AEROSPACE

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For the U.S., a defensive shift away from monolithic satellites has proved harder than envisioned. PAGE 18

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AIAA
Shaping the Future of Aerospace

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AIAA
Shaping the Future of Aerospace

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Tom Risen
has reported on policy, science and tech business for U.S. News & World Report, Slate and The Atlantic.
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Tom Jones
flew on four space shuttle missions. On his last flight, STS-98, he led three spacewalks to install the American Destiny laboratory on the International Space Station.
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Adam Hadhazy
reports on astrophysics and technology. His work has appeared in Discover and New Scientist magazines.
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Joe Stumpe
is a freelance reporter based in Wichita, Kansas. His work has appeared in The New York Times, Agence France-Press and The Huffington Post.
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DEPARTMENTS

▲ **An astronaut's photograph** from the International Space Station shows a line of thunderstorms as the crew looked west-southwest from the Amazon Basin, along the Rio Madeira toward Bolivia.

Measure twice, cut once on space matters

When it comes to space policy, I'm relieved that change in Washington, D.C. never comes easily, no matter who is president.

Consider the Space Launch System rocket and Orion crew capsule. The frustration that many felt over the slow development of those vehicles during the Obama administration can't be overcome by rushing to get a crew aboard. Former astronaut Tom Jones, in "Fly when it's safe" (Page 26), cautions readers not to make too much of historical anecdotes like the first space shuttle mission, STS-1, as tempting as that might be.

In the case of SLS, the human stakes of that decision are apparent. The crew will be right there in front of us, and we all have vivid memories or knowledge of the Columbia, Challenger and Apollo 1 disasters and how those incidents jolted the nation.

As important as it is to get human spaceflight right, the quality of life, and in some cases life and limb, are at stake for more people in other space-policy areas.

Consider the arguments over which agency — NASA or NOAA — should manage Earth science programs. This sounds like an inside-the-Beltway, bureaucratic dilemma, but the stakes could not be more human. The only way out of today's bipolar political debate between climate-change believers and deniers will be to keep gathering scientific data in the most levelheaded and cost-effective manner. For those who aren't fans of Earth science, it looks like the strategy might be to gradually shift responsibility to NOAA, and then cut the agency's budget, forcing a choice between forecasting hurricanes today or what the climate might do decades from now. We know how that choice would turn out.

Keeping Earth science in its full context also will be helpful. As Europe's Josef Aschbacher points out in this month's Q & A (Page 10), watching Earth from orbit is necessary for effective disaster response, water management and agricultural policy, to name a few areas.

Then there's the question of whether the U.S. should disaggregate and distribute its future military communications payloads and sensing technology across more satellites as a resiliency measure. The Trump administration is likely to discover, if it hasn't yet, that this is an area with a long history of discussion and not much action. Resilience in space is a pressing matter, judging by the timeline accompanying our cover story, "Disaggregation" (Page 18), which shows some suspicious actions in space by the leading powers. If the Trump administration is looking for a place to make a big difference fast, the debate over disaggregation, distribution, and next-generation military and intelligence satellites might be a place to start.

Ben Iannotta, editor-in-chief, beni@aiaa.org

NASA's role in 'Defending Earth'

I enjoyed your "Defending Earth" article [February]. The analogies you draw between planetary defense and military defense have occurred to me too. They also arise in the context of defending low Earth orbit assets like the International Space Station from orbital debris impacts, albeit on much shorter time scales than in interplanetary space.

You also set out reasonably objective pro and con rationale for NASA being the lead U.S. planetary defense agency, as opposed to the Defense Department as lead. However, one primary argument in favor of NASA as lead agency is missing from "Defending Earth." Effectively coordinating threat detection and any specific impact response will almost certainly be an international effort posing all sorts of data disclosure problems to DoD. In the detection task, NASA already serves as a "data laundering" partner for DoD, facilitating observations from Pan-STARRS [Panoramic Survey Telescope and Rapid Response System] (and likely other military sensors) shared worldwide.

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Damp versus dampen

On Page 20 [in the graphic in the February issue depicting the EmDrive] we learn that dampers dampen harmonic motion. This is the wrong word in the context under discussion.

While Webster may define dampen as "to lessen," to an engineer, a damper damps, it does not dampen. This is not the first time I have seen this error. The best story on this subject I have heard comes from the automotive side of the house, when an editor told us that the shock absorbers dampened road vibrations well. There were a flurry of letters, commenting that we want our shocks to damp, if they are dampening they are leaking. It may seem a picayune point, but to an aero engineer who deals with vibrations and flutter issues daily, it is my duty to try to promote precise language in our communications.

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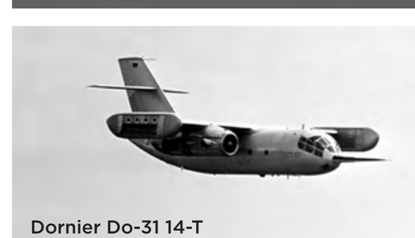
CORRECTIONS

In "**Defending Earth**," (February, Page 42), we incorrectly wrote that the Space Surveillance Telescope is in Australia. The telescope is still in New Mexico pending its relocation to Australia.

In Looking Back (February, pp. 62-63), we transposed the photo illustrating the 1967 entry about the Saab Viggen (Thunderbolt) AJ 37 (top) with the photo for the entry about the Dornier Do-31 14-T (bottom). The error has been corrected in the online version.

Saab Viggen AJ 37



Dornier Do-31 14-T

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Building Our Future

It looks like 2017 is shaping up to be another busy year! The AIAA SciTech Forum in January was a huge success, with nearly 1,000 students participating again. The energy and enthusiasm that was expressed by the attendees was exciting to see. We had great feedback on the Forum 360 sessions, including a panel that featured NASA Langley Research Center directors from 1996 to present day in honor of its centennial.

As you might have noticed, we continue to experiment with programming that will be personally or professionally valuable to different segments of our membership. At SciTech in addition to our Rising Leaders in Aerospace program and a Career Workshop geared toward students and young professionals, we held our first-ever recruiting event, which connected our talented up-and-coming aerospace professionals with AIAA corporate members. Based upon that positive experience, we will implement a similar recruiting event at the AIAA AVIATION Forum, which is also attended heavily by our student members. The other forum organizing committees, from the Executive Steering Committee to the Technical Program Committees, are hard at work creating impressive programs for their respective forums.

Also of importance to our student members is the AIAA Design/Build/Fly (DBF) competition, which occurs annually in April. I have attended DBF for several years now and it is such a great event! For 20 years a committed and energetic group of volunteers has worked tirelessly to create challenging missions, grade proposals and reports, and show up at the field to do technical inspections, judge, and score the entrants. The students, who come from all over the world, have a great first-hand experience learning the ins and outs of the design process and the subsequent impacts of design decisions on performance. This competition has grown every year, a testament to the team of volunteers and the value the students place on their learning experience.

Also every spring our student members gather for the AIAA Regional Student Conferences. I have attended two each year and have enjoyed seeing the talents of our student members on display. Kudos to all the AIAA members who take the time to judge the paper and the oral presentations—every year the students express gratitude and thanks for the comments and thoughtful constructive advice our judges provide them. If you have not taken the opportunity to engage in these important mentoring activities for the next generation of aerospace professionals, I encourage you to do so.

This year we will begin AIAA's transition to the new governance structure ratified by our members last year. The new Board of Trustees and Council of Directors, populated by our current elected leadership whose terms continue, will be stood up and meet for the first time at the spring meetings in May. A group of volunteers with wide-ranging experiences with AIAA has been developing the necessary policies and procedures to kick off the new governance operations. The complete transition to the new system is expected to take three years. For those seeking more details on the governance transition please visit the AIAA website: www.aiaa.org/governance.

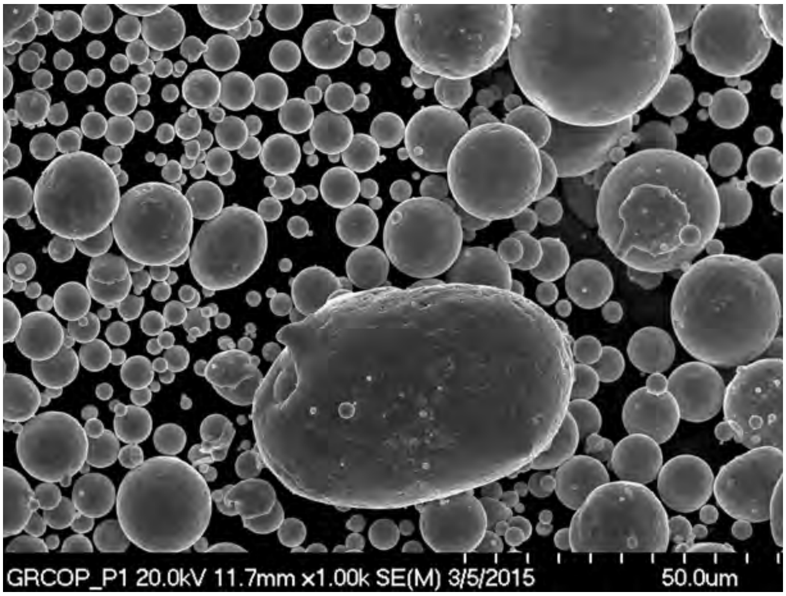
Several standing committees have been engaged in a process of re-examination as we transition to our new governance structure. Dr. Eric Paterson of Virginia Tech has taken over the helm of our AIAA Education Committee and Dr. John Daily of the University of Colorado Boulder is leading our Publications Committee. Our Corporate Member Committee has also been discussing how they can become more engaged and supportive of AIAA's broader mission. All are involved in an examination of our offerings and processes to ensure that we are organized optimally to meet the needs of our members and the greater aerospace community.

In addition, two working groups have been established to work in parallel with the Governance Transition Group. The Resource Working Group's charter is to discuss and recommend policies and practices for resource allocation and management for member-driven activities. This group has been hard at work since September 2016 and has been gathering input from the chairs of committees and sections. The International Strategy Working Group will examine and make recommendations as to what a comprehensive AIAA global engagement plan might encompass. Both working groups will be presenting their findings to the Board of Trustees at the fall meetings.

During the next year AIAA will licensing a comprehensive, user-friendly Learning Management Platform System to establish an educational portal for members and the larger aerospace community. This system will allow us to offer content via webcast and webinar format. The Board approved the measure in January and staff, working with several of our technical committees, are establishing some initial online course webinars to experiment with content format, delivery, and financial models. In addition, webcasts in areas of the AIAA Growth Plan such as cybersecurity are being planned. We are very excited about being able to serve the community in this way.

There is a lot of activity by members and staff to ensure that AIAA continues to stay aligned with not only our member's needs but the needs of the aerospace industry at large. I want to thank you all, again, for the time and effort that you engage with AIAA. I hope that you can see that your contributions are making a difference and are leading change and creating the future of the aerospace industry and in 2017 we are making a lot of progress! ★

Sandra H. Magnus, AIAA Executive Director



NASA

Envisioning "designer aerospace materials"

BY KEITH BUTTON | buttonkeith@gmail.com

▲ **This electron microscope image** shows a copper-powder alloy invented at NASA Glenn Research Center in Ohio and 3-D printed to form the liner of a rocket combustion chamber. NASA wants to merge component design and materials design, so that materials can be tailored for specific needs.

Aerospace engineers of the future might design airplanes while simultaneously inventing new materials with the properties that the aircraft designs would require. NASA expects to release a final report in October that will explain in detail how this would work.

After delivering a draft of the report to NASA in November, the agency's contractor for the report, Pratt & Whitney, is working with subcontractor Nexight Group of Silver Spring, Maryland, to organize workshops with aerospace and materials industry groups. Draft concepts will be presented and feedback will be solicited. NASA is also forming panels of experts to review and rewrite sections of the report, called "Vision 2040 for Integrated, Multiscale Materials and Structures Modeling/Simulation." The report will lay out the issues, goals and implementation plans in each of about 10 core areas.

Fundamentally, NASA wants to harness advances in software and massive computing power to combine aerospace design with materials design. Today, those areas are largely treated as separate domains. "The idea is: In 2040, you're going to marry the paradigm of 'designing with the material' to a paradigm called 'designing the material,'" says Steven Arnold, manager of the 2040 Vision project and chief of NASA's mechanics and life prediction branch at Glenn Research Center in Cleveland.

Dale Hopkins, deputy manager of the 2040 project, who also works at Glenn, says engineers could "explore the benefits of inventing that new material by examining how it will perform in a system design, and do that all as a connected process."

Today, designers of airplanes and airplane engines select known materials based on the properties the designers are looking for, such as tensile strength or ability to withstand certain temperatures — like looking up words in a dictionary, says Xuan Liu, a senior engineer for the coatings development group at Pratt & Whitney and the program manager for the vision report. The materials engineers then come up with a plan for testing the materials as they will be built into the designed engine or aircraft.

In the future, with computing tools drawing on vast stores of data on all of the known materials and their properties, designers could create airplanes or airplane engines from yet-to-be-invented materials. That could mean combinations of two or three or more metals in a new alloy, for example, or new composite ceramics or polymer materials, Liu says. Designers could draw up plans for airplanes down to the molecular scale, with the help of sophisticated computer models that would accurately predict how the materials would perform.

The project has two more workshops planned to solicit perspectives from the aerospace and materials industries, both at conferences in May: at the 4th World Congress on Integrated Computational Materials Engineering in Ypsilanti, Michigan, and the 27th AeroMat Conference and Exposition in Bellevue, Washington. ★

"In 2040, you're going to marry the paradigm of 'designing with the material' to a paradigm called 'designing the material.'"

Steven Arnold of NASA,
manager of the 2040 Vision project

The U.S. struggles to free itself of Russian RD-180 engines

U.S. Atlas 5 rockets have proved amazingly reliable at launching national security satellites. For that reason, the Air Force remains reluctant to do anything rash about the fact that each Atlas 5 first stage is powered by a Russian RD-180 engine. Another camp, led by Sen. John McCain, R-Ariz., wants to move away from RD-180s as quickly as possible. This timeline shows the complex chain of actions by the Air Force, White House, Congress and industry.

2014

March
- U.S. imposes sanctions on Russia in response to annexation of Crimea.

April
- Judge issues injunction against RD-180 purchases for upcoming Air Force launch competitions pending sanctions review.

September
- United Launch Alliance, Blue Origin announce partnership to develop BE-4 engine.
- Aerojet Rocketdyne announces funds from ULA for AR1 engine.

December
- SpaceX drops lawsuit against Air Force after service agrees to open more near-term launches to competition.
- Congress appropriates $220 million toward RD-180 alternative and authorizes a limit of five RD-180s beyond those already assigned for launches.

2015

February
- Air Force tells Congress it's not feasible to replace RD-180s by 2019, as required by law.

April
- ULA unveils details of proposed Atlas 5 replacement, the Vulcan.

December
- Air Force awards rocket research contracts to Aerojet Rocketdyne, Orbital ATK and Northrop Grumman.

2016

April
- Sen. John McCain contests Air Force estimate of $5 billion to replace Atlas 5s with Delta 4s and Falcon 9s.
- Air Force announces a contract with SpaceX to launch a GPS 3 satellite; ULA did not bid Atlas 5, citing RD-180 limit among reasons.
- House committee's 2017 defense authorization draft would permit up to 18 RD-180s for military launches, double the previous limit.

May
- Obama administration lauds House proposal to relax RD-180 limit, but objects to barring funds for broader rocket development.
- Senate committee proposes limit of nine RD-180s beyond those already assigned for Atlas 5 launches.

June
- Senate version of 2017 defense authorization sets RD-180 limit at 18 beyond those already assigned for Atlas 5 launches.

September
- ULA defers choice between BE-4 and AR1 engine to "spring" 2017, according to SpaceNews.

December
- Obama signs 2017 defense authorization limiting U.S. to 18 more RD-180s for upcoming competitions through 2022. Air Force gets to spend up to 31 percent of replacement funds on broader work.

2017

February
- AR1 engine testing yields highest chamber pressure ever for a kerosene-fueled main combustion system, says Aerojet Rocketdyne.

March
- Twitter photos from Blue Origin's Jeff Bezos show first fully assembled BE-4 rolling off production line.

Research by Warren Ferster

Josef Aschbacher, director of Earth observation programs for the European Space Agency.

European Space Agency

Earth-observer in chief

Under the Trump administration, the U.S. is expected to rethink how and why it conducts Earth science research, especially anything related to climate change. By contrast, the way ahead for Europe has been firmly set since the late 1990s. The European Space Agency and European Union are in the midst of launching a multi-billion-dollar series of satellites, called Sentinels, that for decades to come will measure land change, ocean height, carbon dioxide and a host of other factors. The data will guide European officials on issues from natural-disaster response to climate policy. I spoke by phone with Austrian scientist Josef Aschbacher, director of the European Space Agency's Earth observing programs, to discuss the arrival of the new administration in Washington and what it might mean for Earth observing.
— Ben Iannotta

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JOSEF ASCHBACHER

POSITIONS: Director of Earth observation programs for the European Space Agency since June 2016; head of the European Space Research Institute, ESRIN.

NOTABLE: Based in Frascati, Italy; born in Ellmau, Austria. In 1998, as a scientific assistant at the European Commission, helped conceive Europe's Global Monitoring for Environment and Security Program, later renamed Copernicus. Joined the European Space Agency in 2001 to plan an $8 billion series of spacecraft called Sentinels, which are the space component of Copernicus. Ph.D. thesis examined the application of satellite data to hydrological research involving snow height and snowfall. Master's thesis examined application of satellite data for rainfall prediction.

AGE: 54

RESIDENCE: Rome

EDUCATION: Master's and Ph.D. in natural sciences in 1985 and 1990 from University of Innsbruck.

Challenge of Copernicus

What makes it so ambitious is that it is a long-term operational program. We have now already funded infrastructure, meaning satellites, to date through 2030 and of course there's a plan to have satellites afterward. It's a continuous, longtime mission and of the same type of sensors with improvements along the way. So a little bit of what we are already doing with meteorology already, successfully, where we have one satellite following the other in a longtime series of the same measurements, in this case applied for agriculture, forestry, marine applications, atmospheric measurements, climate observations and so on.

Politicians, technologists on same page

We need a long-term observation capability which doesn't exist, neither in NASA nor in Europe. So this was one of the drivers to establish a more operational system as compared to a scientific mission, where very specific questions are being addressed one by one, and mission by mission. What European politicians, technical people, together, considered [as] important was a long-term observation capacity.

Why Europe doesn't have a CO_2 satellite yet

Measuring CO_2 from space is rather complex and not so easy, not so straightforward. In order to have a meaningful CO_2 measurement, we need to well understand the fluxes in the atmosphere and these changes of carbon between the various elements — the ocean surfaces, the land surfaces, the atmosphere. This obviously requires a high resolution of sensors. High means less than 10 square kilometers. And frequent observations, at least once a day, if not more often. And an instrument that can do this, to really meaningfully retrieve CO_2, [has] not been developed. Technology is still a challenge and this is something that we are starting now.

CO_2 highest priority

CO_2 is the number one priority. We are starting now studies to see exactly what this could mean in terms of satellites, measurements, user requirements, which missions will be required. This is work which is ongoing now. There is an international task force which is looking into this. We actually have some U.S. and Japanese members on this task force, as well as Europeans, to really see what such a CO_2 architecture could look like.

A step beyond NASA's Orbiting Carbon Observatory-2

What we have today is NASA's OCO, then the Japanese GOSAT, also China has just in December launched a mission called TanSat, which are measuring carbon dioxide. So, what we want to dream up is something complementary and, I would say, the next generation, or next step in this evolution. Something that has a wide swath width and a high enough resolution to really understand better these processes and the fluxes of carbon dioxide. Of course we will work with, quite closely with, our U.S. colleagues but also other colleagues from other countries.

Once you have an expertise accumulated over decades in Earth science, it is not something that can just be transplanted from one place to the other.

Cooperation with U.S. at risk

I would strongly wish and hope that the U.S. will be a strong partner in this activity, not only in the CO_2 monitoring part, but also in some of the other activities in Earth science. We already have an excellent cooperation, and in many cases working without the U.S. would not be feasible. U.S. scientists and the U.S. science community simply have a very, very strong and very good knowledge of many aspects of the Earth system.

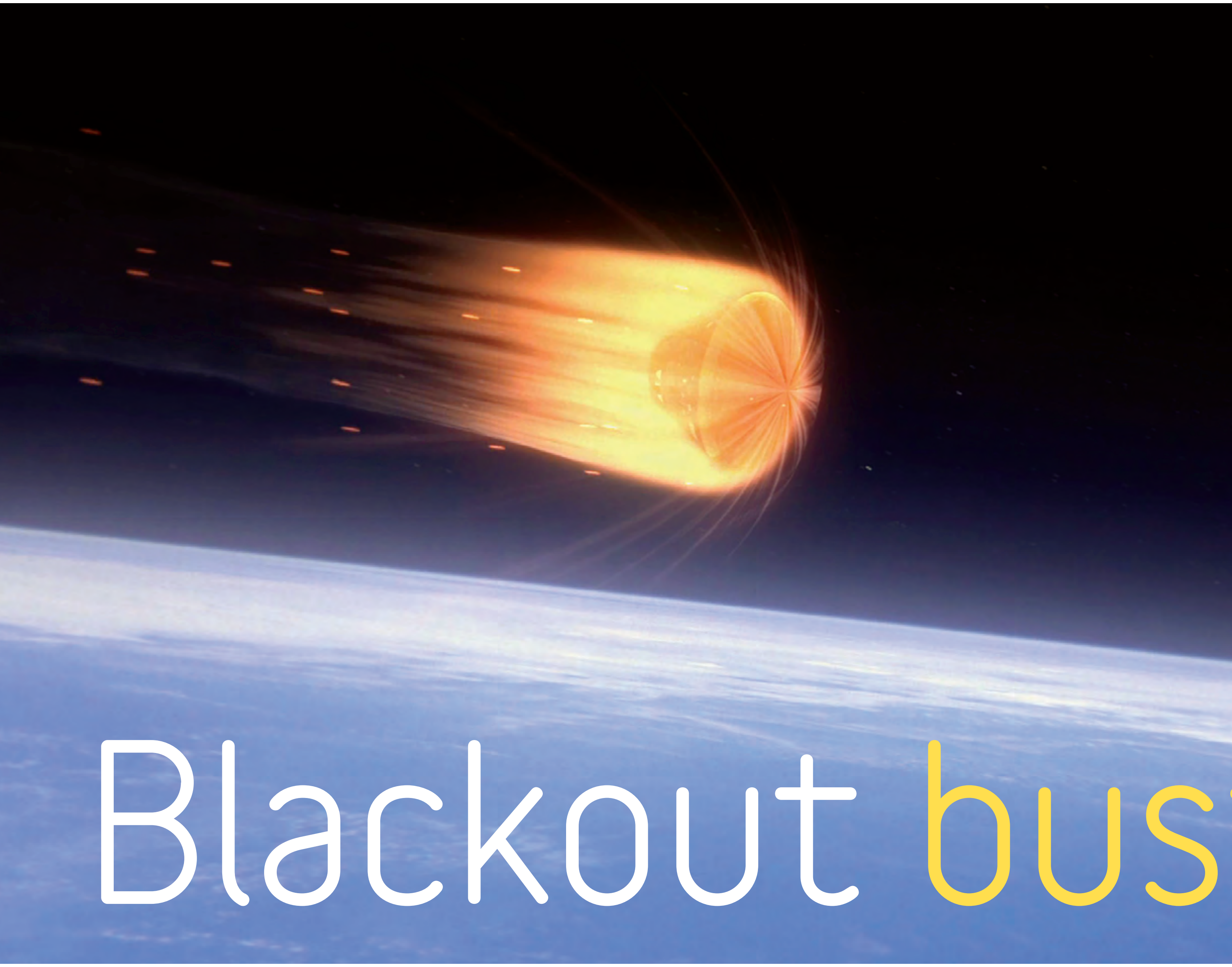
I think at the end of the day, it will be at the benefit of America to participate in these activities because it goes way beyond climate change. Sometimes people say "climate research" but of course this instrument measures many parameters which are very beneficial to the society and country, the U.S. in this case, but also other countries. So therefore, I think this is not a black and white position, or a black and white view. It really has to be seen in a much wider context.

Earth science means more than studying climate

There are many other good reasons for observing the Earth system. As I said, sometimes I hear the notion that Earth science at NASA is limited to climate change. No. I think the Earth scientists at NASA are doing a thousand things and they are for many applications: agriculture, to forestry, resource management, environmental monitoring, or to make sure people, in this case in the U.S., but also around the globe, understand how the Earth system functions and therefore one could be there in case of disasters, in case of climate change to address these issues.

Possible transfer of NASA Earth sciences to NOAA

I can certainly say from the European example, or European perspective, once you have an expertise accumulated over decades in Earth science, it is not something that can just be transplanted from one place to the other. Expertise is bound to people and people represent the history and also do all the capital investment which there is. So I think this is something that whoever makes these wise decisions would be very likely to consider. ★



Blackout bus

Wouldn't it be great if the crew in a space capsule could communicate with mission control even during the fiery entry into Earth's atmosphere or that of Mars? Engineers from Stanford University and DLR, the German Aerospace Center, plan to put a possible solution to the test this year. Keith Button spoke to them.

BY KEITH BUTTON | buttonkeith@gmail.com

Aerospace engineers in Germany watched through cameras as they activated a superconducting magnet to push aside electrons in a plasma layer surrounding the surface of a simulated space capsule in a vacuum chamber. They hoped to form a narrow channel in the plasma through which radio signals could travel.

The engineers in these May 2015 tests were trying out a possible solution for the radio blackouts that have plagued returning space capsules since the 1960s. The heat and pressure generated as a capsule plows into the atmosphere at 7 to 9 kilometers per second break electrons away from molecules of oxygen and nitrogen. The resulting plasma blocks transmission and reception of radio signals for up to several minutes.

This is an artist's rendering of the spacecraft Orion flying with its base heat shield facing Earth as it re-enters the atmosphere around the planet.

NASA

These tests and others at DLR, the German Aerospace Center, could ultimately point the way to solving the blackout problem. If so, the scientists and engineers have their work cut out. The technique tested in 2015 could prove difficult to convert into a functional blackout-busting tool, and the results of those tests were mixed. The team hopes for better results when the alternative Stanford University technology is tested at DLR sometime after July 1.

The first challenge the engineers faced for the 2015 tests was devising a setup that could accurately mimic the extreme plasma conditions of a spacecraft returning to Earth. The engineers chose argon, because it's easier to turn into plasma than the atmospheric gases a spacecraft would encounter. Argon turns to plasma at about 3,700 degrees Celsius (6,700 Fahrenheit), versus about 6,700 C (12,000 F) for normal air, says Ali Guelhan, head of the DLR's supersonic and hypersonic technology department.

Even at these lower temperatures, the engineers must be careful not to burn up the electrodes that create the electric arc that heats the argon. They achieved that by rotating the position of the arc with magnets, so that the heat was never in one spot on the electrodes long enough to damage them.

The argon was compressed into plasma in a high-pressure chamber and then spewed through a nozzle into the vacuum chamber where the capsule was located. The pressure differential accelerated the plasma to a hypersonic speed of about 2,000 meters per second.

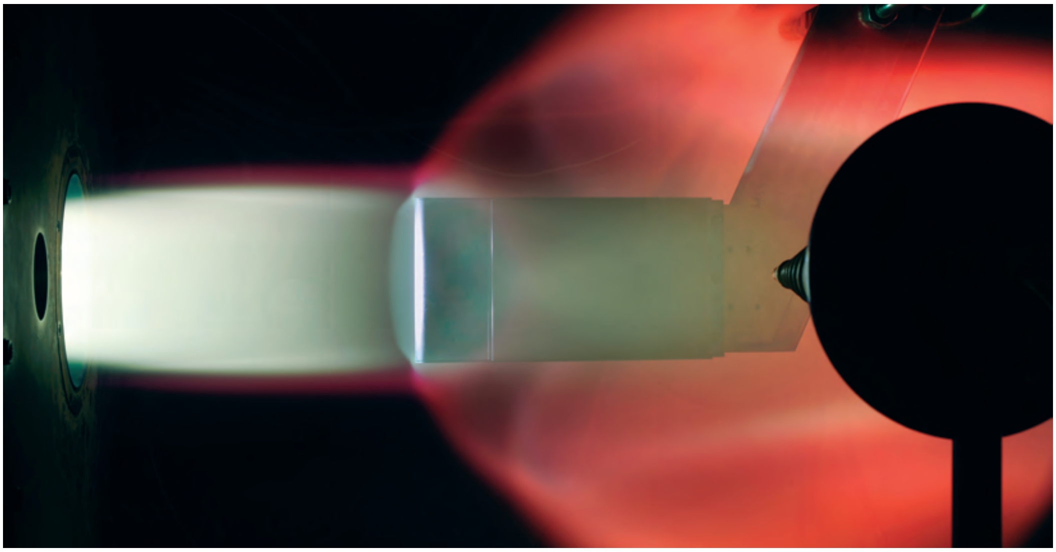
One task in the tests was to define the characteristics of the plasma — the density of its electrons, for example — that determined the point at which radio signals could get through, says Lars Steffens, a DLR engineer who worked with Guelhan on the blackout tests. In general, transmitting on higher radio frequencies gave the signal a better chance of getting through the plasma. Penetrating the plasma was more and more difficult as the density of electrons in the plasma grew.

The argon nozzle produced a shroud of plasma that was 20 to 30 centimeters wide and 10 centimeters thick. The radio transmitter inside the capsule produced signals that exited the capsule through a radio-wave-friendly quartz surface — not the copper nose — to reach a receiver behind the plasma and the nozzle.

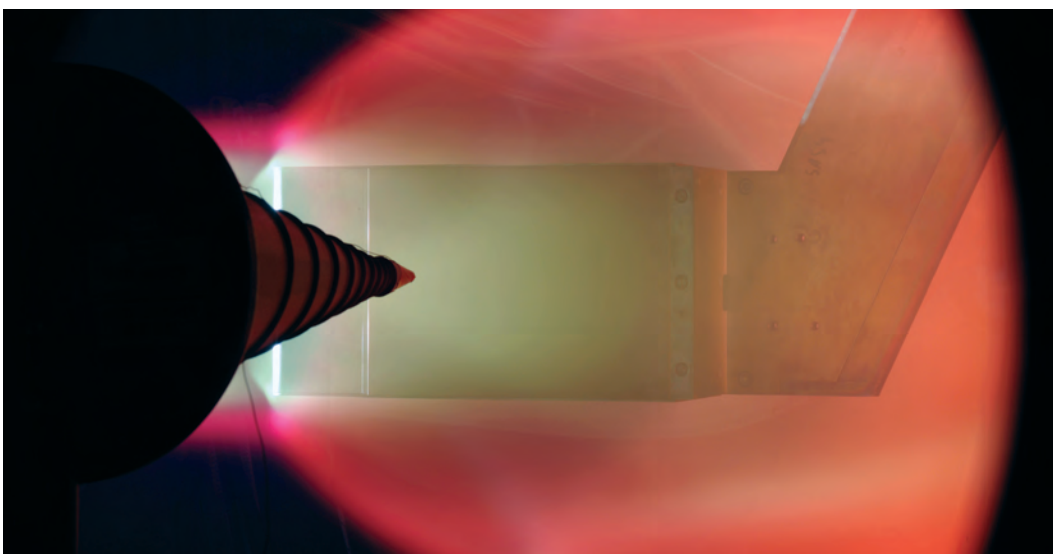
The engineers manipulated the argon plasma with superconducting magnets mounted inside the capsule, producing a magnetic field with a strength of up to 1.5 teslas, which cleared a path through the plasma electrons for certain high-frequency signals to make it through. The effect was not as great as the engineers initially believed it would be, Guelhan says.

Keeping the superconductor magnets at the right temperature was a challenge. The magnets had to remain at temperatures below minus 265 degrees C while the super-hot plasma flowed just 1 centimeter away, along the surface of the capsule. That cooling issue, along with their weight, would make it extremely difficult to carry the magnets aboard a space vehicle, Guelhan says.

Sometime after July 1, Guelhan and Steffens will apply this test setup to an alternative concept — pulsed electrostatic manipulation — developed by Siddharth Krishnamoorthy, an aerospace engineer at Stanford University studying the blackout issue. Krishnamoorthy wants to zap an electrode just under the surface of a space vehicle with short bursts of electricity to push electrons in the plasma aside, similar to the magnet concept, to create a path for the radio signal to get through.



DLR



DLR

In a vacuum chamber at DLR, the German Aerospace Center, researchers installed a simulated space capsule and blasted it with plasma. An antenna, at right in top photo and at left in bottom photo, was outside the hot gas to receive the radio signals from the simulated spacecraft. An electric field was applied to push aside the electrons in the plasma layer, although that is not shown in these photos.

Krishnamoorthy says he decided to study an electric pulse solution to the radio blackout problem because it seemed more promising than other possible solutions, such as shaping spacecraft to produce thin areas of plasma during entry.

Radio blackout wasn't a problem for returning space shuttle orbiters, once NASA could relay radio signals to the ground through the orbiting Tracking and Data Relay Satellite System spacecraft. The shape of the orbiters created an area on top, facing away from Earth, where the plasma's density was low enough for radio signals to get through, Krishnamoorthy says. It is possible for engineers to design specially shaped spacecraft that can create low-density areas of plasma during re-entry, like the space shuttle did, so radio signals could pass through. One problem with that idea is that the design can't adapt to changing flight conditions that create different plasma issues.

"If your flow conditions change, or if your trajectory changes, you would have to go through the entire design process again and come up with a new shape," Krishnamoorthy says. "So it's not very agile in terms of shifting conditions, and it turns out that hypersonic flow actually is very noisy and very shifting."

Another problem with the aerodynamic shaping solution for re-entry blackout is that the designs produce sharp edges, which are not desired for re-entry vehicles because they transfer more heat to the spacecraft.

Krishnamoorthy is focusing on capsule vehicles, like Orion, which he calls the "go-to shape for most re-entry vehicles," now that NASA has retired the shuttle fleet. It is the electrons in the plasma that are blocking the radio signal, because of their increased density in the plasma, Krishnamoorthy says. The electrons are so light, and have such little inertia, that when the radio signal — an electro-magnetic wave — attempts to pass through, the electrons just cancel it out.

An electrode inside the capsule will apply an

electric field to the plasma to repel electrons from the antenna region. That electric field also attracts ions, but because the ions are much heavier than the electrons, they are attracted much slower than the electrons are rejected, and a path is cleared for the radio signal.

A magnetic field also can accomplish the electron movement, but integrating a magnetic field on a spacecraft would be complicated, he says. "My guiding principal was let's try to investigate what it takes to do this if you just use an electric field, and no magnetic field."

Krishnamoorthy knew that electric fields could also pose safety problems for spacecraft, so he came up with the idea for pulsed electric fields. "Leaving high electric fields on all the time on a spacecraft is very dangerous, because it can cause arcs, and sparking and shorting," he explains.

The Stanford professor has been running computer simulations of the pulsed electrostatic manipulation to help define the specific characteristics of the electrode, insulation, voltage level and other factors to employ in the DLR chamber testing. The computer testing model is based on particle-in-cell simulation of the plasma, involving hundreds of millions of particles and a large digital grid to account for them. Each simulation of the testing run on Stanford's computing network — taking up the equivalent of about 500 central processing units — takes from a few hours to more than a day, in some cases.

Based on the simulations, applying a higher voltage clears a larger area for the radio signals to get through, as does applying the pulses faster, Krishnamoorthy says. The reduction is enough to let L-band and S-band radio signals through.

DLR's Guelhan says high voltage testing of Krishnamoorthy's approach presents some challenges for the upcoming tests. Up to 10 kilovolts of short, 0.01- to 10-microsecond bursts must be generated, but the researchers must block those sparks from jumping to surfaces they aren't intended for. "But," he says, "It's probably much easier to achieve than the cooling of the magnets." ★

Perhaps the most famous radio blackout in U.S. space history occurred when the crew of Apollo 13 re-entered Earth's atmosphere on April 17, 1970. It lasted six minutes.

NASA

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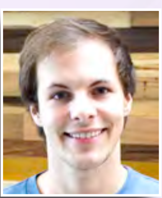

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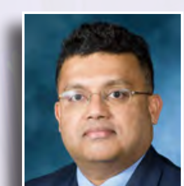

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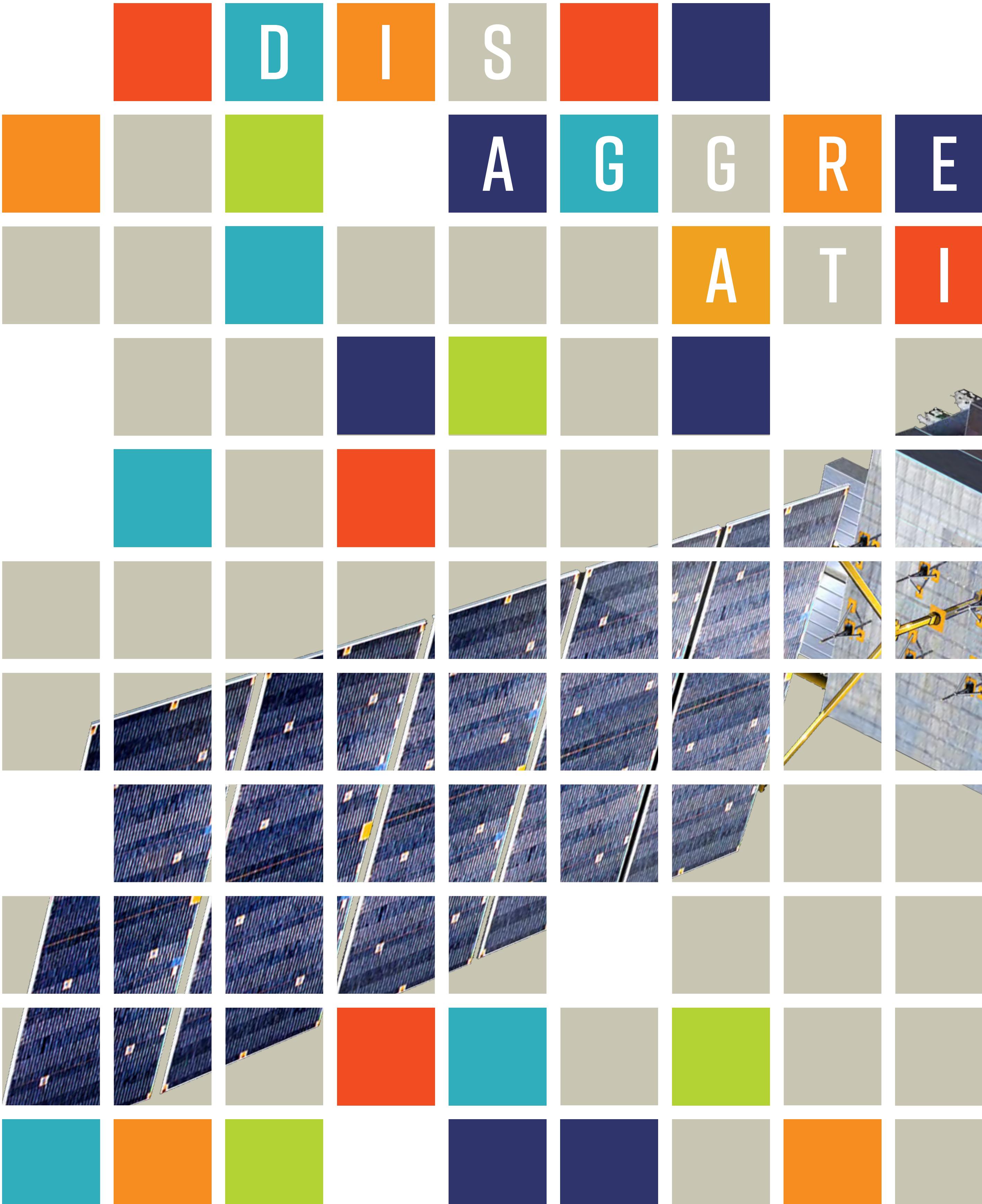
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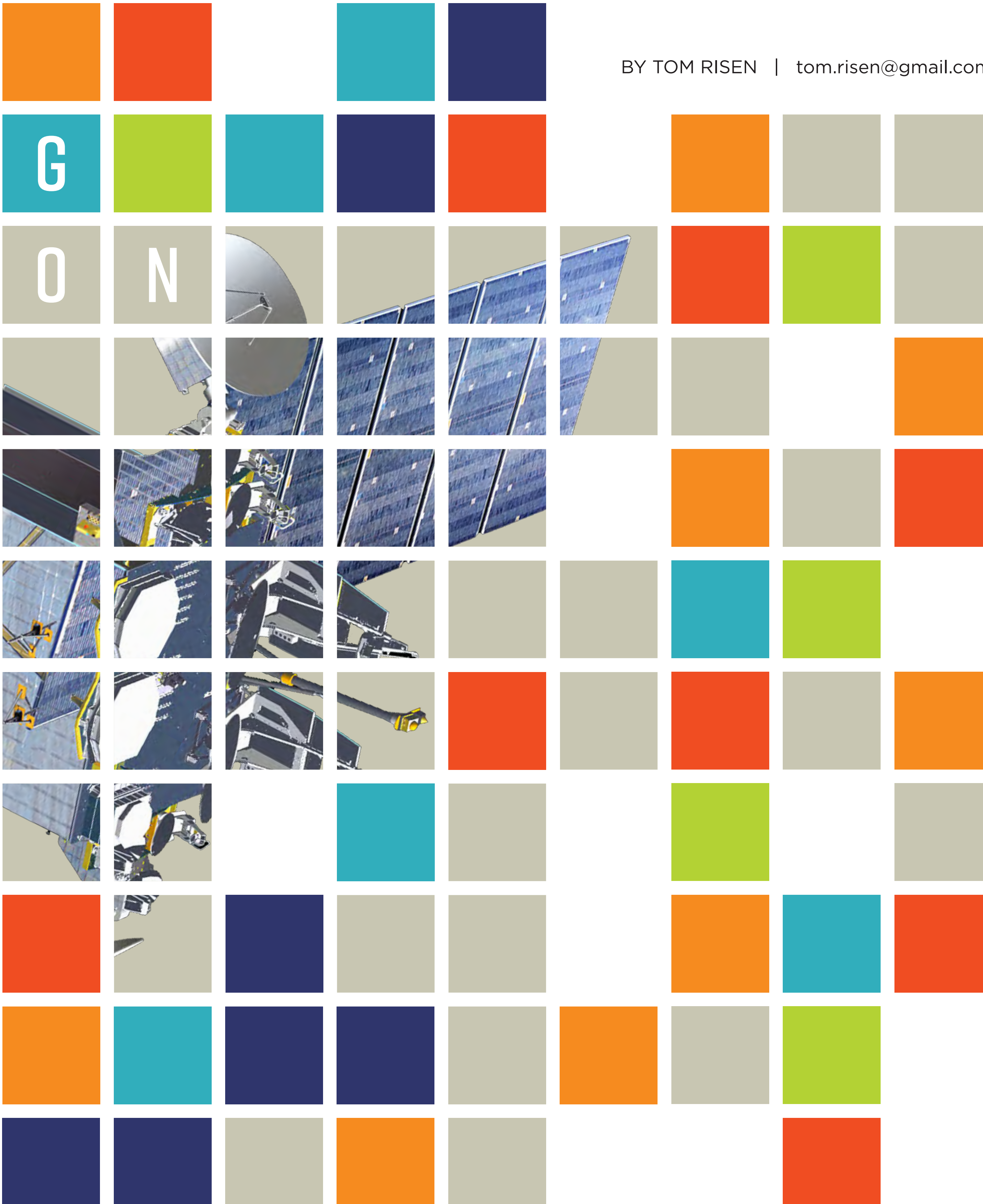


Some U.S. military strategists think the country's reliance on geosynchronous satellites for communications and missile warning make it vulnerable to a devastating attack in space. Why not spread technology across more spacecraft? Getting bureaucratic buy-in for disaggregation, and the related concept of distribution, has proved harder than anyone imagined. **Tom Risen** tells the story.

When he was active duty, Air Force Gen. William Shelton often brainstormed with his fellow generals about how to make America's defense satellite networks less susceptible to being knocked offline by an attack. He hoped a 2011 speech at the Space Symposium in Colorado Springs, Colorado, would be a turning point. Shelton described how a space mission, such as missile-launch detection, would be harder for an enemy to disrupt if the tasks were split among multiple satellites of varying designs. Shelton was referring to the fact that today the Air Force relies on a few handfuls of school-bus sized satellites in geosynchronous orbit to watch or provide communications within discrete regions of the globe. A single satellite high above the equator over Africa might cover Europe, Africa and Southwest Asia; one to the east over India might cover much of Asia and so on for nearly global coverage. Shelton recalls, "there were crickets in the room" when he finished his presentation about a proposed alternative strategy, called disaggregation. Shelton believes contractors incorrectly perceived that the concept might upend their existing deals to build military satellites, when in fact it was aimed at next generation satellites.

Six years after Shelton's speech, and with the operational lives of the current geosynchronous constellations ticking away, Pentagon strategists

Suspicious maneuvers

Actions in orbit suggest that the major space powers may be working on technologies to attack each other's satellites, even if the projects are not always described in those terms.

JANUARY 2007
China destroys one of its aging weather satellites. The U.S., U.K. and Japan criticize the missile launch and resulting debris.

FEBRUARY 2008
U.S. destroys one of its own spy satellites with a missile launched from a Navy cruiser. Stated goal is to prevent the nonfunctional satellite from crashing into the atmosphere causing a hydrazine explosion. Most experts see Operation Burnt Frost as the U.S. answer to China's anti-satellite test.

MAY 2013
China launches a rocket close to the geosynchronous satellite belt, where U.S. military satellites and numerous commercial communications spacecraft orbit. China calls the mission a science experiment.

FEBRUARY 2014
U.S. Air Force Gen. William Shelton declassifies plans to launch surveillance satellites to near-geosynchronous orbit to maneuver near "objects of interest" for enhanced surveillance. Two Geosynchronous Space Situational Awareness Program satellites are launched in July.

Workers encase a U.S. Air Force Advanced Extremely High Frequency satellite into a nose cone for mounting on an Atlas 5. The first AEHF satellite will be 7 years old in August, half its projected lifespan.

Lockheed Martin

remain undecided about the best way to make future constellations less vulnerable.

Experts have questioned the wisdom of such a drastic strategic shift and whether disaggregation would counter the nonkinetic attacks that might be the 21st century's biggest threats. At issue at a minimum are the designs that should follow three of today's geosynchronous constellations: the Lockheed Martin-built Advanced Extremely High Frequency satellites, whose Northrop Grumman-built payloads provide the most secure communications links for troops, commanders and the U.S. president; the Wideband Global Satcom spacecraft that provide less protected, but higher-volume communications; and the Space Based Infrared System satellites that detect such events as North Korean missile launches.

AEHF satellites have design lives of 14 years, and the first one will turn seven years old in August; SBIRS spacecraft have design lives of 12 years and the first one turns 6 next month; the first WGS will be 10 in October.

Nomenclature war

Advocates such as Shelton, now a board member of the Aerospace Corp. but not speaking on its behalf for this article, continue to carry the disaggregation torch while also pushing for a more recent, related

Sources: Aerospace America research; Xinhuanet.com; U.S. Air Force Fact Sheets; Russianspaceweb.com

APRIL 2015
Russian military satellite Luch/Olimp-K parks within 10 kilometers of the Intelsat 7 and Intelsat 901 communications satellites for five months. Russia gives no comment.

MARCH 2016
DARPA unveils the Robotic Servicing of Geosynchronous Satellites program, saying space drones would repair satellites in geosynchronous orbit with two multi-jointed robotic arms and a toolkit. Congress is debating the program amid a contracting policy conflict lawsuit filed by Orbital ATK.

JUNE 2016
China launches the Aolong 1 "Roaming Dragon" debris removal drone into low Earth orbit. It reportedly ends its mission in August 2016 after grappling objects with its robotic arms and tossing them back to Earth.

U.S. Air Force Gen. William Shelton, now retired, has been advocating for years for a new approach to protecting military satellites' missions.

A Delta 4 rocket carries the seventh Wideband Global Satcom communications satellite into orbit for the U.S. Air Force in 2015. The first WGS will be 10 years old in October.

ULA

U.S. Air Force

concept called distribution. With distribution, constellations of small, identical satellites would provide such services as communications, missile warning or precision navigation and timing. If a few satellites were destroyed or temporarily spoofed or blinded, all capability would not be lost over a specific region. By contrast, with disaggregation, distinct functions, such as tactical and strategic communications, would be separated onto satellites of varying designs.

Many of today's generals see advantages to disaggregation and distribution. "We must make ourselves less vulnerable to the disruption of large, monolithic systems," says Air Force strategist Brig. Gen. Stephen Whiting by email. "That means spreading our investment over a larger number of simpler and less expensive satellites, integrating commercial capabilities in new ways and through new business models," says Whiting, the director of Integrated Air, Space, Cyberspace and Intelligence, Surveillance and Reconnaissance Operations at Air Force Space Command in Colorado Springs.

Rep. Jim Bridenstine, R-Okla., likes the idea too, saying "any analysis of alternatives which doesn't evaluate disaggregation is incomplete."

The question is how and when to integrate one

Blame game

U.S. lawmakers and generals are fond of citing a list of provocations in space by China and Russia dating back to 2007. Not surprisingly, the way critics in those countries see it, the U.S. has taken actions that suggest the Pentagon wants the ability to go on the offensive.

There was Operation Burnt Frost in 2008, when a U.S. Navy cruiser fired a Standard Missile-3 into orbit and shot down an old U.S. reconnaissance satellite, just a year after China destroyed one of its own satellites with an anti-satellite missile. More recently, DARPA announced a project to create robot modules that would repair satellites in geosynchronous orbit with the aid of two robotic arms, a capability that in theory could be applied to clasp onto foreign satellites.

Retired Air Force Gen. Robert Kehler, a former commander of Strategic Command, doesn't see the U.S. as the provocateur. He acknowledges that "nations act in their own self-interests" but he doesn't think U.S. behavior has encouraged or provoked Russia or China to escalate their counter-space efforts. "All the actions the U.S. is taking to prepare for a conflict that extends to space are ultimately about deterrence," he says.

To counter the risk of escalation in space, however, Kehler would like to see more rules to create norms among satellite operators, just as maritime law governs activity when ships maneuver near one another in international waters.

One fact that no one doubts is that a war in space could have huge repercussions for the increasingly connected global economy. The potential to disconnect global networks by destroying satellites and the resulting debris that would threaten everyone's satellites makes such a war in no one's interest, says space historian Roger Lanius, now an associate director of the Smithsonian Institution's National Air and Space Museum.

ATTACKING A TACTICAL OR COMMERCIAL SATELLITE SHOULD ELICIT CONVENTIONAL RESPONSE. ATTACKING A STRATEGIC CAPABILITY WOULD BE MORE ESCALATORY."

– **Rep. Jim Bridenstine,** R-Okla.

United Launch Alliance

SES Government Solutions

or both of these concepts into acquisition plans.

Shelton does not expect much movement on that score in the 2018 and 2019 budgets. The former commander of Air Force Space Command predicts that the military will decide to buy near-copies of existing Advanced Extremely High Frequency and Space Based Infrared System satellites, for instance.

He's not happy about that. "We have gotten ourselves to the point where a nondecision is a decision, especially when planning what comes next for our key strategic satellites," Shelton says. "It's frustrating because I think these decisions could have been made much earlier."

The Air Force declined to comment about future plans because the fiscal 2018 program budget review "is pre-decisional."

Planning and more planning

This lack of action, however, is not due to lack of questions from the Air Force to industry about how to build more defensible satellites. Air Force Space Command published requests for information as recently as February asking industry for ideas on how to disaggregate tactical communications from designs that will come after WGS and Advanced EHF. Today, the WGS constellation is complete, with six satellites in geosynchronous orbit. Three Advanced EHF satellites are in orbit, with a fourth planned for launch in the near future and two more in production.

The Air Force wants to find the best way to shift some of its tactical communications technology onto commercial or military satellites, a concept known as hosted payloads. The request seeks suggestions, including how commercial or military satellites might host a protected tactical waveform, a communications technology in development for secure, jam-proof connections between military and commercial networks.

An Air Force study that examined a successor to the Space Based Infrared System proposed a mix of hosted payloads with disaggregated missions across six or eight satellites. The Air Force has not decided whether to follow its recommendations. The third model of the Lockheed Martin-built missile warning satellite launched in January on an Atlas 5 rocket, and three others are in development.

One reason people talk less often about disaggregation than in 2011 is because "distribution" became a more widely used buzzword after major contractors considered disaggregation as a less palatable concept that could disrupt business as usual, Shelton says. Purveyors of small satellites, by contrast, expressed interest in helping to build larger constellations for the Air Force.

The military and industry have refined how they apply disaggregation and distribution in discussions

▲ **The U.S. Air Force Commercially Hosted Infrared Payload**, or CHIRP, mission placed an experimental missile-warning sensor on a commercial telecommunications satellite. A 2016 Air Force study proposed using hosted payloads across six or eight satellites.

over resilience and mission assurance strategies. "I think if you look back to 2013, 2014, and earlier in 2015, people were using 'disaggregation' essentially as a replacement for the word 'resilience,' because they hadn't really thought through all the different ways you could achieve resilience," says Audrey Schaffer, director of space strategy and plans in the Office of the Secretary of Defense.

Retired Air Force Gen. Robert Kehler, whose final assignment was as commander of Strategic Command, says commercial satellites might eventually host tactical communications payloads, but that strategic missions like nuclear missile detection probably would never be hosted on commercial satellites. In the view of some, the concept of distribution could be extended beyond satellites to include conventional airplanes, drones or in some cases ground equipment. Kehler is skeptical about extending the strategy so broadly.

"As a global military there are some things we can only do in space," he says. "The communications connectivity in space is unparalleled."

Bridenstine, a member of the House space subcommittee, says the growing private space industry is key to helping the military with capabilities like communications and imagery, so the government should clearly define which satellites America considers vital to national security.

Bridenstine last year introduced the Space Renaissance Act with the aim of beefing up investment in U.S. space infrastructure. "It is important to differentiate tactical and strategic satellites. Attacking a tactical or commercial satellite should elicit conventional response. Attacking a strategic capability would be more escalatory."

Anti-satellite missiles could be one mode of attack, but since they would create debris that could collide with an adversary's own satellites, some strategists see these ant-satellite weapons as a less likely threat than hackers hijacking a satellite's network, or jammers disrupting communications with radio transmitters.

"The appeal to jamming is that you can turn it off, it doesn't create debris — all it does is disrupt the signal of the satellite," Kehler says. "Because of that we are going to encounter jamming."

Commercially available jamming technology is relatively inexpensive, and a ground-based transmitter could block a satellite signal from reaching a radius of more than 100 kilometers if it were powerful enough, says Martin Faga, a former director of the National Reconnaissance Office and assistant secretary of the Air Force for space. In theory, jamming could be done in space with a satellite, but that's unlikely because it is difficult to launch a large enough power source to do that effectively over the required distances, Faga says.

"WE HAVE GOTTEN OURSELVES TO THE POINT WHERE A NON-DECISION IS A DECISION, ESPECIALLY WHEN PLANNING WHAT COMES NEXT FOR OUR KEY STRATEGIC SATELLITES."

Retired Air Force Gen. William Shelton

"The benefits of disaggregation are hard to be confident about," Faga says, because the strategy would likely not make them less vulnerable to hacking or jamming.

Disaggregation could also be more expensive than expected, says Loren Thompson, chief operating officer of the Lexington Institute think tank. Splitting mission functions across a larger constellation would require building several high-quality satellites instead of one to ensure top performance of the mission, he says. Technological advances could mean that better options for space resiliency would be available by the time the next generation of disaggregated satellites launches, along with new threats that would undermine their resilience, he says.

"Just designing, testing and launching the new spacecraft will take two decades," Thompson says. "I'm betting that 20 years from now we will have tech options we can't even imagine."

Launching pieces of an overall mission across a constellation, however, could be a chance to upgrade technology faster by launching a single one-function satellite instead of building a large satellite to replace an obsolete one, says Mark Lewis, a former chief scientist of the Air Force and former AIAA president.

For U.S. strategists, the main goal is to deter aggression in space so that disaggregation, distribution and resiliency are never put to the test. "The concept of war in space is so counterproductive," says space historian Roger Lanius. "Only insanity would lead us down that road." ★

NASA

Fly when it's safe

For advocates of human space exploration, it was frustrating to watch the Obama administration slowly develop the Space Launch System rocket and Orion spacecraft. The Trump administration seems to support spaceflight, but it would be a mistake to rush a crew aboard these untried NASA vehicles. Former astronaut Tom Jones explains.

Put a pair of astronauts atop a brand-new booster with more takeoff thrust than the Saturn 5, strapped into a spacecraft with an unflown life support and propulsion system, and hurl them around the moon. What could go wrong?

Yet NASA is examining, at the request of the Trump administration, the feasibility of flying astronauts on the initial flight of the Space Launch System rocket now targeted for late 2018. Although it's certainly a bold idea, it's a risky gamble whose benefits don't warrant risking a crew and NASA's exploration future on an untried rocket and spacecraft.

NASA has been properly noncommittal on the idea of committing astronauts to SLS's first flight. It is, after all, a mammoth booster generating 8.8 million pounds of liftoff thrust to put 70 metric tons into low Earth orbit (where any flight to the moon or beyond would begin). NASA has said only that after discussions with the new administration, it is studying what opportunities "crew on first SLS" offers, and what it would take to accomplish the first step of pushing humans farther into space.

The approach would be a radical departure from existing plans that call for an SLS to boost an unpiloted Orion spacecraft into a distant retrograde lunar orbit, a flight termed Exploration Mission 1, or EM-1. The next SLS launch, EM-2, would be the first with people aboard. A crew would circumnavigate the moon sometime in 2021.

The up side

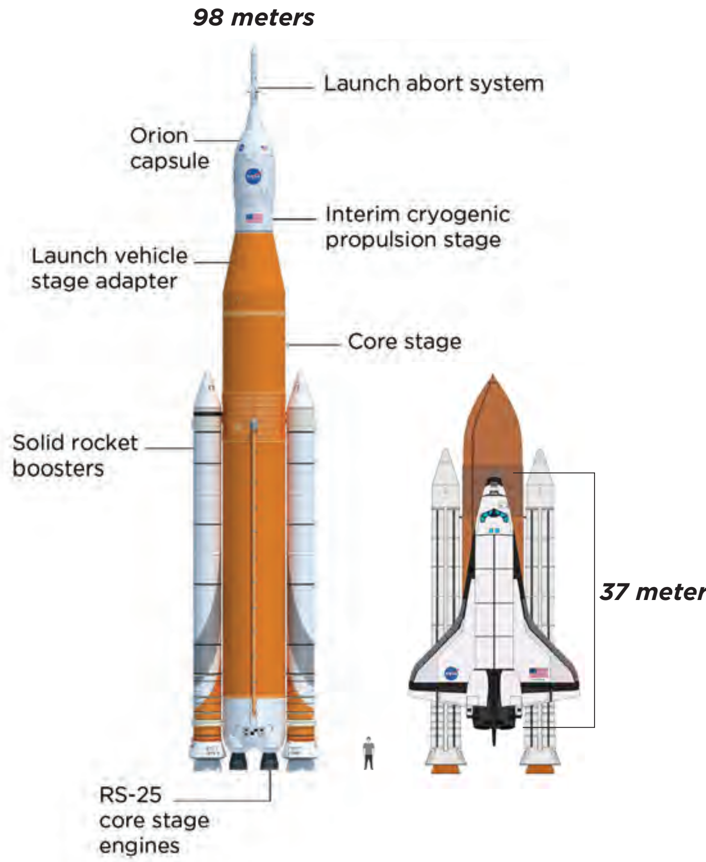
Swinging around the moon close to the 50th anniversary of Apollo 11's first lunar landing, a crew on EM-1 would speed America's lunar return by at least two years. And this spectacular lunar circumnavigation would, of course, occur during the Trump administration's first term, in marked contrast to the slow pace of human exploration under the last president, who after canceling lunar return plans in 2010, slow-walked the development of both SLS and Orion.

Putting a crew on EM-1 would engage that billion-dollar-class SLS in productive work immediately, advancing plans for a full lunar orbit mission, a possible return to the lunar surface, and eventual sorties to nearby asteroids and Mars. Jumping out of the blocks with a crew aboard the very first SLS would underline like nothing else a robust American commitment to human space exploration.

Risks

The first flight of any rocket inevitably carries more risk. Ground tests don't fully replicate flight conditions, and even proven rockets still break. The most advanced computational techniques cannot guarantee that a complex system on its first launch will perform as designed. An unpiloted test flight gives

NASA



Source: Aerospace America research; NASA

▲ **Columbia lifts off** April 12, 1981, with John Young and Bob Crippen in the cockpit for STS-1, the first space shuttle mission.

◀◀ **Commander John Young**, left, and pilot Robert Crippen train in the orbiter Columbia at Kennedy Space Center in Florida. STS-1 was the only first test flight of a U.S. spacecraft that carried a crew.

designers, controllers and managers a chance to learn invaluable lessons about their machine, and fix problems before risking human life.

NASA launched its boosters for the Mercury, Gemini and Apollo programs several times each without astronauts to prove their reliability. Apollo's Saturn 5 exhibited serious problems on its second unmanned launch, but NASA fixed them convincingly in time for Apollo 8, the first crewed lunar mission.

The shuttle, it's true, had John Young and Bob Crippen at the controls on its first launch, STS-1 in 1981, but only because the hybrid booster-spaceplane required flight with humans in the loop.

Unpleasant surprises on STS-1 nearly doomed that courageous duo. A reflected acoustic wave off the launch pad from booster ignition inflicted structural damage on the orbiter. The same overpressure deflected the body flap — a vital hypersonic control surface — well beyond its flight range, risking critical damage to the hydraulic aero control system. Sixteen heat shield tiles were lost during ascent. And a badly installed heat shield tile allowed hot gases to buckle the door protecting Columbia's right main landing gear. Only the safety margins built into the hydraulic and landing gear systems — plus luck — saved the orbiter and crew. STS-1 proved that a crew should not fly an untested vehicle unless driven by absolute operational need. Columbia commander Young often told us in the astronaut corps: "One test is worth a thousand analyses."

Flying a crew on EM-1 would be a tall order for NASA, SLS and Orion. SLS awaits structural testing and a full-up, ground firing of all four core-stage RS-25 engines. To fly a crew, SLS's second stage, the new Cryogenic Propulsion Stage, must be human-rated, a process not envisioned for EM-1.

Orion's launch abort system must still pass a high-altitude launch abort test. NASA would have to add to EM-1 a life support system and crew displays and controls, originally planned for EM-2. These tests and additions will consume too much money and time, negating any benefits from flying a crew on the first flight. NASA would do better to fly EM-1 unpiloted as planned, learn the flight's many lessons, and give astronauts a proven, well-understood EM-2 machine. That second flight could then take place as early as 2020.

We learned after Challenger's tragic 1986 loss that the right approach to spaceflight is not "show me that it's unsafe to launch," but "prove the machine is safe to fly." The latter approach is just as right-minded today as it was when proven — at agonizing cost — three decades ago. ★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ARTIFICIAL GRAVI

ITY'S ATTRACTION

NASA astronaut **Catherine "Cady" Coleman** participated in an experiment to study the effects of long space flights on the cardiovascular system while she was on the International Space Station in 2010-11.

NASA

Some spaceflight experts are concerned that the exercise techniques pioneered aboard the International Space Station won't be enough to counteract the effects of years in microgravity during missions to the region around the moon and to Mars. Adam Hadhazy spoke to scientists leading the renaissance of interest in artificial gravity concepts.

BY ADAM HADHAZY | adamhadhazy@gmail.com

The prospect of floating, exhilaratingly unbound, in microgravity has long drawn people to space exploration, but now that some astronauts and cosmonauts have spent upward of a year in space, it turns out that the thrills of weightlessness do not come scot-free.

Living in a near lack of gravity can trigger a daunting range of ailments. A mere sampling: Muscle atrophy. Bone deterioration. Weight loss. Bodily fluid redistribution. Balance problems. Cardiovascular dysfunction. Anemia. Kidney stones. Trouble sleeping. Nasal congestion. Weakened immune systems. And, to add insult to injury, increased flatulence.

Countermeasures including astronaut exercise regimens and nutrient supplementation have been increasingly deployed on the International Space Station over the last decade and a half. These measures have reduced some of the negative effects, but space medicine practitioners are not entirely sure how explorers will be affected by even longer exposure to microgravity. Even now, they have no solution for an impairment of vision, thought to arise from the pressure buildup of fluid in spacefarers' heads. With space agencies and the private sector firmly setting sights on journeys to Mars lasting two years or more, a comprehensive remedy for this and other gravity-related impacts is in higher demand than ever.

The most logical of silver bullets: artificial gravity, induced by rotation. Some concepts call for astronauts to live and work in a cylindrical or wheel-shaped, revolving spacecraft or portion of their space vehicle. Other setups could see astronauts spend time or even sleep in spinning centrifuges, and then work in conventional, microgravity modules. Whichever way, the goal is to deliver astronauts to their extraterrestrial destinations healthy and ready to explore. Accordingly, the voguish systems are being freshly reassessed for future missions. In 2014, NASA restarted its moribund artificial gravity research program, and aerospace companies are giving the idea serious consideration.

"Artificial gravity does not countermeasure for just one thing; it addresses all physical systems," says Gilles Clement, the lead scientist for artificial gravity in the Human Health Countermeasures Element of the Human Research Program at NASA's Johnson Space Center in Houston.

"We think about long durations in the exploration of space as a way to expand our planet to other planets," Clement adds. "We bring food and air — why not take gravity with us?"

Gravity's hold on us

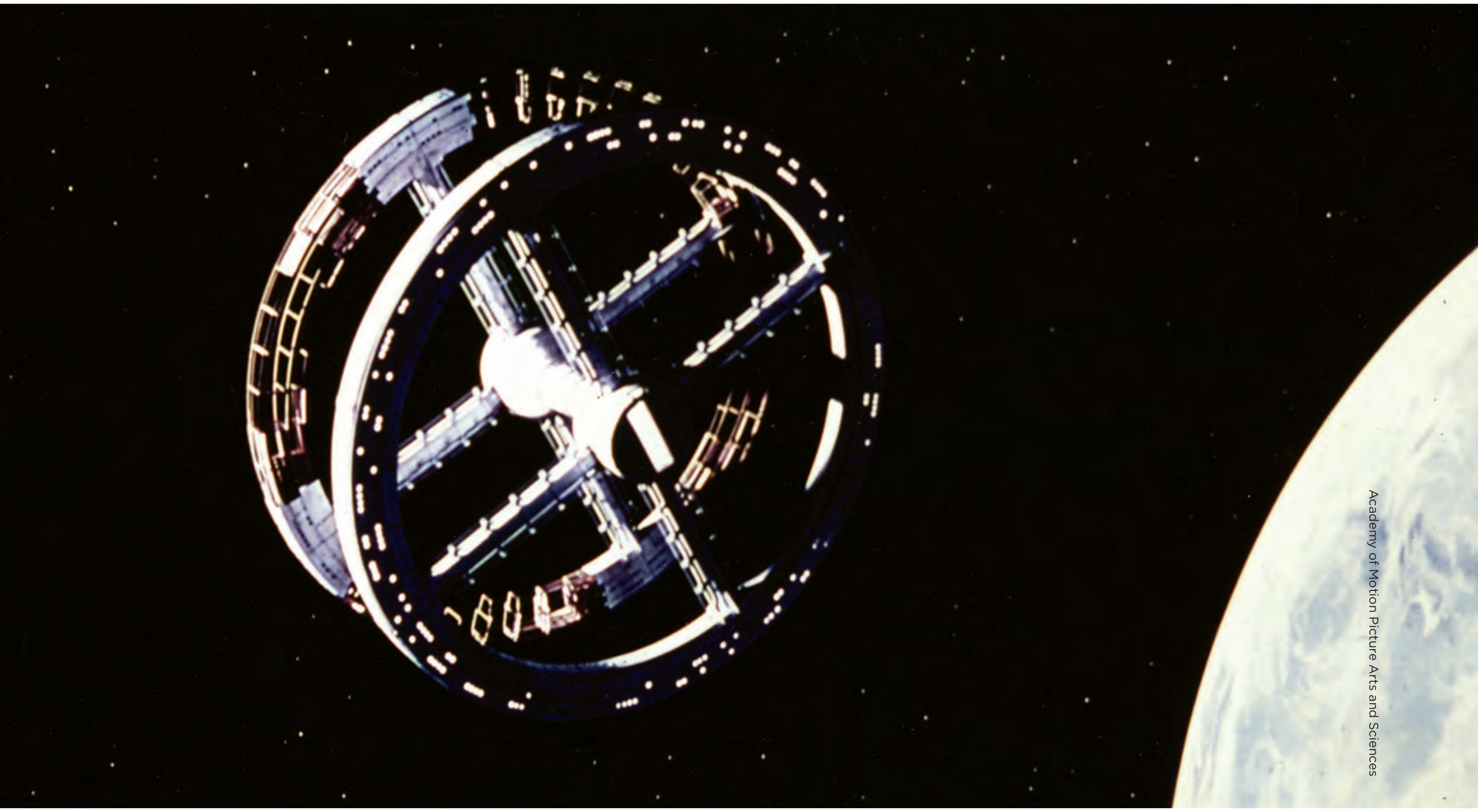
The idea of artificial gravity goes back to an 1883 description by the Russian rocket scientist Konstantin Tsiolkovsky, who famously remarked: "Earth is the cradle of humanity, but one cannot remain in the cradle forever." By the dawn of the Space Age, seven decades later, engineers took artificial gravity as a given in their visions for huge, wheel-shaped outposts on the final frontier. Stanley Kubrick's 1968 film "2001: A Space Odyssey" and Arthur C. Clarke's novel of the same name further popularized the concept, depicting a revolving space station and astronaut living area on a vessel outbound to Jupiter.

The principle at work behind these notions of artificial gravity is centripetal force, which acts on an object moving in a curved path. A familiar demonstration is how water will stay at the bottom of a bucket when spun outward horizontally by a person twirling in place. The bucket's bottom pushes toward the rotation axis, just as the hull of a spinning spaceship, or the footrest in a centrifuge, pushes "up" against an astronaut's feet, mimicking the gravitational effect we experience living on a massive planet.

The amount of artificial gravity produced in this manner depends on three things: the mass of the object being rotated, its radius from the center of rotation, and the rotation rate. Increasing any of those factors ups the overall centripetal force. As such, creating a desirable apparent gravity for a human inside a vessel, whether a spacecraft or an onboard centrifuge, is a tradeoff between radius size and rotation rate.

During early astronautic decades, numerous studies examined these tradeoffs. The studies involved everything from placing people in rotating

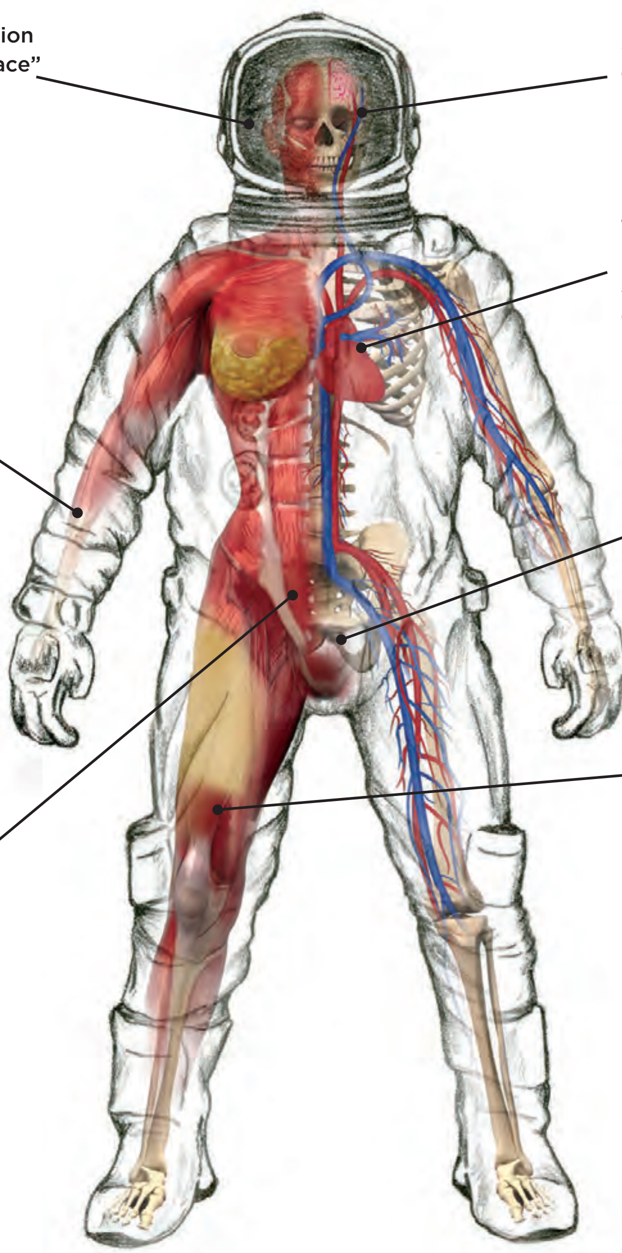
▼ **The space station** in 1968's "2001: A Space Odyssey" simulated gravity while revolving in low Earth orbit.



Academy of Motion Picture Arts and Sciences

Effects of spaceflight

Humans suffer a variety of side effects when exposed to microgravity. Here are some research findings:



WHOLE BODY SIDE EFFECTS

Decreased red blood cell production

Immune system weakening

Source: NASA; “Artificial Gravity for Low Earth Orbit (ISS) & Deep Space Exploration,” AIAA Space 2016

DLR

▲ **A researcher straps a subject into the short-arm centrifuge** at the DLR Institute of Aerospace Medicine in Cologne, Germany, where scientists are researching the effects of artificial gravity.

rooms on Earth to centrifuging animals in space aboard satellites to spinning a Gemini capsule in 1966 while tethered to another spacecraft, bola-style, generating a temporary whisker of artificial gravity for the crew.

Among the broad, albeit indirect, takeaways from these forays: humans could likely tolerate a space station, say with a 100-meter radius rotating perhaps three times a minute without experiencing sensorimotor trouble like dizziness and nausea. This rate would produce force equivalent to the 1 G of gravity we feel on Earth. Deriving 1 G from a small centrifuge, though, would mean spinning significantly faster, up to an uncomfortable 10 revolutions per minute. Plus, the well-spun occupants would have difficulty adapting to low gravity after a session ended.

Early studies of artificial gravity suggested that it "created more problems than it solved," Clement says. At the time, there wasn't the awareness there is today of the need to address the myriad medical issues that arise for humans when they are in microgravity for months or years.

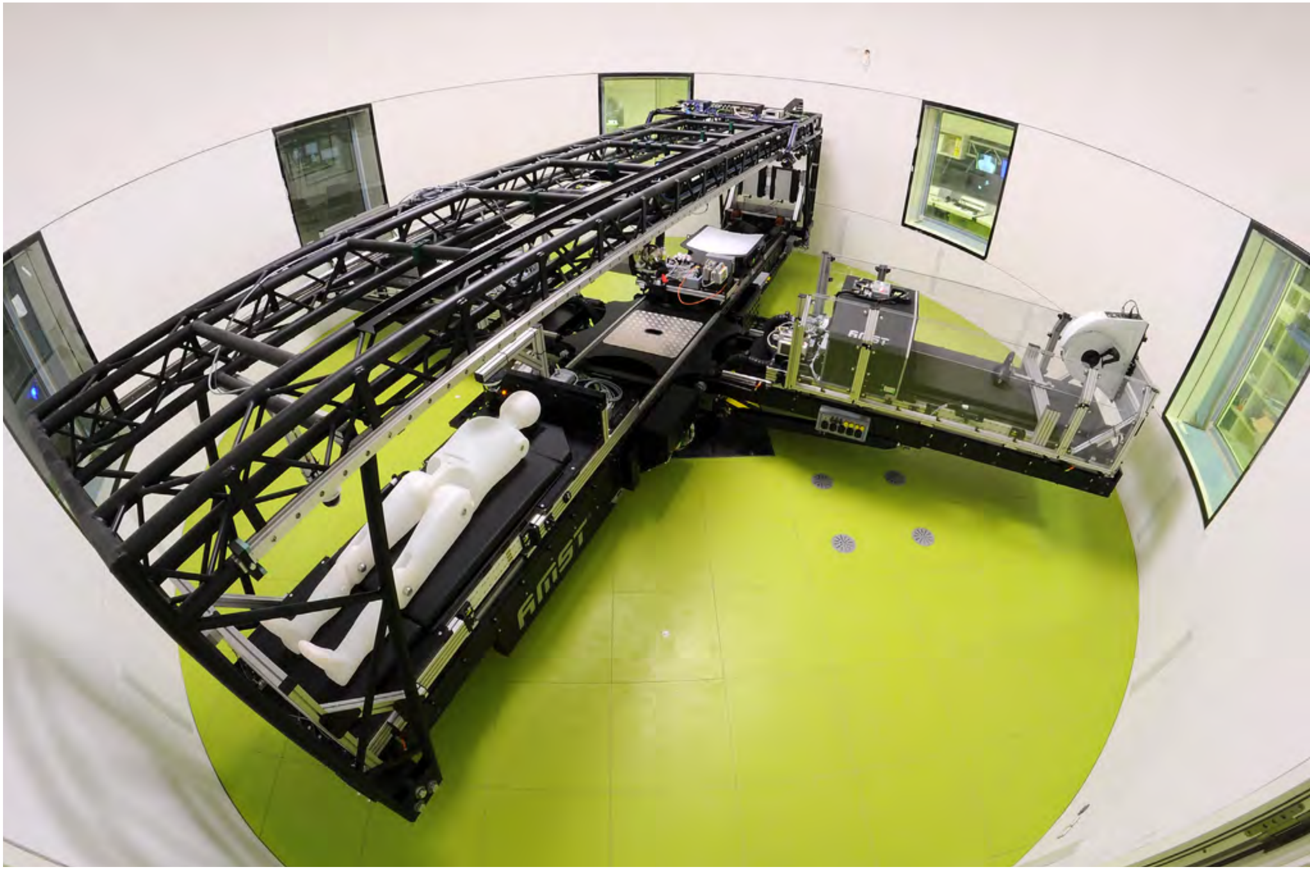
Moreover, the missions then at hand, and until recently, never truly demanded it. Indeed, astronauts seemed to get by well enough on the Apollo missions to the moon. After a few days, spacegoers recovered from the disorientation, nausea and headaches of "space sickness" that marked their transition to microgravity, as well as back to the 1 G environment upon terrestrial return. Eating food and going to the bathroom in space, while tedious at first, soon became manageably routine.

A weighty matter

Deeper concerns emerged, however, with the prolonged periods of weightlessness undergone onboard the Skylab space station in the 1970s, as well as the Soviet Union and Russian Mir station starting a decade later. The chief problems of bone- and muscle-mass loss were investigated during space shuttle flights, though these lasted at most only two weeks. As humans took up residence in the International Space Station in late 2000, medical testing technology advances began laying out the scope of zero G's ravages.

In parallel, progress in diet, nutrient supplementation and heavy resistive exercise began to peg artificial gravity again as a bridge too far. The deployment of treadmills, stationary bikes, and the equivalent of a gym apparatus for doing daily exercises such as squats, dead lifts and calf raises made ISS life far less deleterious.

"We've got an advanced countermeasures suite up there," said astronaut Michael Barratt in comments to an audience at the AIAA SPACE 2016 Forum



DLR

▲ **When the short-arm centrifuge spins a person**, it creates artificial gravity that forces blood back toward their feet. The device is at the DLR's ":envihab," short for enviroment and habitat.

in Long Beach, California, in September. "We are now preserving bone and muscle and aerobic fitness better than any time in history. So what used to be a huge enemy is something we have a solution for."

It so happens that Barratt's six-month stay on the ISS in 2009 is what first hinted at why artificial gravity might prove necessary aloft after all. After he and another crew member developed nearsightedness, examinations revealed optic nerve swelling and changes in their eyeballs' shapes. Those ocular problems are linked to fluid shifts into the head during long stints in space. The condition, dubbed visual impairment and intracranial pressure syndrome, or VIIP, appears to worsen over time. If unaddressed, it might leave humans on a Mars mission unable to see. Fully 90 percent of astronauts acquire VIIP to some degree; previous generations of astronauts had also noted vision problems, but the issue had never been pursued. "We've been flying in space for 50 years and we missed this," said Barratt in Long Beach. The discovery begs another alarming question, Barratt added: "What else are we missing?"

The hope is that VIIP, as well as other as-yet-unknown ailments kindled by chronic weightlessness, can be corralled by keeping fluids more normally distributed in the body — which exercise unfortunately cannot do. With NASA on a mid-2030s timetable for a possible mission to Mars, perhaps with a long layover at the moon or an asteroid, artificial gravity's scattershot history of research is ripe for a re-evaluation.

"Research was distributed and uncoordinated across numerous government and research organizations," says Clement. "Now that there are plans to send humans to Mars, using artificial gravity as an integrated countermeasure is logical and practical."

Making headway

In February 2014, NASA gathered participants from space agencies worldwide at an artificial gravity workshop at Ames Research Center in Moffett Field, California. From that starting point, Clement is coordinating international efforts to develop a research road map with enough lead time to affect next-generation mission designs.

Among scientists' key questions: How much gravity must a person be exposed to in order to stay healthy — the so-called G dose-response relationship? "We know how people work in 1 G and we know a lot about how people respond to zero G, but there's almost no data in between," Clement says. It could be that, say, just a low dose of 60 percent of Earth's gravity, provided by a slowly spinning centrifuge while its occupant soundly sleeps, may suffice in warding off VIIP and other nasties.

To fill the knowledge gap, NASA, the European Space Agency and other organizations have over the last couple of years announced a series of grants to study the physiological effects of varying gravity levels and intervals on cell cultures and animals, on Earth and in space. Humans, meanwhile, will partake in new studies at the DLR Institute of Aerospace Medicine in Cologne. Subjects in a facility called ":envihab," short for environment and habitat, will endure 60 days of bed rest with a 6-degree tilt down toward their heads, an orientation that mimics some of the physiological strain of weightlessness. Intermittently, subjects will go inside a horizontally spinning, 3.8-meter centrifuge to receive varying gravitational doses.

Other, no-less-intrepid participants will climb aboard NASA's McDonnell Douglas C-9B and outside contractor Zero Gravity Corp.'s Boeing 727 for new runs of the agency's "Vomit Comet" program, in which sudden drops in aircraft altitude induce periods of varying weightlessness lasting about 25 seconds. Researchers assess subjects' sensorimotor and perceptual systems, as well as rapid cardiovascular responses, during these brief windows that are repeated dozens of times over the course of a flight session, thus better gauging minimal G levels for comfort and countermeasure purposes.

Still, for all these gains, what will ultimately be needed are tests on astronauts inside a cosmic centrifuge. "We must validate in space," says Clement. "It's impossible to [fully] simulate on Earth." At present, no plans are afoot for putting a human-rated centrifuge on the ISS. The last effort, the Centrifuge Accommodations Module, got the ax in 2005 before it ever reached orbit. ISS cost overruns and concern over the centrifuge's vibrations interfering

▼ **NASA astronaut Karen Nyberg** looks into a fundoscope, a device that images the back of the eye, so that researchers can monitor any effects of microgravity on her eyes during her 166 days on the International Space Station.

NASA

Is there such a thing as zero gravity? The short answer is no, though even experts utter the term for the sake of simplicity. Technically speaking, objects in Earth orbit experience "microgravity," which is a state of continuous free-fall around the planet. The objects are traveling fast enough that they match the falling away of Earth's curving surface below. Even in deep space, gravity is still there, although weaker, otherwise "our entire solar system would drift apart," as NASA notes on its Science Fiction or Science Fact? web page.

with delicate on-orbit experiments, like crystal growing, that require pristine microgravity, doomed the endeavor.

Clement flatly believes there is "no hope" of flying a human-rated centrifuge to ISS, whose operations are anyway slated to cease in 2024. Instead, he is looking ahead to the mid-2020s to NASA's "deep space habitats," proposed to take crews out of low Earth orbit into cislunar space, between the Earth and the moon, in preparation for an eventual mission to Mars.

Escaping Earth's orbital clutches

Several companies received two-year NASA grants, estimated to cost $65 million, in August 2016 through the public-private Next Space Technologies for Exploration Partnerships, or NextSTEP, initiative. The companies will develop ground prototypes of deep space habitats. A centrifuge might just find its way into the proposals or even a finalized mission, Clement says, fingers crossed.

Lockheed Martin and Orbital ATK, two recipients, do not look to be considering artificial gravity research — or operational — options at present. But there are indications Boeing is. Space Exploration division engineers presented a paper at the Long Beach event explaining how the company has nine patents pending on designs to address technical challenges of artificial gravity systems. In this vein, Boeing is conducting studies on potential centrifuge designs.

Bigelow Aerospace, another NextSTEP recipient, has not announced specifics for its cislunar habitats, though the high volumes of its hallmark inflatable modules do leave the door open for centrifuges. Ditto for Sierra Nevada Corp., whose proposed habitat made of multiple Dream Chaser spacecraft cargo modules could afford ample real estate for experimentation.

The idealistic covers of classic sci-fi novel notwithstanding, a paradigm shift to a rotating spacecraft, or spacecraft module, is not really in the cards. Budgetary, design and operational hurdles are clear and present — as is astronaut trepidation. "It's not easy to build Stanley Kubrick's space station that spins," Barratt, the astronaut, said in Long Beach. "Astronauts fear artificial gravity. Why? Because we don't like big, moving parts. They break."

Nevertheless, seed money is out there from NASA, including $500,000 for a study looking into how robots might build a lightweight plastic, expandable spacecraft that would rotate on its way to Mars. Back in 2011, NASA engineers boldly proposed the $3.7 billion Nautilus-X, a long-duration crew vehicle that would have included a large, rotating wheel section to give astronauts partial Earth G while sleeping.

"WE BRING FOOD AND AIR — WHY NOT TAKE GRAVITY WITH US?"

– Gilles Clement, NASA's Johnson Space Center

For the foreseeable future, centrifuges will therefore be the focus. Astronauts might enter a centrifuge for gravity-dosing sessions during working hours, or perhaps sleep in one. The challenge is that the necessary revolutions-per-minute for adequate medical countermeasures might be uncomfortable physically and perceptually, with even a stray, sideways glance potentially causing motion sickness. Barratt, for one, has concerns. "From an engineering standpoint, [a centrifuge is] a more practical solution," he said. "From an astronaut's perspective, it's a nightmarish form of countermeasure."

Even if space agencies do not soon go whole hog for centrifuges, their ongoing efforts to characterize G levels for human health will help set the stage for the main rationales behind the gyrating devices: Mars. The Red Planet's gravity is just 38 percent of Earth's — right in that scientific no-man's-land between 1 and zero G, meaning how explorers will fare in the world's weak embrace is an open question. "We know nothing about Martian G," says Clement.

There is room for optimism. Mars' gravity might itself serve as a sufficient countermeasure, letting astronauts forego lugging gym equipment or a heavy centrifuge down to its ruddy surface. Humans may be more prepared to take on Mars than we realize. And with artificial gravity and other countermeasures in place, even more exotic solar system destinations with partial Earth gravities — asteroids, Europa, Titan — will increasingly become within our species' grasp.

"From a teleological standpoint, until we develop interstellar travel, everything of interest to us involves zero to 1 G," said Barratt. "We need to operate in that band." ★

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REPR

BY JOE STUMPE | jstumpe@cox.net

Since its first combat deployment during the 1991 Persian Gulf War, the A-10 has been a favorite of ground troops for close-air support.

U.S. Air National Guard

RIEVE

Even in the age of drones, stealth and automation, the U.S. Air Force is having a hard time letting go of its Cold War-era planes. To wit, the A-10. Joe Stumpe spoke to members of Congress and military experts about the debate over whether to keep flying them.

It's got a long history, a storied reputation, a cool nickname and a questionable future. This is the story of the U.S. Air Force's A-10 jet — known as the "Warthog" — and the close-air support for ground troops that has been its primary mission.

Slated for retirement, the fleet of jets received a reprieve in February when the Air Force announced plans to extend its service at least through 2021. That gives the military more time to sort out what has at times been an emotion-charged debate over replacing it with newer, more expensive aircraft such as the F-35.

Consider this: In 2015, an Air Force general lost his job reportedly for telling airmen they should not communicate their support for the A-10 to members of Congress, even using the word "treason" in his remarks. U.S. Rep. Mac Thornberry, R-Texas, chairman of the House Armed Services Committee, and Rep. Martha McSally, R-Ariz., a former Air Force A-10 pilot, have been some of the most vocal supporters of the A-10.

In a world where the latest technology gets most of the attention, the A-10 qualifies as old school. It flies low and slow — usually about 300 knots — while delivering deadly bursts from a 30 millimeter rotary cannon. That up-close-and-personal approach makes it a favorite of many ground troops, who count on it to kill and intimidate the enemy without endangering friendly troops.

"The folklore in our community is that the gun was built and then they went to the engineers and said 'figure out how to fly this gun,'" McSally says. "It's an amazing weapon."

But technologically speaking, the A-10 is at least a generation behind planes like the F-35. The last of more than 700 produced was manufactured in 1984, although the 283 still in operation have undergone many upgrades. They would be vulnerable in contested airspace, which has led to questions about whether they are a good option going forward.

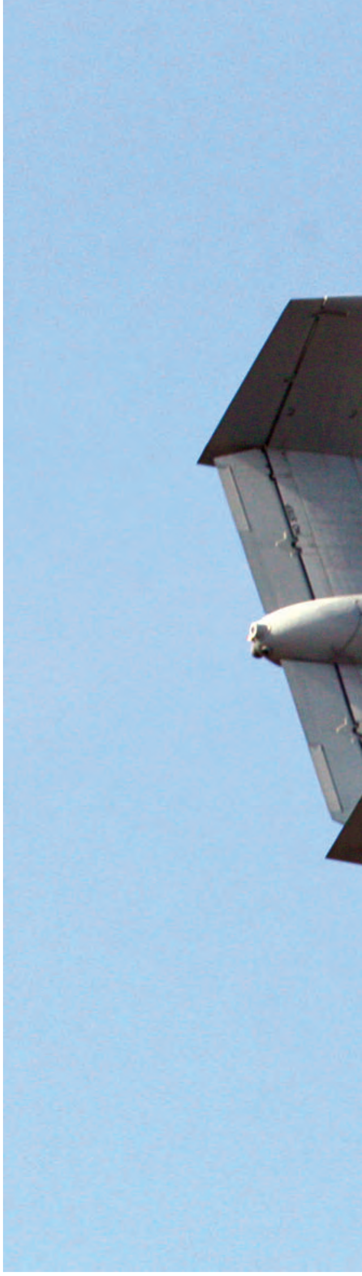
"The A-10 is becoming very, very aged," says retired Air Force Lt. Gen. Dave Deptula, now dean of the Mitchell Institute for Aerospace Studies, a nonprofit research arm of the Air Force Association in Arlington, Virginia. "At some point, you need to recapitalize the force."

A single-seat twin-engine manufactured by Fairchild Republic, the A-10 Thunderbolt II is a product of the Cold War, originally intended to be flown if Warsaw Pact forces ever invaded Western Europe.

The A-10 wasn't deployed in combat until the 1991 Persian Gulf War. Some of the most detailed information about the plane's flights in that war can be found on a website maintained by the 2951st Combat Logistics Support Squadron, which kept them flying during the Gulf War. According to www.2951clss-gulfwar.com, a total of 165 A-10s and OA-10s (a version designated for forward air control) flew 8,775 sorties — about 16 percent of the total and the highest of any aircraft — destroying 987 tanks, plus thousands of artillery pieces, two helicopters, other military vehicles and enemy assets.

The site quotes an interview with a captured Iraqi captain who said the A-10 evoked terror not just through attacks "but also the plane's ability to loiter around a target area prior to its attack caused additional anxiety, since Iraqi soldiers were unsure of the chosen target."

Only five A-10s were lost in combat, although



▲ **Some advocates** for the A-10 say that any replacement would have to be able to fly low, slow and for long periods, and effectively attack enemy forces on the ground.

U.S. Air Force

nearly half were damaged in some way. The site calls the A-10 "probably the most difficult plane ever built to shoot down due to its extreme maneuverability, self-sealing fuel tanks, wide separated jet engines on top of the fuselage, twin vertical tails, multiple independent hydraulic systems, manual backup flight control system and redundant wing spars."

That doesn't even count one of the plane's best-known features — a 540-kilogram titanium "bathtub" around its cockpit. It's able to maneuver at low speeds and under 300-meter ceilings due to its wing area — 47 square meters — and ailerons that take up almost half of the wingspan.

McSally's 325 combat hours over Afghanistan and Iraq convinced her that the A-10's design enables it to perform some missions better than any other plane in the U.S. Air Force's inventory. Those are the type of missions where the pilot must determine with his or her own eyes what's going on below, in a situation where enemy and friendly

The F-35 should focus on air superiority "instead of chasing around 30-year-olds on mopeds in some of these countries."

Former A-10 pilot Rep. Martha McSally, R-Ariz., expressing doubts about flying F-35s for close air support troops are in close proximity, and the plane itself is likely to be targeted.

"Right now we have nothing else in the inventory that provides that kind of capability," McSally says. "It's getting older, but it's all relative, right?"

A-10s were also flown in the Balkans in the mid and late 1990s, in Afghanistan during the next decade and during the Iraq War starting in 2003. Since then, A-10s have operated against combatants in Afghanistan, Iraq, Libya and Syria.

The A-10 has been a workhouse but far from the only aircraft used for close-air support, which is defined as action against an enemy operating close to friendly forces. In Bosnia-Herzegovina, for instance, the F-15, F-16, F-18 and AC-130, plus the Army's helicopter gunships, all provided close-air support.

A-10s are only used where the U.S. military has clear air superiority — that is, "against people who have no air force," says Richard Aboulafia, aviation analyst for the Teal Group.

"In that environment, the A-10 is incredibly effective," Aboulafia says. But "against a near-peer adversary, they're dead meat. I think the Air Force for that reason has been interested in replacing them."

But McSally and others say the existing A-10 fleet should continue to be effective for years, rather than turning its role over to the F-35 and other aircraft. The F-35 is the most technologically advanced plane in the Air Force and the costliest in history, with a current price tag of up to $132 million per plane, compared to $18.8 million for an A-10.

McSally notes that the F-35 is not designed to survive a direct hit, meaning it most likely would deliver its weapons from a high-altitude, "stand off" position. The F-35 can spend 20 to 30 minutes over a battlefield, compared to about 90 for the A-10.

The F-35's real mission is establishing air superiority, McSally says.

"Let it focus on that instead of chasing around 30-year-olds on mopeds in some of these countries," she said. "That's not a good use of the F-35."

McSally emphasizes that she's a supporter of the F-35 but adds, "Why would you put something that valuable in a position to be potentially shot down by somebody with an AK-47? Why are you using your Ferrari for something your pickup truck can do?"

McSally says the Air Force's original plan to keep the A-10 in service until 2028 makes sense to her. Aboulafia agrees, saying it "makes eminent sense to upgrade and sustain the A-10 fleet. There's nothing about these planes that would need replacement."

Aboulafia discounts two more proposals that have been floated: producing a new generation of A-10s or buying a fleet of light attack planes, such as a Textron Scorpion.

"A replacement for the A-10 is basically the A-10," he says. "They're not going to be able to find the

Lockheed Martin

▲ **The F-35's mission is air superiority**, not close-air support, says Rep. Martha McSally, a former A-10 pilot.

Textron AirLand

▲ **One proposal for replacing the A-10** is to buy a fleet of light attack planes, such as the Textron Scorpion.

cash to create a new A-10, and even if they could, it would look like an A-10."

As for the light attack planes, he says, "Compared to the A-10, they'd be like bicycles compared to a car. … I'm not a fan of casualties, so I'm going to say it's a bad idea."

Deptula calls light attack planes "a good thing to look at" and says the Air Force "shouldn't be continuing to upgrade airplane designs that are 40 years old. We need to capitalize on technology changes that have been introduced over time."

Deptula points out that a variety of aircraft can perform close-air support, some better than the A-10 in certain circumstances. In Afghanistan, he says, other aircraft have carried out about 70 percent of the close-air support mission. Where there are greater distances to fly, for instance, "a B-1 is probably a better platform to operate than an A-10 is."

"Close-air support is a mission, it's not an aircraft," he says.

Deptula says much of the A-10 discussion has been "emotionally based."

"If you're ground personnel coming under fire from an enemy force, do you really care whether the boom came off an A-10, an F-35, a B-52 or anything else? The answer is no."

Deptula says comparisons of operating cost can be misleading. In an area where the enemy presents a medium-level air defense threat, the Air Force would need other aircraft to make the skies safe for the A-10.

"Total up all of the costs and measure that against the one F-35 it would take to accomplish that mission," he says. "It's not about individual unit cost. It's about cost per mission."

None of this means, by the way, that Deptula doesn't like the A-10. "The A-10's a great aircraft, and close-air support is one of the most important [missions] — if not the most important — because we've got friendly lives at stake."

"The mission's going to get accomplished," he says. "The question is what's the most cost-effective way to do that."

Deptula notes that the Air Force "never wanted to get rid of the A-10" but only moved in that direction because of the Budget Control Act of 2011.

That's pretty much the view of Air Force officials, who say the federal budget cap left them no alternative but to cut somewhere. Mothballing the A-10 would have saved an estimated $4 billion.

Plans to shelve the A-10, however, ran into opposition in Congress. Last year, Thornberry, the Armed Service chairman, introduced legislation that would stop the Air Force from retiring the A-10 until it can prove that an effective replacement is available. Thornberry wants the military to prove that a replacement can fly low, slow and for long periods, demonstrate air-to-ground assault and land without a paved runway if necessary.

Air Force officials say comparison testing is underway, but rather than characterize that as a fly-off between the A-10 and F-35, they say multiple aircraft are being evaluated.

They acknowledge that the A-10's 30 mm cannon gives it unmatched punch, but note that laser-guided rockets carried by several aircraft — including the A-10 — are a good substitute. In terms of cost, they say the A-10 is not as cheap to operate as some people think: The aircraft costs $17,000 an hour to fly, compared to

“Against a near-peer adversary, they’re dead meat.”

Richard Aboulafia, the Teal Group, describing a weakness of the A-10s

$20,000 for the F-16. Light aircraft, which would be significantly cheaper than either, are in play as a possible supplement to the A-10, not a replacement.

President Donald Trump’s call for $54 billion in additional military spending has further lessened the necessity of doing anything immediately.

Whatever happens during the Air Force’s deliberations, officials expect the large majority of remaining A-10s to remain in operation past 2021.

The Air Force wants to shift debate away from the A-10 or any other single kind of aircraft to the service’s desire to have a balanced portfolio of options. Still another consideration is that close air support may look different in the future with the advent of drones and other technology.

In remarks to defense writers earlier this year, Air Force Chief of Staff Gen. Dave Goldfein recalled that the Air Force divided Afghanistan into four quadrants — north, south, east and west — and only the rolling terrain and open fields of the southern section were optimal for A-10s. MQ-9 Reaper drones, B-1s and F-16s were flown elsewhere.

“The longer we have this discussion about the A-10 and don’t connect it to how the A-10 fits into the family of systems,” Goldfein said, “the more we are having a 20th-century dialogue about close-air support.”

But McSally says the A-10 belongs in any conversation about close-air support.

“It’s not just because I flew it. It’s not nostalgic in that sense. I am very clear-eyed and have the personal credibility about the unique capabilities of this airplane.” ★

AIAA Bulletin

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Calendar

Notes About the Calendar

For more information on meetings listed below, visit our website at www.aiaa.org/events or call 800.639.AIAA or 703.264.7500 (outside U.S.).

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2017			
5–7 Apr	Region VII-Europe-Pegasus/AIAA Student Conference (Masters Division Only)	Berlin, Germany (https://www.aiaastudentconference.org/)	
7–8 Apr	Region I Student Conference (University of Virginia Student Branch)	Charlottesville, VA (https://www.aiaastudentconference.org/)	
7–8 Apr	Region V Student Conference (Metropolitan State University of Denver Student Branch)	Denver, CO (https://www.aiaastudentconference.org/)	
18–20 Apr†	17th Integrated Communications and Surveillance (ICNS) Conference	Herndon, VA (Contact: Denise Ponchak, 216.433.3465, denise.s.ponchak@nasa.gov, http://i-cns.org)	
20–21 Apr	Aircraft Noise and Emissions Reduction Symposium (ANERS)	Alexandria, VA	
25–27 Apr	AIAA DEFENSE Forum (AIAA Defense and Security Forum), Featuring: – AIAA Missile Sciences Conference – AIAA National Forum on Weapon System Effectivenss – AIAA Strategic and Tactical Missile Systems Conference	Laurel, MD	4 Oct 16
25–27 Apr†	EuroGNC 2017, 4th CEAS Specialist Conference on Guidance, Navigation, and Control	Warsaw, Poland (Contact: http://www.ceas-gnc.eu/)	
29–30 Apr	Region IV Student Conference (University of Houston Student Branch)	Houston, TX (https://www.aiaastudentconference.org/)	
2 May	2017 AIAA Fellows Dinner	Crystal City, VA	
3 May	AIAA Aerospace Spotlight Awards Gala	Washington, DC	
8–11 May†	AIAA/AUVSI Symposium on Civilian Applications of Unmanned Aircraft Systems	Dallas, TX (www.xponential.org)	
15–19 May†	2017 IAA Planetary Defense Conference	Tokyo, Japan (Contact: http://pdc.iaaweb.org)	
25–29 May†	International Space Development Conference	St. Louis, MO (Contact: ISDC.nss.org/2017)	
29–31 May†	24th Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (Contact: Ms. M. V. Grishina, icins@eprib.ru, www.elektropribor.spb.ru)	
3–4 Jun †	Dawn of Private Space Science Symposium 2017	New York, NY (Contact: www.privatespacescience2017.com)	
3–4 Jun	1st AIAA Geometry and Mesh Generation Workshop	Denver, CO	
3–4 Jun	3rd AIAA CFD High Lift Prediction Workshop	Denver, CO	
3–4 Jun	Optimal Design in Multidisciplinary Systems Course	Denver, CO	
3–4 Jun	Practical Methods for Aircraft and Rotorcraft Flight Control Design and Hands-On Training Using CONDUIT® Course	Denver, CO	
5–9 Jun	AIAA AVIATION Forum (AIAA Aviation and Aeronautics Forum and Exposition) Featuring: – 24th AIAA Aerodynamic Decelerator Systems Technology Conference – 33rd AIAA Aerodynamic Measurement Technology and Ground Testing Conference – 35th AIAA Applied Aerodynamics Conference – AIAA Atmospheric Flight Mechanics Conference – 9th AIAA Atmospheric and Space Environments Conference – 17th AIAA Aviation Technology, Integration, and Operations Conference – AIAA Flight Testing Conference – 47th AIAA Fluid Dynamics Conference – 18th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference – AIAA Modeling and Simulation Technologies Conference – 48th Plasmadynamics and Lasers Conference – AIAA Balloon Systems Conference – 23rd AIAA Lighter-Than-Air Systems Technology Conference – 23rd AIAA/CEAS Aeroacoustics Conference – 8th AIAA Theoretical Fluid Mechanics Conference – AIAA Complex Aerospace Systems Exchange – 23rd AIAA Computational Fluid Dynamics Conference – 47th Thermophysics Conference	Denver, CO	27 Oct 16

†Meetings cosponsored by AIAA. Cosponsorship forms can be found at https://www.aiaa.org/Co-SponsorshipOpportunities/.

AIAA Continuing Education offerings

AIAA Symposiums and Workshops

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
5 Jun	Cybersecurity Symposium at AIAA AVIATION Forum	Denver, CO	
6–7 Jun	DEMAND for UNMANNED at AIAA AVIATION Forum	Denver, CO	
6–9 Jun†	8th International Conference on Recent Advances in Space Technologies (RAST 2017)	Istanbul, Turkey (Contact: www.rast.org.tr)	
7–9 Jun	Transformational Electric Flight Workshop & Expo at AIAA AVIATION Forum	Denver, CO	
19–21 Jun†	9th International Workshop on Satellite Constellations and Formation Flying	Boulder, CO (Contact: http://ccar.colorado.edu/iwscff2017)	
27–28 Jun†	Cognitive Communications for Aerospace Applications (CCAA) Workshop	Cleveland, OH (Contact: www.ieee.org/CCAA)	
8–9 Jul	Emerging Concepts in High Speed Air-Breathing Propulsion Course	Atlanta, GA	
8–9 Jul	Liquid Rocket Engines: Fundamentals, Green Propellants, & Emerging Technologies Course	Atlanta, GA	
8–9 Jul	Missile Propulsion Design, Development, and System Engineering Course	Atlanta, GA	
8–9 Jul	Turbulence Modeling for Modern Industrial CFD Course	Atlanta, GA	
10–12 Jul	AIAA Propulsion and Energy Forum (AIAA Propulsion and Energy Forum and Exposition) Featuring: – 53rd AIAA/SAE/ASEE Joint Propulsion Conference – 15th International Energy Conversion Engineering Conference	Atlanta, GA	4 Jan 17
20–24 Aug†	2017 AAS/AIAA Astrodynamics Specialist Conference	Stevenson, WA	24 Apr 17
22–24 Aug†	International Conference on Aerospace Science and Engineering (ICASE)	Islamabad, Pakistan (Contact: http://www.ist.edu.pk/icase)	
12–14 Sep	AIAA SPACE Forum (AIAA Space and Astronautics Forum and Exposition)	Orlando, FL	23 Feb 17
13–16 Sept†	21st Workshop of the Aeroacoustics Specialists Committee of the Council of European Aerospace Societies (CEAS)	Dublin, Ireland	
25–29 Sept†	68th International Astronautical Congress	Adelaide, Australia	28 Feb 17
16–19 Oct†	Joint 23rd Ka and Broadband Communications Conference and 35th International Communications Satellite Systems Conference (ICSSC)	Trieste, Italy (www.kaconf.org)	10 May 17
13–15 Nov†	1st International Academy of Astronautics (IAA) Conference on Space Situational Awareness	Orlando, FL (www.icssa2017.com)	
2018			
8–12 Jan	AIAA SciTech Forum (AIAA Science and Technology Forum and Exposition) Featuring: – 26th AIAA/AHS Adaptive Structures Conference – 56th AIAA Aerospace Sciences Meeting – AIAA Atmospheric Flight Mechanics Conference – AIAA Information Systems — Infotech@Aerospace Conference – AIAA Guidance, Navigation, and Control Conference – AIAA Modeling and Simulation Technologies Conference – 20th AIAA Non-Deterministic Approaches Conference – 28th AAS/AIAA Space Flight Mechanics Meeting – 59th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference – 5th AIAA Spacecraft Structures Conference – 36th Wind Energy Symposium	Orlando, FL	12 Jun 17
3–10 Mar †	IEEE Aerospace Conference	Big Sky, MT (Contact: www.aeroconf.org)	
28 May–1 Jun	SpaceOps 2018: 15th International Conference on Space Operations	Marseille, France (Contact: www.spaceops2018.org)	

Karen Berger Wins 2017 AIAA Lawrence Sperry Award

By Duane Hyland, AIAA Communications

Each year, AIAA presents the Lawrence Sperry Award for a notable contribution made by a young person, age 35 or under, to the advancement of aeronautics or astronautics. The award honors Lawrence B. Sperry, pioneer aviator and inventor, who died in 1923, in a forced landing while attempting a flight across the English Channel. The winner of the 2017 award is Karen Berger, an AIAA Senior Member, and the Langley Aerothermodynamics Laboratory Facility Manager at the NASA Langley Research Center, Hampton, VA. Berger received the award at the AIAA SciTech Forum in January.

Berger began her career at NASA working on the Space Shuttle Return-to-Flight program in 2005. In response to a critical program need, she became a subject-matter expert on boundary-layer transition. As her responsibilities grew, she contributed to Space Shuttle on-orbit mission support from 2005 until the end of the Space Shuttle program in 2011. Between 2009 and 2011, Berger joined the Hypersonic Infrared Measurements (HYTHIRM) project that gathered ground- and air-based thermal images of the Space Shuttle during its reentry to the Earth's atmosphere. In 2010 Berger became Deputy Principal Investigator of the Space Shuttle Boundary Layer Transition Flight Experiment (BLTFE) and in 2011, she became Principal Investigator for the Space Shuttle BLTFE. While a part of the Space Shuttle BLTFE, Berger oversaw experiments that modified the Space Shuttle's thermal protection system to create extremely high temperatures during reentry as a way to test the upper end of the design limits of the shuttle's protection system – a hazardous undertaking that had been banned since the fifth shuttle flight (STS-5) and to test the computational and experimental tools that were used to design thermal protection systems. The Space Shuttle BLTFE experiments were carried out on five flights (STS-119, STS-128, STS-131, STS-133, and STS-134) and were all successful, with critically useful data obtained from each of the flights. Through those experiments, researchers gained knowledge of high Mach number boundary transition that they applied to the design of the Orion Multi-Purpose Crew Vehicle. Those data have been critical to gaining a better understanding of uncertainties for flight boundary-layer transition predictions based on ground-based testing results. Other projects that Berger has worked on include the X-51, HIFiRE, Orion, Ares and the Sierra Nevada Corporation's Dream Chaser spacecraft.

Berger has also been very involved with the AIAA Hampton Roads Section, serving as the Section's Pre-College STEM Outreach Chair for eight years and as a Section Council Member (2009–2012; 2013–2016). Her past honors include the 2015 AIAA Hampton Roads Section Robert A. Mitcheltree Young Engineer of the Year; the 2015 Peninsula Engineers Council Doug Ensor Young Engineer of the Year Award; a 2013 NASA Early Career Achievement Medal; the 2013 NASA Silver Snoopy; and a 2010 Space Flight Awareness Award.

We began our interview by discussing what sparked Berger's interest in hypersonic boundary-layer transition research. She said, "I first started working in hypersonics as an undergraduate co-op student at NASA Langley, while attending Virginia Tech. I got involved in wind tunnel testing early on and got to work on the Columbia Accident Investigation and Return-To-Flight testing while still in school. The group I was working with was very focused on hypersonic boundary layer transition (BLT) and it really peaked my interest at that point." She explained the significance of the research she performs: "Of course there was the immediate use of that information to help determine what happened to the Space Shuttle Columbia, but we also used it to help create tools to understand the risks on future flights. Pretty much any hypersonic vehicle has the potential to have BLT issues in flight and a better understanding of when transition occurs and how hot the vehicle will get helps in the design of effective thermal protection systems (TPS). Without an understanding of when BLT will start, a vehicle may have to be designed for fully turbulent flight, increasing the thermal protection system thickness and thus increasing the weight and potentially decreasing the payload."

I asked Berger how the knowledge gained from these specific research projects help the aerospace community at large. "A better understanding of BLT (causes and when it will start) helps the community develop better tools for vehicle design and analysis. This can lead to more realistic thermal protection system design (materials and thickness) and help us avoid significant overdesign. The overdesign leads to increases in weight and thus decreases in payload and/or vehicle size that can eventually result in the cancelling of a program. Better wind tunnel testing and computational tools will lead to more successful flight tests and safer, more accurately designed vehicles. There's very little flight data in the hypersonic regime (because flights are often one of a kind opportunities and very expensive) so any opportunity to collect data on hypersonic BLT is a great thing."

Berger described how her research benefited the Space Shuttle and how researchers might apply it to the Space Launch System and the Orion Crew Capsule. "The BLT Flight Experiment was started because of the realization that although we had tools to look at BLT prediction on the Space Shuttle, they were almost exclusively based on ground testing and computational tools. There was very little flight data to help with the extrapolation or validation. The desire was to do a flight test with the purpose of collecting data on the vehicle in a controlled and instrumented manor. Through the five flights of the experiment (along with extensive ground testing and computational predictions) we were able to show that the correlations we were using to predict when the vehicle's boundary layer would transition to turbulent were actually pretty good. The predicted temperatures from our tools though were significantly higher than the measured temperatures so it left room for improvement. We created the Space Shuttle tools using our extensive history of testing the Space Shuttle configuration, but we're using some of the same correlations to design many other vehicles including Orion and SLS. Having a better understanding of how well they worked with the Space Shuttle helps us better understand their strengths and weaknesses on other vehicles and configurations."

Expounding on the practicality of her research to aid future space exploration efforts, Berger noted, "The better the TPS design is for a vehicle, the more likely a flight is to succeed. If we overdesign everything, it might be safe, but it also might be too heavy or too large (or both), especially for travel to other planets/moons and that can lead to the cancelation of programs. It's really important to try to get the design as close as we can. By using what we've learned from the Space Shuttle BLTFE, we hope that we can improve the computational tools to a more realistic design. The flight experiment provides a set of comparison data for that purpose."

I always dreamed of working with the Space Shuttle ... so when I got to do it in real life, it was amazing. Being a part of the Damage Assessment Team for the Space Shuttle and then the BLT Flight Experiment is really what put me in a position to win the award.

When I asked Berger to look ahead in her field and speculate what advances we can expect to see, she replied, "I think the big thing right now is trying to figure out how to model boundary-layer transition computationally. There are a number of techniques that are being used but we need to get a better understanding to how well they relate to both ground testing (since that's the easiest place to test our configurations and gather data) and flight testing. People have been working this problem for a long time and we still have a lot of work to do. We also are looking at better ways to correlate ground testing and flight testing results."

We then discussed Berger's thoughts on winning the 2017 Lawrence Sperry Award: "First of all I was really surprised and honored to win the award. There are a LOT of really great young professionals within AIAA so it really is something special to me. I always dreamed of working with the Space Shuttle when I was growing up and in college so when I got to do it in real life, it was amazing. Being a part of the Damage Assessment Team for the Space Shuttle and then the BLT Flight Experiment is really what put me in a position to win the award. That work would not have been possible without the countless other people with whom I got the opportunity to work on the Space Shuttle program and without some really amazing mentors and colleagues."

We closed the interview by discussing her thoughts on the value of AIAA to the aerospace community as a whole. Berger said, "I have been a member of AIAA since I was an undergraduate at Virginia Tech. While I was there, AIAA was invaluable as a way to meet people within the professional aerospace world as well as gain the skills to help get a job (like interviewing). When I graduated I became a professional member and have been active within the group ever since. I think AIAA provides critical technical resources through conferences, speakers, networking events, etc., but it also provides mentoring for younger professionals, a social environment to get to know coworkers and a way to meet people throughout the aerospace field. I've had many coworkers looking for information on something outside of their field of expertise and through local AIAA contacts, we've been able to connect the right people to make sure that the necessary information gets to where it needs to go. Now I also serve as the K–12 STEM Outreach Co-Chair for my section and through that AIAA has a hand in raising the next generation of aerospace professionals."

AIAA congratulates Karen Berger on being this year's recipient of the Lawrence Sperry Award!

Twelve AIAA Student Members Named to 20 Twenties List

Twelve AIAA student members have been named winners of Aviation Week Network's awards program: "Tomorrow's Engineering Leaders: The 20 Twenties." The winners were honored during Aviation Week's 60th Annual Laureate Awards on 2 March at the National Building Museum in Washington, DC. (Full details can be found at: http://www.aiaa.org/SecondaryTwoColumn.aspx?id=15032386449)

News

Developing Future Aerospace Leaders for America

The STEM Pipeline Program for AIAA Sections

The K–12 STEM Outreach Committee would like to recognize outstanding STEM events in each section. Each month we will highlight an outstanding K–12 STEM activity; if your section would like to be featured, please contact Supriya Banerjee (1Supriya.Banerjee@gmail.com) and Angela Diggs (Angela.Spence@gmail.com).

Dr. Supriya Banerjee, FAMES®, AIAA STEM K–12 Committee

Anusha Dixit, Poolesville High School, MD, participated in a five-week internship at GSFC. Shown with mentor Rick Harman, Ms Dixit used MATLAB to model spacecraft dynamics, and credits her internship opportunity for solidifying her decision to study aerospace engineering in college.

Summary

Purpose: To develop a pipeline of future aerospace leaders ready for the challenges of tomorrow. The STEM Pipeline Program is available to all AIAA Sections as a proven tool to engage students in exploring STEM careers in aerospace through structured engagements including science fairs, internships, and continuing education.

Benefits: The Pipeline Program benefits both students and employers. Students are exposed to real-world experiences beyond academic coursework. High school students are better equipped to make informed decisions about their college education. Undergraduate students are better prepared for future employment. Employers have an opportunity to equip and train their future workforce.

Internship Opportunities: Any STEM-related industries in your AIAA Section: NASA centers, government and DoD facilities, national laboratories, industry partners, and universities.

The Program

The AIAA National Capital Section (NCS) developed the Pipeline Program in collaboration with NASA Goddard Space Flight Center's (GSFC) Education Office in 2015. The Section leverages and enhances the Summer Internship Program that NASA offers. The program consists of the following three elements:

1. High School Science Fair Judging: AIAA members judge students' aerospace-related projects at science fairs. The 1st-, 2nd-, and 3rd-place student-winners at each fair are selected and invited to participate in the STEM Engagement Experiential Learning Program.

2. STEM Engagement Experiential Learning Project (EELP): Science fair winners participate in a three-day STEM engagement activity, EELP developed in 2014 by Drs. Supriya Banerjee and Natalia Sizov in collaboration with NASA GSFC's Education Office. EELP is designed to inspire future scientists and engineers by offering broad exposure to STEM. Students learn about innovative technologies and NASA's mission through laboratory tours. They take a trip to Wallops Flight Facility, and have the opportunity for direct discussions with scientists and engineers. In 2014, the students met with GSFC Center Director Christopher Scolese, Nobel laureate John Mather and astronaut Paul Richards. This AIAA program provides the students with exceptional opportunities to experience broad range of technologies and ongoing programs, as well as discussions with senior managers, scientists, and engineers.

3. STEM Pipeline Project: Expanding on EELP, the STEM Pipeline Project was developed in 2015 by Dr. Banerjee in conjunction with NASA GSFC's Education Office. It provides students with a longer, continuous exposure to working in STEM fields. Students participate in the existing NASA Summer Internship program, which they can continue through college, provided they satisfy NASA selection criteria. Through these exceptional internship opportunities, students gain knowledge and real-world training impossible to attain in a classroom setting. This stable educational environment is a powerful tool in the STEM vision of building an American workforce ready for the challenges of tomorrow.

Setting up the Internship Program Through Collaboration

While this program focused on NASA GSFC, Sections can work with any local STEM employers. Internship opportunities with local industries and universities may be flexible, whereas internships with local DoD or government agencies may need to be coordinated more carefully to fit within specific regulations. When more flexibility in internships is possible, the Sections may 1) identify the students by following the STEM Pipeline Process Summary, 2) work with employers to set up the program, and 3) coordinate with students to continue internships in the following years. The selection criteria for internships and stipends depend on the employer.

Acknowledgements: Sincere thanks to Dr. Sandy Magnus of AIAA for encouraging me to develop the program and to share it with AIAA Sections, Dr. Robert Gabrys of GSFC's Education Office for collaborating with AIAA NCS and providing opportunities for the students at the center, and Dr. Sandy Magnus of AIAA, Lt. Col. Tucker Hamilton and Dr. Angela Diggs of the USAF for their review and comments on the document.

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 the Crystal City Hilton Hotel, Arlington, VA on Wednesday, 3 May 2017, at 1:00 PM. *William Seymore, AIAA Corporate Secretary/Treasurer*

U.S. Navy X-47B UCAS-D Team Received 2016 AIAA Aircraft Design Award Honor

On 4 August 2016, AIAA honored the **U.S. Navy's Unmanned Combat Air System Carrier Demonstration (UCAS-D) Program Team** at a banquet held at the Patuxent River Naval Air Museum in Lexington Park, MD. The AIAA Aircraft Design Award is presented to a design engineer or team for the conception, definition, or development of an original concept leading to a significant advancement in aircraft design or design technology. The award is sponsored by the AIAA Aircraft Design Technical Committee. The 2016 award was presented to Rear Admiral Mathias Winter and U.S. Navy X-47B UCAS-D Team "in recognition of the significant advances to autonomous aircraft operations, both on an aircraft carrier and in the aerial refueling environment, as enabled by the X-47B."

The UCAS-D program marked several aviation firsts. In 2013, the X-47B accomplished autonomous carrier launch and recovery in a flight from the USS George H.W. Bush (CVN 77). This was followed in August 2014 by a demonstration of the aircraft's integration with naval aircraft operations as it operated alongside F/A-18 fighter jets aboard the USS Theodore Roosevelt (CVN 71). Shortly after, the X-47B completed autonomous aerial refuelling in April 2015.

Around 50 members of the U.S. Navy X-47B Team and 25 X-47B industry representatives participated in the AIAA Aircraft Design Award ceremony. The guest speakers for the event were James MacStravic, Acting Under Secretary of Defense, Acquisition, Technology & Logistics, and Adm. Mathias Winter, who led the X-47B Team's historic efforts in 2013 and 2014. The night concluded with remarks from Maryland State Senator Steve Waugh (also a former Marine Corps AV-8B Harrier pilot) who presented a citation from the Maryland General Assembly congratulating the Navy X-47B Team and Adm. Winter on the award achievement.

Above: RADM Mathias Winter and Northrop Grumman X-47B Design Team posing with AIAA Aircraft Design Award Certificate From Left: Joan Yazejian, Chris del Palacio, RADM Mathias Winter, USN, Aaron Munger, John Whittenbury (Photo by Joan Yazejian). Below: RADM Mathias Winter delivers remarks following presentation of the Aircraft Design Award (Photo by Liz Wolter)

CONGRATULATIONS!

AIAA congratulates the following students who won student paper competitions held during the 2017 AIAA Science and Technology Forum and Exposition (AIAA SciTech Forum). Thank you to our sponsors for their generosity.

AMERICAN SOCIETY FOR COMPOSITES BEST STUDENT PAPER AWARD

Phillip Deierling, University of Iowa, AIAA 2017-0124, "Investigation of the Effects of Porosity on the Overall Thermomechanical Properties of Graded Metal-Ceramic Composites."

GUIDANCE, NAVIGATION, AND CONTROL BEST STUDENT PAPER

Behrad Vatankhahghadim, University of Toronto, Institute for Aerospace Studies, AIAA 2017-1738, "Passivity-Based Magnetic Attitude Control with Impulsive Thrusting"

HARRY H. AND LOIS G. HILTON STUDENT PAPER AWARD IN STRUCTURES

Yile Hu, University of Arizona, AIAA 2017-1140, "Peridynamic Modeling of Fatigue Damage in Notched Composite Laminates"

INTELLIGENT SYSTEMS BEST STUDENT PAPER

Brett Israelsen, University of Colorado Boulder, AIAA 2017-0343, "Towards Adaptive Training of Agent-based Sparring Partners for Fighter Pilots"

JEFFERSON GOBLET

Zachary R. del Rosario, Stanford University, AIAA 2017-1090, "Developing Design Insight Through Active Subspaces"

Kan Liu, Air Force Institute of Technology, AIAA 2017-1144, "Continued Improvements on the Internal Convective Colling System of a Notational Hypersonic Vehicle"

LOCKHEED MARTIN STUDENT PAPER AWARD IN STRUCTURES

Kevin Knapp, Air Force Institute of Technology, AIAA 2017-1139, "Comparison of Finite Element Strain Distribution to In Situ Strain Field of a Plastically-Deformed Plate"

SOUTHWEST RESEARCH INSTITUTE STUDENT PAPER AWARD IN NON-DETERMINISTIC APPROACHES

Laurence W. Cook, University of Cambridge, AIAA 2017-0590, "Horsetail Matching for Optimization Under Probabilistic, Interval and Mixed Uncertainties"

Obituaries

AIAA Fellow Hyer Died in February

Michael W. Hyer died on 15 February. He was 74 years old.

Dr.. Hyer received degrees from SUNY-Buffalo, Purdue University, and the University of Michigan. He worked on the Super Sonic Transport at Boeing for several years after he received his master's degree in the late 1960s. He then went to the University of Michigan where he completed his Ph.D. in Aerospace Engineering.

His first faculty job was at Old Dominion University in Norfolk, VA. In 1978, Dr. Hyer started his long career at the Virginia Polytechnic Institute and State University (Virginia Tech) as a professor of Engineering Science and Mechanics, retiring as the N. Waldo Harrison Professor. He loved his teaching and research on the mechanics of composite materials and structures, but he especially cherished the relationships he built with his graduate students.

Although he retired in 2010, he remained very active in professional societies, reviewing journal articles, co-authoring papers with his former students, and supporting colleagues around the country. Among the many professional honors he received, he was especially proud to have been chosen as a Fellow of AIAA. In 2013, Dr. Hyer was awarded the AIAA-ASC James H. Starnes Jr. Award.

AIAA Fellow Cox Died in February

Dr. Kenneth J. Cox died on 27 February. He was 85 years old.

Dr. Cox earned both a B.S. and an M.S. in Electrical Engineering from the University of Texas at Austin, and later completed his Ph.D. in Digital Flight Systems at Rice University. He worked briefly at Temco in Garland, TX, and Lockheed Martin, in Denver, CO, but most of his career was at NASA working at the Johnson Space Center in Houston. He was passionate about his work on the space program and over his 40-year career with NASA he played a significant role in the Apollo and Shuttle programs, created and chaired the Avionics Technology Working Group (ATWG), and co-authored several books.

An AIAA Fellow, Dr. Cox was a member of the Technical Activities Committee in the 1990s and was also on the AIAA Board of Directors from 1992 to 1998. He also won the AIAA Mechanics & Control of Flight Award, (1971) and the AIAA Dr. John C. Ruth Digital Avionics Award (1986).

Congratulations AIAA Class of 2017 Fellows and Honorary Fellows

Photos from AIAA Aerospace Spotlight Awards Gala 2016

2017 Honorary Fellows

Natalie W. Crawford, *RAND Corporation*

Alan H. Epstein, *Pratt & Whitney*

Bradford W. Parkinson, *Stanford University*

2017 Fellows

Naval Agarwal, *The Boeing Company*

Karl Bilimoria, *NASA Ames Research Center*

Thomas Butash, *Innovative Aerospace Information Systems*

N. Jan Davis, *Jacobs Technology, Inc.*

Ari Glezer, *Georgia Institute of Technology*

Steven Griffin, *The Boeing Company*

Naira Hovakimyan, *University of Illinois at Urbana-Champaign*

Eric Loth, *University of Virginia*

Frank Lu, *University of Texas at Arlington*

Roger McNamara, *Lockheed Martin Corporation*

Daniel Miller, *Lockheed Martin Corporation*

Gary Polansky, *Sandia National Laboratories*

Richard Powell, *Analytical Mechanics Associates*

Mark Psiaki, *Virginia Polytechnic Institute and State University*

Lesa Roe, *NASA Headquarters*

Heidi Shyu, *U.S. Army (ret)/Heidi Shyu, Inc.*

George Sowers, *United Launch Alliance*

Ben Thacker, *Southwest Research Institute*

John Valasek, *Texas A&M University*

Julie Van Kleeck, *Aerojet Rocketdyne*

Todd Zarfos, *The Boeing Company*

AIAA Fellows Dinner

Tuesday, 2 May 2017
Hilton Crystal City
Arlington, Virginia

AIAA Fellows and Honorary Fellows are invited to join us to celebrate the Class of 2017 at the AIAA Fellows Dinner.

Reception: 1830 hrs

Dinner: 1930 hrs

Attire: Business

Tickets: $130/each

By Invitation Only

More information and registration:

www.aiaa.org/FellowsDinner2017

"The work and leadership of AIAA Fellows and Honorary Fellows consistently ensures that today's aerospace dreams become tomorrow's realities."

– James Maser, AIAA President

AIAA
Shaping the Future of Aerospace

SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY (SUSTech)
Assistant/Associate/Full Professors
Department of Mechanics and Aerospace Engineering

The Southern University of Science and Technology (SUSTech) Department of Mechanics and Aerospace Engineering invites applications for a number of tenured or tenure-track faculty positions. Candidates with research interests in all areas of Mechanics and Aerospace Engineering are encouraged to apply. We are seeking applications with experience in specific areas, including, but not limited to, solid mechanics, vibration, control, and the general area of aerospace engineering. Candidates should have strong commitment to teaching and demonstrated excellence in research. A doctoral degree is required at the time of appointment. Candidates for senior positions must have an established record in conducting globally recognized research and securing external funding.

Established in 2012, the Southern University of Science and Technology is a public institution funded by the municipal of Shenzhen, a special economic zone city in China. SUSTech is a pioneer in higher education reform in China. The mission of the University is to become a globally recognized institution which emphasizes academic excellence and promotes innovation, creativity and entrepreneurship. The University currently has over 200 faculty members, and is planning three faculties: Faculty of Science, Faculty of Engineering, and Faculty of Life and Health Science. The target faculty number will be 200 for Science, 300 for Engineering, and 150 for Life and Health Science Faculty.

The newly founded Department of Mechanics and Aerospace Engineering is one of the nine departments in the College of Engineering. The department expects to add more than twenty new faculty members in core research areas in Mechanics and Aerospace Engineering.

SUSTech offers internationally competitive compensation packages with fringe benefits including medical insurance, retirement and housing subsidy. Salary and rank will commensurate with qualifications and experience.

To apply, please provide a cover letter identifying the primary area of research, curriculum vitae, and research and teaching statements, and arrange for at least three recommendation letters, all forward to hiring@sustc.edu.cn.

FACULTY POSITION
AIR FORCE INSTITUTE OF TECHNOLOGY
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The Department of Aeronautics and Astronautics seeks applicants for a tenure-track Aerospace Engineering faculty position (preferably at the assistant or associate professor level). The department's most urgent needs are in the following areas: Propulsion, Controls, or Aerodynamics. In addition to an earned Ph.D. in Aeronautical Engineering, Astronautical Engineering, Mechanical Engineering or a related field, the candidate should have a demonstrated or a potential ability in teaching at the graduate level and in conducting independent research for the Air Force and other government agencies. Good communication skills, both oral and written, are essential. Applicants must be U.S. citizens and must currently possess or be able to obtain/maintain a SECRET clearance. If selected, applicants must produce proof of citizenship at time of appointment. Link to full posting can be found at https://www.usajobs.gov.

The Department offers M.S. and Ph.D. degrees in Aeronautical Engineering, Astronautical Engineering, Space Systems and Materials Science. The Department has several state-of-the-art computer and experimental laboratories. Interested candidates should send a resume and the names of three references to:

Dr. Brad S. Liebst, Professor and Head
Department of Aeronautics and Astronautics
AFIT/ENY
2950 Hobson Way
Wright-Patterson AFB, OH 45433-7765
Phone: (937) 255-3069 | E-mail: Bradley.Liebst@afit.edu

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is an Equal Opportunity/Affirmative Action employer.

1917

April 4 As a prelude to the Battle of Arras, the British Royal Flying Corps and Royal Naval Air Service begin a five-day aerial assault against German positions. Using new Sopwith Triplanes and Bristol F2B fighters, the British offensive attempts to wrest control of the airspace. Despite the new aircraft, British forces are decimated, losing 56 aircraft in five days. The campaign continues throughout the month, by which time British losses reach 139 planes in combat and many more in crashes. This month is forever known as "Bloody April." David Baker, **Flight and Flying: A Chronology**, p. 95.

April 6 The United States declares war against Germany following the resumption of unrestricted submarine warfare by Berlin. David Baker, **Flight and Flying: A Chronology**, p. 95.

1942

April 9 The Navy tests a radio-controlled TG-2 drone against the destroyer USS Aaron Ward. The drone is guided by a target-viewing TV camera in its nose. E. M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 43.

April 13 Lord Louis Mountbatten, who holds the ranks of vice admiral, lieutenant general and air marshal, is appointed chief of combined operations of Great Britain's three military services. **The Aeroplane**, April 24, 1942, p. 464.

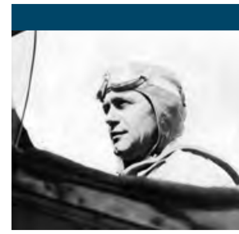
April 15 The U.S. War Department presents awards to the crew of the Consolidated B-24 Liberator, which took lend-lease administrator W. Averell Harriman on his round-the-world flight in September and October 1941, for achieving the fastest flying time around the world. Total flying time for the mission, which included a diplomatic stop in Moscow, was 121 hours and 55 minutes. Maj. A.L. Harvey commanded the crew. **The Aeroplane**, April 24, 1942, p. 464.

April 15 The island nation of Malta is awarded the George Cross by King George VI of Britain in recognition of its heroism having withstood German and Italian wartime air raids almost daily. This is the first time the king confers a decoration on a part of the British Commonwealth. **The Aeroplane**, April 24, 1942, p. 464.

April 18 Lt. Col. James Doolittle makes his daring raid on Tokyo, Yokohama, Kobe and other Japanese cities with 16 North American B-25B Mitchell medium bombers flying from the aircraft carrier USS Hornet. The surprise attacks start fires in war industry factories and naval establishments. Although damage is minimal and most of the planes must crash because they do not have enough fuel to reach Chinese bases, the mission greatly boosts American morale and shocks the Japanese leadership. Doolittle is awarded the Medal of Honor and is promoted to brigadier general. **The Aeroplane**, May 15, 1942, p. 550; Roger Bilstein, **Flight in America 1900-1983**, pp. 146-147.

April 19 A Macchi C.205 Veltro prototype makes its first flight. It is essentially a Macchi C.202 Folgore equipped with a more powerful license-built version of the Daimler-Benz DB 605 engine and armed with two wing-mounted 20 mm cannons. It subsequently becomes the best Italian fighter aircraft of the war, capable of combating the best Allied fighters of the war. William Green, **Warplanes of the Second World War — Fighters, Vol. 2**, pp. 166-167.

April 24 A Douglas A-20A twin-engine bomber completes 44 takeoffs using liquid-propellant jet assisted takeoff, or JATO, rocket units developed by the Guggenheim Aeronautical Lab at the California Institute of Technology. This development originated in 1939 as a student project by Frank Malina under the guidance of Theodore von Kármán. E.M. Emme, ed., **Aeronautics and Astronautics, 1915-60**, p. 43; R. C. Hall, ed., "Essays on the History of Rocketry and Astronautics," **NASA Conference Publication 2014**, Vol. 11, pp. 153-191.



April 30 Brig. Gen. H.H. George, who commanded the U.S. Army Air Forces in the Philippines during the struggle for the Bataan Peninsula, is killed in an airplane accident in Australia. **The Aeroplane**, May 8, 1942, p. 522.

1967

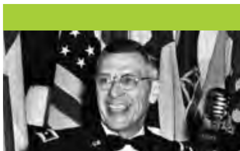
April 6 Trans World Airways, or TWA, retires the last of its propeller-driven Lockheed Constellation airliners, thereby becoming the first major American airline to be equipped with an all-jet fleet on domestic and overseas routes. **New York Times**, April 7, 1967, p. 62.

April 10 The Douglas DC-8-63 stretched jet transport takes off from Long Beach, California, on its first flight; at 158,760 kilograms it is the heaviest of the three stretched DC-8s. **Aviation Week**, April 17, 1967, p. 43.

April 17 Aeroflot Soviet Airlines and Japan Air Lines initiate their Moscow-Tokyo-Moscow air service, flying Tupolev Tu-114 aircraft. **Aviation Week**, April 3, 1967, p. 37.

April 18 Norwood Hanson, an aerobatic exhibition aviator and philosophy professor at Yale University, dies in the crash of a Grumman F8F Bearcat. **Aviation Week**, May 1, 1967, p. 25.

April 19 The U.S. Air Force's SV-5D Lifting Body is launched by an Atlas booster rocket from Vandenberg Air Force Base, California, for a re-entry mission and telemeters some excellent data. This is the third of four SV-5Ds in the program. **Technology Week**, April 24, 1967, p. 13.



April 19 Retired Maj. Gen. Holger Toftoy dies at Huntsville, Alabama. Toftoy was the U.S. Army Ordnance officer who recommended that Wernher von Braun, the former technical director of Germany's V-2 rocket development team during World War II, be allowed to come to the U.S. Toftoy had also been responsible for acquiring and shipping about 100 operational V-2s to the U.S., where von Braun's team of approximately 120 people worked on them and imparted their knowledge of large-scale rocketry to the Americans, **New York Times**, April 20, 1967.

April 19 The Surveyor 3 becomes the second U.S. spacecraft to soft-land on the moon when it touches down in the Ocean of Storms and transmits the first of 6,000 detailed TV pictures to NASA's Jet Propulsion Laboratory. Surveyor's primary mission is to take photos in the search for likely landing sites for the upcoming manned Apollo missions. **Washington Post**, April 22, 1967, p. A4.

April 20 The fifth Environmental Survey Satellite, ESSA 5, is placed into orbit by an improved NASA/Douglas Delta DSV-3E booster in a launch from Vandenberg Air Force Base, California. ESSA 5 will become part of the Tiros operational system. **Aviation Week**, April 24, 1967, p. 35.

April 23 The USSR launches its new manned Soyuz 1 spacecraft with cosmonaut Vladimir Komarov as the pilot, although Komarov dies when his space capsule fails to re-enter properly and crash-lands. **New York Times**, April 24, 1967, pp. 1, 27.

April 26 Italy's San Marco 2 satellite is launched into orbit from a converted off-shore drilling rig near the African port of Mombasa by an American four-stage solid-propellant Scout vehicle. The 129 kilogram satellite was designed and prepared by the Italian Commission for Space Research. **Aviation Week**, May 1, 1967, p. 25.

April 28 McDonnell Aircraft Co. and Douglas Aircraft Co. merge, becoming McDonnell Douglas Corp. and based in St. Louis. Before a merger in 1986 with Boeing, McDonnell Douglas produces such well-known aircraft as the DC-10 and F-15 Eagle fighter. **Aviation Week**, April 24, 1967, p. 35.

April 28 A Titan 3-C boosted five satellites into orbit: two Vela nuclear detection satellites and three scientific satellites. The Velas are designed to monitor space for violations of the nuclear test ban treaty. The scientific ERS-series satellites obtain data on radiation of Van Allen belts and solar radiation. **Washington Post**, April 29, 1967, p. A4.

1992

April 23 German test pilot Karl-Heinz Lang makes the first flight of an X-31A Enhanced Fighter Maneuverability, or EFM, demonstrator from its new home at NASA's Dryden Flight Research Facility at Edwards Air Force Base, California. The X-31 EFM Program developed the first international X-plane to demonstrate the feasibility of agile flight in the deep post stall regime, as well as the potential value of this type of maneuvering in close-in, air-to-air combat. The two X-31s were relocated to Dryden from Rockwell's Palmdale facility in January at the same time as the formation of the multination, multiagency X-31 International Test Organization that would conduct flight research and test operations over the next 3 1/2 years.

Contributed by AIAA fellow Michael S. Francis, former X-31 program manager for DARPA.

April 27 NASA reports that the Hubble Space Telescope discovered the hottest star ever recorded, in the Great Magellanic Cloud. It burns at 199,982 degrees Celsius (360,000 Fahrenheit), or 33 times hotter than our sun. NASA, **Astronautics and Aeronautics, 1991-1995**, p. 198.

DON MAHR, 36

Orion Jettison Motor Program Manager
Aerojet Rocketdyne

Don Mahr leads a 50-person team at Aerojet Rocketdyne in Sacramento, California, that's building solid rocket motors for Lockheed Martin Space Systems, prime contractor for NASA's Orion crew capsule. An Orion capsule would be propelled away from an exploding or crumbling Space Launch System rocket by a stack of three solid rocket motors attached to an aeroshell over the capsule. Within this Launch Abort System, Mahr's team builds the jettison motor that would, after some harrowing moments, lift the aeroshell and motors off the capsule so that Orion and crew can descend slowly earthward under parachutes. On a normal ascent, the jettison motor will fire before Orion reaches orbit to prepare it for the return trip to Earth. One of the motors will fly in late 2018 on the first SLS launch, likely a crewless trip around the moon, called Exploration Mission 1.

How did you become an aerospace engineer?

My grandfather worked at Aerojet in the late 1960s, through the 1970s and into the '80s as a welder. I was inspired by that. In high school, physics was a subject I really liked, so I chose to become a mechanical engineer. I went to the University of California, Santa Barbara, where I earned an engineering degree in 2003 and went to work in heating and air conditioning. But that wasn't nearly as cool as rockets so I went to work for Aerojet Rocketdyne. I started work on the jettison motor as a manufacturing engineer in about 2008 and was responsible for taking the design and creating instruction manuals on how to build it. Then I became the manufacturing lead where I defined and managed the tools, people, schedules that it took to build the jettison motor. In 2014, I became the jettison motor program manager. Now, my job is the whole project, including customer interaction, negotiations, proposals, schedules and contract deliveries.

Imagine the world in 2050; what do you expect to see in space?

I expect by 2050 we will have thermonuclear and solar propulsion technologies fielded for human space applications enabling humanity to colonize Mars. I think the country and humanity are very motivated to go to Mars and beyond because there is much to learn about our existence. Challenging ourselves to push beyond current limitations is what makes us better as a human race. ★

By Debra Werner | werner.debra@gmail.com