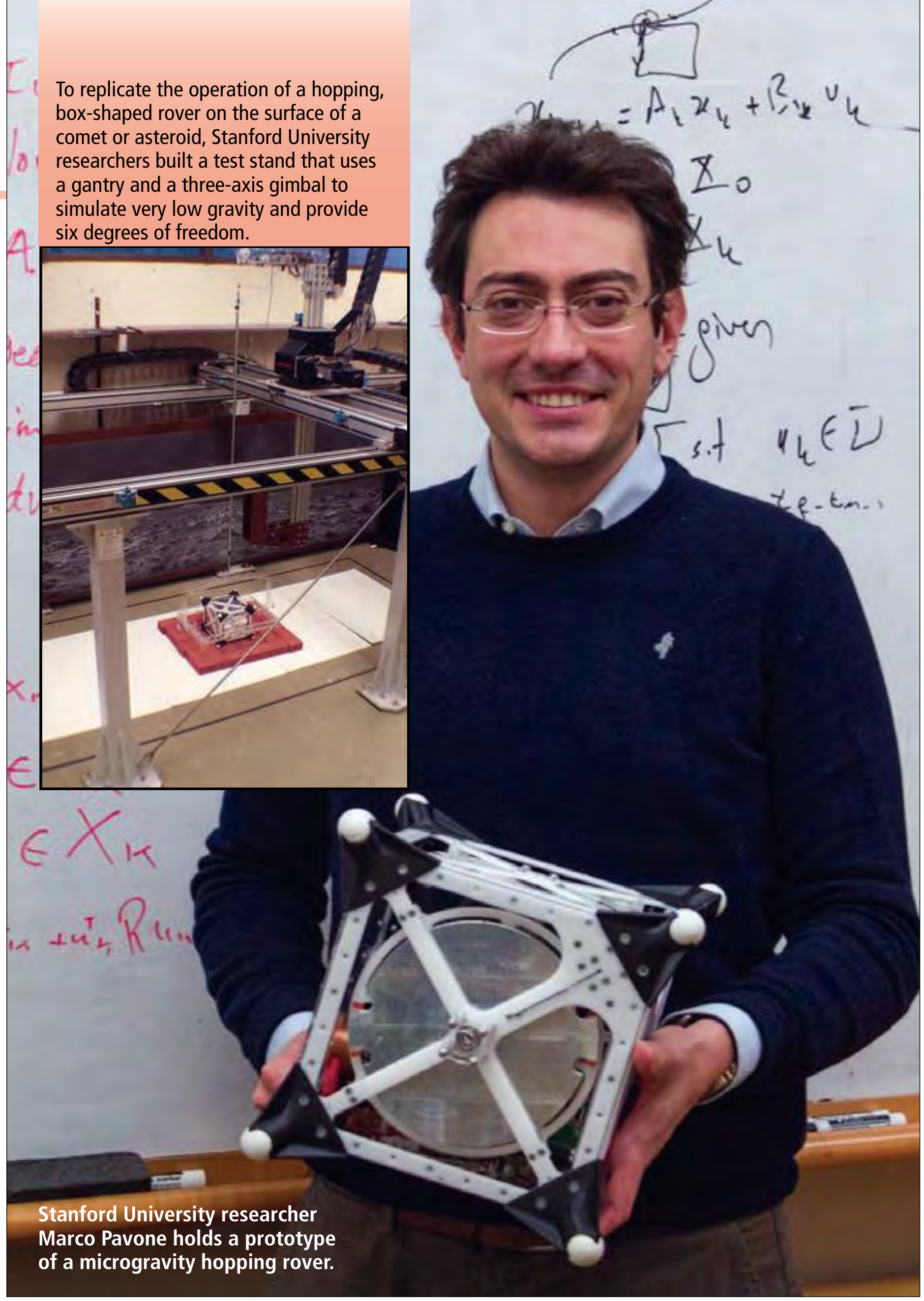
The initiative is led by Marco Pavone, director of the Autonomous Systems Laboratory at Stanford. He wants to drop small, box-shaped spacecraft to the surfaces of such bodies and command them to tumble for regular maneuvering, hop when the time comes to explore a new location and shuffle to point science instruments at specific features.

"Try to play golf on a bumpy terrain," Pavone told Aerospace America. "This is an analogue to the challenge of controlling a hopping robot on an asteroid, the key goal of this project."

Pavone's spacecraft would be released cubesat-style from a main spacecraft and bound several times on the surface. Once at rest, a trio of internal flywheels would be spun up and stopped very rapidly. This produces a jolting torque that causes the device to hop or tumble depending on the speeds of the flywheels, explained Stanford graduate student Benjamin Hockman, Pavone's assistant on the project. It's all about swapping angular momentum to get to where you want to go.

The two researchers detailed their work at the NASA Innovative Advanced Concepts 2015 symposium in January. NIAC is funding their work.

Pavone said the NIAC-backed research draws on control theory, autonomous systems, coordination of multi-robot networks, formation flying and bio-inspired robotics. He also sees lessons in the Philae lander's bumpy touchdown in November on Comet 67P/Churyumov–Gerasimenko. The European Space Agency's Philae lander appears to have bounced across the comet's surface a total of four times, including the final full-stop.



To replicate the operation of a hopping, box-shaped rover on the surface of a comet or asteroid, Stanford University researchers built a test stand that uses a gantry and a three-axis gimbal to simulate very low gravity and provide six degrees of freedom.

Stanford University researcher Marco Pavone holds a prototype of a microgravity hopping rover.

Stanford University

"Philae illustrated the challenges of landing on low-gravity bodies," Pavone said, "and how useful a mobility option would be to get out of bad landing spots and point instruments in a desired direction."

On the surface, Pavone's spacecraft would literally spring into action. Short treks to select spots would be done through a sequence of controlled tumbles. High-altitude, point-to-point jumps are feasible too.

Pavone and Hockman are considering an approach in which the main spacecraft would observe the landers and perhaps help guide them as they move from target to target.

To mimic the movement of the hardware on a small body, they've built a six-degrees of freedom microgravity test bed at the Stanford lab. In addition, prototypes are to be flown in parabolic flights later this year.

A conceptual study is also underway for a mission to Phobos, a moon of Mars. Instrument-laden landers could probe the nature of Phobos' soil and scout for water and organics.

"The robotic exploration of small bodies will be a main NASA focus in the years to come," Pavone said. It's a quest that requires disruptive mobility concepts to obtain new science at an affordable cost.

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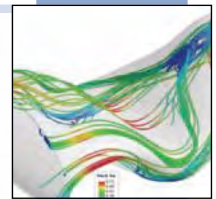
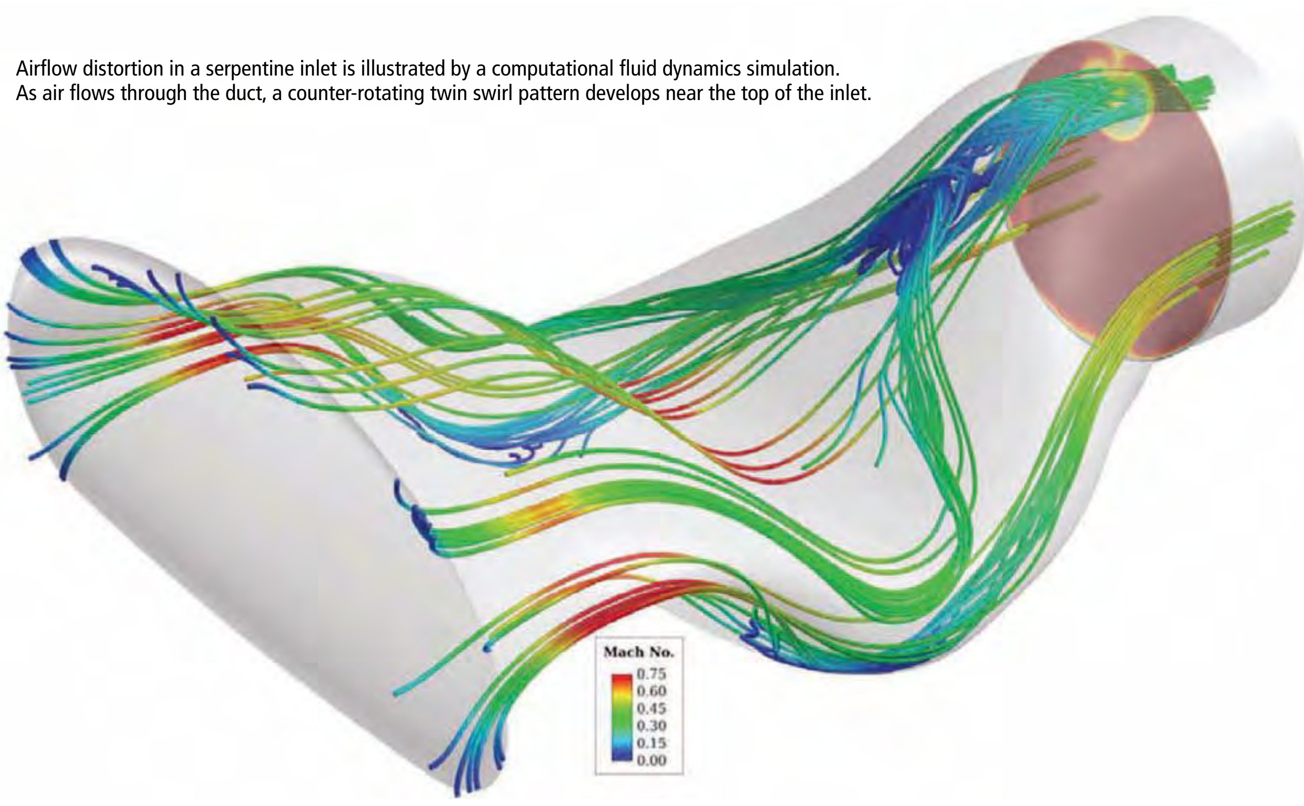


Distorting airflows on purpose

Drawing up exotic, environmentally friendly airliner shapes won't do much good if no one has an engine that can handle the distorted airflow. Henry Kenyon explains how a university team built a device that promises to expose such engine incompatibilities and save scarce research dollars in the process.

NASA is researching designs for next-generation commercial aircraft through its Environmentally Responsible Aviation program, but there's a catch: Some of the engineering models require inlets that are bent to match the shape of the plane's wing or fuselage. Others are recessed into the fuselage or mounted above the aircraft's wings.

These engine and body configurations could improve fuel economy and reduce engine noise, but they come with a price. Serpentine or recessed inlets can cause airflow distortions. Mounting engines next to the fuselage or over a wing can subject them to turbulent air. Engine designers need to know how these configurations will turn and swirl the air as it passes through the inlet to the engine turbine blades, so that they can predict whether these distortions are likely to result in reduced engine per-



Airflow distortion in a serpentine inlet is illustrated by a computational fluid dynamics simulation. As air flows through the duct, a counter-rotating twin swirl pattern develops near the top of the inlet.

formance, unacceptable blade wear or an increased risk of the blades failing catastrophically. They can then get to work designing out these incompatibilities or better yet finding a way to take advantage of the distortions to improve fuel efficiency.

The trouble is, it would be costly and time-consuming to build all these proposed inlets to scale and test them in wind tunnels with various engines, make adjustments to the engines and test them again.

Engineers at Virginia Tech set out in 2009 to solve this problem with funds from NASA as part of the ERA program. The Virginia Tech engineers saw that the ERA designs showed promise, but "there were certain enabling technologies that weren't there," says K. Todd Lowe, an assistant professor at Virginia Tech's Department of Aerospace and Ocean Engineering. One of the missing pieces was a low-cost way to replicate airflow distortions.

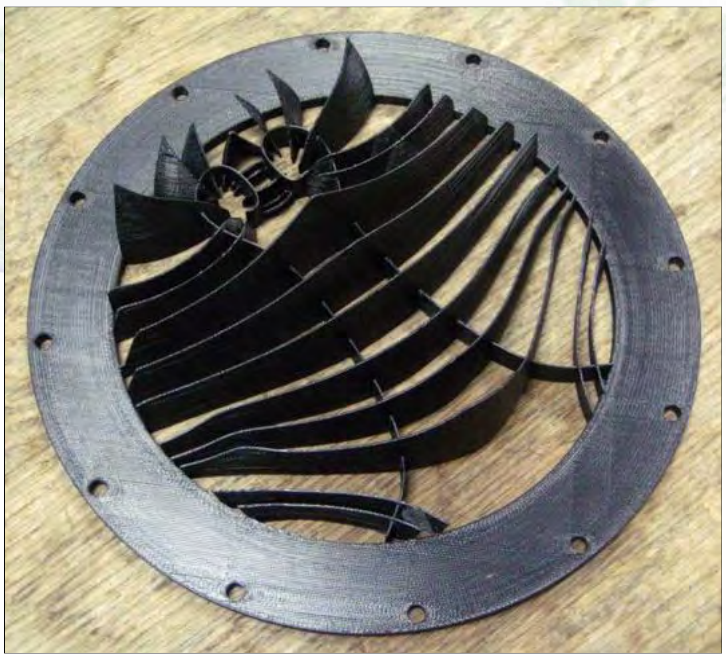
The Virginia Tech team came up with a device called a StreamVane — a circular high-strength plastic screen that can be fitted over an engine inlet to produce the same airflow profiles as specific inlet designs. Each StreamVane is made by an industrial three-dimensional printer according to a digital design.

StreamVanes were developed and tested in Virginia Tech's large wind tunnel. The devices were installed on the university's PWC JT-15D jet turbine engines, which it maintains for research purposes. Because the StreamVanes are made in an industrial 3-D printer, they can be made of almost any material. Researchers hope to make future StreamVanes from spray-deposited titanium.

If the results of ongoing design tests are good, ERA designers could soon have a new, low-cost method for proving that specific jet engines can tolerate the distortion produced by the inlets of their host aircraft. StreamVanes also might replicate airflow over propellers for fixed wing aircraft and helicopters. In fact, developers say requests for 3-D-printed StreamVanes are beginning to pour in.

The devices allow engineers to rapidly model new engine configurations and modify them to either mitigate or take advantage of any airflow distortions. Money is saved that would otherwise be spent building a series of physical prototypes. StreamVanes can also replace or be used together with pressure screens, which have been the standard airflow tool, explains Walter F. O'Brien, a Virginia Tech professor of mechanical engineering and the program's principal researcher. The key difference is that pressure vanes do not produce airflow distortions, which is the main purpose of the StreamVane.

The StreamVane team expects the technology to be a key part of designing next-generation aircraft. Although advanced aircraft designs have been around for decades, there was a missing technological component — the ability to model airflow distortions for maximum performance advantages, Lowe says.


A StreamVane replicates airflow distortions of specific inlet designs in a wind tunnel. This one was made with a 3-D printer.

Developing StreamVane was not easy. For starters, the team needed to digitally represent the airflow of a specific inlet in three dimensions, called a profile. This would require precise measurements, which was Lowe's specialty on the StreamVane team. Virginia Tech researchers used computational fluid dynamics and particle image velocimetry to track airflow and distortions. PIV measurements are made by seeding the flow with tiny liquid particles, explains O'Brien, the principal researcher. These particles are usually a type of dye that can be tracked visually. PIV measures how clouds of these particles move during very small time intervals and then uses that data to create an airflow model.

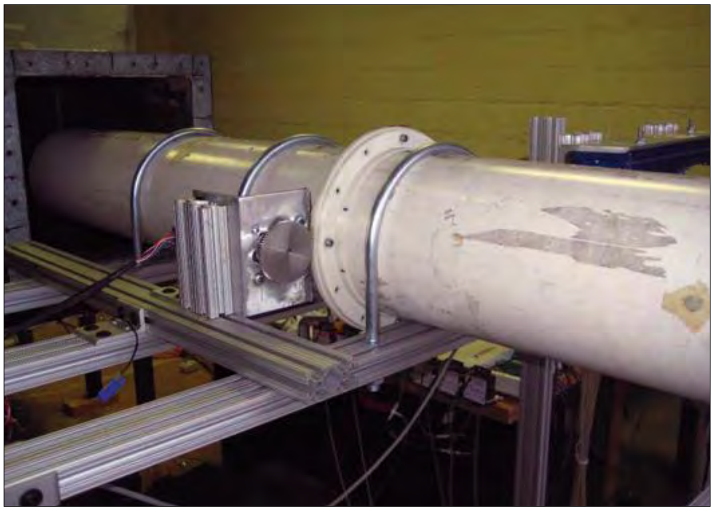
Researchers initially plugged their real-world understanding of these swirling, vortical airflows and their related mathematics into computer simulation software such as MATLAB, CFX and CFD to model airflow and distortion dynamics.

A Virginia Tech mechanical engineering masters student, Kevin Hoopes, devised a "push button" technique for exporting the airflow profiles into a computer-aided design tool, says Lowe. Each StreamVane is designed within that tool so it can be printed in three dimensions. At first, a small-scale StreamVane is printed and tested in a small wind tunnel to make sure that it creates the desired distortions and airflow patterns. "It's just like any sort of engineering program — there's a layer of experimentation and testing prior to doing the full-blown application," Lowe says.

For now, Virginia Tech plans to use the StreamVane technology to focus on jet engine and inlet research. "We actually are going to change our engines here, based on what we think we should do," O'Brien says.

O'Brien contends that the StreamVane technology could be very useful for companies developing new jet engines or airframes. For example, if a company wanted to install or test a jet engine on a new airframe, a StreamVane could be applied to determine if there is distortion and whether the engine will work with that distortion.

Handled properly, inlet airflow distortion can actually increase an aircraft's performance, says O'Brien.



In a low-speed wind tunnel test, a StreamVane is mounted in a 6-inch-diameter PVC pipe. An external motor can rotate the StreamVane to any angle.

Besides supporting research, the StreamVane has turned out to be a product that the university can supply to customers. There are currently two thrusts, Lowe says. One is fundamental and applied research toward better turbine fans. The school is also being approached by industry and government to provide them with StreamVanes. For 2015, the university has multiple StreamVane orders from Boeing and NASA.

Virginia Tech has copyrighted the StreamVane process. The university will build a StreamVane to order for labs and universities wanting to use the technology. Several of the devices have already been built. In the future, it may be possible that customers could acquire the software to make StreamVanes on their own printers, "but we aren't there yet," O'Brien says.

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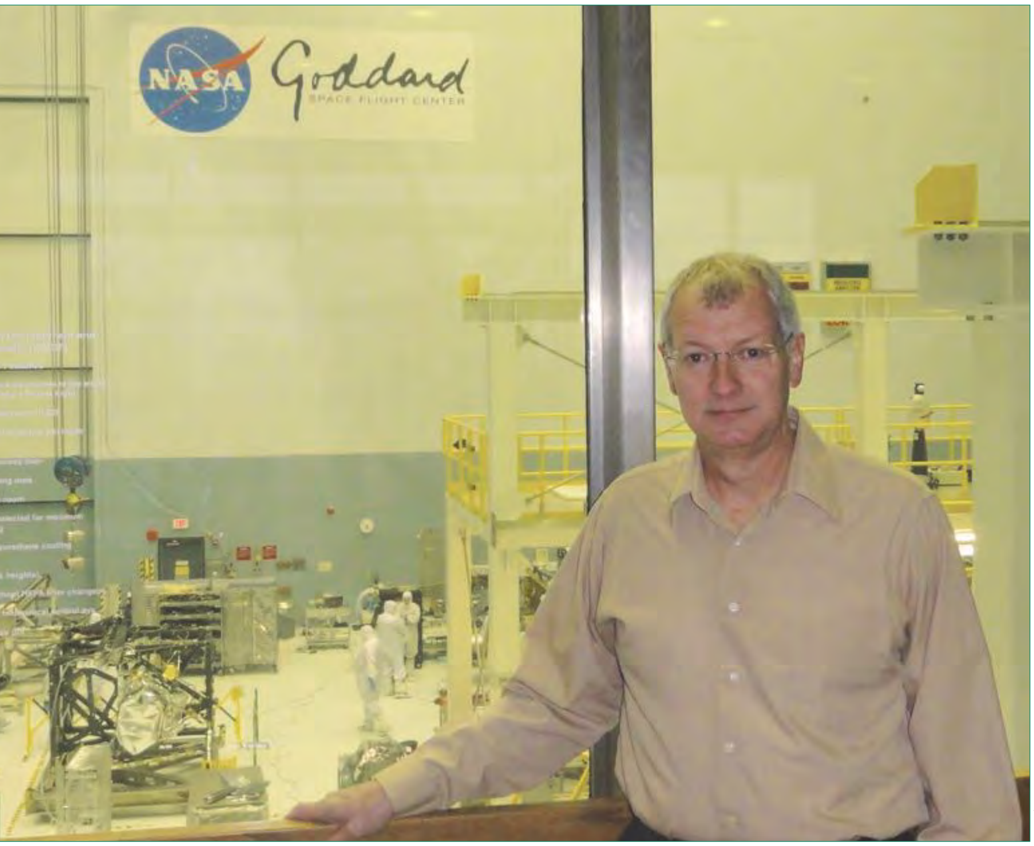

Exelis

As a kid in the summer of 1969, Gary Matthews spread a map of the moon on his floor. His interest in space came naturally, and 46 years later he is one of the country's foremost experts on telescope engineering. After graduating from Penn State with a degree in mechanical engineering, "I joined a company that was interesting to me, and then I kind of grew from there," he says. The year was 1979, and the company was Eastman Kodak in Rochester, New York. Matthews worked in a unit that would became part of ITT and later Exelis, a company that's in the process of being acquired by Harris Corp. The result will be an enterprise with "greater scale, a global reach and a cutting-edge technology portfolio," Matthews says by email. Much of Kodak's work in 1979 was classified, so Matthews didn't always know what he was working on. Everything changed when he got an opportunity to work on NASA's Chandra X-ray telescope. Matthews spoke to ***Ben Iannotta*** *by phone about the James Webb Space Telescope (Exelis will assemble the telescope for Northrop Grumman and test it), improving telescope affordability and the quest to see an Earthlike exoplanet.*

What's challenging about Chandra's X-ray observations?

If you think about Hubble, you have a large primary mirror, a secondary mirror, light comes in, bounces off. You can kind of picture how all that works. An X-ray will pass directly through things it hits, right? So [German physicist Hans] Wolter showed that if I have the X-ray graze at a 1 degree angle or so, it'll actually bounce and I can image. If you look at pictures of Chandra, you can see it looks like these big pieces of glass that are kind of nested together sort of like coffee cups of different sizes. There's a lot of X-ray telescopes that do spectroscopy, but these crisp images you get from Chandra are very much unique.

What are the lessons from designing Chandra?

One of the ones is [the need for] a pathfinder. The pathfinder telescope on Chandra was critical in helping us understand how to build that hardware. We just finished the path-

Interview by Ben Iannotta


Spare mirrors are installed on a replica of the center backplane of the James Webb Space Telescope. The replica, called a pathfinder, allows technicians to practice the precise installation of the mirrors on the actual telescope.

NASA

finder telescope JWST [the James Webb Space Telescope]. Without that kind of experience, our ability to be successful with something like JWST or Chandra would be dramatically reduced. You're in new territory, relying on analysis and engineering judgment. Having some hardware to — I don't want to say play with, but that's effectively what you're doing — increases your success rate dramatically.

You did that on Chandra with the VETA-1, -2 experiments?

Yes, VETA-1 [Verification Engineering Test Article-1] was a congressional milestone that had to be passed. Congress said, "Listen, before we give you any more money, you have to demonstrate that these very difficult mirrors can be manufactured." We demonstrated that the mirrors could actually be made. Congress said, "Thank you very much, continue on." Then we built VETA-2 which was the alignment, integration and test part of the program where we verified that we could mount those mirrors in a manner that was consistent with the imaging performance and make it all work.

And so the equivalent of that has been done with JWST?

That's correct. There's a telescope [equivalent to] VETA-2. We call it the pathfinder. It is a composite structure. If you're familiar with JWST, there's two wings that fold out. This is just the central core and the secondary. We took two flight spares, mounted those on the pathfinder telescope. It was shipped by NASA to Johnson Space Center in Houston. It's going to go into a series of tests we call Optical Ground Support Equipment-1 and Optical Ground Support Equipment-2, and then finally a pathfinder thermal test where we will go exercise all of the support equipment we're going to use to test the flight telescope.

Let's talk about the mirrors that were gifted to NASA by the National Reconnaissance Office. You're repurposing these for the Wide-Field Infrared Survey Telescope, right?

That's correct. They've been sitting around for over 10 years, so the coating has degraded. There's typically a three- or four-year lifetime on a coating that's left out in the air. It's a silver coating with an overcoat. Any pinholes you can get leakage and just like your silverware, you can see some tarnishing there. So the mirrors do need to be recoated. And because the use is slightly different, the WFIRST prescription needs to change slightly.

You have to reshape the optics?

Minimally. I think it's a fraction of a wave or two. We put it in a vacuum. We have an ion gun that points at the mirror and basically ablates glass off the surface in a very deterministic manner. The computer has what we call a hit map: Where is it high, and where is it low? The high spot, the computer goes slow, and the low spots, it goes quickly. So on the WFIRST mirrors, we can use this ion ablative process to do the final tweaking of that figure. It's very quick and it's very cost effective.

These mirrors are going to need a lot of work. Is it still worth it to use these gifts?

I kind of leave that to NASA, but there have been studies done and the science return is certainly cost effective. The other thing is we do want to run these telescopes a little bit cooler, again to expand the wavelength range that we can observe. All the studies that NASA's done have said that it's a very cost effective way to get some excellent science.

What's meant by the AFTA that sometimes appears after WFIRST?

If you look at the 2010 Decadal [a survey of possible astronomy and astrophysics missions], WFIRST was listed in there. It's had several names. It was J-DEM – Joint Dark Energy Mission. It became WFIRST with inclusion of doing some planet finding, Subsequent to the 2010 Decadal Survey, these telescopes became available [from the National Reconnaissance Office]. When they decided to use the gifted telescopes, they wanted to kind of segregate it from the 2010 Decadal Survey telescope that could have been a 1.5 or 1.3 [meter-diameter primary mirror]. AFTA stands for [Astrophysics Focused Telescope Assets].

WFIRST-AFTA will go in the direction of viewing Earthlike planets but won't actually do that. What would be some of the optical breakthroughs required to do that?

There was a program called Terrestrial Planet Finder. It was canceled. The technology just wasn't ready yet. WFIRST will kind of start the process, but you're right: it's not going to be able to image Earthlike planets. What's going to be necessary is really big telescope, certainly JWST size or larger, looking in the more visible wavelengths. Think about a Hubble on super-steroids that goes from a 2.4 to 6, 10, 12 meters [in mirror diameter]. Well how do we do that? There's going to be a lot of very rich engineering [discussion] between the science community, optics and mechanical engineers to really figure out what this thing is going to look like.

Exelis

A technician checks the alignment of the Chandra X-ray Observatory's high-resolution mirror assembly, which consists of four nested pairs of mirrors.

JWST will have mechanical actuators to do adaptive optics, to keep the mirror in the exact shape. Is that going to be necessary on that future telescope?

Probably, but it'll be very different. JWST runs at about 40 kelvin. It images in the infrared to look at high redshifted stars and galaxies. This exoplanet finder will be a general use observatory. It won't be just a planet finder. There will be a coronagraph on it or a starshade – hard to tell which. There will be likely some kind of adaptive optics. Whether those will be actuators on the mirrors themselves or whether they will be deformable optics in the back that reimage the primary, it's hard to tell. A lot of engineering needs to be done to truly understand what this thing will look like.

Will the deployment approach be like Webb's or will it be very different?

We don't know. Will it go in SLS [NASA's forthcoming Space Launch System rocket] that has an 8-meter shroud and 10-meter shroud? Do you launch pieces and do robots or astronauts put it together – or both? [Studying] what the next large system looks like is just rich with wonderful things to go think about to create a system that's affordable and that will work as the scientists need it to work.

Could the MOIRE membrane technology [Membrane Optical Imager for Real-Time Exploitation technology] figure in?

That's basically a large diffractive optic. So if you had a large sheet of stuff, I'll just call it stuff, with the right kind of lines on it, the right kind of etchings, you can actually get it to focus. It could be made out of potentially something like Mylar. You could kind of just roll it up and fling it out into space and it would image. It's very interesting, very large. The downside is that like any diffractive optic it only works at a fairly small wavelength band, so you get large diameter, but you get kind of a limited wavelength usability.

Black and white, in other words?

Not even black and white. Remember, black and white is a mixture of all the colors. You could get red, and just a very small sliver of red. Or blue or whatever you wanted. It would not be a broadband imager like a Hubble or a JWST. It would be a fairly narrow imager in wavelength space, [but an option] if you needed that diameter to get high resolution if you had a very specific wavelength band that you were interested in. Very cool technology. How you apply that and to what mission is a rich area of optical engineering.

You couldn't get a picture of a blue dot but you'd get some kind of interesting biosignature?

I am not a scientist, [but] there's probably several biosignatures. There's water, there's methane. Do you need both? Do you need one? That's something I'd look to the science community to tell me. As we start to plan this next mission, the scientists come first. They have to say, "This is what I need."

So, it's not you guys saying, "We can do this really funky new mirror. How would you scientists use it?"

That's kind of like the pill looking for the disease. I think the scientists would take the opposite approach of: "This is what I need to see. How can you get me there?" People like the Space Telescope Science Institute and other scientists around the country are learning a lot about what it's going to take to find other planets [with] signatures that say, "Yes, there's life there." Frankly, we will do it spectroscoptically first. That's much easier. I mean, when you only get 1 or 2 pixels on a planet, the best you're going to do is some spectroscopy. Then, how do you go image that and really identify it as something that looks like us?

Is there going to be a point in your work here soon where you shift from JWST to: "OK, now I have time to think about the future more"?

I always think about the future, even in my current job. JWST is very important but I also am responsible for WFIRST. We won the secondary mirror on LSST, the Large Synoptic Survey Telescope, so that's under my purview. And I've been working with the Thirty Meter Telescope group since about 2004. I have lots of patience. My programs tend to work in multiples of decades. I wrote the JWST proposal in 2001 [as an Eastman Kodak employee working with TRW, now part of Northrop Grumman] and it'll launch in '18. And we're just now starting to build real hardware. So, long incubation periods in astrophysics.

Talk to me about a couple of key breakthroughs you've been involved with and then extrapolate to the future.

From an astrophysics perspective, obviously Hubble was a major turning point. Even though Exelis didn't have a large part in Hubble – we [Eastman Kodak at the time] did the backup primary mirror that's down in the Smithsonian. An incredibly rich astrophysics program emerged from that. There were obviously astrophysics programs before that, but Hubble really made it public. One of the biggest achievements is taking that Hubble legacy and moving it forward into Chandra, moving it forward into JWST and hopefully moving forward into WFIRST and then finding another blue ball. That's the direction that we're all headed here.

How will LUVOIR, the Large UV Optical IR surveyor, fit in?

That is the next big thing after WFIRST. It's got several names. It could be called ATLAST [Advanced Technologies Large Aperture Space Telescope], it could be called Big Planet Finder.

Why not just dust off the plan for the Terrestrial Planet Finder?

I don't want to speak for NASA, but if you look at the cost versus the science return, Terrestrial Planet Finder was kind of a hard sell. That's why LUVOIR is looking at a general purpose observatory like Hubble that can give us all those incredibly rich pictures and science return, but with a coronagraph, with the ability to go see exoplanets.

The budget is always tricky. What are some of the interesting things you could do to make space telescopes more affordable?

Costs are always tough. You can look at the NASA budget for JWST. Digging through, I think we'll find that electronics are expensive. Optics are expensive but I would contend that they don't necessarily drive the cost of the entire program. You could get a free primary mirror and you would barely notice it, for example. When you're looking at building these systems, there's a lot of testing and a lot of double and triple testing to make sure things are right. Looking at ways to either not do some things or looking for cheaper ways to do them — that's the real challenge here. It comes down to risk. These are very high-profile programs and they have to work and they have to work right. How to spend the public's money and give an excellent return is always on our minds.

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Shaping the Future of Aerospace

15-529

Satellite manufacturers are beginning to equip spacecraft with metal parts made on 3-D printers. Someday, those additively manufactured parts might be assembled into spacecraft largely by robots operating in clean rooms. Debra Werner looks at the coming satellite manufacturing revolution.

Reimagining satellite

by Debra Werner

Lockheed Martin's booth at the annual Defense Manufacturing Conference in San Antonio was a popular stop for the curious. Inside a plexiglass box, a 6-foot-tall orange robotic arm deposited tiny beads of a carbon fiber-reinforced polymer a layer at a time. Within minutes, a satellite model the size of a small refrigerator began to take shape, although the whole process took hours. A second robot carved away excess material and used a laser tracker to inspect its work and verify the dimensions of the final product.

This is how Lockheed engineers think they will eventually build satellites: by marrying additive manufacturing with robotics. That would be a radical departure from today's processes, which go something like this:

Engineers and technicians in clean suits typically receive structures made by vendors or subcontractors in far-off factories or in house. A small but increasing fraction of those parts are today made by additive processes, but joining them together into a functioning spacecraft, called integration in industry parlance, is still done almost entirely by hand. It is as though a great sculpture slowly takes shape, and indeed, even commercial communications satellites — among the fastest to build — take two to three years to complete.

Lockheed insists that an entirely new approach is no longer a far off dream. The revolution will start with the frame and subsystems including power propulsion and communications gear, collectively called the bus.

"Our goal is to print an entire satellite bus with additive manufacturing in the next four years, and we may accelerate that goal," says materials engineer Slade Gardner, a Lockheed Martin fellow focused on advanced manufacturing and materials.

Lockheed Martin engineers don't plan to build a satellite's advanced optics or electronics on additive machines, but they do envision a turntable surrounded by ro-

construction

Robotic arms build a satellite model at the Lockheed Martin booth at the the Defense Manufacturing Conference in San Antonio.

Lockheed Martin

bots working together to build a lightweight spacecraft bus embedded with many of its subsystems including propulsion and antennas.

"Where it makes sense, a human will install payload elements and cabling," Gardner says.

Lockheed is not alone in seeing this potential. Satellite manufacturers including Space Systems/Loral of Palo Alto, California, are vying to convince customers that reliable spacecraft can be built through additive processes, and someday with robotics. The payoff for manufacturers could be an edge in the lucrative but crowded market for construction of communications satellites, spy satellites and scientific spacecraft.

Time is money, and building a satellite faster is one way to reduce costs and win a competition. Trimming component weight through additive processes could also let engineers pack more equipment on a satel-

Space Systems/Loral produced a 3-D printed titanium antenna bracket, at left, that has half the mass of its 0.4-kilogram conventionally machined titanium counterpart. A computer-aided design optimization process minimizes the material needed to meet strength and stiffness requirements.

Space Systems/Loral

lite or alternatively a customer could reduce the spacecraft's overall mass to reduce launch costs, given that rocket providers charge customers partly by the weight of their spacecraft.

Part of the mass of a conventional component comes from limitations in the dexterity of the machining tools, limitations in the details that can be cast in a mold, and the need to make multiple parts and assemble them. Some material is designed not for strength or insulation, but simply because of manufacturing constraints or to provide surfaces to join parts together. Additive manufacturing could reduce parts counts and lead to streamlined components.

"As we start to permeate this technology through the satellite, we can take out 15 percent of the mass in most cases and often 50 percent," says Derek Edinger, director of advanced materials and structural technology for Space Systems/Loral, a subsidiary of Richmond, British Columbia-based MDA Corp. and one of the world's largest manufacturers of commercial communications satellites. "That is the real draw for our customers, because reduced satellite mass means more room for radio frequency payloads, which generate revenue, and more fuel to extend the satellite's life."

Moving cautiously

Although 3-D printing promises savings, satellite builders are proceeding cautiously as they move additively manufactured parts from their ground-based applications into space. NASA's Juno mission, which launched in 2011 on its way to a 2016 rendezvous with Jupiter, carried the first ones: four sets of waveguide brackets printed using electron beam melting, an additive process that turned a powdered titanium alloy into the finished product. That success prompted Juno prime contractor Lockheed Martin to expand its use of additive manufacturing and to install equipment used in 3-D printing of polymers and metals in its factories in Colorado, California, Louisiana and Mississippi.

Additive parts are happening now, but a shift to robotics is expected to take longer, because each satellite is different and requires painstaking assembly. Vendors such as MDA and Wolf Robotics are working to perfect robots for satellite assembly.

Space Systems/Loral is preparing to send its first titanium parts created through additive manufacturing into space later this year and to include 3-D printed metal parts on almost all subsequent satellites. The first parts destined for space are identical fittings that go on each end of the struts that crisscross a satellite's interior. Although the fittings do not look very complex, the simple fact that manufacturers are trusting additive manufacturing to build load-bearing elements of a spacecraft is significant because satellite customers are notoriously risk-averse. Space Systems/Loral can't yet reveal publicly which satellite will carry the parts, but executives confirm that they are destined for a communications satellite slated for launch into geostationary orbit in late 2015.

Commercial communications satellites cost hundreds of millions of dollars to build and launch. To become profitable, satellite operators need their spacecraft to remain healthy for more than a decade in an environment where temperature extremes and punishing radiation are the norm. Satellite customers typically want manufacturers to use only flight-proven parts on their spacecraft, says David Bernstein, Space Systems/Loral senior vice president of program management.

To reduce the risk inherent in introducing any new satellite components, manufacturers conduct extensive testing. Last year, Lockheed Martin worked with Sciaky Inc., a company based in Chicago that specializes in electron beam welding and additive manufacturing, to build a large propellant tank simulator for a new satellite design. Lockheed Martin tested the tank at its maximum expected operating pressure on 50 separate occasions and then subjected it to pressure levels 25 percent beyond that anticipated maximum pressure 12 more times. Finally, Lockheed Martin conducted destructive testing, adding pressure until the tank burst, which occurred at more than twice its anticipated maximum pressure.

"Customers love to see data because it builds confidence," Gardner said.

Saving time, money and weight

Satellite customers are eager to realize the potential savings additive manufacturing promises. In general, it cuts the cost of producing metal components in half and reduces the time it takes to build them by 80 percent, Gardner says.

In many cases, companies can save time and money because additive manufacturing allows them to print complex designs that marry several individual compo-

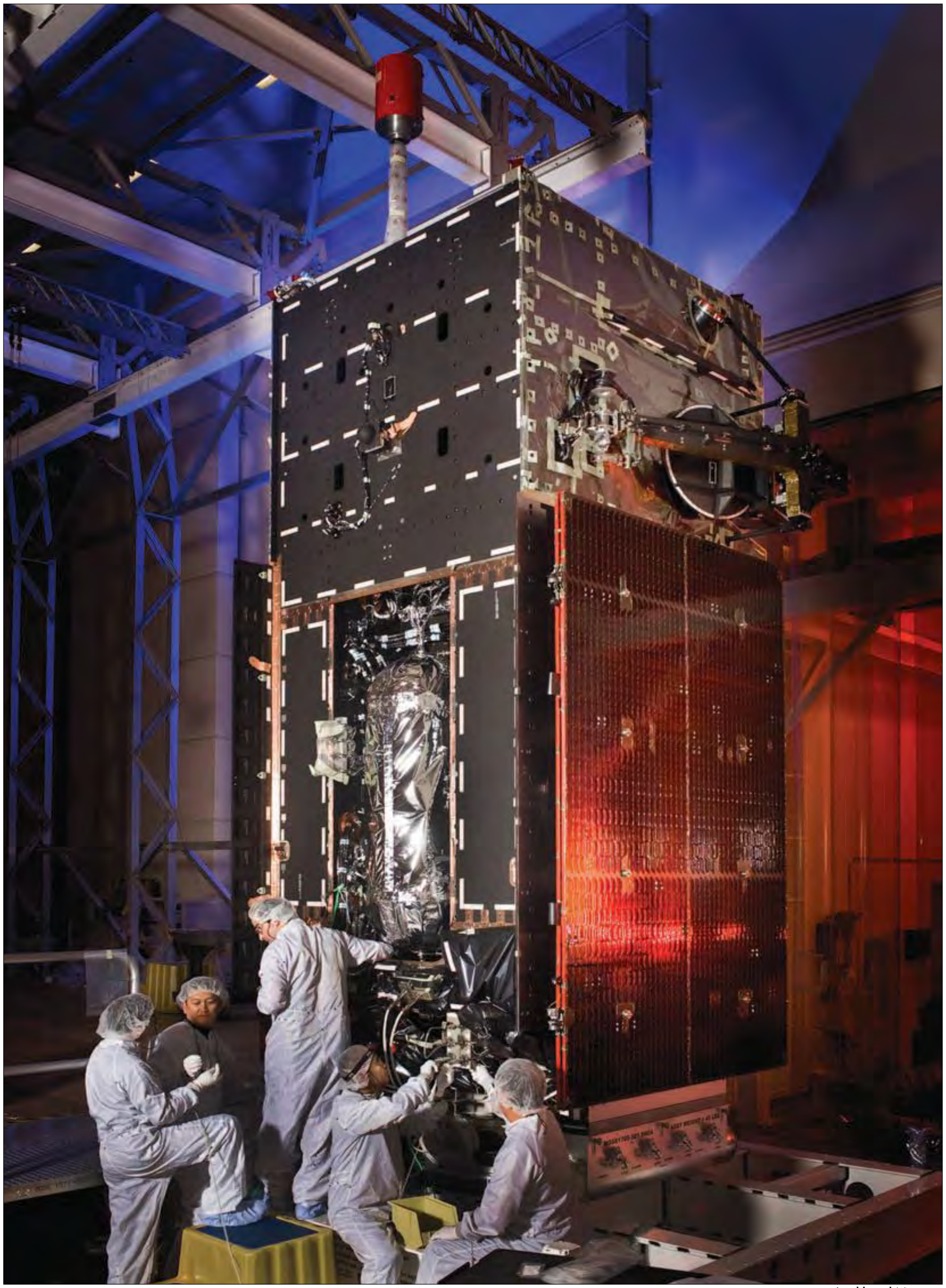
European Space Agency

Thales Alenia Space used a 3-D printer to produce a prototype deployment mechanism for satellite solar panels. The titanium device has fewer parts and about one-fifth the mass of a similar, conventionally produced mechanism, according to the European Space Agency.

nents into a single unit. Reducing the total number of parts leads to cost, schedule and weight reductions. "Fewer parts mean less material, fewer assembly operations and fewer part numbers," Gardner said. "Each part number requires engineering attention, testing and quality inspection."

Over the last decade, satellite manufacturers have used 3-D printed parts in their ground-based operations. Space Systems/Loral uses 3-D printers to turn plastic polymers into the type of complex tools and fixtures engineers need for various jobs, such as holding spacecraft parts in place until they can be bolted down or serving as a stand-in for a component not

Lockheed Martin engineers work on a Space-Based Infrared System satellite. In the near future, experts say, 3-D printing and robotics will reduce the number of people and the amount of time needed to build satellites.



Lockheed Martin

yet built. With the temporary parts in place, workers can lay out wiring and perform other assembly tasks without waiting for the finished parts.

Before 3-D printing, manufacturers built the same types of custom tools and fixtures on machines using aluminum. That process often took months. Their replacements can be designed in a week and printed in a couple of days.

"This is the unsung hero of additive manufacturing," Edinger says. "In addition to cost and schedule savings, it has enabled us to make much more complicated satellites."

Space System/Loral's Ka-band data satellites, for example, which use powerful beams to broadcast communications to small antennas on Earth, carry radio frequency payloads composed of thousands of parts. That level of complexity would not have been possible without 3-D printing and other sophisticated manufacturing tools, Edinger says.

Within the last year, Space Systems/Loral also began using 3-D printers to produce lightweight brackets and thermoplastic shields to protect motors and optical lenses.

"We can make complex parts more quickly and inexpensively than we did with machined aluminum or fiberglass," Edinger says.

Engineers use software tools to determine the desired characteristics of the new parts, including the forces they will need to withstand. Then the engineers design the components to withstand those forces in a compact, lightweight form.

Now that printed parts are beginning to move from the factory floor to satellites, manufacturers and suppliers expect their use and complexity to grow rapidly.

"We haven't even scratched the surface of where we will be two to five years from now," says Joel Smith, strategic account manager for aerospace and defense at Stratasys Direct Manufacturing of Minneapolis, which makes 3-D printers and production systems.

In November, Stratasys began working with NASA's Jet Propulsion Laboratory to print 30 antenna supports for a joint U.S.-Taiwan satellite project designed to use GPS radio occultation systems on forthcoming clusters of small satellites to improve weather forecasts. GPS radio occultation systems measure the refraction of GPS signals traveling through the atmosphere to obtain information on temperature and water vapor. Clusters of Taiwanese Formosat-7 spacecraft — six to be launched in 2016 and six in 2018 — will carry U.S. supplied COSMIC-2 instruments, short for Constellation Observing System for Meteorology, Ionosphere and Climate-2. The satellites will be built with "the first additively manufactured parts on the outside of a spacecraft," says Jim Bartel, Stratasys senior vice president for direct manufacturing.

Stratasys' 3-D printers can produce objects in a variety of materials, including ULTEM 9085, a thermoplastic the company uses to print antenna supports for Formosat-7 satellites.

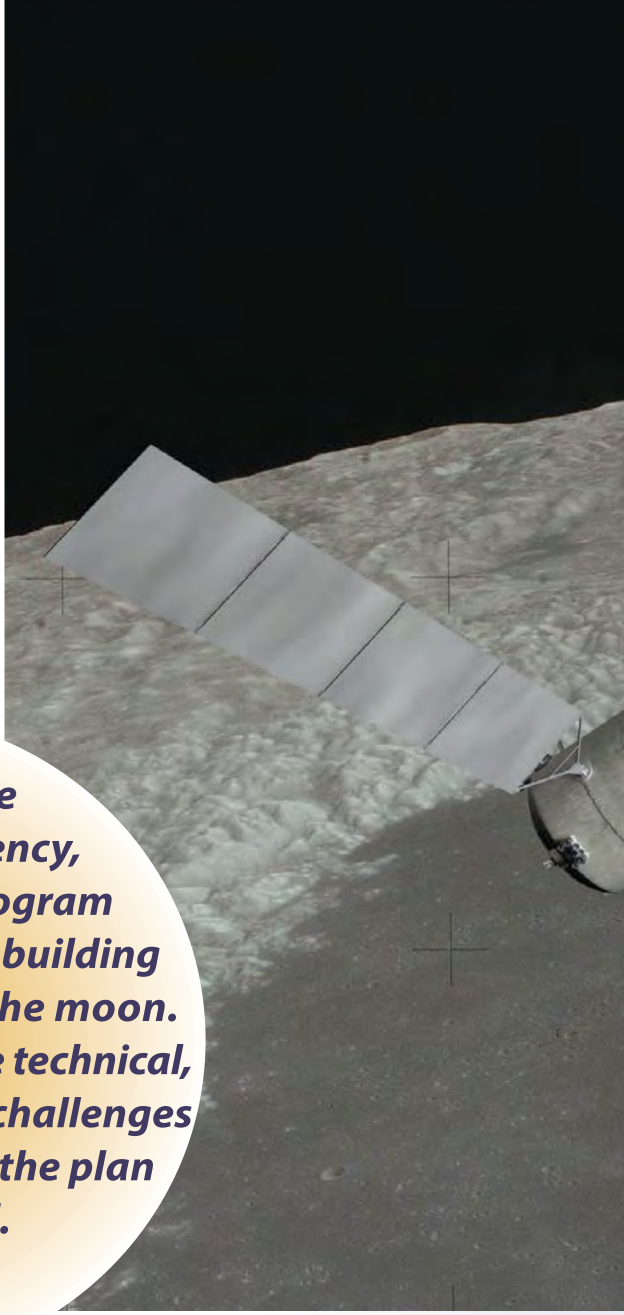
Stratasys

Stratasys is building the supports, which will be used to attach two phased array antennas to each one of the 12 satellites, using a strong thermoplastic called ULTEM 9085 that is similar in strength to metal but weighs less. The same material is used in commercial aircraft and approved by the FAA because it meets the agency's flame, smoke and toxicity requirements. NASA plans to coat the 3-D printed parts with a paint designed to shield them from ultraviolet radiation.

The mission is technically daring, with a potentially large payoff, says Bartel: "If we can make parts that hold up on the outside of a spacecraft, we can make parts that go pretty much anywhere else."

Russia shoots for the moon

Roscosmos, the Russian space agency, has developed a program that sets the stage for building a permanent base on the moon. Anatoly Zak explains the technical, economic and political challenges that threaten to keep the plan on the ground.

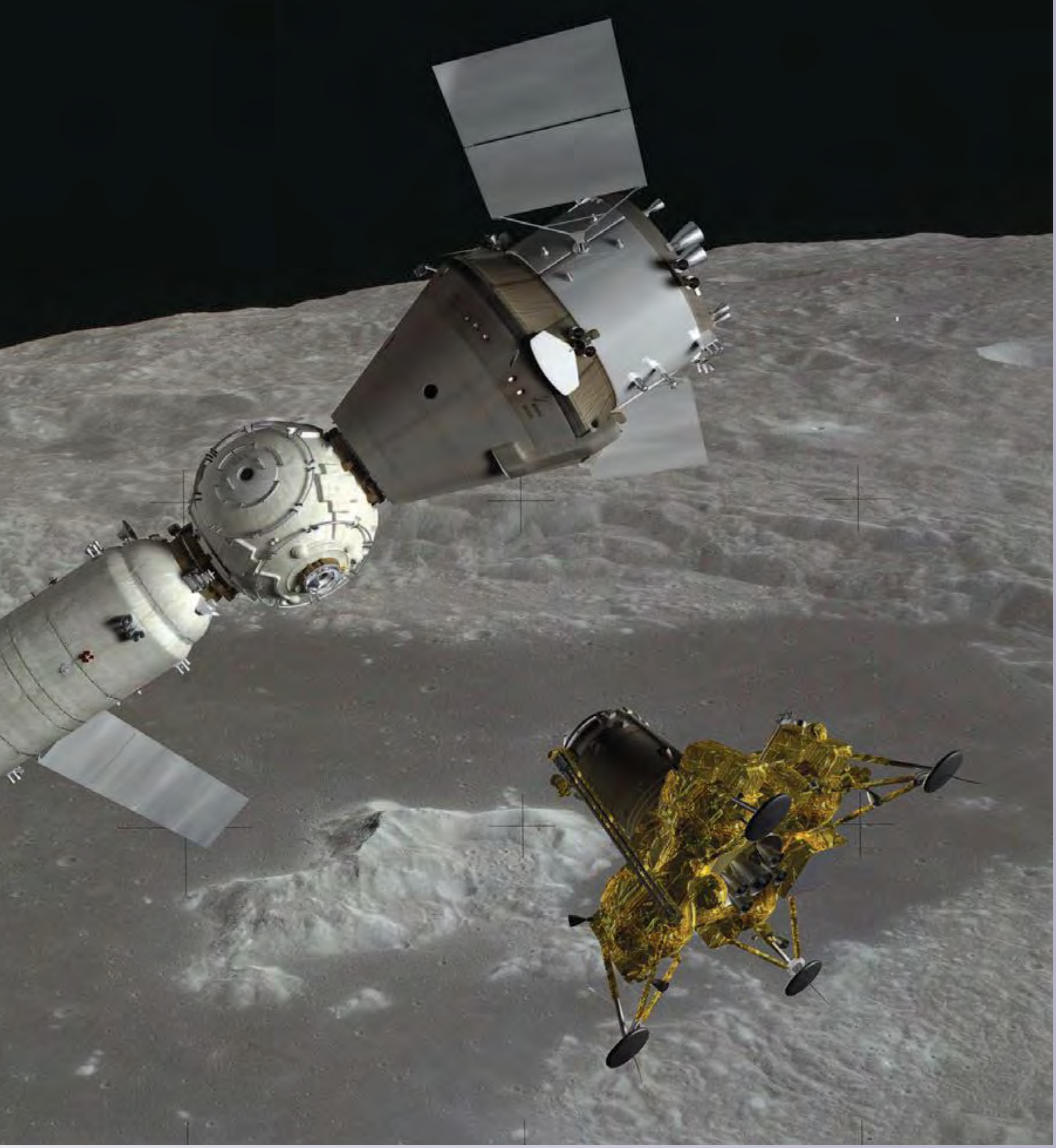


by Anatoly Zak

In April 2014, on the eve of the 53rd anniversary of Yuri Gagarin's pioneering flight into space, Russian Deputy Prime Minister Dmitry Rogozin called on the nation to undertake a bold quest: Establish a permanent human outpost on the moon.

Writing in the government daily Rossiyskaya Gazeta, Rogozin outlined a lunar cosmonaut program more ambitious than the Apollo project.

"We are not targeting the moon as a limited program in terms of time and resources. The moon is not a way station in a journey but an independent and self-suffi-



Anatoly Zak

The unmanned Korvet lander carrying samples of lunar soil approaches a manned orbiter in an artist's rendering of a proposed Russian lunar mission. Roscosmos, the Russian space agency, sees the mission as a steppingstone toward establishing a human outpost on the moon sometime after 2030.

cient goal!" he wrote, according to a translation. "It doesn't make much sense to launch 10-12 missions to the moon and then give up everything and fly to asteroids and Mars. This process has a beginning but has no end: We plan to come to the moon forever."

The audacious plan came as a wave of Russian nationalism was building in the wake of the Sochi 2014 Winter Olympics in February and the annexation of Crimea from Ukraine in March. Other factors may have been NASA's plans for the manned Orion spacecraft and China's growing reach into space.

When Rogozin revealed his vision for a lunar base, rising oil prices were fueling the Russian economy and the country's space budget was growing, from about a half-billion dollars in 2004 to $4.3 billion in 2013, just short of the European Space Agency's spending. But by the end of 2014, the price of oil had plummeted, new Western sanctions over the Crimean annexation were imposed, and the value of the ruble against the dollar dropped by more than 40 percent.

Rogozin voiced a change of heart.

"Some experts, including those from Roscosmos, tell us, 'Let's go to the moon and let's explore it.' I previously liked this idea myself. But now it is necessary to cal-

Cosmonaut Alexander Misurkin works outside the International Space Station in 2013. Russia is considering new human space flight destinations after the space station is retired.

NASA

culate how much money it is going to cost," he said in a Dec. 24 interview on the Russia-24 news channel.

The question now is not only whether Russia can reach the moon, but what will become of its entire human space flight program.

Russia's space advocates are not giving up. For more than two decades the International Space Station has been the primary destination for Roscosmos, the Russian Federal Space Agency. But with the station set to be retired within a decade, Roscosmos, like ISS-partner NASA, is seeking new objectives for humans in space. While NASA is laying the groundwork for manned deep-space missions with its Orion program, Roscosmos has an ambitious proposal that comes amid difficult economic times.

The agency's goals are outlined in its latest 10-year Federal Space Program, known as FKP-2025. The 2016-2025 roadmap sets the strategic direction for all segments of Russia's civilian space program, including human space flight, unmanned deep-space probes, Earth-watching satellites and orbital observatories.

Roscosmos seeks $56 billion to carry out the 10-year program, according to a copy of the document.

Oleg Ostapenko, the head of Roscosmos, submitted the program to the Russian government before the end of 2014, and Russia watchers say the proposal has made its way to Rogozin, who oversees defense and space programs.

Back from the abyss

The Russian space program spent the first post-Soviet decade near a financial abyss. Once additional funds were allocated by the Kremlin at the turn of the century, experts got to work developing science missions, the Angara rocket family and new navigation and Earth-observation satellites, and crafting a long-term vision for Russian human space flight. The authors of FKP-2025 likely believed they had come up with a winning plan, but then came the economic fallout of the Western sanctions and the falling oil prices.

FKP-2025 would lay the groundwork for a goal that eluded the Soviet Union during the height of the Cold War: an expedition to the moon. The Soviet lunar landing effort was abandoned in 1974, two years after the last Apollo landing.

"A timely development of rocket and space technology for lunar exploration will not only provide Russia with a leading position in this field and exclude a risk of other countries' getting strategic advantage," FKP-2025 states, "but will also create a powerful 'locomotive' effect for bringing all areas of the national space program to the advanced positions in the world during the immediate next phase of the space program."

FKP-2025 calls for developing technologies that could include the ability to place cosmonauts in lunar orbit while a robotic lander samples the surface. Lunar soil-moving machines and cranes would also be developed under the program in anticipation of establishing a human base on the moon after 2030.

Anatoly Koroteev, the director general of the Keldysh Research Center, a Roscosmos development organization, confirmed that schedule in an email, adding that landing cosmonauts on the moon would not be realistic before 2030.

The rocket gap

Roscosmos envisions a two-stage effort to land humans on the moon. A pair of rockets would place up to 90 tons of payload into orbit around Earth, including a manned transport ship with crew and an uninhabited lunar lander. The spacecraft would then travel separately and link up in lunar orbit, where the crew would transfer to the lander for the descent to the surface.

But Russia cannot yet place that much payload in orbit in two launches — its most powerful rocket, the Angara-A5, which made its first test launch in December, can carry about 25 tons — and making several smaller deliveries is considered too complex and risky, according to the FKP-2025 document. Roscosmos' budget request would not permit development of a launch vehicle powerful enough for the mission before 2030, such as the proposed Energia-5KV, which would carry payloads of at least 70 tons. Financial constraints have also hampered development of a manned lunar lander.

But if stepping foot on the moon before 2030 is out of the question, experts at the Moscow-based Space Research Institute, known as IKI, and NPO Lavochkin, the nation's prime developer of planetary probes, devised a plan that might be the next best thing. They want to place a manned spacecraft and an unmanned tanker in lunar orbit, where they would rendezvous with a reusable robotic lander that would be launched separately. The lander, dubbed Korvet, would refuel from the tanker and then descend to the lunar surface to gather soil samples. The Korvet would make up to five trips between the moon and the orbiting crew. The cosmonauts would finally return to Earth with samples from multiple locations.

In November, Lev Zeleny, the head of IKI, told the Tass news agency that the Korvet concept had been included in FKP-2025.

New space station

Closer to home, and before any lunar mission, Roscosmos sees another gap to fill: The projected retirement of the International Space Station in the mid-2020s could leave cosmonauts without a destination in low-Earth orbit.

Over the years, Russian engineers have considered plans to build a smaller, cheaper successor to the space station, possibly even recycling the newest pieces of the existing Russian segment. These plans have received a new impetus in FKP-2025. Beginning in 2018, Roscosmos wants to start providing seed money for the development of next-generation orbital modules, including a laboratory, an inflatable habitat, a power-supply module and an orbital assembly dock. The modules would be con-

The Energia-5KV rocket is among several super-heavy launch vehicle concepts proposed by the Russian space industry to help achieve the country's lunar ambitions.

Illustration by Anatoly Zak

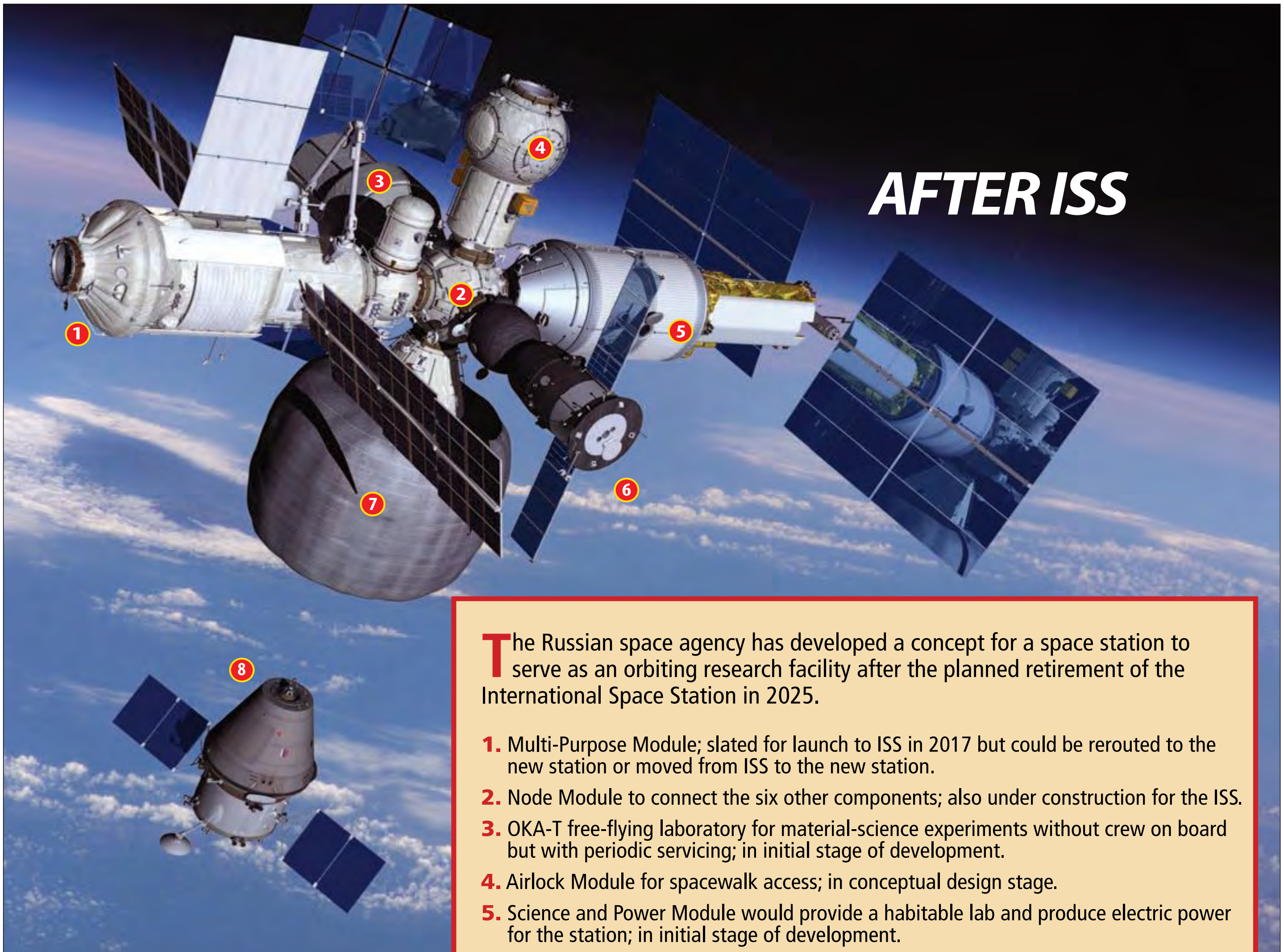


Illustration by Anatoly Zak

The Russian space agency has developed a concept for a space station to serve as an orbiting research facility after the planned retirement of the International Space Station in 2025.

1. Multi-Purpose Module; slated for launch to ISS in 2017 but could be rerouted to the new station or moved from ISS to the new station.
2. Node Module to connect the six other components; also under construction for the ISS.
3. OKA-T free-flying laboratory for material-science experiments without crew on board but with periodic servicing; in initial stage of development.
4. Airlock Module for spacewalk access; in conceptual design stage.
5. Science and Power Module would provide a habitable lab and produce electric power for the station; in initial stage of development.
6. Soyuz transport vehicle.
7. Inflatable habitat; in initial stage of development.
8. PTK NP new-generation piloted transport ship; in development.

Source: Aerospace America research

nected, allowing crews to move among them in a shirt-sleeve environment, while the exterior of the outpost could be complemented with robotic arms.

Unlike the massive 20-ton components Russia supplied for the nascent ISS, most modules of a future Russian station would weigh about eight tons to fit in the medium-class Soyuz rockets based at the soon-to-be-completed launch site in Vostochny. The proposed station, which would make extensive use of off-the-shelf hardware to reduce costs, could be launched into a high-inclination orbit to provide better coverage of the Russian territory than is currently possible from the ISS.

"This project has very good prospects," Ostapenko said at a Dec. 15 press conference. "It will allow us to watch more than 90 percent of the Russian territory and, in the future, use it as a way station to the moon and into deep space."

Oil and politics

To achieve its ambitions above the Earth, Russia must rely on what lies beneath it. Oil and gas sales accounted for more than half of Russia's federal budget revenues in 2012, according to the U.S. Energy Information Administration. Even before the political and economic turmoil of 2014, including declining oil prices, the Russian economy had started moving from surplus to deficit, primarily under the weight of ever-growing social welfare programs, according to Moshe Yanovskiy of the Gaidar Institute for Economic Policy in Moscow. In December, the Russian Ministry of Economic Development reversed its forecast of slight economic growth of 1.2 percent in 2015 to a decline of 0.8 percent, heralding the beginning of the recession.

In addition, the Kremlin's "suppression of political opposition and heavy-handed involvement into business created a negative climate for future investments" in the Russian economy, Yanovskiy says.

It has also become more difficult for the government to attract the expertise it needs. During the past two decades, the traditional destinations for Russian high-tech workers — the nuclear industry and the military-industrial complex, including space activities — have been competing with domestic and foreign businesses for young talent, Yanovskiy says.

According to estimates by Russia's own statistics agency, Rosstat, 186,382 people left the country in 2013.

"We are losing the most educated, most active, most entrepreneurial people," Lev Gudkov, director of the independent Levada Center research organization in Moscow, told Reuters.

Even if it can attract the necessary engineering talent, Roscosmos will have to join a long line of candidates for limited federal funds, while its lunar exploration proposals are criticized as too extravagant by skeptics.

"It is difficult to imagine that any government would be ready to spend trillions on the construction of lunar bases, especially when it has many other more important tasks," Andrey Ionin of the Russian Cosmonautics Academy told the Russian daily Izvestiya.

To some people in Russia, the way the nation's grand plans for space have clashed with economic reality might bring to mind an expression popularized by former Prime Minister Viktor Chernomyrdin: "We wanted the best, but it turned out as always."

The manned-unmanned DEBATE


An X-47B unmanned demonstrator is prepared to take off alongside a manned F/A-18 fighter aboard the carrier Theodore Roosevelt. The Navy is trying to determine requirements for a future unmanned, carrier-launched, airborne surveillance and strike aircraft.

U.S. Navy

Planning a future mix of manned and unmanned combat aircraft poses the daunting task of comparing the cost effectiveness of competing airframes. Robert Haffa and Anand Datla offer an analytical framework for building the most appropriate mix.

ANALYSIS
by Robert Haffa and Anand Datla

The recent battle over whether to keep flying the Air Force's fleet of 32 U-2 spy planes or replace them with unmanned Global Hawk aircraft looks like a harbinger of future manned-unmanned debates. After examining the advantages and disadvantages of each aircraft, the Obama administration included funding for both in the fiscal 2016 Defense Department budget request. This compromise reflects the challenges the Pentagon encounters whenever it tries to integrate unmanned aircraft into a force. As the military services and Congress contemplate a future mix of multimission, manned and unmanned combat aircraft, they will try to weigh the cost effectiveness of competing airframes.

Doing so is inevitably complicated, but it is doable. The competing planes may be of different generations, which means they will have different capabilities, fuel efficiency figures, spare parts costs and reliability predictions. Comparisons of traditionally piloted and unmanned combat aircraft, however, can be simplified by first calculating the cost of the capability — surveillance, strike, electronic warfare or some combination thereof — provided by an unmanned platform and then determining the cost of that same capability for a manned combat aircraft. In conducting this analysis of alternatives for new aircraft acquisitions, all platform characteristics are assumed to be identical — the only differences are the number of aircraft, people and flying hours required to generate the specified capability.

Unmanned aircraft show a significant life-cycle cost advantage over manned aircraft when both airframes are assumed to have identical range, payload, sensors and survivability in contested airspace. This is primarily because advanced unmanned aircraft will have highly autonomous flight and navigation systems that obviate control from the ground by trained pilots. Instead, they receive a set of mission objectives to be executed by on-board computers directing the aircraft to specific places at designated times and activating appropriate sensors. A human controller is needed only to redirect the aircraft if required and to release precision-guided weapons. This approach frees the human operators of remotely piloted vehicles to manage and analyze mission objectives and alter them according to changing mission requirements. Because all of the aviation skills reside in the vehicle's software, there will be no need to teach a human to fly the aircraft. Today, training pilots and maintaining their proficiency account for a large portion of the total life-cycle cost of combat aircraft. Eliminating this training in our analysis results in significant immediate and long-term savings because fewer flying hours are required and fewer aircraft must be procured.

But that's just the entering argument. The ultimate mix of manned and unmanned combat aircraft also depends on the mission assigned and the degree of man-in-the-loop decision making required to accomplish that mission. The long-endurance capability of unmanned aircraft, eventually to be enhanced by aerial refueling, gives them a decided edge in missions requiring persistence in a target area. On the other hand, manned aircraft have the advantage in situations such as dynamic strike missions or air-to-air combat, because in situ human pilots are still better in those scenarios than computer-programmed flight paths. However, unmanned aircraft can assume most tasks requiring significant combat persistence, surveillance and strike currently performed by manned aircraft — an advantage evident in Predator and Reaper counterinsurgency and counterterror operations.

Carrier aircraft

The Navy is struggling with the requirements for its unmanned, carrier-launched airborne surveillance and strike, or UCLASS, aircraft. Those decisions can be aided by this framework for analysis, as well as by the Navy's earlier decision to replace the manned P-3 Orion maritime surveil-

Line-of-sight communications, instead of satellite links, could make it affordable to fly unmanned surveillance and strike planes from carriers.

Lockheed Martin

lance and patrol aircraft with a mix of traditionally piloted Boeing 737-based P-8 Poseidons and unmanned long-endurance Tritons, a Global Hawk variant.

Choosing unmanned aircraft for the persistence mission will result in considerable cost savings, but opting for an all-unmanned fleet would require non-line-of-sight satellite communication links to allow remote operators halfway around the world to control long-range operations. Non-line-of-sight links tend to be expensive and susceptible to jamming, so an alternative would be to establish line-of-sight links between unmanned planes and traditionally piloted aircraft whose crews would communicate with them and adjust their flight paths as required. The Navy could assign the persistent surveillance/strike mission to UCLASS, with the attack of time-sensitive targets in contested airspace controlled by standoff manned aircraft. The fixed-target attack mission could be delegated to manned attack aircraft supported by an advanced unmanned formation.

The F-35 might be the last fighter that requires a human pilot for all versions of the aircraft. Next generation fighters are likely to be produced in manned and unmanned variants.


Lockheed Martin

Such a communications-connected force mix would address all target classes, permit robust command and control of unmanned platforms without the need for vulnerable and expensive beyond-line-of-sight communication links, and optimize the cost and effectiveness of the carrier air fleet.

Long-range strike bomber

A similar approach might be applied to analyzing the Air Force's acquisition of long-range strike bombers. The new bomber might have an unmanned variant, and that could lower the life-cycle costs considerably. Another option would be to buy an unmanned combat aircraft similar to UCLASS. In either case, the aircrews in the manned bombers could provide the human-in-the-loop functions required to control the unmanned bombers in a dynamic, persistent surveillance/strike role. The manned and unmanned variants would be able to communicate through line-of-sight links to minimize the need for expensive, secure satellite communications. The crew members could monitor and confirm the unmanned aircraft's route, threats and target coordinates; appraise potential targets detected by the long-dwell unmanned bombers; authorize attacks; and assess battle damage.

Some have warned against making the new bomber capable of delivering nuclear weapons lest it become entangled in future strategic arms control treaties. However, it is likely that the new bomber will have a nuclear weapons capability. The prospect of an unmanned aircraft launching a nuclear weapon should not be difficult to accept for those who have fielded an intercontinental ballistic missile and cruise missile force over the decades. But having a mixed manned/unmanned bomber fleet would mitigate the problem by assigning nuclear weapons delivery missions to the manned version.

Next-generation fighter

What of the next conventional fighter — the so-called sixth generation likely to be granted seed money in the fiscal 2016 budget? Although former Chairman of the Joint Chiefs Adm. Mike Mullen speculated that the F-35 would be the last manned fighter the U.S. would field, it is probable that a next-generation fighter will have manned and unmanned versions. That's because manned aircraft deal better with situations requiring human judgment and unforeseen events while mitigating the potential vulnerability of most existing unmanned aircraft to communication failures.

Nevertheless, there are two important fighter missions that could be supplemented by unmanned aircraft at considerable savings and increased effectiveness. The first is cruise missile defense of forward military bases and facilities. Armed with advanced air-to-air missiles similar to those carried by the manned variant, an unmanned sixth-generation fighter could contribute to both ground and airborne alert missions for cruise missile defense, reducing procurement and operating costs significantly. In this case, crew members aboard an airborne warning and control system aircraft, or AWACS, equipped with secure communications suites would direct the unmanned fighters to the desired launch point and issue fire instructions.

Another possible mission for an unmanned fighter would be defensive counterair patrol. In many cases, defensive counterair will be conducted in an environment cluttered with enemy and friendly aircraft. That dynamic dogfight will still require voice communications and human judgment to distinguish friendly fighters from the adversary and to adjust flight tactics accordingly. Therefore, unlike cruise missile defense, where an unmanned aircraft might be able to assume the mission completely, in defensive counterair the unmanned variant will likely supplement manned fighters. Nevertheless, the unmanned fighters could be controlled via line-of-sight communication links either by crew members on an AWACS or the pilots of the manned fighters. In the latter case, the fighter pilots could employ sensors and weapons on board their unmanned wingmen as well as those on their own aircraft in a complementary, cost-effective concept of operations.

So, how does all this balance out in our notional analysis? The framework offered here suggests that fleets composed solely of unmanned aircraft, owing to reduced training, acquisition and life-cycle costs, are less expensive to acquire and operate. In missions such as gathering intelligence, surveillance and reconnaissance, where a premium is placed on persistence rather than flexibility, unmanned systems can do the job as well as, if not better than, manned aircraft, at significantly lower cost. The Global Hawk, for example, provides longer range and endurance while carrying more sensors (but not the same sensors with equal fidelity; hence the manned-unmanned mix we referred to earlier) than the U-2, for less than half the cost per flying hour.

For other missions, a mix of manned and unmanned combat aircraft would prove more cost-effective and capable than a single force of either type. For the Air Force and the Navy, acquiring a mix of fighter-size unmanned combat aircraft and manned, or optionally manned, bombers offers cost and effectiveness advantages. Those services should consider procuring advanced unmanned combat aircraft at a more aggressive pace.

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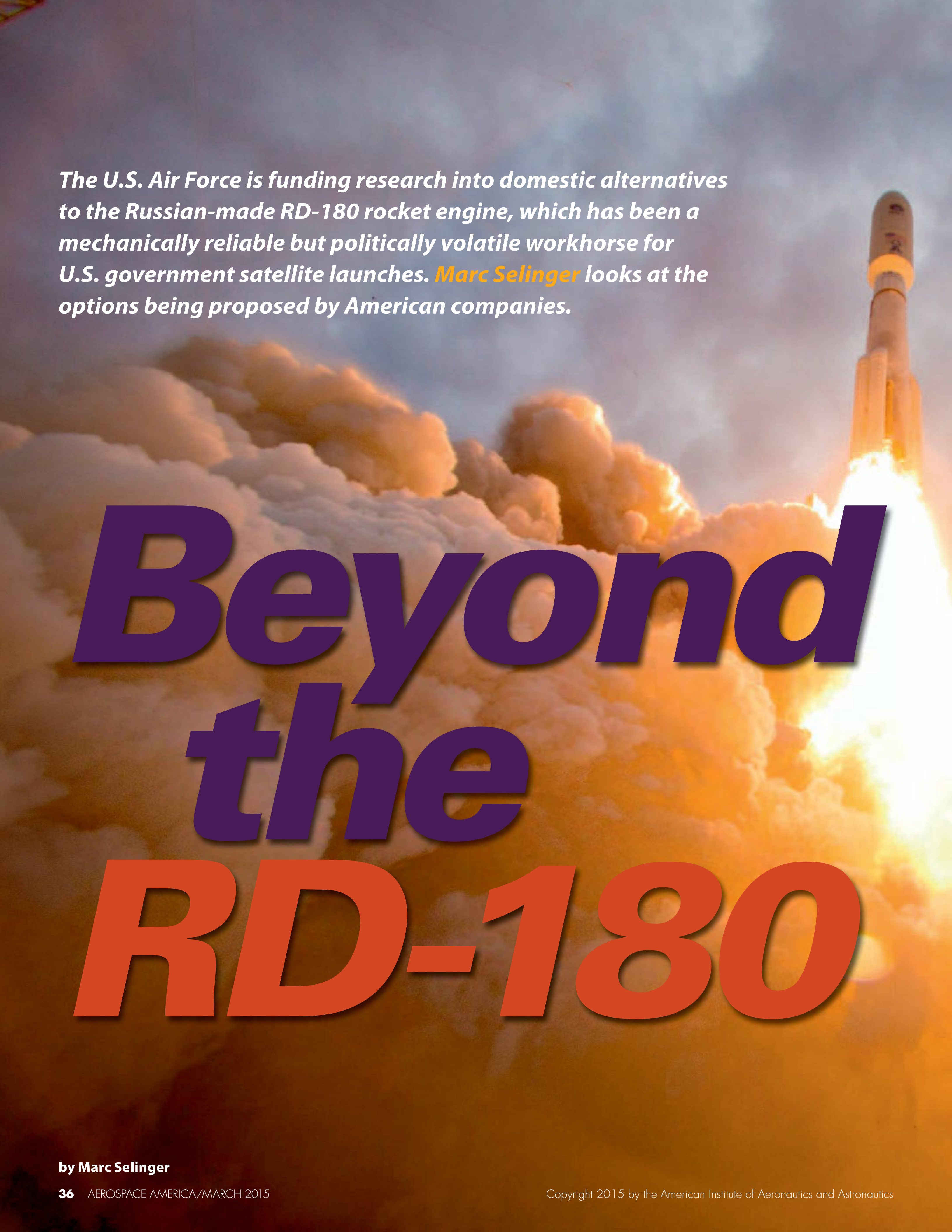
Anand Datla is a consultant based in the Washington, D.C., area. He is a former Defense Department strategic planning analyst and served as a professional staff member of the House Armed Services Committee.



The U.S. Air Force is funding research into domestic alternatives to the Russian-made RD-180 rocket engine, which has been a mechanically reliable but politically volatile workhorse for U.S. government satellite launches. Marc Selinger looks at the options being proposed by American companies.

Beyond the RD-180

by Marc Selinger

An Atlas 5 powered by an RD-180 main engine lifts off from Cape Canaveral Air Force Station in Florida in July 2013.

ULA

The 20-story rocket stood in the evening darkness on a Florida launch pad in January, ready to transport a military communications satellite into space. Shortly after 8 p.m. the countdown ended: "five, four, three, two, we have RD-180 ignition and we have liftoff of the United Launch Alliance Atlas 5 rocket carrying the third Mobile User Objective System mission for the United States Navy," an announcer declared, flames roaring from a single Russian-supplied main engine.

The satellite reached orbit safely, continuing the Atlas 5's near-flawless launch performance since its 2002, but bringing the U.S. a step closer to running out of RD-180s to power the Atlas 5s.

Rising tensions over Ukraine prompted the U.S. to impose economic sanctions on Russia, and Moscow in turn threatened to cut off RD-180 supplies to the U.S. for national security launches. Fed-up members of Congress responded by directing the Air Force to develop an American-made engine.

The Air Force is now engaged in a high-stakes undertaking to define the best way to end reliance on RD-180s before the stockpile of roughly a dozen runs out. Such a development could, in theory, strand spy satellites and communications spacecraft on the ground.

U.S. defense officials say they could have new engines ready in time to avoid delays in satellite launches, but the Air Force still must deliver on that promise, and designing a new engine is, after all, rocket science.

In August, the Air Force told industry it would also be open to "alternative launch vehicles."

The RD-180 "provides a unique blend of reliability and power," says William Ostrove, an aerospace/defense analyst at Forecast International. "It is definitely possible to design a new engine, but it will take time and money to do that."

Options abound

The Air Force used the opportunity of its fiscal 2016 budget request to underscore that it wants to consider more than simply installing a different kind of engine or engines on the Atlas 5s. It said it wants to line up at least two "commercially-viable, domestically-sourced" space launch providers. August's request for information will be followed later this year by a request for proposals exploring a broad range of options, including mixing in other American rockets for national security launches.

As for the new engine options, the Air Force said it would consider many variables, including the cost and time involved in engine development and how much seed money industry is willing to invest.

To jump start engine development, the Air Force has budgeted $513 million through fiscal 2020, including $220 million that Congress provided in the 2015 omnibus appropriations act signed into law in December. To date, early engine work involves research in such areas as components, materials and manufacturing processes, budget documents indicate.

"We need to continue to mature those key technologies while at the same time bring forward an acquisition strategy and plan," Maj. Gen. Roger Teague, director of space programs in the Air Force acquisition office, told reporters at a space budget briefing in February. "We are continuing to look at all sources of supply, as well as all vehicle type configurations, whether it be liquid or solid."

Competitors for a new propulsion system include two liquid oxygen/kerosene engines, Aerojet Rocketdyne's AR1 or SpaceX's Merlin; Blue Origin's BE-4 liquid oxygen/methane engine; and an Orbital ATK solid-fuel engine, says Ostrove, the analyst. Orbital ATK was formed in February with the completion of the merger of Orbital Sciences Corp. and the aerospace and defense groups of Alliant Techsystems.

Aerojet Rocketdyne and Blue Origin have been doing engine development work for years that they say could pave the way for an RD-180 replacement by 2019.

ULA, a Boeing-Lockheed Martin joint venture that provides Atlas 5 and Delta launch services to the government, an-

Two potential RD-180 alternatives are the planned Aerojet Rocketdyne AR1 (left) and the Blue Origin BE-4. The liquid oxygen/kerosene AR1 would produce 500,000 pounds of thrust and could be configured for the Atlas 5, Aerojet Rocketdyne says. The BE-4, which would produce 550,000 pounds of thrust with liquid oxygen/liquefied natural gas, is being developed by Blue Origin and United Launch Services for ULA's next-generation rockets.

Aerojet Rocketdyne; Blue Origin

SpaceX

The SpaceX Falcon 9 rocket is powered by nine of the company's Merlin 1D engines, each producing 147,000 pounds of thrust at liftoff. The Falcon 9 could be certified to compete with the Atlas 5 for national security launches this year, the Air Force said.

nounced in September that it would partner with Blue Origin to complete the BE-4's development. The BE-4 would power a soon-to-be-unveiled update of the Atlas 5.

"We have a complete vision of where this launch vehicle ends up, starting with the American engine replacing [the engine in] the first stage and a whole set of trades [or studies] just now finishing on what that new launch system will look like," said Tory Bruno, ULA's president and chief executive officer, who spoke at an Atlantic Council event in November.

Bruno said it typically takes about seven years to develop a rocket engine, and Blue Origin has already been at work for about three years on the BE-4. That work includes testing the pilot-light-like preburner and the propellant-mixing injector. In addition, Blue Origin built an engine test stand in West Texas, where full engine testing is scheduled to begin in 2016.

"Large engine test facilities cannot be done quickly," Blue Origin founder Jeff Bezos said at a press conference with Bruno in September. "There's just a lot of pouring of concrete and waiting for it to dry. They're big."

ULA and Blue Origin contend that liquefied natural gas, which would fuel the BE-4, is easier to use than kerosene. Engines fueled with LNG do not require tank pressurization systems, which typically use helium, a gas that "is in increasingly scarce supply," Blue Origin says in BE-4 marketing materials. LNG would also make it easier to reuse the engine, the company says. Aerojet Rocketdyne says the kerosene-fueled AR1 would benefit from knowledge the company is gaining from two government-sponsored efforts: NASA's Advanced Booster Engineering Demonstration and/or Risk Reduction program, or ABEDRR, and the Air Force's Hydrocarbon Boost Technology Demonstrator program, or HBTD.

Under ABEDRR, Aerojet Rocketdyne, Dynetics and NASA's Marshall Space Flight Center are exploring options for advanced boosters for NASA's deep-space Space Launch System rocket. Dynetics manufactured a full-scale tank that contains liquid oxygen used to feed a booster's main engines. Dynetics said it plans to test the tank this summer at its test site in Iuka, Mississippi.

The ABEDRR team also test-fired a refurbished gas generator from an Apollo-era Saturn 5 F-1 rocket engine. The gas generator drives the F-1's turbopump. Data collected from the testing were used to design and build a new gas generator injector that will undergo hot-fire testing at Marshall this year.

Under the HBTD program, Aerojet Rocketdyne is working with the Air Force Research Laboratory to design and test a liquid oxygen/kerosene engine that could be used up to 100 times.

The company also says the AR1, which uses the same fuel as the RD-180, would require minimal changes to the Atlas 5 and the rocket's ground support equipment and launch infrastructure.

While SpaceX and Orbital ATK both declined to comment for this story, Air Force officials said SpaceX's Falcon 9 rocket could be certified to compete with Atlas 5 by mid-year. Ostrove says an Orbital ATK

(Continued on page 45)

GETTING CREATIVE ABOUT AIRLINER TRACKING

Representatives at a global aviation safety conference in Montreal liked the idea of requiring flight crews to report their positions to airline operations centers every 15 minutes, but it could take years to see the standards fully blessed and reflected around the world in laws and regulations. This is true despite the Montreal target date of November 2016.

Rather than trying to tame a bureaucracy that might not be tameable, the U.N.'s International Civil Aviation Organization and its air navigation chief, Nancy Graham, are getting creative. They want the airlines and aviation authorities to just do it.

ICAO views "voluntary implementation of global tracking using available technologies as a matter of urgency, which underscores the sector-wide consensus on tracking priorities." ICAO's 36-member state governing council plans to do its part by approving the new standards by the end of 2015, she adds.

Doing something fast is not a technical problem.

"There's no reason to drag heels," says Ann Heinke, president of Overlook Consulting of Loveland, Colorado, and one of the original developers of Future Air Navigation System FANS 1/A, a widely used avionics suite that links pilots with air traffic controllers. "The technology is out there. The technology can do it. It's just a matter of willpower."

If ICAO can get the airlines to fall in line, the odds of more cases like the disappearance of Malaysia Airlines flight 370 could be reduced by tapping existing communciations technologies and without requiring most airlines to install new equipment. Airlines and aviation authorities would then need to decide the best long-term technical solution and consider the views of outliers, like the U.S. National Transportation Safety Board, which wants reporting every minute, not every 15.

by Debra Werner

Tracking big planes

The 15-minute rule approved at ICAO's Second High Level Safety Conference in Montreal puts the responsibility on operators to track all aircraft with more than 19 seats and a takeoff mass of more than 27,000 kilograms — aircraft larger than Bombardier Q400 NextGen turboprops, for example. The rule would only apply to airliners that have equipment capable of reporting locations, which experts say is most of them. The rule does not encompass business jets flying over oceans, polar regions and vast unpopulated areas like Siberia where ground-based radar can't track planes.

Malaysia Airlines flight 370 disappeared a year ago, and aviation authorities say the coming months could be a turning point in the effort to get some kind of airliner tracking system in place quickly, while longer-term technical questions are sorted. *Debra Werner explains.*

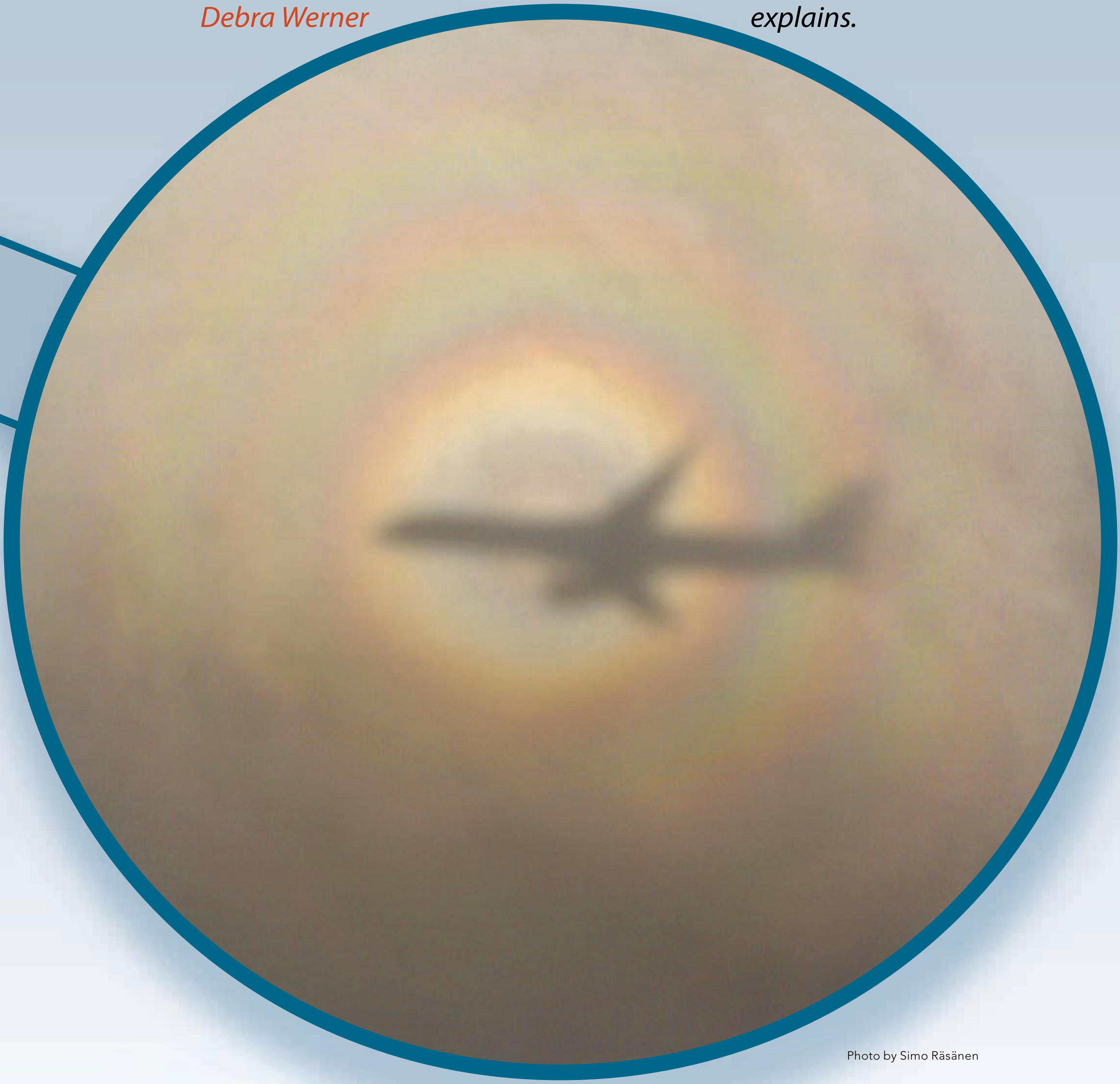


Photo by Simo Räsänen

For commercial airliners, position reports every 15 minutes still isn't enough, according to the National Transportation Safety Board, which would be responsible for locating a missing plane in U.S. airspace and investigating the accident. NTSB wants aircraft to voluntarily report their position once per minute so that the location of a downed plane could be traced to within six nautical miles of the point of impact, NTSB said in a January safety recommendation to the FAA.

At the Montreal meeting, ICAO's member countries also approved a longer-term goal of requiring aircraft to report their position every minute, but only when they divert from their intended flight plan by making an unanticipated altitude change or exhibiting other unusual behavior. The target date for implementing that rule is January 2021. That's considered speedy in an industry that often takes more than a decade to certify technology for aircraft.

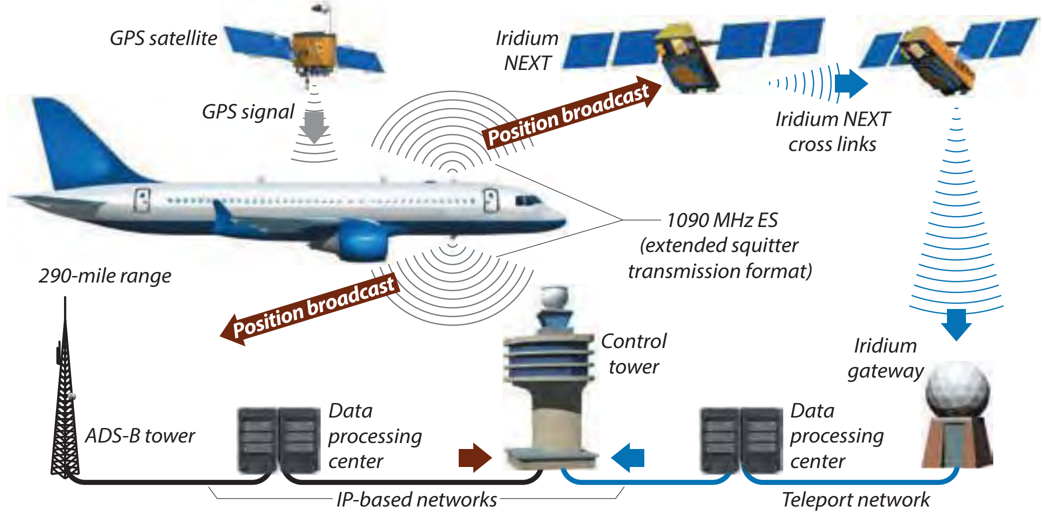
The new tracking systems will have to be as fault-tolerant and fail-safe as flight data recorders and cockpit voice recorders, cautions Robert Mann, an airline industry analyst and principal at R.W. Mann & Co. of Port Washington, New York.

Many major carriers already have equipped their widebody jets with transponders and communications systems that can meet the 15-minute standards and even announce their position every 64 seconds. Most use Automatic Dependent Surveillance–Contract, which is part of FANS 1/A. ADS-C enables air traffic controllers and airline operators to request detailed information from aircraft at specified intervals. An air traffic controller could establish a "contract" with an aircraft in its airspace to report its exact location every five minutes, for example, or to report any deviation from its planned flight path. Even if an aircraft is already using ADS-C, operators may incur additional expenses if they are not already reporting their location every 15 minutes as required by the new standards.

Mobile satellite communications provider Inmarsat is alleviating cost concerns for some carriers by offering to transmit tracking data free of charge for the 11,000 passenger jets already equipped to send data through its geostationary constellation of L-band satellites. The Inmarsat proposal will not eliminate all satellite data expenses because carriers still will have to pay to send the tracking information from Inmarsat ground stations to their home bases. Not to be outdone, rival Aireon, a joint venture among satellite operator Iridium and air traffic managers in Canada and Europe, announced in September that it will provide a service called ALERT, for Aircraft Lo-

EXPANDED SURVEILLANCE

Airlines are equipping planes to broadcast GPS locations to controllers via Automatic Dependent Surveillance-Broadcast, ADS-B, services. These signals are meant for ground towers, but they also radiate into space. Beginning in 2017, Aireon plans to use receivers on new Iridium satellites to listen for ADS-B signals and track planes when they are out of range of towers.



Sources: FAA, Iridium, Exelis

Illustrations by John Bretschneider

cating and Emergency Response Tracking, for free in the event an airliner were lost. This would be separate from Aireon's planned money-making service of providing real-time tracking information to airlines so they can save fuel by planning more efficient routes over mountains and oceans. ALERT would not be available until the Iridium NEXT satellites are in orbit and the tracking service is operating, which Aireon hopes to do by the end of 2017. The first batch of Iridium NEXT satellites is scheduled for launch in June on a Russian Dnepr rocket, a converted ICBM.

ADS-C is not the only short-term option for complying with the 15-minute standard. Airliners also could rely on their Aircraft Communications Addressing and Reporting System, or ACARS, datalinks, which are widely used to send aircraft performance data to maintenance facilities. Those links could be augmented with software to expand tracking and reporting capabilities. ACARS is not as comprehensive as ADS-C because it is not designed to highlight changes to an aircraft's planned route, but it will allow carriers to meet the 15-minute tracking standards, according to a report issued last year by the Aircraft Tracking Task Force. That panel was established after the Malaysia Airlines flight 370 disappearance in another case of creativity by ICAO. The U.N. group asked the International Air Transport Association, a global organization of airlines, to form the task force in the name of expediency.

Longer term tech

Another technology, called ADS-B, for broadcast, could bring dramatic improvements to surveillance. Airlines are installing ADS-B transponders to comply with the FAA's NextGen air traffic control modernization initiative and the Single European Sky Initiative. The transponders broadcast GPS signals to ground controllers and other aircraft through a feature known as ADS-B Out. A feature called ADS-B In lets aircrews receive reports from other planes or air traffic and weather information from aviation authorities. ADS-B's signals are directed at land towers, but some of the energy radiates into space, which is where the Iridium NEXT satellites come in. They will carry ADS-B receivers to listen for those signals. The

MAKE IT TAMPER PROOF?

No one knows exactly what happened aboard Malaysia Airlines flight 370 last March, but speculation that someone intentionally disabled tracking and communications devices on the jetliner has prompted contentious debate among aviation experts over whether aircraft should be equipped with autonomous flight tracking systems that cannot be turned off without phyiscally ripping out circuitry.

The National Transportation Safety Board and some airline executives endorse the idea of tamper-proof tracking equipment. Pilots vehemently reject it, saying they must be able to turn off any electrical system on board the aircraft in case it malfunctions or starts a fire. But in a January safety recommendation, the NTSB noted that on some planes the circuit breakers for flight recorders are not easily accessible to pilots. The NTSB recommends that the FAA require all transport aircraft to have protections against disabling flight recorders. Flight tracking equipment should also be "tamper-resistant," NTSB said.

While no definitive answer on the tamper question came out of the ICAO safety conference in Montreal in early February, member states inched toward resolution by approving a long-term goal of requiring aircraft operators to report their position every minute when certain events occur, such as an aircraft diverting from its flight path. Those minute-by-minute reports could be activated "automatically based on flight behavior, manually from the air by the flight crew, or manually from the ground," Nancy Graham, ICAO Air Navigation Bureau director, says by email. "It could only be de-activated by the same means by which it was activated, and power and position information provision would also be autonomous from other aircraft systems."

That means an aircraft that exhibits unexpected behavior could be tracked every minute at the request of air traffic controllers even if the aircrew does not initiate the frequent reports.

In January, the NTSB recommended that airplanes operating more than 50 nautical miles from shore be equipped with a "tamper-resistant method" to broadcast their location to ground stations with enough frequency to find an aircraft that crashes within six nautical miles of its point of impact. In practice, that means most planes would announce their position once per minute.

Emirates Airline President Tim Clark and Qatar Airways CEO Akbar Al Baker have been lobbying for flight tracking systems that cannot be shut off while an aircraft is flying. Those systems must "continue uninterrupted, irrespective of who is controlling the aircraft," Clark told the German magazine Spiegel in an October interview.

"If you have that, with the satellite constellations that we have today even in remote ocean regions, we still have monitoring capability."

Debra Werner

Aircraft Tracking Task Force predicts that space-based ADS-B will have a significant impact on global aircraft tracking.

Using data drawn from onboard ADS-B receivers and transmitted over Iridium's constellation of low-Earth-orbit satellites, Aireon plans to tell rescue agencies the location and last flight track of any 1090 MHz ADS-B equipped aircraft flying in airspace without surveillance. Aireon announced Feb. 4 that the ALERT service will be managed from the Irish Aviation Authority's North Atlantic Communications Centre in Ballygirreen on the west coast of Ireland.

"Aircraft operators would not be required to make any additional investments in avionics and won't have to pay any additional service fees," says Don Thoma, Aireon president and chief executive officer. "If air navigation services providers are customers of Aireon or have a similar service, they already have the infrastructure to deal with this; if they are not customers, through the ALERT service they will be able to get access to the information in an emergency situation."

New rules for emergencies are the focus of another international panel, the Ad Hoc Working Group on Aircraft Tracking, established by ICAO to help air carriers and air traffic control agencies improve their ability to identify aircraft that divert from their intended flight path or exhibit any unexpected behavior. In an October report, the group called on airlines to adopt a Global Aeronautical Distress and Safety System, which in addition to tracking aircraft in emergencies would promote frequent autonomous tracking of aircraft in distress, flight data recorders designed to eject from the aircraft and a comprehensive list of organizations worldwide responsible for coordinating rescue efforts.

"There is a growing consensus in the aviation community that more needs to be done to ensure the location of an aircraft and its flight recorders will always be known," according to the ad hoc panel's report, "Global Aeronautical Distress and Safety System: Concept of Operations."

RD-180
(Continued from page 39)

solid-fuel engine would provide more thrust and a smoother flight performance than a similarly sized liquid-fuel engine. It would also require less ground and launch infrastructure because it would be more stable than a liquid-fuel engine.

"However, liquid-fuel motors offer variable thrust and can be restarted," Ostrove says. "These characteristics can be valuable for launching payloads into a variety of orbits."

February. But he added that the service will have to "husband our resources" by moving some Atlas 5 missions to other rockets, such as ULA's larger Delta 4, and to new entrants, such as SpaceX's Falcon 9.

"We're looking at all the capabilities that are out there to maximize the use of the RD-180s that we have already under our control," Whelan said.

Navy Adm. Cecil Haney, head of U.S. Strategic Command, said he is confident

United Launch Alliance has about a two-year stockpile of RD-180 first-stage engines for Atlas 5 launches.

ULA

Unknowns persist

A key question is whether the Air Force and ULA can keep the Atlas 5 flying until new engines become available.

The 2015 defense authorization act bars the Air Force from buying more RD-180s. Furthermore, a panel of experts led by retired Air Force Maj. Gen. Howard J. "Mitch" Mitchell reported last spring that the United States had only 16 RD-180s stockpiled despite having 38 Atlas 5 missions on its launch manifest through fiscal 2020. Even so, the Air Force has "sufficient RD-180s to support our mission," Maj. Gen. Martin Whelan, space operations director for the Air Force deputy chief of staff for operations, plans and requirements, said at the Air Force space budget briefing in

new engines can be developed and fielded before the RD-180 supply runs out.

'We're always concerned as we transition to a new capability, but I think we have a good plan," Haney said in February at a Capitol Hill seminar on space operations. "We have to work our way through that just as we've done through so many different, various requirements with exquisite technology."

But even space industry leaders acknowledge that the Air Force has a difficult job ahead of it.

"There is no way to rush a rocket development process," Bezos said. "You can't cut corners. It needs to be methodical and deliberate."

Out of the

25 Years Ago, March 1990

March 6 While flying to its retirement at the Smithsonian's National Air and Space Museum, a Lockheed SR-71 sets four speed records, including a coast-to-coast flight from California to Maryland in 1 hour, 8 minutes, 17 seconds at an average speed of 2,112 mph. David Baker, Flight and Flying, p. 480.

50 Years Ago, March 1965

March 5 The General Dynamics F-111 Aardvark medium-range tactical strike aircraft breaks the sound barrier for the first time during a 1-hour, 32-minute flight test. New York Times, March 6, 1965, p. 53.

March 5 Clyde W. Tombaugh, the American astronomer known for his 1930 discovery of the dwarf planet Pluto, says in an editorial that the so-called canals on the planet Mars seen through telescopes are probably fractures of the planet's crust. Their origin, he says, "may be due to asteroids impacting on the surface, much as what happens when a stone hits the windshield of a car." Kansas City Star Times, March 5, 1965.

March 7 A Qantas Airways Boeing 707 becomes the first commercial airliner to make a non-stop flight across the Pacific, from Sydney, Australia, to San Francisco, in 14 hours, 33 minutes. Washington Daily News (Washington, D.C.), March 8, 1965.

March 9 A Thor-Agena D vehicle launches eight military satellites at one time, from Vandenberg Air Force Base, Calif., the most in any single launch to date. The satellites include the GREB 6 and SOLRAD 7B to measure solar radiation; the GGSE 2 and GGSE 3 for testing stabilization methods for future satellites; the SECOR 3 for geodesy studies; the SURCAL 2B and Porcupine satellites to help calibrate satellite tracking networks; and OSCAR 3 to transmit radio broadcasts for ham operators. Washington Post, March 10, 1965, p. A12.

March 12 President Lyndon Johnson signs a bill establishing March 16 as Robert H. Goddard Day, commemorating Goddard's launch of the first liquid-propellant rocket on this day in 1926 at Auburn, Mass. Among other activities on the 16th, NASA's Hugh L. Dryden and other officials telephone greetings via the Relay II satellite to Goddard's widow, Esther, in Worcester, Mass.; a film on Goddard's life is premiered at the Goddard Space Flight Center; and a new laboratory at Worcester Polytechnic Institute in Goddard's memory is dedicated. New York Times, March 15, 1965, p. 8; NASA release, 65-87; Baltimore Sun, March 17, 1965.

March 13 It is reported that two Russian pilots have set an altitude and load-carrying record for helicopters by flying a Soviet Mil Mi-4 helicopter carrying nearly two tons up to 20,894 feet. New York News, March 14, 1965.

March 15 The Lance battlefield missile is test-fired for the first time at the White Sands Proving Ground, N.M. Aviation Week, March 22, 1965, p. 19.

March 18-19 The Soviet Union's Voskhod 2, manned by Col. Pavel Belyayev and Lt. Col. Aleksey Leonov, is launched from the Baikonur Cosmodrome in Kazakhstan and reaches a record altitude of 309 miles. During the second orbit, Leonov does a 12-minute spacewalk outside the craft in which he takes photos and demonstrates somersaults in space. Voskhod completes 17 orbits before returning to Earth on March 19. Aviation Week, March 22, 1965, p. 23; Flight International, March 25, 1965, p. 436.

March 21 NASA's Ranger 9 spacecraft, carrying six TV cameras, is launched toward the moon from Cape Kennedy, Fla., by an Atlas-Agena B vehicle. Ranger 9 takes and transmits more than 5,800 lunar photos before impacting in the crater Alphonsus. New York Times, March 22, 1965, p. 1, and March 25, 1965, pp. 1, 25; Aviation Week, March 29, 1965, pp. 26-27.

March 22 Britain's Blue Streak medium-range ballistic missile, planned to be the first stage of the Europa satellite launch vehicle of the European Launcher Development Organization, is launched to an altitude of 150 miles from Woomera, Australia, in the third flight of the vehicle. Washington Post, March 23, 1965; Flight International, March 25, 1965, p. 437.

March 23 NASA's Gemini 3 spacecraft, with Air Force Maj. Virgil I. Grissom and Navy Lt. Cmdr. John W. Young, is launched by a Titan 2 from Cape Kennedy, Fla. After a five-hour, three-orbit mission, the capsule, nicknamed Molly Brown, touches down in

Past

An Aerospace Chronology
by **Frank H. Winter**
and **Robert van der Linden**

the Atlantic Ocean off Grand Turk Island, where it is recovered by a helicopter from the aircraft carrier Intrepid. The spacecraft is the first to maneuver in orbit, changing its orbital path, and the first U.S. spacecraft to be crewed by more than one astronaut. Aviation Week, March 29, 1965, pp. 18-19.

March 24 North American Aviation's experimental XB-70A Valkyrie, prototype of the B-70, breaks world aviation weight and speed endurance records during a 1-hour, 40-minute flight. At 500,000 pounds it is the heaviest aircraft flown to date, and flies at continuous supersonic speeds longer than any other aircraft. The plane, flown by Al White and Van Shepard, reaches a top speed of 1,500 mph. New York Times, March 25, 1965.

March 25 Wolfgang B. Klemperer, a pioneer in glider and missile designs, dies at age 72. He had been active in preparations for a NASA project to photograph a coming solar eclipse from a jet airliner over the South Pacific. The German-born Klemperer started building aircraft in 1912 and later invented a visual flight simulator and the pressurized flight cabin. He also helped develop zeppelins. He became the pre-eminent missile scientist at Douglas Aircraft Corp. and in 1958 was named the director of the guided missile research section that developed the Nike, Sparrow, Honest John and Thor missiles. New York Times, March 27, 1965, p. 27.

75 Years Ago, March 1940

March 6 The first TV broadcast from an airplane is made over New York City by a United Airlines Boeing 247-D. RCA Labs developed the mobile two-camera unit, which weighs 65 pounds and has an output of 6 watts. The cameras are mounted at the cabin windows, the transmitter is placed forward in the cabin and an omnidirectional antenna is placed atop the fuselage. Power for the unit comes from a special gas-driven aircraft single-phase generator, delivering 4,000 watts at 110 volts. Aero Digest, April 1940, p. 112.

March 9 A new altitude record for the Antarctic regions is set by a Beechcraft D17A Staggerwing used by the U.S. Antarctic Expedition. Piloted by Marine Corps Sgt. T.A. Petras, the Beechcraft climbs to 21,050 feet above Little America, carrying an observer and scientific instruments for registering cosmic ray radiation. Aircraft Year Book, 1941, p. 195.

March 15 Heinrich Koppenberg, managing director of the German Junkers aircraft company, celebrates his 60th birthday. His importance is indicated by the congratulations bestowed upon him by Chancellor Adolf Hitler. Koppenberg began his career as a locksmith at the Krupp Steel Works. He then worked his way up, becoming chief of the Junkers works in 1934, and developed the company into perhaps the biggest aeronautical engineering firm in the world. Interavia, March 20, 1940, p. 8.

March 26 The Curtiss-Wright CW-20 twin-engined commercial high-altitude transport plane makes its first flight. Although it never enters commercial service, the military version becomes the C-46. The prototype cost $900,000 to construct. Interavia, April 2, 1940, p. 8.

March 28 During a parade at the air base at Ciampo-sud, Rome, marking the 18th anniversary of the Italian air force, a number of twin-engined Savoia-Marchetti SM.85 bombers are demonstrated for the first time. Benito Mussolini, the Italian premier, is present and decorates a number of Italian pilots. Interavia, April 2, 1940, pp. 5, 7.

March 30 The Soviet Lavochkin I-22 or LaGG-1 fighter makes its first flight. The plane will be used extensively by the Soviet Air Force during the early part of the Nazi invasion of the USSR. William Green, Warplanes of the Second World War: Fighters, Volume Three, pp. 122-123.

100 Years Ago, March 1915

March 3 The National Advisory Committee for Aeronautics is formed as part of the Naval Appropriations Act. The group, a predecessor to NASA, is "to supervise and direct the scientific study of the problems of flight." President Woodrow Wilson appoints the first 12 members to this organization on April 2. Brig. Gen. George P. Scriven, the Army's chief signal officer, is NACA's first chairman. The committee's first report, released December 9, is "Report on Behavior of Aeroplanes in Gusts," by Jerome C. Hunsaker and E.B. Williams. Eugene M. Emme, ed., Aeronautics and Astronautics 1915-60, pp. 3-4.

AEROSPACE ENGINEERING

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New Faculty Search — Aerospace Engineering, University of Michigan

The Department of Aerospace Engineering at The University of Michigan invites applications for two tenure-track/tenured faculty positions in areas of Aerospace Engineering that align with the principal research interests pursued in the Department. One of these positions is intended for junior-level applicants only while candidates at all levels will be considered for the second position. Applicants must have extensive knowledge of and experience with disciplines relating to Aerospace Engineering.

The Department presently has 27 full-time faculty members. Both its undergraduate and graduate programs are highly ranked nationally. Research interests of the faculty cover a broad spectrum of Aerospace Engineering including high-performance multiphysics computational sciences, aerostructures, smart structures and materials, flight dynamics and control, avionics and software systems, propulsion, combustion, and sustainable energy with a mix of air and space applications. More information about the department can be found at aerospace.engin.umich.edu. Applicants should have earned a doctoral degree in Aerospace Engineering or a closely related field. The successful candidate will be expected to participate in all aspects of the Department's mission, including the development of a strong and relevant externally funded research program, the teaching of undergraduate and graduate courses, and the supervision of graduate students.

Applicants should send an email with an attached ***single*** PDF file that contains a curriculum vita, a statement of research and teaching interests, three representative publications, and the names and contact information for at least three references to the Faculty Search Committee, c/o **Dr. Venkat Raman**, Department of Aerospace Engineering, University of Michigan at aero-search@umich.edu.

The evaluation process will start on January 31, 2015 and will continue until the positions are filled. The University of Michigan is an equal opportunity/affirmative action employer with an active dual-career assistance program. The college is especially interested in candidates who can contribute, through research, teaching, and/or service, to the diversity and excellence of the academic community.

Tenure Track Faculty Position

Assistant Professor of Aerospace – Space Engineering

The Division of Engineering and Applied Science at the California Institute of Technology invites applications for a tenure-track position in the Department of Aerospace (GALCIT). Our department is a unique environment where innovative, interdisciplinary, and foundational research is conducted in a collegial atmosphere and in strong collaboration with the Jet Propulsion Laboratory (JPL). We are looking for candidates who have demonstrated exceptional promise in a field related to **Space Engineering**. Research areas of particular interest include but are not limited to **dynamics, guidance and autonomous control of distributed spacecraft systems, space mission architecture and implementation**. A commitment to teaching and mentoring is expected.

Candidates should submit an online application at **https://applications.caltech.edu/job/galcit**.

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AIAA Bulletin

The 2015 Associate Fellows were honored at the AIAA Associate Fellows Recognition Ceremony and Dinner on 5 January, in conjunction with AIAA SciTech 2015. Photographs of the new Associate Fellows by region can be viewed on pages **B10–B11**.

MARCH 2015

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Addresses for Technical Committees and Section Chairs can be found on the AIAA Web site at **http://www.aiaa.org**.

We are frequently asked how to submit articles about section events, member awards, and other special interest items in the *AIAA Bulletin*. Please contact the staff liaison listed above with Section, Committee, Honors and Awards, Event, or Education information. They will review and forward the information to the *AIAA Bulletin* Editor.

Event & Course Schedule

DATE	MEETING (Issue of *AIAA Bulletin* in which program appears)	LOCATION	ABSTRACT DEADLINE
2015			
4 Mar	**AIAA Congressional Visits Day**	Washington, DC	
7–14 Mar†	**2015 IEEE Aerospace Conference**	Big Sky, MT (Contact: Erik Nilsen, 818.354.4441, erik.n.nilsen@jpl.nasa.gov, www.aeroconf.org)	
8–9 Mar	**Overview of Missile Design and System Engineering**	Laurel, MD	
10–12 Mar	**AIAA DEFENSE 2015 (AIAA Defense and Security Forum)** **Featuring:** **AIAA Missile Sciences Conference** **AIAA National Forum on Weapon System Effectiveness** **AIAA Strategic and Tactical Missile Systems Conference**	Laurel, MD	**4 Nov 14**
25–27 Mar†	**3rd Int. Conference on Buckling and Postbuckling Behaviour of Composite Laminated Shell Structures with DESICOS Workshop**	Braunschweig, Germany (Contact: Richard Degenhardt, +49 531 295 3059, Richard.degenhardt@dlr.de, www.desicos.eu	
30 Mar–2 Apr	**23rd AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar**	Daytona Beach, FL	**30 Sep 14**
30 Mar–1 Apr†	**50th 3AF Conference on Applied Aerodynamics – Forthcoming Challenges for Aerodynamics**	Toulouse, France (Contact: Anne Venables, +33 1 56 64 12 30, Secr.exec@aaaf.asso.fr, www.3af-aerodynamics2015.com)	
13–15 Apr†	**EuroGNC 2015, 3rd CEAS Specialist Conference on Guidance, Navigation and Control**	Toulouse, France (Contact: Daniel Alazard, +33 (0)5 61 33 80 94, alazard@isae.fr, w3.onera.fr/eurognc2015)	
13–17 Apr†	**2015 IAA Planetary Defense Conference**	Frascati, Italy (Contact: William Ailor, 310.336.1135, william.h.ailor@aero.org, www.pdc2015.org)	
5 May	**AIAA Fellows Dinner**	Crystal City, VA (https://www.aiaa.org/FellowsDinner2015)	
6 May	**Aerospace Spotlight Awards Gala**	Washington, DC	
25–27 May†	**22nd St. Petersburg International Conference on Integrated Navigation Systems**	St. Petersburg, Russia, (Contact: Prof. V. G. Peshekhonov, 7 812 238 8210, icins@eprib.ru, www. Elektropribor.spb.ru)	
4 Jun	**Aerospace Today ... and Tomorrow—An Executive Symposium**	Williamsburg, VA	
16–19 Jun†	**7th International Conference on Recent Advances in Space Technologies – RAST 2015**	Istanbul, Turkey (Contact: Capt. M. Serhan Yildiz, +90 212 6632490/4365, syildiz@hho.edu.tr or rast2015@rast.org.tr)	
20–21 Jun	**Optimal Design in Multidisciplinary Systems**	Dallas, TX	
20–21 Jun	**FUN3D Training Workshop**	Dallas, TX	
22–26 Jun	**AIAA AVIATION 2015 (AIAA Aviation and Aeronautics Forum and Exposition)** **Featuring:** **21st AIAA/CEAS Aeroacoustics Conference** **31st AIAA Aerodynamic Measurement Technology and Ground Testing Conference** **33rd AIAA Applied Aerodynamics Conference** **AIAA Atmospheric Flight Mechanics Conference** **7th AIAA Atmospheric and Space Environments Conference** **15th AIAA Aviation Technology, Integration, and Operations Conference** **AIAA Balloon Systems Conference** **AIAA Complex Aerospace Systems Exchange** **22nd AIAA Computational Fluid Dynamics Conference** **AIAA Flight Testing Conference** **45th AIAA Fluid Dynamics Conference** **22nd AIAA Lighter-Than-Air Systems Technology Conference** **16th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference** **AIAA Modeling and Simulation Technologies Conference** **46th AIAA Plasmadynamics and Lasers Conference** **45th AIAA Thermophysics Conference**	Dallas, TX	**13 Nov 14**
28 Jun–2 Jul†	**International Forum on Aeroelasticity and Structural Dynamics (IFASD)**	Saint Petersburg, Russia (Contact: Dr. Svetlana Kuzmina, +7 495 556-4072, kuzmina@tsagi.ru, www.ifasd2015.com)	
6–9 Jul	**20th AIAA International Space Planes and Hypersonic Systems and Technologies Conference**	Glasgow, Scotland	**8 Dec14**

DATE	MEETING (Issue of *AIAA Bulletin* in which program appears)	LOCATION	ABSTRACT DEADLINE
12–16 Jul†	**International Conference on Environmental Systems**	Bellevue, WA (Contact: Andrew Jackson, 806.834.6575, Andrew.jackson@ttu.edu, www.depts.ttu.edu/ceweb/ices)	
25–26 Jul	**Business Management for Engineers**	Orlando, FL	
25–26 Jul	**The Application of Green Propulsion for Future Space**	Orlando, FL	
25–26 Jul	**Advanced High Speed Air Breathing Propulsion**	Orlando, FL	
27–29 Jul	**AIAA Propulsion and Energy 2015 (AIAA Propulsion and Energy Forum and Exposition)** **Featuring:** **51st AIAA/SAE/ASEE Joint Propulsion Conference** **13th International Energy Conversion Engineering Conference**	Orlando, FL	**7 Jan 15**
9–13 Aug†	**2015 AAS/AIAA Astrodynamics Specialist Conference**	Vail, CO (Contact: Dr. W. Todd Cerven, william.t.cerven@aero.org, www.space-flight.org/docs/2015_astro/2015_astro.html)	
29–30 Aug	**Introduction to Space Systems**	Pasadena, CA	
31 Aug–2 Sep	**AIAA SPACE 2015 (AIAA Space and Astronautics Forum and Exposition)**	Pasadena, CA	**10 Feb 15**
7–10 Sep†	**33rd AIAA International Communications Satellite Systems Conference and Exhibition (ICSSC-2015)**	Gold Coast, Australia (Contact: Geri Geschke, +61 7 3414 0700, Geri.geschke@emsolutions.com.au, www.satcomspace.org)	**1 Apr 15**
12–16 Oct†	**66th International Astronautical Congress**	Jerusalem, Israel (Contact: www.iac2015.org)	
2016			
4–8 Jan	**AIAA SciTech 2016 (AIAA Science and Technology Forum and Exposition)** **Featuring:** **24th AIAA/AHS Adaptive Structures Conference** **54th AIAA Aerospace Sciences Meeting** **AIAA Atmospheric Flight Mechanics Conference** **15th Dynamics Specialists Conference** **AIAA Guidance, Navigation, and Control Conference** **AIAA Information Systems—Infotech@Aerospace Conference** **AIAA Modeling and Simulation Technologies Conference** **18th AIAA Non-Deterministic Approaches Conference** **57th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference** **9th Symposium on Space Resource Utilization** **4th AIAA Spacecraft Structures Conference** **34th Wind Energy Symposium**	San Diego, CA	**2 Jun 15**
5–12 Mar†	**2016 IEEE Aerospace Conference**	Big Sky, MT (Contact: Erik Nilsen, 818.354.4441, Erik.n.nilsen@jpl.nasa.gov, www.aeroconf.org)	

For more information on meetings listed above, visit our website at www.aiaa.org/calendar or call 800.639.AIAA or 703.264.7500 (outside U.S.).
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From the Corner Office

ALIGNING STAFF FOR OUR FUTURE

Sandy H. Magnus, Executive Director

AIAA members are at the center of creating, developing, and building new technologies that drive the aerospace industry. As an organization, AIAA is focused on the preservation and dissemination of the rich technical content produced by its members and the aerospace industry at large. Preserving and curating aerospace science and technology development was a touchstone for the founders of both ARS and IAS. This has continued to be of primary significance through the merger that created AIAA and has sustained the organization for more than 50 years. Therefore, it is not surprising that continuing this mission and being the clearinghouse for the wealth of aerospace technical content and information plays a significant role in the current AIAA Strategic Plan. In fact, identifying, prioritizing, capturing, interpreting, publishing, distributing, and preserving technical content and information are critical elements of all three of our strategic imperatives:

- Develop and Expand our Community
- Strengthen our Existing Community
- Deliver Exceptional Results

To ensure that we are well equipped to support the AIAA community in technology development, interpretation, publication, curation, and dissemination of information, while expanding the Institute's existing technical legacy, the AIAA staff has undergone some realignment and reorganization. I would like to take a moment and highlight some of the significant changes.

Content Development

The key to delivering on all three strategic imperatives is the constant identification, capture, and curation of state-of-the-art technical content. The forums and publications that AIAA offer are the vehicles the organization uses to disseminate and curate the output of our members and the industry. Having strong, relevant content is vital to attract new and returning attendees and readers: without this technical core, no one will participate or read. This applies to both adjacent disciplines, new to long-time AIAA communities, and the latest developments in the long-established fundamental technologies. Content development requires a strong strategic collaboration between staff and members. To accomplish this, we established a new staff division called, appropriately, **Content Development**, in late 2014. This new division, staffed by Tom Irvine and Craig Day, works directly with the forums' executive steering committees, the Emerging Technologies Committee, and Technical Activities Committee to identify new areas of science, technology, and development—in other words, content—that AIAA should incorporate into the forums or in other ways. While many technical societies frequently employ staff credentialed in the society's focus area, AIAA has not consistently done so over its history. Aligning staff members with backgrounds like those of our members should logically pay significant dividends in content and product development. Tom and Craig are both aerospace engineers, so with these two focused upon content, working collaboratively with technically focused members, we expect strong results with an ever-expanding foundation for exceptional technical content.

The content development team collaborates principally with two other staff divisions: **Products and Programs** and **Strategic Outreach**. The Products and Programs division, led by Megan Scheidt, encompasses the Institute's traditional product lines with staff supporting the forums, publications (journals, books, and technical papers), and standards. While there is much new going on in Products and Programs, with many critical contributions to make to the Strategic Plan, its divisional alignment is relatively unchanged.

A major area of collaboration between the Content Development and Products and Programs staff is the development of the plenary sessions and the more in-depth Forum 360 sessions that are held at our forums throughout the year. A good example of this is the "Big Data Analytics in Aerospace" panel at the recent AIAA SciTech 2015 Forum. The session brought together panelists from industry, government, and academia—including Verizon, Georgia Tech, Boeing, NASA, and Lockheed Martin—to discuss the expanding field of big data and its analysis. The applications of these technologies to the aerospace domain are quickly emerging in numerous areas including air traffic management, with the potential to enable higher degrees of autonomy in both manned and unmanned missions, as well as in the area of health management of complex systems.

Strategic Outreach

Content Development's other principal partner, Strategic Outreach, is another newly aligned division.

Strategic Outreach comprises *Aerospace America*, Communications, and Public Policy. This division is about delivering AIAA's and the aerospace profession's message, telling our stories, and connecting our many subcommunities by communicating directly with members through vehicles such as the website, newsletters, and broadcast emails. It also involves sharing the AIAA message with other audiences, including nontechnical aerospace professionals, the media, policy- and lawmakers, and the general public. We have a great staff involved in all aspects of communications: *Aerospace America* (led by Editor-in-Chief Ben Iannotta); Steve Sidorek, AIAA's Public Policy and Government Relations Manager; and the Communications team made up of John Blacksten, Director of Communications; Lawrence Garrett, Web Editor; Duane Hyland, Media Relations Coordinator; and Hannah Thoresen, Social Media Coordinator. All of this is under the leadership of Rodger Williams.

Strategic Outreach works with Content Development to identify additional venues, platforms, and opportunities to highlight the Institute's technical content and ensure that the message and relevance of what aerospace professionals do comes through. As part of this, *Aerospace America* is looking more and more at the innovative activity occurring in the Institute's technical areas, as well as examining cutting-edge technologies that the Institute should engage for topics of coverage. In addition, the magazine is featuring the discussions and speakers from the forums on a regular basis, while still maintaining its own independent thought-provoking journalism.

The changes to AIAA's public policy program in the last year will allow us to connect AIAA's key issues (as described in the February 2015 "From the Corner Office") to audiences through sessions at forums, features in *Aerospace America*, and outreach through traditional and social media. Print and online journalists are beginning to pay more attention to what AIAA members are doing and reporting—particularly at the forums. To support and cultivate relationships with reporters, writers, and producers, Duane Hyland is now fully focused on media relations and we're seeing results. We've had a more than 50 percent increase in the number of media inquiries year-to-date (FY2015) and increased media attendance at—and coverage of—our forums. Social media channels are growing in importance and influence, and Hannah Thoresen, the newest member of the Communications team, is aggressively taking AIAA's social media to new heights.

She is adding new outreach channels as well as actively facilitating the conversation. We're seeing results here too with a 68 percent increase in Facebook followers in FY 2014, and very successful Twitter contests at each of our forums, that, combined, generated nearly 17 million timeline deliveries. So overall we are now well positioned and continuing our mission of communicating the great things our community is doing!

We still have work to do: in time Strategic Outreach will lead the Institute's efforts in new virtual delivery methods and curation of content in all of its varied forms and for all audiences.

Market Development and Sales

Significant thought also has been devoted to 1) Marketing & Design Services (headed by Jessa Foor) and 2) Corporate Relations (led by Tobey Jackson). These areas fall under a new division: **Market Development and Sales (MDS)**. MDS was envisioned to provide broad institutional support to AIAA products and services as well as establish a more integrated and relationship-based experience for our corporate member partners and institutional customers.

Driven by the changes in technology that have occurred over the past decade, there has been a shift in the manner in which information is processed and consumed; we all recognize this. It is no longer sufficient to communicate with our members and the community strictly via traditional means of print mail, e-mail, phone, or fax machine. We have entered an era where information must be timely, succinct, in multiple formats simultaneously, and accessible via a myriad of electronic devices (phones, tablets, laptops). AIAA will continue to evolve its content marketing capabilities and the way in which we communicate the work of our members and achievements of the industry.

No great organization becomes great on its own. AIAA is comprised of individual members across industry, academia, and government as well as numerous corporations. Working together we are Shaping the Future of Aerospace and our corporate partners play an influential role in that endeavor. Not only is AIAA addressing how to meet the needs of our individual members, but AIAA has also committed to better support the evolving needs of our industry partners.

Over the past six months, AIAA has deliberately moved away from its siloed approach to working with our corporate partners and customers, toward one that offers a more comprehensive, streamlined, and tailored experience. Philosophically, the primary purpose for this pivot is to move the organization away from "transactional relationships" that have historically defined our interactions with corporate members to a more strategic approach that supports an "experiential relationship" with those partners. Plainly stated, we anticipate that this shift will mean better, customer-centric service for our corporate partners.

To achieve this, AIAA's Corporate Partnership Program will now be segmented into three tiers defined by market demographics, not by company size and revenue. Each tier will be supported by a Strategic Relationship Manager (SRM). Tier I will focus on original equipment manufacturers (OEMs), prime contractors, and government agencies and will be staffed by Tobey Jackson; Tier II will focus on major assemblies, integrated systems and subsystems, and federally funded research and development companies (FFRDCs) and will be supported by Paul doCarmo; and Tier III will focus on supply chain and services and will be supported by Chris Grady. Each SRM will manage the entire relationship with companies in their respective tier, working with them to customize and tailor the AIAA member, sponsorship, and exhibit experiences. In so doing, it is AIAA's goal to better align the company's business objectives and improve its ROI through its involvement with AIAA.

Future of the Foundation

Late last year, in this column, I updated you on the AIAA Foundation, but we have more exciting news to share. As many of you are aware, we have been laser-focused on reimagining and refocusing the AIAA Foundation and its mission of educational outreach and support. To that end we have restructured the Foundation Board of Trustees and established a new K–12 STEM Committee to ensure we are providing top-notch programs for students—who we hope will become the next generation of aerospace proessionals—and educational assistance through resources and classroom grants for the educators who teach them.

As our industry evolves to meet the economic realities of today, so too must the ways the Foundation fosters and supports student growth, achievement, and success. To do that successfully requires substantial financial resources to sustain long-term planning and program development. It also needs something we haven't had for the past 18 months—dedicated staff. I am excited to announce that Merrie Scott has assumed a new role as the Development Director for the AIAA Foundation. This position is critical to reigniting the Foundation successfully and will involve Merrie working with individual donors, other foundations, and of course, our corporate partners, as we "Invest in the Future" of the aerospace community.

We've also promoted Felicia Ayoub to a new position as AIAA Foundation Program Coordinator. In this role Felicia will work with closely with the Development Director, other AIAA staff, and volunteers on scholarships and grants, new STEM projects and partnerships such as the innovative Aurora Flight Sciences-AIAA Sky Robotics program, and a host of legacy programs like Design/Build/Fly and student paper competitions.

It has taken the time and the hard work of many volunteers and staff, but the AIAA Foundation is now well positioned to grow and flourish. I'm counting on you to support our worthwhile, noble, and transformative efforts.

We've come a long way—in a relatively short amount of time—in realigning the AIAA staff and organizational structure to better serve the evolving needs of our members—both individual and corporate—and the aerospace industry writ large. Change is never easy but it is necessary if the Institute is to remain relevant and responsive. Shaping the Future of Aerospace isn't just our tagline, it's what we at AIAA are doing every day through our forums, publications, member services, and outreach. We have more work to do to implement our Strategic Plan fully: it will take all of us working together to ensure our continued success.

ANNUAL BUSINESS MEETING NOTICE

Notice is hereby given that the Annual Business Meeting of the American Institute of Aeronautics and Astronautics will be held at Hilton Crystal City, Arlington, VA, on Thursday, 7 May 2015, at 12:00 PM.

William Seymore, AIAA Corporate Secretary/Treasurer

AWARDS GIVEN AT FOUNDATION INTERNATIONAL STUDENT CONFERENCE

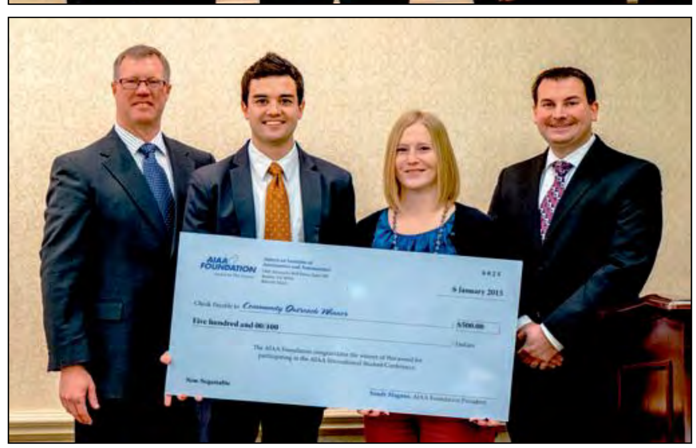
On 5 January, the AIAA Foundation held their International Student Conference, in conjunction with AIAA SciTech 2015, in Kissimmee, Florida. The first-place winners of the Regional Student Papers Conferences competed to be best overall in their category. The awards for the four categories were given on 6 January as part of the AIAA Student Award Ceremony.

- ***Undergraduate Team Division*** – **Braden Hancock and Timothy Nysetvold**, Brigham Young University, Provo, UT, "A New Mechanism for Combining (epsilon)-Dominance and Pareto Knee Exploration in Evolutionary Multi-Objective Optimization."
- ***Individual Undergraduate Division*** – **Jonathan Tsosie**, New Mexico Institute of Mining and Technology, Socorro, NM, "Colorimetric Hydrogel-Based Microfluidic Assay System to Monitor Malnutrition in a Microgravity Environment."
- ***Graduate Division*** – **Gabriele Fabbi**, University of Rome "La Sapienza," Rome, Italy, "Theoretical and Numerical Approaches for Impact Load Identification on an Aerospace Structure Correlation with Experimental Data."
- ***Community Outreach Division*** – **Carlie Shields** and **Robert Swasey**, Brigham Young University, Provo, UT, "Engineers on Deck."

"AIAA congratulates each of the winners in this year's International Student Conference's paper competition," said Sandy Magnus, AIAA executive director. "Their work shows that the future of aerospace is in capable hands, and is testament not only to their abilities but to the inspiration of their instructors and mentors as well. We look forward to seeing how they will shape the future of aerospace as members of our community through the years to come."

For more information on the AIAA Foundation International Student Conference, please contact Rachel Andino at 703.264.7577 or at rachela@aiaa.org.

Above: Attendees of the AIAA Foundation International Student Paper Conference. Below: Steve Gorrell of Brigham Young University, AIAA Vice President–Education (left), and Jeff Corbets, Lockheed Martin, Chair of the Student Activities Committee (right), pose in each photo with the award winners (clockwise from top left: Undergraduate Team, Graduate, Community Outreach, and Individual Undergraduate).



SPECIAL SECTION: AIAA COLLABORATION WITH INDIA

As part of its international strategy, AIAA strives to increase its international participation, in particular through bilateral partnering with other societies in other countries. To fully reflect the desired global perspectives, AIAA has focused on currently under-represented international aerospace communities, specifically Argentina, Brazil, China, Eastern Europe, India, Japan, Korea, and Russia.

AIAA collaboration with India dates back more than 10 years. In 2004, AIAA and the Astronautical Society of India (ASI) co-organized the India-United States Conference on Space Science, Applications, and Commerce in Bangalore. Sponsored by the Indian Space Research Organization and the U.S. Department of State in coordination with NASA and NOAA, this event was the first serious bilateral engagement about space cooperation between India and the United States, bringing together scientists, policy makers, and the private sector to explore additional cooperation between the two countries.

In 2013, AIAA signed a collaborative Memorandum of Understanding (MOU) with the Aeronautical Society of India (AeSI). On the occasion of the MOU signing, AIAA Vice President–International Susan Ying noted, "As India has become a major player in the world aerospace community, and is one of the world's largest economies, it is fitting for our organizations to have reached this agreement. As many great advancements in aerospace have been the result of international partnerships, we look forward to the future with anticipation and excitement as AIAA and AeSI members begin to work together." The MOU calls for cooperation between AIAA and AeSI on a wide range of activities, including cosponsoring and promoting the activities of the other organization to one's own members; copublishing information of mutual interest; collaborating on student activities, professional development, technical lectures, training and related activities; organizing official visits between the organizations; and cooperating on issues of importance to the international aerospace community and its member organizations. As a direct result of the MOU between AIAA and AeSI, a delegation of AIAA Corporate Members visited various sites in India in December 2014. (See the article later in this section about the delegation visit.)

Also, in September 2014, AIAA partnered with Lockheed Martin to organize an activity in the Washington, DC, area as part of the India Innovation Growth Program—a joint initiative of the Department of Science and Technology, Government of India; Lockheed Martin Corporation; Indo-US Science and Technology Forum; Federation of Indian Chambers of Commerce and Industry; Stanford Graduate School of Business; and the IC2 Institute at the University of Texas. The aim of this program is to accelerate innovative Indian technologies into the global markets. The India Innovation Growth Program is the only program of its kind because of its focus on teaching the use of world-class commercialization strategies and the business development assistance provided. For more information, visit **http://www.indiainnovates.in**.

AIAA Membership in India

- 80 Professional Members (*19 Associate Fellows, 28 Senior Members*)
- 121 Student Members
- 15 Educator Associates
- 3 Student Branches (*MLR Institute of Technology, Hyderabad; Indian Institute of Technology, Kanpur; Hindustan University, Tamil Nadu*)

About the Aeronautical Society of India (AeSI)

AeSI was founded in 1948 and has its Head Office in New Delhi with 16 branches located in major Indian cities that are hubs of aeronautical and aviation-related activities. AeSI branches organize seminars, symposiums, and promotional activities for advancement and diffusion of the knowledge of aeronautical sciences and aircraft engineering as well as elevation of the aeronautical profession. The society publishes the *Journal of Aerospace Sciences and Technologies*, and it conducts examinations for students leading to undergraduate degrees in Aeronautical Engineering recognized by the Government of India. AeSI has more than 9,000 members in various grades, from organizations in the field of space, defense, and civil aviation. The society has 53 Corporate Members from both national and international sectors.

For additional information about AeSI, visit **http://www.aerosocietyindia.in**.

AIAA Corporate Members Visit India

In December 2014, an AIAA delegation of U.S. aerospace industry executives visited India, stopping in Bangalore, Hyderabad, and Chennai. The trip, part of AIAA's Corporate Member program, was aimed at:

- Determining current and future interests of AIAA membership toward engagement with the Indian aerospace community, within the framework of the MOU between AIAA and the Aeronautical Society of India (AeSI).
- Gaining an understanding of the operational aspects of defense and aerospace laboratories and industries in India.
- Providing an opportunity for AIAA Corporate Members to understand the Indian business environment and to explore opportunities.

See below for a summary of the delegation's visit.

Bangalore

- *U.S. Consulate and Chamber of Commerce*: Met with representatives who provided an overview of trade, commercial, and financial issues involved in doing business in India.
- *Jack F. Welch Technology Centre and GE Global Research Center*: Visited GE facilities related to healthcare, materials, and aerospace (design, CFD, corrosion testing, etc.).

AeSI President G. M. Rao and AIAA Vice President for International Activities Susan Ying sign the MOU between societies in 2013.

- *Altair*: Briefed about the Indian operations of Altair and toured the facility. Altair generously organized a reception and dinner and invited local industry representatives to join and meet the delegation members.
- *Aeronautical Development Establishment*: Visited the UAV simulation and Light Combat Aircraft simulation facilities.
- *Hindustan Aeronautics Limited*: Toured the Light Combat Helicopter design and production facility.
- *National Aerospace Laboratories (NAL)*: Visited the ACD Exhibition Bay, the Hansa Hanger, and 4' Wind Tunnel. Established in 1959, it is the only government aerospace R&D laboratories in India's civilian sector.
- *Alpha Design Technologies*: Toured this research and design and technology industry supplier of land, shipborne, airborne, and simulation systems.

Hyderabad

- *Hindustan Aeronautics Limited, Avionics Division*: Visited avionics facilities where electronic circuit boards, transponders, and other relevant components are designed and fabricated for Indian space and missile programs.
- *MTAR Technologies*: Visited machining and manufacturing facilities related to nuclear, aerospace, rocket engines, and oil industries.
- *SEC Industries*: Toured machining and manufacturing facilities related to army tanks, rocket motor casings, aerospace components and assembly.
- *MAS GMAR Aero Technic*: Visited aerospace park, which has aircraft maintenance and repair operations and plans.
- *Astra Microwave Products*: Briefed on microwave energy related products and services.
- *VEM Technologies*: Visited facilities related to missile components and assembly (e.g., Brahmos).
- *Research Centre Imarat, Defence Research and Developmemt Organization, Government of India, Ministry of Defence*: Toured Exhibition Hall that included participation by local labs—DMRL, DLRL, ARCI, DRDL, RCI and ASL.

Chennai

- *Data Patterns Corporation*: Briefed about this defense and aerospace electronics systems company.
- *Indian Institute of Technology*: The Aero Engineering Department of this institute was founded in 1969. Research areas include aerodynamics, propulsion, and structures. With a faculty of 25, 50% of whom studied in the United States, the department has 230 undergraduate students and 15 scholars.

AIAA delegation members on the steps of the Indian Institute of Technology with the chairman of the AeSI Chennai Branch, Professor V. Kanagarajan.

AIAA Delegation Members

- Supriya Banerjee (Bangalore only), The Finehas Group
- Mark and Jennifer Cherry, Aurora Flight Sciences
- Sivaram Gogineni, Spectral Energies, LLC
- Anjaney Kottapalli (Chennai only), Lockheed Martin
- John and Barbara Langford, Aurora Flight Sciences
- Sandy Magnus, AIAA
- Paul Nielsen, Software Engineering Institute
- Merrie Scott, AIAA
- Robert Yancey, Altair Engineering
- Susan Ying and Rob Armstrong, COMAC

At the end of the visit, the delegation was in agreement that the trip was a productive one. The delegation had the following observations:

- The aerospace business in India is tremendously impacted by ITAR, largely serves Indian domestic needs, and is more allied with Russia, Israel, and the EU.
- There are a tremendous amount of resources and energy going into their aviation industry toward building a commercial capability.
- They are trying to change the old paradigm where the government does everything, from R&D to manufacturing, both in civil and, to a certain extent, military (i.e., grow an infrastructure for the aerospace industry in general).
- The space industry appears to have a more defined, mature method of engagement between the government and commercial entities.
- The structure of Indian government presents difficulty in understanding the business environment.
- India is looking for partnerships from a business viewpoint as well as a connection to their peers in the engineering/R&D world on a collaborative basis.
- There is potential for engagement with the engineering and AIAA communities.

Based on the various meetings they had while in India, the group identified some opportunities for AIAA in continued collaboration both from a business perspective and a society perspective. In addition, there was support for organizing other Corporate Member delegation trips to other countries where AIAA wants to grow its presence, such as Brazil.

This trip would not have been successful without strong support and cooperation from AeSI and the U.S. Consulate in Chennai, as well as all the organizations that hosted meetings and tours of their facilities. Without the support of our Corporate Members the trip would not have been possible. AIAA would like to thank all of these groups for making this trip worthwhile and productive.

Doing Business in India

As the world's fastest growing, free market democracy, India presents opportunities for U.S. companies of all types and sizes. U.S. exports to India exceed $18 billion annually, and grew almost 125% from 2005 to 2008. The U.S. Commercial Service of the U.S. Embassy helps U.S. firms export goods and services to India. As part of the U.S. Department of Commerce's network of seven offices throughout India, 107 offices in the United States, and 145 international offices, the Commercial Services has export promotion resources that help companies develop business in the Indian market.

For more information, visit **http://export.gov/india**.

2015 AIAA ASSOCIATE FELLOWS HONORED

The 2015 Associate Fellows were honored at the AIAA Associate Fellows Recognition Ceremony and Dinner on 5 January at the Gaylord Palms Hotel and Convention Center, Kissimmee, Florida, in conjunction with AIAA SciTech 2015.

2015 Associate Fellows by Region.

Top photo: Region I.

Middle left: Region II; middle right: Region III.

Bottom: Region IV.

Top left: Region V.
Top right: Region VII.
Bottom left: Region VI.

ORANGE COUNTY SECTION PLANNING ASAT 2015

The AIAA Orange County Section is planning its annual AIAA Southern California Aerospace Systems and Technology (ASAT) Conference 2015, its most prestigious regional conference, which will be held on **2 May 2015**. In its 12th consecutive year, this local conference provides student and professional members alike an opportunity to present original work across a wide variety of tracts over the morning and afternoon sessions. It offers quite a few opportunities for networking in a more intimate setting than larger conferences. The amazing caliber of aerospace work going on in Southern California also allows the section to bring in some very exciting speakers for the morning and lunch keynote presentations. The ASAT 2015 evening banquet that follows the conference is dedicated to recognizing the accomplishments of some of AIAA's well-deserving members and culminates with a banquet speaker.

Conferences play an important part in sharing ideas and information amongst peers, but not everyone can afford the time and cost associated with many of the large venue conferences. Locally hosted technical symposiums that offer networking and sharing of ideas are a great way for sections to address the desire of members to participate. The AIAA Orange County Section expects similar success this year. John Rose, AIAA Associate Fellow, is the ASAT 2015 Conference Chair. For additional information, please navigate yourself to the following link: **http://events.r20.constantcontact.com/register/event?oeidk=a07ea0dfsuy47d3a5c6&llr=vitem6fab&showPage=true**.

The 2015 event features a similar agenda to ASAT 2014, which was held on 3 May 2014, in Santa Ana, CA. The speakers and presenters of the 2014 conference and annual section awards banquet represented some of the brightest minds in Southern California's aerospace sector, including distinguished conference keynote speakers Abe Karem (Karem Aircraft) and Jayanth Kudva (NextGen Aeronautics) with John Callas (NASA JPL) as the banquet speaker. The day consisted of a four parallel track morning and afternoon sessions with 39 presentations given. The audience included potential prospective AIAA members, members of similar groups, societies, and associations as well as civic, industry, and education professionals. Both precollege and college students were well represented at the conference both as attendees and presenters. This event was jointly sponsored by the AIAA Orange County Section and The Boeing Company, with a record-breaking success of over 100 registrants.

Mr. Abe Karem, one of the keynote speakers of ASAT 2014.

Mr. Bob Welge (left), Mr. Phil Ridout (sitting), and Mr. John Rose (right), AIAA Orange County section council members during the ASAT 2014 event.

Dr. Amir S. Gohardani (standing in the middle on the right hand-side of the picture) discusses various aspects of Mr. Abe Karem's presentation during the keynote QA at ASAT 2014 with Mr. Dino Roman (ASAT 2014 Technical Chair) and Dr. Omid Gohardani by his side.

During the 2014 banquet, the 2013–2014 AIAA Orange County Section Awards were presented to the Student of the Year (Lawrence Ng, UCI), Young Professional of the Year (Philip de Armendi, Boeing), Engineer of the Year (Amir S. Gohardani, (L'Garde Incorporated), and the Aerospace Leader of the Year (Ted Kerzie, Boeing). Dino Roman, the Technical Chair of ASAT 2014 expressed his optimism for future ASAT conferences in Southern California, stating: "The ASAT conference and banquet event is always an outstanding activity. It really shows how the AIAA OC Section is building a significant working relationship with members, their families, and the community, while encouraging and showcasing our STEM-related programs."

OBITUARIES

AIAA Associate Fellow Gupta Died in May 2014

Dr. Tej Gupta died on 7 May 2014. He was 72 years old.

Dr. Gupta completed his Master's and first Ph.D. in Applied Mathematics from Roorkee University. In 1975, he began studying at Virginia Tech, where he completed his second Ph.D. in Engineering Mechanics in 1977 and began teaching. In 1979, he joined Embry-Riddle Aeronautical University and established an exemplary record of dedicated service and teaching excellence in the Aerospace Engineering program.

Throughout his distinguished career, Dr. Gupta received numerous awards and recognition including the Overall Professor of the Year Award in 2011 from Embry-Riddle's Alpha Mu chapter of the Pi Kappa Alpha fraternity, Outstanding Teacher of the Year Award in 2004, and the AIAA Faculty Advisor Award—Region II in 1995–1996.

AIAA Fellow Rosen Died in December 2014

Milton W. Rosen died 30 December 2014. He was 99.

Mr. Rosen received a bachelor's degree in electrical engineering from the University of Pennsylvania in 1937. Joining the staff of the Naval Research Laboratory, he teamed with nuclear physicist Ernst H. Krause in 1945 to establish the lab's first rocket development program. The team designed and developed the multistage Viking rockets, which were launched between 1949 and 1955.

From 1947 to 1955, he served as the rocket program's chief engineer and supervised development of the research missiles. Mr. Rosen later was the technical director of a successor space program, Project Vanguard. He oversaw the success of Vanguard 1. Moving to NASA Headquarters in 1958, he served as the agency's launch-vehicle director. He became a senior scientist in NASA's office of the deputy associate administrator for defense affairs and deputy associate administrator for what is now the science mission directorate. In the 1960s, he helped oversee the development of innovative programs, including NASA's Apollo spaceflight program. Retiring from NASA in 1974, Mr. Rosen later served at the National Academy of Sciences as executive director of its Space Applications Board.

AIAA Associate Fellow Sforzini Died in January

Richard H. Sforzini died on 8 January 2015.

A 1947 graduate of the U.S. Military Academy at West Point, Mr. Sforzini was on active duty until March 1959. He also received a graduate degree in Mechanical Engineering from the Massachusetts Institute of Technology in 1954. He taught in the Department of Ordnance at West Point from 1954 to 1957. His final assignment in uniform was as director of an anti-tank guided missile project for the Army Missile Command at Redstone Arsenal, AL, where he resigned as a major in 1959.

Mr. Sforzini next was employed for eight years by Thiokol Chemical Corporation. As Director of Engineering for Thiokol's Space Booster Division, he led the engineering effort that culminated in 1965 in successful test firing of the world's first three-million-pound thrust solid-propellant rocket motor. Mr. Sforzini began a 15-month appointment as Visiting Professor of Aerospace Engineering at Auburn University in 1966, and remained there until his retirement in 1985. At Auburn, he taught jet propulsion and aerodynamics and worked on a number of NASA-sponsored research projects related to the space shuttle.

Mr. Sforzini was a member of the AIAA Solid Rocket Technical Committee (1977–1981), serving as chairman for the final two years. He was the author of numerous articles on jet propulsion. In 1994, he was the recipient of the Hermann Oberth Award presented by AIAA's Alabama–Mississippi Section in recognition. He was also honored nationally as the recipient of the 1996 AIAA Wyld Propulsion Award.

AIAA Honorary Fellow Covert Died in January

Eugene E. "Gene" Covert, the T. Wilson Professor of Aeronautics, Emeritus in the Department of Aeronautics and Astronautics at MIT, died on 15 January 2015. He was 88.

The head of MIT's Aeronautics Department from 1985 to 1990, Covert was an aeronautics specialist, credited with developing the first practical wind tunnel magnetic-suspension system. In the 1970s, Covert served as Chief Scientist of the U.S. Air Force, and was also a technical director of the European Office of Aerospace Research and Development. Covert was the former director of MIT's Center for Aerodynamic Studies. In the aftermath of the Space Shuttle Challenger disaster in 1986, Covert served on the commission that investigated the disaster and determined its cause.

Among Covert's many honors were the 2010 AIAA Reed Aeronautics Award; the 2005 AIAA/ASME/AHS/SAE Daniel Guggenheim Medal; the 1997 AIAA Wright Brothers' Lectureship in Aeronautics; the 1992 AIAA Durand Lectureship in Public Service; the 1990 AIAA Ground Testing Award, and the NATO Advisory Group for Aerospace Research and Development's 1990 von Kármán Medal. In addition to being an AIAA Honorary Fellow, Covert was also a Fellow of the Royal Aeronautical Society and an elected member of the National Academy of Engineering.

CALL FOR NOMINATIONS FOR AIAA SUSTAINED SERVICE AWARD DUE 1 JULY

Do you know an AIAA member who has dedicated time and efforts to AIAA? Someone who has participated in AIAA's activities and programs over a period of years? If so, AIAA encourages members to nominate them for the Sustained Service Award!

The Sustained Service Award recognizes sustained, significant service and contributions to AIAA by members of the Institute. The nominee/recipient must be a member in good standing who has shown continuing dedication to the interests of the Institute by making significant and sustained contributions over a period of time, typically 10 years or more. Active participation and service at the local section/regional level, and/or the national level is a potential discriminator in the evaluation of candidates. A maximum of 20 awards are presented each year.

Any AIAA member in good standing may serve as a nominator. A scoresheet detailing the nominee's participation and service to AIAA must accompany the signed nomination form. Technical accomplishments are not a consideration for this award. Additional information (no more than one page) that provides details to substantiate the scores for various activities is required. The Nomination Form and Scoresheet can be downloaded at **www.aiaa.org** after logging into MY AIAA. Nominators are encouraged to review the award guidelines for nominee eligibility, page limits, etc., at http://www.aiaa.org/Secondary.aspx?id=2915.

For more information, please contact Carol Stewart, Manager, AIAA Honors and Awards, at carols@aiaa.org.

NEW WORKING GROUPS—LOOKING FOR VOLUNTEERS!

- ***Diversity***—At the January meetings, one of the recommendations to the Board was to create a longer-term working group—reporting to the Board—focused on the diversity across the aerospace community writ large. The Diversity Working Group was thus chartered. This is an important topic that affects us across the industry! Interested members can email **DiversityWG@aiaa.org**.
- ***K–12 STEM***—The Board of Trustees of the Foundation, along with concurrence from the Board of Directors of the Institute, established the K–12 STEM Committee under the auspices of the Foundation. The K–12 STEM Committee has several working groups encompassing its activities. Interested members can email **STEMK-12WG@aiaa.org**.
- ***Career and Professional Development***—The Career and Workforce Development Committee and the Professional Member Education Committee recently merged so that these efforts can be synergistic to better serve members. This combined committee will have five new working groups focused on different aspects of outreach, engagement, resources, programs, and partnerships. For more details, interested members can email **CPDC-WG@aiaa.org**.

To submit articles to the *AIAA Bulletin*, contact your Section, Committee, Honors and Awards, Events, Precollege, or Student staff liaison.

Date: Tuesday, 5 May 2015
Reception: 6:30 pm
Dinner: 7:30 pm
Attire: Business

Register and for more information:
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Or mail your check to:
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Please help us celebrate the Class of 2015 AIAA Fellows and Honorary Fellows

2015 Honorary Fellows

Frederik J. Abbink – *The National Aerospace Laboratory of the Netherlands (retired)*
Kyle T. Alfriend – *Texas A&M University*
Wanda M. Austin – *The Aerospace Corporation*
Ben T. Zinn – *Georgia Institute of Technology*

2015 Fellows

Allen Arrington, Jr. – *Sierra Lobo, Inc.*
Thomas Beutner – *Office of Naval Research*
Lawrence Brase – *The Boeing Company*
John Crassidis – *University at Buffalo, State University of New York*
David Eames – *Rolls-Royce Corporation*
Eric Evans – *Massachusetts Institute of Technology Lincoln Laboratory*
Debra Facktor Lepore – Ball Aerospace & Technologies Corporation
Alison Flatau – *University of Maryland*
Michimasa Fujino – *Honda Aircraft Company*
Wayne Goodman – *The Aerospace Corporation*
Jayanth Kudva – *NexGen Aeronautics Inc.*
Timothy Lieuwen – *Georgia Institute of Technology*
E. Glenn Lightsey – *University of Texas at Austin*
Eli Livne – *University of Washington*
James Maser – *James G Advisors, LLC*
Paul McManamon – *Exciting Technology LLC*
David W. Miller – *Massachusetts Institute of Technology/NASA*
Alton Romig, Jr. – *Lockheed Martin Corporation*
Robert H. Smith – *Honeywell International Inc.*
Ashok Srivastava – *Verizon Corporation*
James Walker – *Southwest Research Institute*
Zhi Jian Wang – *University of Kansas*

15-590

Upcoming AIAA Continuing Education Courses

Course at AIAA Defense and Security Forum 2015 (AIAA DEFENSE 2015)
www.aiaa-defense.org/ContinuingEd

8–9 March 2015

Overview of Missile Design and System Engineering (Instructor: Eugene L. Fleeman)

This course provides an overview of missile design and system engineering. A system-level, integrated method is provided for missile design, technologies, development, analysis, and system engineering activities in addressing requirements such as cost, performance, risk, and launch platform integration. The methods presented are generally simple closed-form analytical expressions that are physics-based, to provide insight into the primary driving parameters. Sizing examples are presented for rocket-powered, ramjet-powered, and turbo-jet powered baseline missiles as well as guided bombs. Typical values of missile parameters and the characteristics of current operational missiles are discussed as well as the enabling subsystems and technologies for missiles and the current/projected state of the art. Videos illustrate missile development activities and performance. Attendees will receive a copy of the course notes.

Key Topics
- Key drivers in the missile propulsion design and system engineering process
- Critical tradeoffs, methods, and technologies in propulsion system sizing to meet flight performance and other requirements
- Launch platform-missile integration
- Sizing examples for missile propulsion
- Missile propulsion system and technology development process

Courses at AIAA Aviation and Aeronautics Forum 2015 (AIAA AVIATION 2015)
www.aiaa-aviation.org/ContinuingEd

20–21 June 2015

Optimal Design in Multidisciplinary Systems (Instructors: Joaquim R. R. A. Martins and Jaroslaw Sobieski, Ph.D)

When you are designing or evaluating a complicated engineering system such as an aircraft or a launch vehicle, can you effectively reconcile the multitude of conflicting requirements, interactions, and objectives? This course introduces you to methods and tools that have been developed over the years for the design optimization of engineering systems.

You will be presented with a review of the state-of-the-art methods for design optimization that exploit the modern computer technology for applications with large numbers of variables, and design constraints. You will learn how to evaluate sensitivity of the design to variables, initial requirements, and constraints, and how to select the best approach among the many that are currently available.

The last part of the course will take you to system-level applications where the primary problem is in harmonizing the local disciplinary requirements and design goals to attain the objectives required of the entire system, and where performance depends on the interactions and synergy of all its parts. In addition to imparting skills immediately applicable, the course will give you a perspective on emerging methods and development trends.

Key Topics
- Multidisciplinary design-components, challenges, and opportunities
- Optimization methods
- Sensitivity analysis
- Decomposition architectures in multidisciplinary design
- Surrogate modeling in design
- Soft computing methods in optimal design

FUN3D Training Workshop

Please note that FUN3D is export-controlled software and may only be provided to U.S. persons.

This workshop will provide participants with guidance on how to install and execute the NASA Langley Research Center FUN3D computational fluid dynamics software for common aerospace applications. The objective of this workshop is to provide engineers and scientists with sufficient instructions to apply a large-scale Navier-Stokes solver to their analysis and design applications of interest. Detailed instructions will be provided for topics including analysis of steady and unsteady flow, boundary conditions, application to dynamic and overset mesh simulations, adaptive gridding, aerospace computations, geometry parameterization, and adjoint-based design optimization.

Courses at AIAA Propulsion and Energy Forum 2015
www.aiaa-propulsionenergy.org/ContinuingEd

25–26 July 2015

Business Management for Engineers (Instructors: Alan C. Tribble and Alan Breitbart)

This course will help individuals with a technical background master the business principles that guide the leadership of an engineering-oriented company. The course will prepare students for the transition from the role of a technical contributor to that of a business leader.

Key Topics
- Capitalism and free markets
- Business finance
- Business structure and functions

- Relationship between systems engineering and program management
- Communicating for business impact versus technical
- Globalization

The Application of Green Propulsion for Future Space

Liquid propulsion systems are critical to launch vehicle and spacecraft performance and mission success. This two-day course, taught by a team of government, industry, and international experts, will cover propulsion fundamentals and topics of interest in launch vehicle and spacecraft propulsion, non-toxic propulsion drivers, propellants and figures of merit, applications of non-toxic propulsion, flight experience, and advances in smallsat propulsion. Lessons learned from development and flight of components and systems will be discussed.

Key Topics

- Rocket propulsion fundamentals
- Structural considerations in rocket engine design
- Rocket engine testing
- Development and flight experience with green monopropellants
- Microsat, nanosat, and cubesat propulsion
- Dual mode engines and propulsion system trades

Advanced High Speed Air-Breathing Propulsion

Revolutionary methods of high speed air-breathing propulsion are needed to extend the flight regime of aircraft, missiles, and improve Earth-to-orbit spacecraft. Advanced High Speed Air-Breathing Propulsion will introduce students to the design and development processes of high speed propulsion, including ramjet/scramjets and TBCC concepts. The course will present a comprehensive overview of the state of the art, including highlights of current high speed propulsion programs in the world. An introduction to multidisciplinary design optimization (MDO) will help students appreciate the challenges of developing this breakthrough propulsion technology.

The instructors are actively engaged in high-speed propulsion R&D. They will discuss the challenges, and development trends and future of the propulsion technologies needed to make truly high speed flight a reality. This course is sponsored by the AIAA High Speed Air Breathing Propulsion Technical Committee (HSABP TC).

Key Topics

- Mission requirements
- Combined cycle propulsion concepts
- Ramjet/scramjet inlet design
- Ram/scramjet combustion structural design
- Fuels and thermal management engine/airframe integration, TBCC integration
- Advanced materials
- CFD modeling and simulation of high speed reacting flow
- Propulsion multidisciplinary design optimization (MDO)
- High speed propulsion ground testing
- High speed flight testing

Courses at AIAA Space and Astronautics Forum 2015 (AIAA SPACE 2015)
www.aiaa-space.org/ContinuingEd

29–30 August 2015

Introduction to Space Systems (Instructor: Dr. Mike Gruntman)

This course provides an introduction to the concepts and technologies of modern space systems. Space systems combine engineering, science, and external phenomena. We concentrate on scientific and engineering foundations of spacecraft systems and interactions among various subsystems. These fundamentals of subsystem technologies provide an indispensable basis for system engineering. The basic nomenclature, vocabulary, and concepts will make it possible to converse with understanding with subsystem specialists.

Key Topics

- Space enterprise
- Solar system
- Coordinate systems
- Space environment and spacecraft interaction
- Basics of orbital mechanics
- Common orbits and space mission geometry
- Mission support systems
- Space mission overview
- Spacecraft propulsion
- Launch systems
- Attitude determination and control
- Space communications
- Spacecraft power systems and thermal control
- Space missions and applications


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