April 2016

AEROSPACE AMERICA

PROXIMA CENTAURI

Could we reach this star before the end of the century?

Learn what it would take

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ON THE COVER

In this Hubble image is our closest stellar neighbour: Proxima Centauri.
Credit: ESA/Hubble & NASA

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AIAA
Shaping the Future of Aerospace

Editor's Notebook

From interstellar travel to Battlestar Galactica

Here's the inside scoop on this month's cover words: When our contributor, Michael Peck, said he wanted to explore technologies that might get a tiny spacecraft to the vicinity of another star by the end of the century, the words "Space: 2099" popped into my head. It was a play on the 1970s TV show, "Space: 1999." Wisely, we tested that reference on a couple of young aerospace professionals, and based on this small sample, I concluded that "Space: 1999" was not a cult hit among millennials.

What I hope will be a hit is the idea that this generation should be unleashed to think big when it comes to space. What we're starting to see is how matters might unfold: NASA and universities will conduct groundbreaking research, governments will lead the way on human and robotic exploration, and private companies will assist and create lines of business that we can't foresee today. Novelist Andy Weir put it succinctly in our March edition, when he said that if he'd written "The Martian" today, he probably would have had SpaceX build the presupply probes, although he's "pretty sure that first manned mission to Mars will be done by governments, not private spaceflight."

For Elon Musk, those might be fighting words. I can't wait to watch this unfold.

Another television show also came to mind when creating this month's edition: "Battlestar Galactica," specifically the original late-1970s incarnation. Since the early 1990s, I've been hearing experts bemoan the size and cost of satellites. They've compared them to school buses, fur-lined glove boxes, giant suitcases (let's squeeze in one more pair of $150-million socks, shall we?) and, of course, Battlestar Galactica.

The advent of cubesats, ride-sharing and small rockets has me believing that we might in fact be witnessing the seeds of "disaggregation," the buzzword describing the possibility of many small satellites doing tasks that today are done by large satellites. This could even include some critical missions, like gathering weather data for severe-storm forecasting, the topic of the story I reported, "Weather soundings: A challenge to the status quo," on page 32.

From reporting that story, I can say there are lots of "ifs" ahead before we know just how large a role disaggregation can play. Those who don't like to alarm the status quo are fond of portraying their small-satellite constellations as "complementary" to what's already up there. At some point, however, buying into something new only makes sense if it can replace something old. That said, I can understand why an agency like NOAA would want lots of evidence before making such a shift, given the importance of severe-storm forecasting.

Expect lots of interesting stories ahead on topics ranging from disaggregation to space business to the quest to understand the cosmos.

Ben Iannotta
Editor-in-Chief

Grill the candidates about space R&D

I am concerned for the lack of words about space research and development from all of the presidential candidates. What is the vision? Is there a national vision other than sweet and slick slogans?

As a young engineer working for NASA Manned Spacecraft Center in Houston, I worked on Apollo. President Kennedy had placed a challenge before us to go to the moon and back. We stretched our intellect and imagination to create new exotic technologies that led to cryogenic medicine, increased computer storage and processor speeds, laser communications, better weather forecasting and many other innovations. The economy was humming beyond our imagination. NASA did much more than meet Kennedy's challenge of landing on the moon before the end of the 1960s.

This is why it is disappointing when the current administration says, "Why go to the moon? We did this, got the ticket punched, and there is no need to return." America is surrendering leadership to the Chinese, Indians and the Russians, who are free to do whatever they wish with the resources on the moon. Helium-3, for example, is on the lunar surface in solid form, but not readily available on Earth. It is an ideal fuel for a fusion reactor.

As others have pointed out, not returning to the moon would be like hearing Lewis and Clark talking about the amazing resources on the West Coast, but then no one else bothering to head west.

As a humble citizen, I place this challenge before the presidential candidates. Let the capable strive and struggle for a worthwhile goal to excite our imagination without government impediments so we can run as fast as possible. Repairing and building bridges, highways or railroads are all important, but they lack imaginative challenges. We have to step beyond our intellectual comfort zone. The moon and Mars may do this, as may knowledge about the brain and developing green energy. Without a solid belief or political courage to meet the challenges of seriously funding R&D, we offer mankind nothing. We need to stroke the worldwide technology edge, thereby creating new jobs and stirring America's imagination. I ask you to make a realistic contract for future generations to enhance technology so Americans can satisfy mankind's curiosity and touch and solve the unknown quests placed before us.

P.A. Murad
AIAA Associate Fellow
Founder, Morningstar Applied Physics, LLC
Vienna, Virginia

Editor's note: NASA says it still loves the moon, but it will leave it to its international partners to land there.

Events Calendar

4 - 6 April 2016
51st 3AF Conference on Applied Aerodynamics:
"Thermal Effects and Aerodynamics"
Strasbourg, France

19 - 21 April 2016
16th Integrated Communications and Surveillance
Herndon, Virginia

16 - 20 May 2016
SpaceOps 2016:
14th International Conference on Space Operations
Daejeon, Korea

24 - 26 May 2016
The Fifth International Conference on Tethers in Space
Ann Arbor, Michigan

30 May - 1 June 2016
22nd AIAA/CEAS Aeroacoustics Conference
Lyon, France

Unsettled climate debate?

In the February edition, the Editor's Notebook column speaks about climate change as if the issue were settled. This implication ignores some very important points based on science:

- Geological research has made clear that the Earth's climate has always been in flux.
- The sun cycles and directly affects the amount of energy deposited on Earth and other planets.
- Ice ages came and went long before the inventions of the internal combustion engine and chlorofluorocarbons.
- It's been reported and to my knowledge not disputed that NOAA has adjusted climatological data. Data are for analysis, not adjustment. That is the bedrock of the scientific method.

In the same edition, the article "Curbing Contrails" includes this incredible statement on page 22: "The contrail cirrus coverage around the globe at any given time exerts a higher radiative forcing than the CO_2 that has been emitted from all aircraft in history." This is incredible hyperbole. The article did include a statement from another individual that said (paraphrasing) our current knowledge of contrails' effect on the atmosphere is quite low.

Exactly!

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Editor's note: The science behind the contrails quote can be found in the 2011 paper, "Global radiative forcing from contrail-induced cloudiness." Bernd Kaercher, who made the statement, says he understands this kind of reaction. "It is an astounding finding and has raised many an eyebrow, but it is not hyperbole."

All letters addressed to the editor are considered to be submitted for possible publication, unless it is expressly stated otherwise. All letters are subject to editing for length and to author response. Letters should be sent to: Correspondence, Aerospace America, 12700 Sunrise Valley Drive, Suite 200, Reston, VA 20191-5807, or by email to: beni@aiaa.org.

Air Force weighs sense and avoid options

The U.S. Air Force plans to start an analysis of alternatives later this year or early next to assess sense and avoid options for its remotely piloted aircraft, including Reapers and Global Hawks.

At the moment, the service prevents collisions by requiring unmanned aircraft to stay on predetermined courses within predetermined operational areas, so that airborne pilots will know where to expect unmanned planes.

That has made it hard for unmanned aircraft to team closely in combat with traditionally piloted planes or to fly from one location to another through civilian airspace. The FAA requires the Air Force to apply for special permission in the form of a certificate waiver or authorization, when it wants to fly an unmanned plane through the national airspace.

To get ready for the analysis of alternatives, the Air Force issued a request for information in January to the industry detailing the capability it wants in a sense and avoid system that could be in production by 2020. The Air Force wants a device that will ensure unmanned aircraft miss other aircraft by a horizontal distance of at least 500 feet, and a vertical distance of at least 100 feet. To maintain safe separation from other aircraft, called due regard, the sense and avoid system should keep a distance of at least 450 feet vertically, with horizontal distance of 4,000 feet. But because of different flight speeds, the aircraft must also stay 35 seconds apart.

The equipment would be primarily designed for Group 4 and 5 remotely piloted aircraft, which are composed of larger unmanned aircraft such as the Predator, Reaper, Global Hawk and Sentinel.

Sense and avoid would make it easier for Air Force unmanned craft to fly in U.S. "national airspace, other nations' airspace, over international waters, and in military (combat) airspace," says Joe Schmidt, the Air Force Life Cycle Management Center's program manager for the Common Airborne Sense and Avoid program.

While the equipment will be designed for Air Force needs, it could be installed on other services' un-

Weaning the U.S. from Russia's RD-180 engines

A debate has raged in the U.S. about how to end the irony of the U.S. monitoring Russian actions in Ukraine and Syria with American satellites launched by Russian RD-180 rocket engines. RD-180s power the first stages of the United Launch Alliance Atlas 5 rockets. The debate is sure to heat up this year as Congress considers the U.S. Air Force's proposal to solve the problem by developing an entirely new rocket. This is a timeline capturing how we got here.

2014

March
- Sanctions imposed after Russia annexes Crimea.
- Russian Deputy Prime Minister Dmitry Rogozin tweets: *"All these sanctions aren't worth a grain of sand of the Crimean land that returned to Russia."*

April
- Elon Musk and SpaceX sue Air Force to void sole-source ULA contract to open more national security launches to competition.
- Judge issues injunction on RD-180 purchases pending sanctions review.

May
- Russia threatens to halt export of RD-180s for U.S. national security use.
- Injunction lifted on RD-180 purchases. Russia's Rogozin tweets: *"Do they think that I keep the money from sales of our engines from state enterprises for myself? Morons."*
- "Mitchell Report" calls for U.S.-made alternative to RD-180.

June
- House 2015 appropriations bill includes $220 million for U.S.-made replacement.
- White House opposes funding for U.S.-made replacement.
- ULA says it will fund studies for replacing RD-180 by 2019.

July
- Air Force asks the U.S. industry for information about a new engine.
- Tory Bruno replaces Mike Gass as CEO of ULA.

September
- ULA, Blue Origin announce partnership to develop BE-4 engine.
- Aerojet Rocketdyne says ULA will continue to fund the AR1 engine as backup to BE-4, a fact ULA later confirms.

December
- Final 2015 defense appropriation includes $220 million for alternative engine; authorization bans future military use of engines designed or produced in Russia, leaving ULA with five RD-180s.
- ULA acknowledges proposal to buy up to 30 more RD-180s despite U.S. ban on use in military launches.
- SpaceX drops lawsuit against Air Force, which agrees to open more near-term launches to competition.

2015

February
- Air Force Secretary Deborah Lee James tells Congress it's not feasible to replace RD-180 by 2019, as required by law.
- ULA says it will phase out most versions of Delta 4 by 2018, eliminating a possible alternative to Atlas 5 and RD-180.

March
- Sen. John McCain accuses Air Force of stalling on RD-180 replacement effort.
- Air Force says RD-180 ban hinders ULA in competition against SpaceX.
- Rep. Mike Rogers of Alabama signals willingness to consider relaxing RD-180 import ban to keep ULA competitive.

April
- ULA unveils details of proposed Atlas 5 replacement, the Vulcan.
- Air Force strategy calls for investing in engine technologies, but not necessarily a specific RD-180 replacement.

KEY
- **Russia**
- **Industry**
- **Congress**
- **U.S. government**

manned aircraft.

Schmidt cautions that even with sense and avoid, permission from the FAA might still be needed in some cases.

Sense and avoid could remove a barrier to unmanned military aircraft flying over international waters where airliners and other planes cruise. Under a Department of Defense instruction issued in June 2015, unmanned aircraft are restricted from flying over international waters unless they meet one of a number of due regard, or safety, conditions, such as operating in visual flying conditions, or being continuously monitored by, and in communication with, surface or airborne control facilities.


Northrop Grumman

The U.S. Air Force is asking commercial companies whether they could quickly develop technology that would enable unmanned aircraft such as the Global Hawk to automatically detect other aircraft and move out of the way. Such sense and avoid capability is critical for military drones to fly through national airspace without restrictions.

In the case of unmanned aircraft, due regard is also met if unmanned aircraft are "equipped with a Military Department-certified system that is sufficient to provide separation between them and other aircraft," according to the Department of Defense directive. Schmidt says sense and avoid will make it much easier to meet that condition.

Michael Peck
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May

- ULA rejects inquiry from Aerojet Rocketdyne, others about obtaining Atlas 5 production rights.
- White House favors a broad replacement strategy rather than direct replacement for RD-180, as mandated in House 2016 authorization bill.
- ULA's Bruno warns that unless RD-180 ban is lifted, ULA will not be able to stay in the military launch market until new Vulcan is ready.

June

- Air Force issues request for proposals seeking propulsion technologies and concepts.
- A SpaceX Falcon 9 explodes during ascent in a setback for Atlas 5's main competitor.

July

- Air Force says 22 more RD-180s will be needed to keep ULA competitive with SpaceX until ULA's Vulcan is ready.

September

- House and Senate agree to authorize ULA to use four more RD-180s for military missions. President Obama vetoes bill over unrelated provisions.

October

- ULA assigns five RD-180s for civil launches; says it will be unable to bid for upcoming GPS launch absent relief from RD-180 ban.

November

- Bidding deadline for GPS launch passes; ULA does not bid, citing RD-180 ban and other issues.
- Obama signs 2016 defense authorization bill with provision making four more RD-180s available for Pentagon competitions.

December

- Air Force awards rocket research contracts to Aerojet Rocketdyne, Orbital ATK and Northrop Grumman.
- Obama signs 2016 defense appropriations bill providing $228 million for RD-180 replacement and overturning ban on use of RD-180s for military missions.
- Sen. John McCain accuses ULA of *"manufacturing a crisis"* and says lifting ban on RD-180 imports *"is the height of hypocrisy, especially for my colleagues who claim to care about the plight of Ukraine and the need to punish Russia for its aggression."*
- ULA orders 20 more RD-180 engines.

2016

January

- Orbital ATK and SpaceX receive Air Force rocket research contracts worth up to a combined $241 million.
- Sen. John McCain and House Majority Leader Kevin McCarthy introduce legislation to reinstate RD-180 ban.

February

- 2017 budget request seeks $297 million toward a "next generation" launch system, rather than new engine for Atlas 5.
- Rep. Rogers states: *"The Air Force is planning a program that violates current law."*
- Pentagon's Frank Kendall says Treasury Department has made a preliminary finding that RD-180 purchases do not violate sanctions, despite reorganization of Russian space sector.
- Air Force announces a contract worth up to $536 million to Aerojet Rocketdyne for development of AR1 engine and a contract worth up to $202 million to ULA for development of Vulcan.

Photo credit: ULA

Research by Warren Ferster

Graphic by: FiscalTrak
www.fiscaltrak.com

ULA, Ball Aerospace interns poised to launch amateur rocket

A five-year campaign by interns working for United Launch Alliance, the Boeing-Lockheed Martin joint venture based in Centennial, Colorado, is slated to culminate in July with the launch of Future Heavy, which may be the world's largest amateur rocket.

If all goes as planned, the 15-meter-tall rocket powered by eight first-stage and two second-stage solid rocket engines will soar 10,000 to 11,000 feet over southern Colorado and dispense scientific instruments and experiments devised by elementary, middle, high school and college students.

Each summer, ULA interns design, build and launch high-power sport rockets, while interns working for Ball Aerospace & Technologies, the Boulder, Colorado, manufacturer of spacecraft and instruments, provide payloads. Ball plans to put this year's summer interns to work designing and building payloads to fit in Future Heavy's 1.8-meter-long, 61-centimeter-diameter fiberglass tube inside the Future Heavy rocket's carbon fiber fuselage.

"You could easily fit an intern in there," jokes Jaron Davis, a Ball Aerospace systems engineer who oversees BIRST, Ball's Intern Rocket Science Team.

With 6,500 pounds of thrust, the Future Heavy rocket also will be powerful enough to lift that intern, says Greg Arend, who leads ULA's additive manufacturing program and the company's Student Rocket Launch program.

In recent years, ULA and Ball interns have launched smaller rockets, ranging in size from about three to seven meters. Because the Future Heavy rocket is more than twice the size of those launch vehicles, Ball employees who volunteer to serve as mentors for the company's interns are getting a head start on the summer project.

United Launch Alliance interns prepare their high-power sport rocket, Stars 'N' Stripes, for launch in Pueblo, Colorado, last July. This summer, ULA interns plan to launch a much larger rocket, the 15-meter-tall Future Heavy, which is designed to break the record for the largest amateur rocket ever flown.

Before the interns arrive, Ball engineers plan to build one or two aircraft that the Future Heavy rocket will release after it reaches its apogee, deploys parachutes and detaches its nose cone. Once the Ball interns arrive in May, they will have about eight weeks to devise missions. The students will decide whether to build instruments to mount on the aircraft that flies out of the rocket or to build instruments that do not ride on the aircraft, but instead are housed in an area of the rocket's payload fairing behind the aircraft. The instruments that are not mounted on the aircraft will be jettisoned from the rocket after the aircraft leaves the rocket.

ULA and Ball interns work 40 hours a week for pay, working for example on ULA's Atlas rocket or helping to test the weather and climate-monitoring instruments Ball is building for the NASA-NOAA Joint Polar Satellite System constellation. Interns can't devote any of that 40 hours on the rocket components or instruments, but the companies provide plentiful pizza or other food to fuel after-hours efforts.

During the core of their internships, students play a small role in a large aerospace program, but the Future Heavy campaign allows them to experience the entire life cycle of a mission from design through construction, testing and flying, Davis says.

The companies also benefit because the program helps them attract talented interns who sometimes continue to work for the company after graduation.

"A lot of folks tell us they heard about how cool our internship program was because in addition to the day job, they get an after-hours opportunity to build and launch a rocket," Arends says.

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Talking hypers

Mark Lewis, director of the Science and Technology Policy Institute at the Institute for Defense Analyses

If Mark Lewis were merely a renowned expert on hypersonic flight, that would be distinction enough for one scientist's career.

But Lewis also directs a think tank in Alexandria, Virginia, that advises the White House on science and technology. He also served four years as chief scientist of the U.S. Air Force, as well as a term as president of AIAA.

*Lewis spoke to **Michael Peck** by phone to share his thoughts on the cutting edges of technology, such as hypersonic flight. What are the challenges of building a hypersonic vehicle that can fly at Mach 6? Can we build a machine that will reliably fly through the atmosphere at Mach 18?*

Lewis also delves into organizational woes that have hampered the development of hypersonic vehicles, as well as the military's plans for hypersonic weapons and how troubled relations between the Pentagon and NASA have softened. He also assesses President Obama's science budget, and the role of commercial companies in spaceflight.

You spent 24 years at University of Maryland, and then four years as chief scientist of the Air Force from 2004 to 2008. What was it like moving from an academic to a military setting?

One of the really fun parts of that job is that the environments are so different. In the Pentagon, people judge their self worth by the meetings they are invited to. On a university campus, people judge their self worth by how many meetings they don't have to go to. In the Pentagon, there is a lot of protocol, which is completely nonexistent in an academic setting. But I actually found the culture of the Air Force quite welcoming. In the military culture, people are constantly moving from job to job. Everyone is the new guy. One of the expectations of the Air Force is that the chief scientist will come with an outsider's perspective.

Any achievements you are particularly proud of during your Air Force tenure?

I can point to a number of things. One is the overall amount of basic research. The Air Force has always had a very strong basic research portfolio. But when it comes time to cut the budget, people are often looking at the basic research portfolio to save money. When I was there, we were able to plus-up the basic research budget. My own research area is hypersonic flight. I was able to get very much involved with that. We had a couple key programs along those lines. The Air Force's X-51 was probably the crowning achievement of hypersonic flight. We also set up a joint program with Australia called HIFiRE [Hypersonic International Flight Research Experimentation] that produced some really good science.

Here's something else I look back on fondly. When I came into the Pentagon, there were strained relations between the Air Force and NASA. There was a lot of blame to go around there, a lot of bad behavior from both NASA and the Air Force.

Previously there had been tensions because each of the organizations had made unilateral decisions that impacted the other; programs canceled without telling the other partner, that sort of thing. We were able to put that aside and build some strong partnerships, especially in aeronautics. Even today, we see a degree of interaction between NASA and the Air Force, especially in aeronautics, and especially in hypersonics.

What is your assessment of the current state of hypersonics? Particularly since there have been at least three spectacular mishaps with DARPA and Air Force hypersonic vehicle tests since 2011?

I'd say this is a good news/bad news story. We have leadership in the Air Force, in the office of the secretary of defense, and in the White House as well that [say] hypersonics is important to the future of our military. DARPA is putting a lot of money into hypersonics. NASA, which had been doing a lot of work in hypersonics but was ramping down quickly, is now ramping back up, and specifically in conjunction with the Air Force. If I were to point to the bad news, it is that we don't have a coherent, consistent national plan for hypersonics. So you have a lot of disparate activities, but not the level of national coordination I'd like to see.

Can you give some examples?

In May 2013, the Air Force had its fourth and final flight of the X-51. It was spectacularly successful, and it showed beyond a shadow of doubt that scramjets — the engine of choice for hypersonic vehicles — are functional and worked as predicted. All the test points went through our onics

Interview by Michael Peck
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Mark Lewis says one of his chief achievements during his stint at the Air Force was to help repair the service's strained relationship with NASA.

predicted data when the program first started, so it was a beautiful conjunction of analysis and computation and ground test that culminated in a flight program that did everything it was supposed to do. It was one of the most important accomplishments in the history of hypersonic flight. And what do we do to follow it up?

Well, the current plan is that the United States might fly another scramjet-powered vehicle in maybe 2018 or 2019 — and only if everything is on schedule. When you have a success, you should immediately build on it. And it's not just the Air Force. NASA flew the X-43 in 2004. Again, a highly successful hydrogen-powered scramjet that got us almost to Mach 10. And what did they do as a follow-up? Not much. You've got lots of people saying we should move forward, but we don't see timelines for a nationally coordinated effort that would get us there.

Would it make sense to designate one agency as the lead organization for hypersonics?

Not necessarily. One question has always been, what is NASA's role in hypersonics? If the first application of a hypersonic system will be a military application, a weapons application, which I think it will likely be, does NASA have a role? I think the answer is yes. There are so many fundamental issues of hypersonics that we need to be working on, and these are the issues where NASA excels. I would argue what we need is better coordination.

What challenges do you see in hypersonics? I'm thinking of issues like controlling vehicles at hypersonic speeds.

There are the classic challenges. Propulsion challenges, materials, control, systems integration. But all of these issues are solvable. We already know how to build an engine that operates at five times the speed of sound. Getting to Mach 6 or 7 will be difficult but not impossible. We know that survival of materials under those conditions is difficult, but we have a good handle on what materials are required and how to manufacture them. You're right about controllability. But there, it's also maneuverability. I may be able to control my vehicle to fly in a straight line or do gentle maneuvers, but for a truly effective system, I want to be able to bank and dive and roll.

Our understanding of what is possible there is a bit lacking. There are also some fundamental aerodynamics challenges. The very basic question of whether the flow near the surface of a hypersonic vehicle is smooth and laminar, or chaotic and turbulent, we don't quite understand yet. But we've learned a lot over the past few years.

What about the question of rocket or scramjet propulsion for hypersonic vehicles?

I've always argued that it's best to be propulsion agnostic. The best evidence so far suggests that if I'm going to fly for long distances in the atmosphere, I want a scramjet. Rockets give you very high thrust-to-weight ratios, and they are very effective at short distances. Rockets are also the best solution if I'm flying a very long distance. For the intermediate range, I probably want to stay in the atmosphere, which means a scramjet.

There is some work on an Air Force and DARPA Tactical Boost Glide system — a rocket-boosted hypersonic vehicle — and it's interesting to develop that technology. It might be a reasonable solution. I don't know whether it will be better than a scramjet, but it might be a complementary solution.

We're speaking of Mach 6 or Mach 7. What about hypersonic vehicles that fly at Mach 18?

In the days of the National Aero-Space Plane in the 1980s, the vehicle was originally supposed to go 25 times the speed of sound. One of the things we learned is that we don't know how to do that. The thing to remember is that energy scales with the square of velocity. When I double my Mach number, I multiply the energies involved by a factor of four. Mach 18 is a lot harder then Mach 6. DARPA tried to fly the HTV-2 [DARPA's Hypersonic Technology Vehicle 2] at high Mach numbers, and it got into some significant heating issues.

So do you think that the practical limit for hypersonic flight is in the single-digit Mach numbers?

It depends on the application. We have already built vehicles that operate at much higher speeds. When the space shuttle reentered the atmosphere from orbit, it was going Mach 24. An Apollo spacecraft returning from the moon was traveling Mach 36 when it reentered into the atmosphere. The question is building things that can be very slender, have very low drag and can fly for long distances at those Mach numbers. I honestly don't know what the limit is. For some of the weapons applications, the airbreathing vehicles, you don't have to fly much faster than Mach 6 or 7. It may not be worth the investment in the extra technology for the higher Mach numbers.

Do you think that Prompt Global Strike, a hypersonic weapon that could hit any target on Earth within an hour, is technically feasible?

I try to separate Prompt Global Strike from tactical applications. I think the first important applications of hypersonic technology will be the tactical ones. It will be high-speed cruise missiles, or the shorter-range systems, will make a lot more sense for the short term than Prompt Global Strike.

So we are only talking faster iterations of what we have now?

Mark J. Lewis

Title: *Director, Science & Technology Policy Institute at the Institute for Defense Analyses*

Age: *Turns 54 on April 3*

Birthplace: *Yonkers, New York*

Education: *B.S. aeronautics and astronautics and B.S. in Earth and planetary science; M.S. in aeronautics and astronautics; doctor of science in aeronautics and astronautics; all degrees from MIT*

Previously: *Faculty member, University of Maryland College Park (1988-2012); chief scientist of the U.S. Air Force (2004-2008)*

Residence: *North Potomac, Maryland*

Family: *Wife, Jill, an aerospace engineer; daugher, Emma, 20; and son, Samuel, 17*

Favorite quote: *"Risk is our business." Captain Kirk from "Star Trek"*

Think about fast cruise missiles. Think about a cruise missile that instead of traveling at Mach 0.8, is performing its mission at Mach 5 or Mach 6.

In the past, you've said that we need to have a balance between government and private space initiatives. With the rise of commercial space companies, do you think we have an imbalance now?

It's hard to say. When the Air Force launches rockets, they are rockets built by industry. I think there has been an artificial delineation between government and industry. What we are seeing now, of course, are new space companies like SpaceX.

It is hard to say what the right balance is. It is fair to say that these new companies have injected a level of enthusiasm and a motivation factor for young aerospace engineers that have been quite refreshing for the field.

Propulsion is one of your specialties. Are there any forms of space propulsion that you see as particularly promising?

I'm a propulsion guy, so at the end of the day, I think the secret to aerospace success is propulsion. The challenge that we have is that rocket engines are about as efficient as we think they can get. So you scratch your head and ask, how do we improve on this? There are a couple of answers we've known for a while. One is nuclear power.

Almost 50 years ago, we were talking about nuclear-powered rocket engines. Even today, we know that a nuclear-powered thermal engine, a rocket that uses the heat from a nuclear reactor, can outperform chemical engines. But of course, they have some baggage with them.

One of the most exciting things I've seen over the last few decades has been the acceptance of electric propulsion as a viable option — almost an off-the-shelf option — for spacecraft. But the catch to electric propulsion is that so far, all of our electric systems are low-thrust. It is not the answer to every mission. One of the reasons I'm a big fan of hypersonics is that I can step back and ask, how do I improve on a launch system? What are the alternatives to rockets? Given that rockets are so efficient, the only thing I can come up with as an alternative is to do airbreathing propulsion. I'm not carrying oxygen with me as I go into space, so I'm saving the weight of the oxygen, and I save on the weight of the structures to haul the oxygen. That's why I think hypersonics is ultimately so promising for access to space. Just not for a while.

President Obama's proposed fiscal year 2017 budget calls for a 4 percent increase in research and development funding. Do you see this as sufficient? Do we have the right priorities?

It's a rule of thumb that we never spend enough money on science and technology. But any increase is a good one. Yet more important than the total dollars is how you're spending them. What's exciting about that is the proposed NASA budget has a significant increase for aeronautics. For those of us who love aerospace systems with wings, that's a very positive development. That's also a tribute to leadership. The current NASA Administrator, Charlie Bolden, even though he flew in space, is a tremendous fan of the first "A" in NASA. He speaks about aeronautics often.

What research areas do you believe we need to invest in?

Hypersonics is one. Autonomy is an area that deserves investment, and new manufacturing technologies are important. One area that we do need to focus on is low-cost access to space. We have been talking about this for decades, and there have been forays into it, and yet there is still a need for inexpensive access for payloads into orbit. This is now more important than ever as we see an explosion of new satellite technologies such as small satellites and cubesats.

You have been in the aerospace field almost 30 years. What are the most striking changes you've seen over your career?

The thing that strikes me is a bit of a negative. When I was growing up, if you had told me that this many years after the Apollo moon landing, we are still not back on the moon, I would have been shocked. In 1968, the movie "2001: A Space Odyssey" depicted a large space station, regular passenger traffic to and from low Earth orbit, regular transits to the moon where we had international bases. We do have a space station now. We no longer have a space shuttle. We never established moon bases.

Back in 1968, I would have said that was insane. Some of our greatest aerospace artifacts are the artifacts that are behind us.

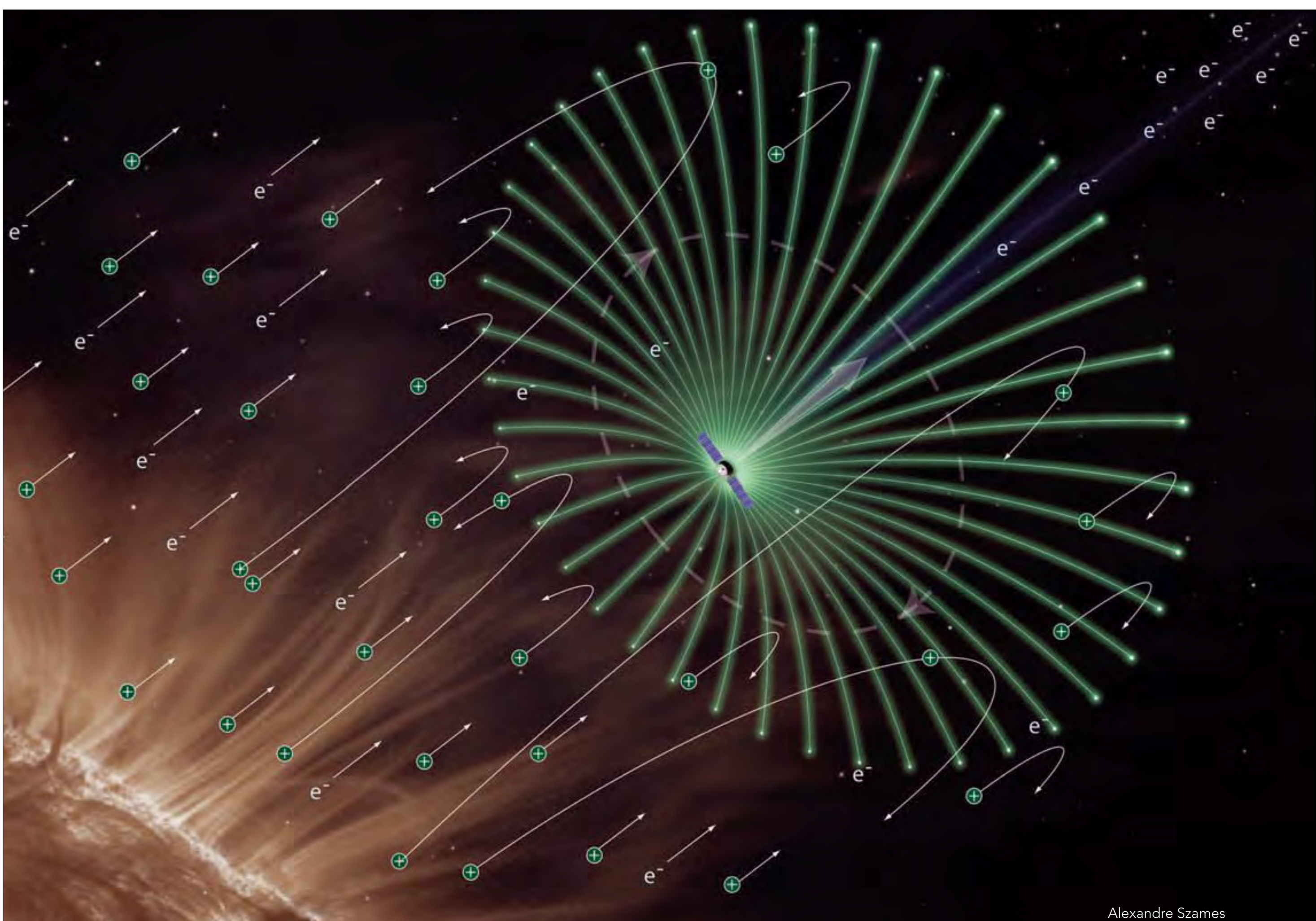
Sailing on electricity

If U.S. scientists want to explore the far fringes of the solar system, they'll need new propulsion options. Michael Peck spoke to NASA researchers who say the answer might lie in tapping the interactions between the solar wind and electric fields.

NASA's Voyager 1 took 35 years to reach the heliopause, the unexplored region where the solar wind stops and the interstellar plasma eventually takes over. There has to be a faster way to explore the outer planets and the heliopause than Voyager 1's chemical-rocket propulsion.

Two researchers at NASA's Marshall Space Flight Center in Huntsville, Alabama, think they've found one. Bruce Wiegmann, an aerospace flight engineer, and Les Johnson, a physicist as well as the technical assistant at NASA's Advanced Concepts Office, have devised a concept they call the Heliopause Electrostatic Rapid Transit System, or HERTS.

Their project, the physics of which is undergoing analysis and testing in a plasma chamber, calls for extending 10 to 20 wires, each 20 kilometers long, from a spacecraft that would slowly rotate as it heads off into deep space. As the wires slice through the solar wind, protons in the wind would strike the electric field surrounding the wires, and the



NASA is researching an electric-sail spacecraft that would trail many long conducting wires to draw propulsive energy from solar wind. Such a craft could reach the heliosphere, or the beginning of the outer solar system, in 10 years, compared to 20 years for solar-sail craft.

momentum of those protons would be converted into propulsive force.

The HERTS team says their craft could travel at 100 to 150 kilometers per second, compared to Voyager 1's 17 kilometers per second, putting it at the heliopause in 10 or 12 years. Though much swifter than the Voyager, the HERTS craft would follow a different, and longer, trajectory. If researchers are right, a heliophysicist could propose a mission to the heliopause and receive the science in the span of a normal career, opening the door to the first detailed study of the heliopause and perhaps the region beyond. Few scientists would stake a career on a mission or element of a mission that won't deliver results for 35 years.

"This is the kind of technology we need to have for propulsion systems [for] the first steps into the interstellar medium," says Johnson, a technical advisor for HERTS.

The team calls the concept an electric or E-sail to distinguish it from solar sail concepts that are also in consideration for other exploration applications. Because there would be fewer photons to propel it farther out from the sun, a solar sail would stop accelerating at a distance of five astronomical units, or five times the distance from Earth to the sun, Wiegmann says. The protons that propel an E-sail taper off at a much more gradual rate, enabling the spacecraft to continue accelerating out to 15 AU. An E-sail would enjoy the additional acceleration compared to a solar sail because the spacecraft's electrical field expands as it moves farther from the sun.


NASA/Emmett Given

Bruce Wiegmann, principal investigator for NASA's Heliopause Electrostatic Rapid Transit System, holds a sample of Amberstrand composite string, one of the tether materials under investigation for use in a spacecraft propelled by electric sails. Behind him is an artist's concept for the electric sail.

Debye sheath

The HERTS team says the technology road will be a long one, but that with the right investments, a scientific spacecraft with this kind of propulsion system could be ready in 10 years and return the first science data sometime between 2025 and 2030, assuming a technical demonstration mission were launched between 2020 to 2022. The team is studying whether to conduct experiments via a high-altitude balloon or a flight on a suborbital rocket as the next steps.

More immediately, the researchers are conducting experiments in a small plasma chamber at Marshall. The chamber is equipped with an ion generator that is capable of very low pressures, like those HERTS would experience.

The chamber experiments can't do it all, but they are a start toward accurately modeling the interactions with its surroundings.

"All of our modeling to date has been built upon some plasma physics models that may have shortcomings when applied to this topic," Wiegmann says.

Specifically, each wire generates an electric field known as a Debye sheath (named after physicist Peter DeBye). The team wants to know how many electrons pass through the Debye sheath and accelerate toward a positively charged wire, as well as how many protons are reflected off the sheath, which will indicate the propulsive force a HERTS spacecraft will experience.

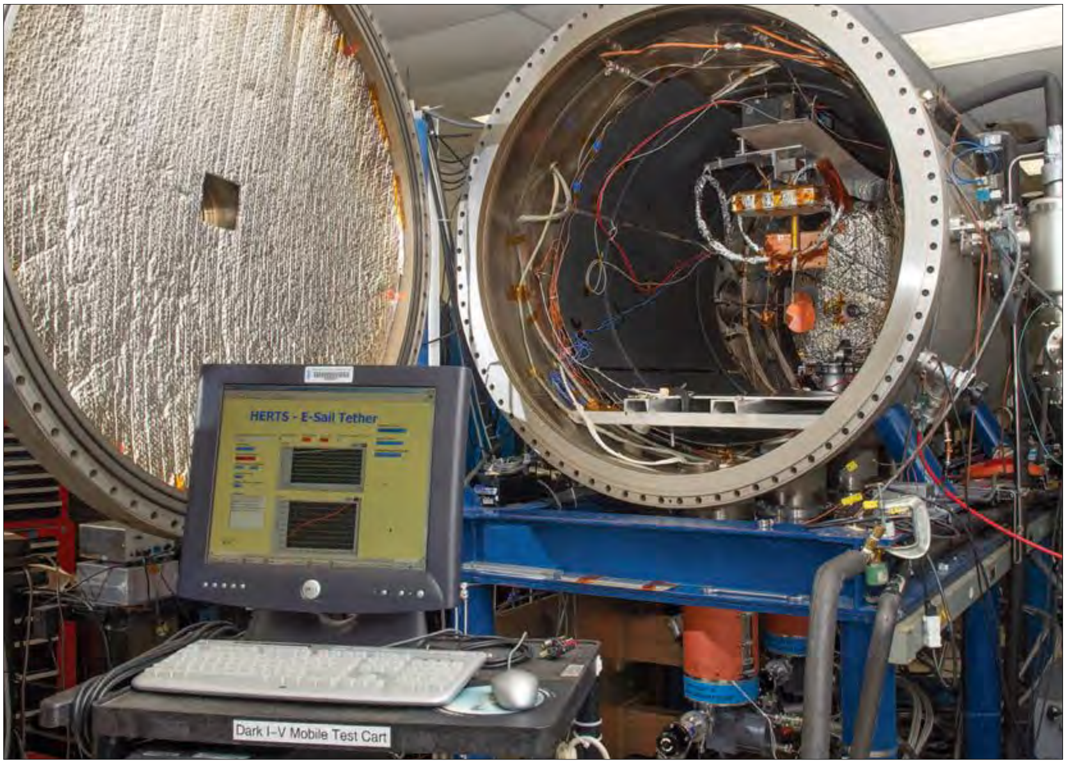
The Debye sheath will extend eight to 10 meters from the wires at a distance of one AU. The spacecraft will also rotate at one revolution per hour, which will ensure that the wires are extended 90 degrees from the axial center.

The NASA chamber test can accommodate just one wire with a Debye sheath length of 0.2 centimeters to one centimeter. So the HERTS team plans to extrapolate the results from this chamber to develop a Particle in Cell engineering model that can predict the thrust on an electric sail spacecraft. The PIC model will also predict the effects of solar winds and coronal mass ejections.

Once the PIC model is developed, the HERTS team will know the rate at which electrons from the solar wind will jump on the E-sail's charged wires, which must maintain a positive electric charge for the propulsion system to work.

"This is a major concern as we must be able to remove these electrons through an electron gun to enable a positive bias on the wires," Weigmann says. The chamber experiment will quantify the rate at which electrons jump on the wires.

Since the Debye sheath of a charged wire would be tens of meters in diameter, there is no vacuum plasma chamber with an ion generation source that could simulate the natural solar wind environment, Wiegmann says.



NASA/Emmett Given

NASA is conducting tests inside a controlled plasma chamber, called the High Intensity Solar Environment Test system, to examine the rate of proton and electron collisions with a positively charged tether from a spacecraft's electric sail.

Space experiments

For maximum confidence, the design would need to be tested outside of Earth's magnetosphere, which deflects the solar wind needed to propel the spacecraft. Wiegmann envisions testing a HERTS spacecraft in the vicinity of the moon and beyond Earth's magnetosphere. On the dayside of Earth, the solar wind compresses the magnetosphere to about 65,000 kilometers. On the nightside, the magnetotail extends to 6.3 million kilometers, far beyond the orbit of the moon. The experiment would need to be timed to coincide when the moon is outside the magnetosphere.

"When the moon is at the 3 o'clock or 9 o'clock position, where 12 o'clock is toward the sun and 6 o'clock is away from the sun, in Earth's shadow, the moon is outside the Earth's magnetic field," Wiegmann says. "This may be the closest location where we can perform a technology demonstration mission for the E-sail."

Two space shuttle missions, in 1992 and 1996, attempted to test a space concept for generating electricity by extending 20-kilometer-long tethers consisting of a wire bundle wrapped in a covering of clear insulation, and then covered by Kevlar and then Nomex. A jammed deployment mechanism on the first shuttle mission ended the experiment after the tether extended just 256 meters, while the second mission managed to extend the wire 19.7 kilometers before it broke.

However, the shuttle tests provided limited data for HERTS because they were conducted within the magnetosphere. Also, the shuttle missions were conducted with an eye toward assessing the ability to gather ions in low earth orbit and use them to generate electricity to power a spacecraft's electronics.

"Nobody was looking at them as propulsion systems, and there was no instrumentation deployed to validate this," Johnson says.

Design considerations

Without much data to go on, the engineers are still weighing key design decisions, such as the best material for their all-important wires.

"Our design is based upon 35-gauge aluminum wire, primarily for mass savings as it is about one-third the mass of copper wire," Weigmann says. "But we have not made a clear down-select yet to the best material to use for the wire."

No matter the material, perhaps the biggest question is how to deploy multiple thin, bare wires 10 to 20 kilometers long from a spacecraft.

Wiegmann says his team is investigating this through modeling and simulation, and then perhaps a small test where wires are laid out on the floor at Marshall. One solution for a HERTS space mission is to unravel the wires by spinning the spacecraft, though the deployment system would need to slowly stop extending the wires without breaking them. A second option would be to have cubesats that are attached to the main spacecraft pull the wires out. Two cubesats might pull five wires each, and once the wires are extended, radial thrusters on the cubesats and the HERTS craft would spin the spacecraft to one revolution per hour, bringing the wires to their deployed position. The team plans to assess these solutions with computer simulation from space technology company Tether Sim.

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Interstellar travel remains the stuff of science fiction, but breakthroughs could be in reach, provided we're willing to compromise on some of our more fanciful visions of interstellar travel. ***Michael Peck*** *spoke to experts about the feasibility of getting a spacecraft to another star before the end of the century.*

The date is December 31, 2099,

the last day of the 21st century. The place is Proxima Centauri, a red dwarf star tucked into a corner of the Milky Way galaxy. A metal cylinder attached to a device that looks like an umbrella approaches the star at one-fifth the speed of light. As it zooms past, a tiny antenna transmits a stream of data. A little over four years later, the first close-up images of another star arrive back at Earth.

For millennia, this could only have been a dream. When the ancients looked at the stars, they beheld the face of heaven. When astronomers peered up, they marveled at the wonders of the cosmos. But always those brilliant points of light seemed unattainable, too distant for humans to visit. However, new technologies and scientific research suggest that travel to the stars may be in reach, if not as easy as "Star Trek" makes it seem. The first interstellar flight could, in theory, begin by midcentury, using technology that isn't far beyond what we have today.

"I think you could send a vehicle the size of a Coke can to the stars," says Kelvin Long, a British aerospace engineer and

by Michael Peck
michael.peck1@gmail.com
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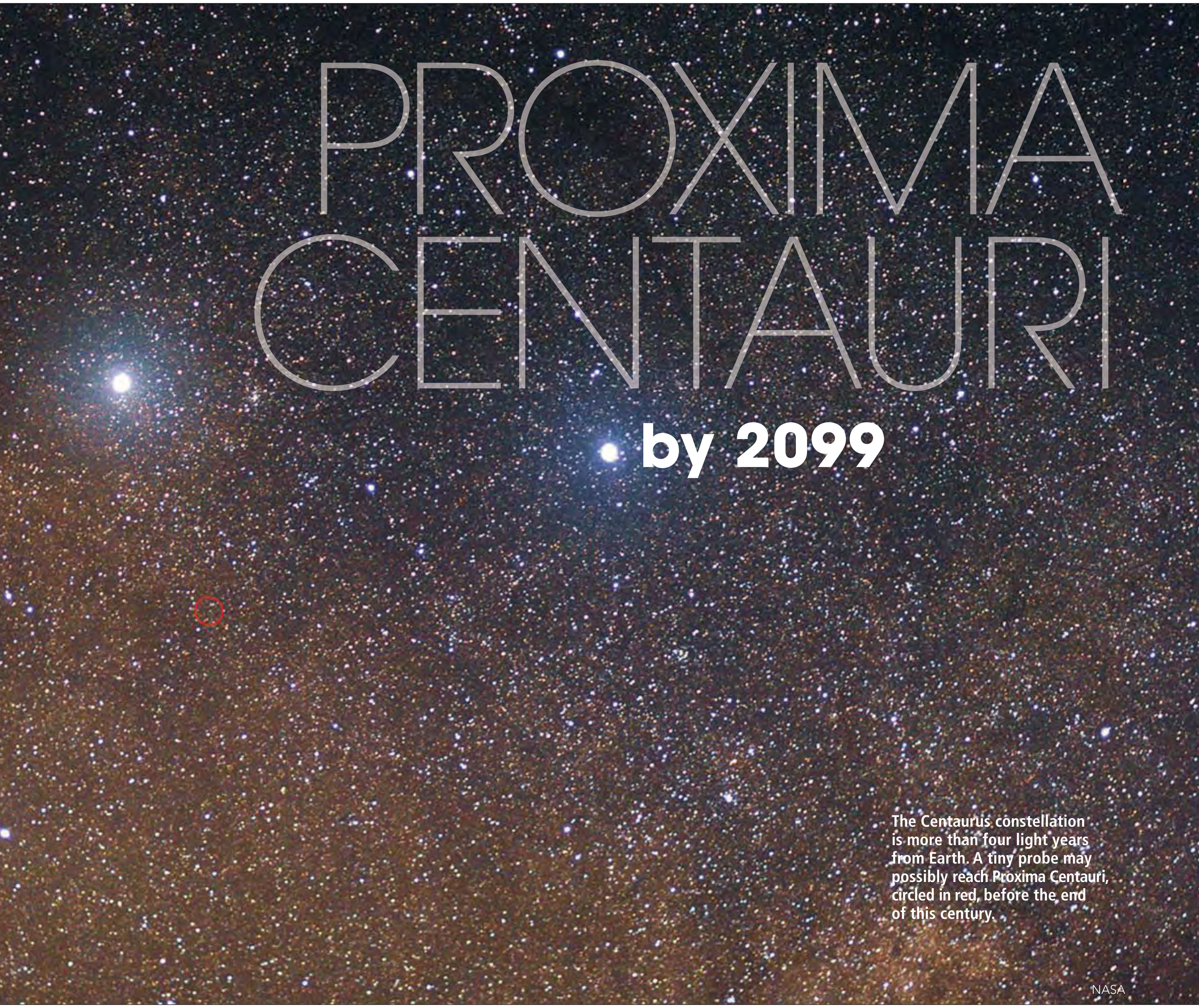
PROXIMA CENTAURI by 2099

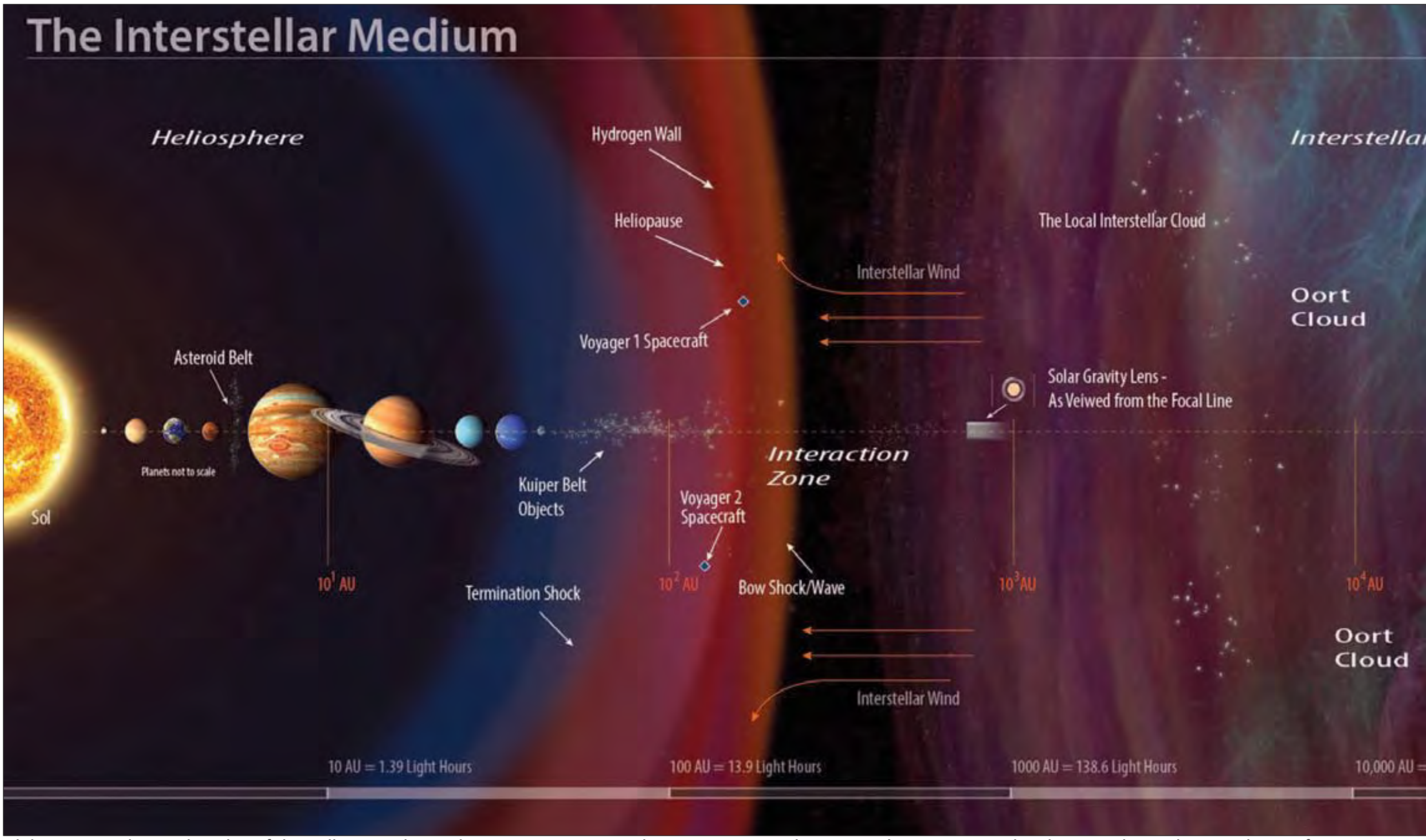


The Centaurus constellation is more than four light years from Earth. A tiny probe may possibly reach Proxima Centauri, circled in red, before the end of this century.

NASA

executive director of the Initiative for Interstellar Studies, a privately-funded offshoot of the British Interplanetary Society. Long imagines a probe propelled by laser beams reflecting off a light sail. Because the spacecraft is small, it would require a comparatively small amount of energy to accelerate it to 20 percent of light speed. If launched around 2050, it could reach Proxima Centauri by the late 2000s, equipped with a variety of instruments to observe Earth's nearest neighbor, as well as any nearby exoplanets.

A starfaring Coke can isn't exactly the starship Enterprise, but it is the sort of practical solution that will probably be needed to confront the daunting obstacles to interstellar journeys. As any science-fiction fan knows, there has never been a shortage of ideas for interstellar travel, from laser propulsion to fusion power to anti-matter driven starships. The real problem has been how to separate fact and feasibility from dreams and wishful thinking. Long is among a new breed of researchers who are attempting to inject here-and-now rigor into



Alpha Centauri lies at the edge of the Milky Way. This Keck Institute map, created in January 2015, shows NASA's Voyager 1 probe, the most distant human object, after it entered interstellar space in 2012, some 20 billion kilometers from Earth and the sun. Voyager 2 is now in the heliosheath, the outermost layer of the heliosphere.

a domain once dominated by futurists.

"A lot of people who work with interstellar think very big picture," Long says. "The problem with being too big picture is you lose your connection with the bottom line of what is really practical."

Scoping the problem

NASA's Voyager 1 probe is now leaving our solar system at 17 kilometers per second. The New Horizons Pluto probe is headed off into our solar system's Kuiper Belt at 14.4 kilometers per second. That sounds fast until you consider the distances. Proxima Centauri, the nearest star to our own, is 4.3 light years away. If a probe were dispatched toward it at Voyager or New Horizons speeds, it would arrive 70,000 years later, long after its makers had died and their descendants had ceased to care. The Apollo 10 spacecraft that passed behind the moon in 1969 was the fastest that humans have ever traveled, and that was 9.3 kilometers per second. At that rate, it would take about 139,000 years to reach Proxima Centauri.

An interstellar vessel would need to have a speed of at least 10,000 kilometers per second, or 3.3 percent of lightspeed, according to Long, a member of the team that in 2011 won DARPA's 100-Year Starship competition to design an interstellar craft.

Wafersat

One option would be to start small. Long's "Cokesat" probe seems positively enormous compared to an even tinier spacecraft envisioned under the Directed Energy Propulsion for Interstellar Exploration project, a research collaboration between NASA and several California universities. The aim is to apply directed energy to send a "wafersat" to the stars. Project leader Philip Lubin, a physicist at the University of California, Santa Barbara, envisions a 10-centimeter probe weighing one gram — about the same weight as a small paper clip — attached to a one-meter sail (the name "wafersat" was derived because one of the spacecraft being developed is literally a silicon wafer).

First, 50 million one-kilowatt laser amplifiers, each weighing perhaps one kilogram, would have to be launched into orbit, where they would be joined together like a

Chuck Carter/Keck Institute for Space Studies

Lego set to form a scalable laser array that might be, say, 10 kilometers long. Once wafersat is launched to a position near the array, photons would be projected onto the wafersat's sail, propelling the craft like wind on an oceanic sailing ship. This would boost the probe to a maximum speed of 20 percent of the speed of light, or 60,000 kilometers a second. Equipped with miniaturized sensors and communications equipment to beam data back to Earth, a wafersat could reach Alpha Centauri, a three-star system composed of Alpha Centauri A, Alpha Centauri B and Proxima Centauri, in about 20 years.

A one-gram probe doesn't sound impressive compared to other starship designs, but the directed energy approach has its advantages. A spacecraft doesn't have to lug its propulsion system, which allows a smaller vehicle. The system can launch any size of sail-driven ship, though the larger the craft, the less velocity. And for bite-sized probes at least, millions can be dispatched at relatively low cost in a shotgun exploration program. "You can launch a new wafer every five or 10 minutes," Lubin says.

Most of all, directed energy appears solidly grounded in current science and technology, such as lasers and orbital structures. "It is very different than invoking a wormhole, or anti-matter engines, or fusion drives," Lubin says.

Fusion

But others continue to pursue the exotic. One option would be to tap the same basic process that lights up Proxima Centauri and our own stars. In the 1970s, scientists and engineers working under the British Interplanetary Society's Project Daedalus conducted a serious attempt to design a spacecraft that could reach Barnard's Star 5.9 light years away. The designers ultimately settled on a fusion drive that would have trained electron beams onto cryogenic deuterium and helium-3 pellets to ignite them, which would fuse their atoms and expel a plasma exhaust that would move the ship at about 12 percent of light speed, according to Rob Swinney, a British researcher with Project Icarus, a privately-funded group that was launched in 2009 to rekindle the dream of Project Daedalus.

Long can foresee a fusion-powered vessel up to several thousand tons in mass and carrying a crew of several hundred. The Daedalus-like vessel would entail a decades-long journey that would tax the limits of human longevity. Thus Long also suggests a vessel capable of at least partly surmounting the challenges of interstellar distance and time: a small ship, using anti-matter engines to transport a crew of 12. Traveling at 30 to 50 percent of light speed, it could reach Alpha Centauri in a couple of years.

In 2013, Project Icarus unveiled five conceptual designs based on various flavors of fusion propulsion, with each ship hundreds of meters long and thousands of kilograms in mass. Four of the five designs would involve fuel pellets and fusion cooling systems, and the fifth would use a plasma stream compressed by a z pinch. Equipped with a 150-ton science payload, including mini-probes, and traveling at around 5 percent of the speed of light, they could reach Alpha Centauri within 100 years.

"In general, the fusion technology we have investigated suggests that it will be possible to make a 100-year journey to Alpha Centauri sometime in the near future, but still quite some decades away," Swinney says.

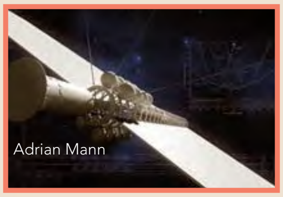
Five fusion concepts

When atoms of deuterium, a hydrogen isotope, or helium-3 are mashed together, the resulting release of energy could, in theory, propel a spacecraft fast enough for interstellar travel. Since 2009, researchers from the U.K., Germany, India, the U.S. and elsewhere have been studying competing concepts for how that might be done. The work is happening under Project Icarus, a volunteer theoretical engineering study to design a spacecraft that could reach another solar system within a human lifetime.


Michel Lamontagne

Firefly

Deuterium fuel would be injected as a continuous plasma stream into the z pinch region, which is created when a large current creates a strong magnetic field that pinches inward and squeezes the plasma until it fuses and is then exhausted rearward.
Lead designers: *Robert M. Freeland II, Michel Lamontagne, Icarus Interstellar nonprofit foundation*


Adrian Mann

Ghost Ship

Deuterium fuel pellets would be ignited by lasers through a fast ignition, inertial confinement process that would compress the pellet until fusion occurs. Pellets would be repeatedly ignited in rapid succession. The concept earned the original Best Entry award in the early Project Icarus Concept Design Competition.
Lead designers: *Lukas Schrenk, Nikolaos Perakis, Technical University of Munich*


Adrian Mann

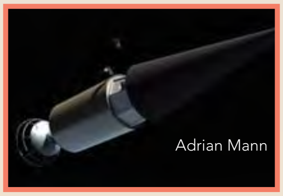
Resolution

Fuel pellets of deuterium and helium-3 would be ignited by lasers. Using helium-3 significantly reduces the release of high-energy neutrons that would otherwise rapidly damage the spacecraft, but helium-3 is a rare commodity.
Lead designers: *Kelvin F. Long, Richard Osborne, British Interplanetary Society*


Adrian Mann

UDD (ultra dense deuterium)

A simplified single laser pulse striking pellets of ultra dense deuterium fuel is sufficient for fusion to occur. To date, there has been no independent validation of the phenomenon of ultra dense deuterium, and UDD is no longer under active consideration under Project Icarus.
Lead designer: *Milos Stanic, Project Icarus*


Adrian Mann

Zeus

Zeus has supplanted UDD in the Project Icarus design program. The complicated ignition has two spherical plasma slugs of magnetically confined deuterium fuel fired together. Then hydrogen plasma is fired at the resulting plasmoid, compressing to fusion. This is known as plasma jet magneto inertial fusion. Researchers so far have been unable to fully model the Zeus's complex ignition physics without making estimates about propulsion, mass and other systems requirements.
Lead designers: *Damien Turchi, David Evinshteyn, Drexel University in Philadelphia*

Sources: Rob Swinney, Project Icarus; Aerospace America reporting

Fusion is not the only theoretical option for interstellar travel, but Swinney says it was the best candidate for the project's goal of using current or near-future technology.

"Chemical, ion and plasma cannot conceivably meet the requirements," he says. "Anti-matter drives are out of near-future reach, and any sort of warp drive or other faster-than-light travel is seemingly beyond reality if not theoretical physics."

Anti-matter

However, other scientists are indeed eyeing anti-matter propulsion. One of them is Eric Davis, a physicist at the Institute for Advanced Studies in Austin, Texas. Anti-matter engines — made famous by Star Trek — would mix particles of matter and anti-matter, such as protons and anti-protons, which are identical but have opposite electric charges.

"When anti-matter meets matter, both annihilate in a flash of energy," explained a 2006 NASA article discussing the possibility of an anti-matter spacecraft sending astronauts to Mars. "This complete conversion to energy is what makes anti-matter so powerful. Even the nuclear reactions that power atomic bombs come in a distant second, with only about 3 percent of their mass converted to energy."

In fact, the NASA article stated that a few tens of milligrams of anti-matter — one milligram being about one-thousandth the weight of a piece of M&M candy — would be sufficient to send a ship to Mars. For interstellar purposes, Davis says that an anti-matter engine would be so efficient that a ship could travel at almost the speed of light, which means a trip to Alpha Centauri would take only about five years.

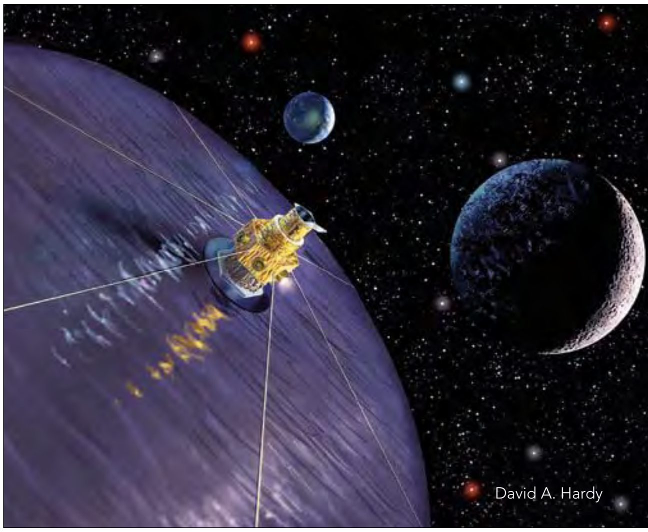
Long imagines a huge spacecraft traveling at 10 to 20 percent of light speed, propelled by fusion engines or anti-matter catalyzed fusion (anti-matter injected into fusion engines).

Davis says key elements are missing though: "The two things that need to be solved to implement anti-matter rocket propulsion is the production of copious amounts of anti-matter, and the storage of anti-matter," he says.

There is one other concept, and it's the most exotic of them all: wormholes, those hyperspace tunnels in which objects enter one end and emerge out the other end at a distant point in space. Davis, who is studying the physics behind this, says the wormhole could be created by negative vacuum energy, which he describes as "an engineered form of quantum vacuum energy produced by the quantum fields of the elementary particles and their interaction forces."

Davis believes a traversable wormhole would have a tunnel several Astronomical Units long, which a ship would have to spend time traveling through. While this means wormhole travel wouldn't exactly be instantaneous, it would be a clever way to bypass the Einsteinian prohibition against faster-than-light travel. "The travelers would move at much less than light speed through the wormhole, while all outside, static observers would view the travelers as having traversed multi-light year distances between the departure star and destination star at faster-than-light speed," Davis says.

What if the goal weren't so much to go fast as it is to carry lots of people? For that scenario, Long imagines a gargantuan "world ship," a gigaton-size vessel carrying millions of people, though only at 1-to-3 percent of light speed. Such a massive vessel would be moved by nuclear-pulse propulsion, in which carefully controlled nuclear bombs generate thrust (a concept explored under Project Orion, a late 1950s U.S. government and private initiative).



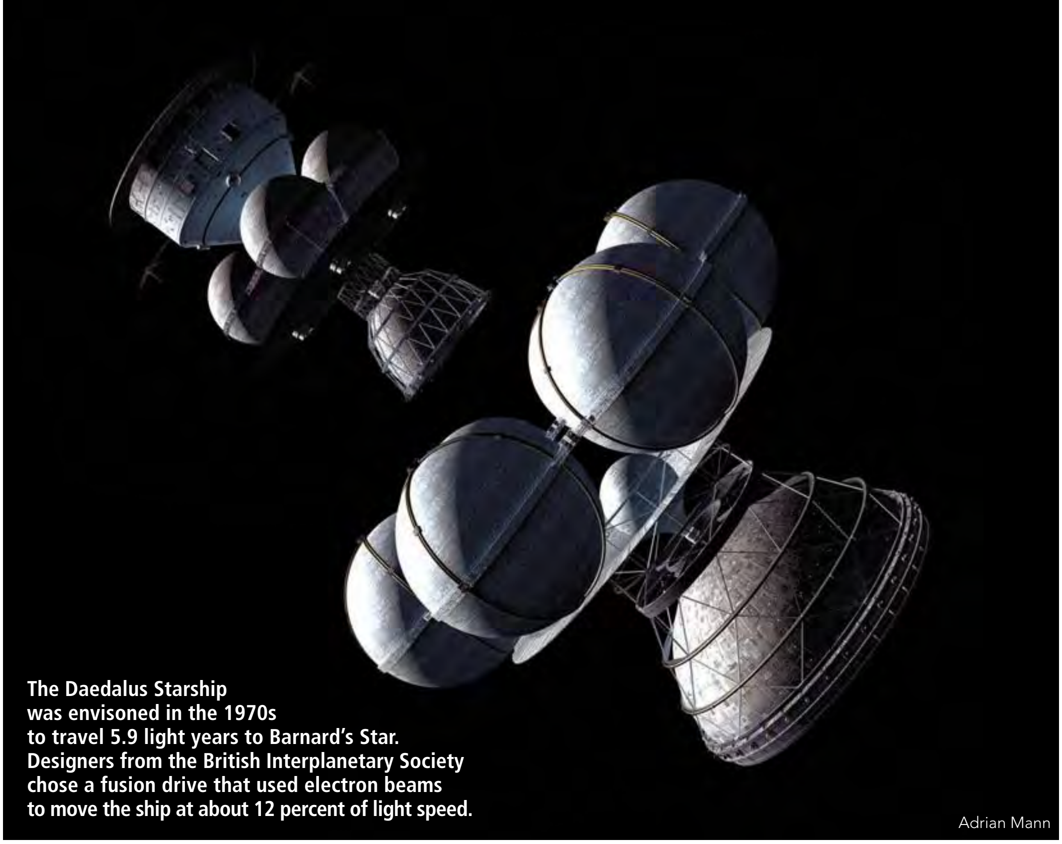
David A. Hardy

The 2015 winner of the Project Dragonfly contest for a small, laser-sail spacecraft, from Technical University of Munich, would be propelled by reflecting laser light off a sail made of graphene, a thin sheet of carbon, mixed with reflective material.

Private research

Ultimately, despite all the ideas, there simply does not seem to be one form of propulsion that stands out as light years ahead of all the others.

"We have never even sent anything to relativistic speeds," notes former NASA astronaut Mae Jemison, who flew as a mission specialist on the space shuttle in 1992. She now heads the 100-Year Starship Foundation, descended from the DARPA project of the same name (though DARPA



The Daedalus Starship was envisoned in the 1970s to travel 5.9 light years to Barnard's Star. Designers from the British Interplanetary Society chose a fusion drive that used electron beams to move the ship at about 12 percent of light speed.

Adrian Mann

no longer provides funding).

Jemison's organization is trying to lay the groundwork for achieving interstellar flight.

"Everybody says, 'let's put together a technology roadmap.' But we're not there yet, because that assumes you know where you are going and you know how to get there."

That is why Jemison's project, which is privately funded, isn't focused on designing specific interstellar craft with a specific launch date, but rather on developing the fundamental capabilities that allow humans — if they so choose — to launch a human interstellar expedition by 2112. These capabilities must span everything from propulsion, to keeping people fed for long voyages, to creating clothing that can endure for years without replacement.

Jemison predicts interstellar flight will be a gradual process that might include stepping stones like a moon base.

"It's not Alpha Centauri or bust," she quips. Long says that once humans can travel to the outer planets of our solar system, humans will be halfway to achieving the capacity for interstellar travel.

Justification

With so many options for interstellar travels, and so many of those options difficult or expensive, critics say that we need to begin with a fundamental question: Why?

Sten Odenwald, a retired NASA astronomer who wrote "Interstellar Travel: An Astronomer's Guide" in 2015, argues that just traveling to another star doesn't make much sense.

"There are three simple questions that drive exploration of any kind: Where are we going to go, what are we going to do when we get there, and how will it benefit people back home?" he says.

As Odenwald sees it, the Alpha Centauri system is unlikely to have terrestrial planets, nor anything else of scientific value that would justify spending hundreds of billions of dollars to explore. For the public to support a long-term project with no immediate benefits, there has to be more of a reward than merely showing the flag on another planet. There has to be something that will interest the taxpayers back home, such as a planet that appears to have signs of life.

"That will be the best motivation for the first interstellar probe," Odenwald predicts. "There will be a destination we know about, a reason for going there, and the prospect of finding something fascinating."

For Jemison, the undertaking would itself be worth the effort, regardless of what is discovered or not discovered.

"The most incredible thing about interstellar travel is the challenge that it presents to us," she says, "and how solving some of those issues will fundamentally change life here on Earth."

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FAA'S cyber awakening

After multiple wakeup calls about its NextGen air traffic control system's potential vulnerability to cyberattacks, the FAA is working to improve the network's defenses. Henry Kenyon spoke to a retired FAA official and independent cyber experts about the problem.

In August 2015, a software error in the FAA's Virginia air traffic control center's automated routing center forced the major airlines to cancel hundreds of flights across the mid-Atlantic region of the U.S. An upgrade to the software that feeds radar and tracking data to flight controllers, called the En Route Automation Modernization, or ERAM, caused a system error at the FAA's high-altitude radar facility in Leesburg, Virginia.

The error forced controllers to limit the number of flights for four hours in the heavily traveled flight corridor served by the center. The restrictions affected major airports in the Washington, D.C.-Baltimore region, causing 492 flight delays and 476 cancellations.

ERAM is part of the FAA's NextGen air traffic control initiative. It replaced a 40-year-old-traffic control system and forms a new communications backbone connecting the nation's 20 air traffic control centers. The new software is designed to make air traffic controllers more productive by allowing controllers at each center to track as many as 1,900 aircraft at once. ERAM also pulls in data from other centers, allowing controllers to view data outside of their coverage area. The FAA says the new system allows controllers to handle additional air traffic more efficiently.

The incident, in the view of some cybersecurity experts, was a wakeup call because its effects directly mirrored those of a deliberate cyberattack. The August event follows an actual cyberattack in February 2015, when a virus was discovered in the FAA's administrative computer system. The FAA's cybersecurity office said the virus was removed and did not affect any critical flight control systems. More serious

by Henry Kenyon
hkenyon@hotmail.com

FAA's NextGen managers are replacing radar tracking with GPS information that will be shared via a network. The strategy raises questions about vulnerability to hacking.

Adobe

breaches have occurred. In 2006, the FAA was forced to partially shut down its air traffic control system in Alaska when hackers broke into the network.

Teams of FAA contractors are modernizing the nation's air traffic control system with digital communications networks and satellite-based tracking and navigation tools under a $40 billion initiative scheduled to run through 2025.

When NextGen is complete, flight controllers across the country will be able to touch a computer screen and view air traffic around an airport on the other side of the nation. In the event of technical or other difficulties, controllers from another region will be able to take over if local coverage is lost. ERAM will allow controllers to handle larger volumes of air traffic more efficiently. The other key element of NextGen is the new automatic dependent surveillance-broadcast transmissions, called ADS-B, that airliners will periodically send. These broadcasts will include the plane's identity, bearing and location. ADS-B transponders are required on all airliners and private aircraft in U.S. airspace by Jan. 1, 2020.

NextGen will also allow pilots to choose their own flight paths, instead of following the highway-like flight paths currently in use. The FAA says that this increased efficiency will also save millions of gallons of aviation fuel and reduce emissions because pilots will be able to select the most efficient routes to their destination.

Government and independent cybersecurity experts have been sounding alarms in reviews and studies since 2009, although questions about the FAA's overall management of the massive software development program were first raised a decade ago. The FAA has heard the message and now

Air traffic controllers track flights on the En Route Automation Modernization system. Upgrades to ERAM will allow controllers at each of the nation's 20 air traffic control centers to track as many as 1,900 aircraft at once.

FAA

says it is working on plans to improve NextGen's cybersecurity. At stake is the security of a system that is expected to route about 26.2 million flights annually by 2020.

Responding to its critics, the FAA is deploying continuous-monitoring software developed by the Department of Homeland Security to watch for and counter any attacks in near real time. The agency has also updated its cybersecurity strategy, which it released in September. Working with the National Institute of Standards and Technology, the FAA is developing software-based tools to record and manage security across its computer networks. It says both the strategic plan and the security architecture will address current security issues and help guide the future evolution of NextGen.

Cybersecurity concerns

The FAA is working on a cybersecurity threat model, a plan that evaluates the risks different types of attacks present to a computer network, such as attempts to shut down or inject false data into traffic control and navigation systems. Besides outlining the types of threats, the model will also list steps the agency is taking to limit the possibility of a cyberattack and what it would do to defend its computer systems. Recent reports by the Government Accountability Office (April 2015) and the National Research Council (May 2015) found that the FAA has not yet developed a threat model, which is a standard government and private sector cybersecurity procedure.

Both reports note that computer modeling is needed to identify potential threats to FAA information systems and to make better use of limited resources.

"While FAA has taken some steps toward developing such a model, it has no plans to produce one and has not assessed the funding or time that would be needed to do so," the GAO report said. It added that without a model, the administration may not have the right tools to properly allocate resources or to defend against major cybersecurity threats. Work on the threat model has begun and is currently under internal review, the FAA tells Aerospace America in a statement. However, the FAA did not specify exactly when it would be shared with the GAO, other than it hoped to release the plan soon.

Other steps are also underway to protect the FAA's computer networks. The FAA is partnering with the Department of Homeland Security to install a continuous diagnostics and mitigation software system designed to scan NextGen's network for signs of attack or unusual activity. The FAA said this system also includes hardware and software asset management, configuration compliance and vulnerability management — capabilities to ensure that equipment and programs are performing properly and meet federal operating and security standards. This will result in two major improvements to the FAA's continuous monitoring strategy and processes.

"First, software agents will replace periodic network security scans for the majority of our IP-based assets in the non-airspace environment. Second, the vulnerability information will be integrated with other information, including hardware-based asset management and network-based vulnerability scanners," the FAA statement says. This data will be collected and made available to the DHS and Department of Transportation officials via a dashboard interface that highlights alerts and system status.

But installing security procedures into a software system after it has been designed usually leads to potential weaknesses. It is better, and cheaper, to build security into a system from the beginning, says Jules White, assistant professor of computer science at Vanderbilt University and a specialist in cyber/physical security.

"Generally in software engineering, the later you discover a problem and make a change to it, the more expensive it is," White says. In the case of complex systems like NextGen, security fixes could be "exponentially more expensive," he adds.

The FAA declined my requests to interview Edward Bolton, FAA's assistant administrator for NextGen, who was brought on to run NextGen in 2014. But Bolton's public appearances make clear that he has wrestled with cybersecurity by reorganizing the program's internal offices with a goal of improved efficiency. In 2015, the agency followed GAO recommendations and made its Aviation Safety Office part of its Cybersecurity Steering Committee. Speaking at the Association of Air Traffic Controllers in 2015, Bolton noted that the FAA is continuing to improve its cybersecurity by working with other agencies such as the DHS, Defense Department, Department of Commerce and NASA.

"We're peddling as fast as we can to get at this problem," he said.

Data link concerns

GPS-based navigation is one of the cornerstones of NextGen, says George Donohue, professor of systems engineering at George Mason's School of Information Technology and Engineering and former FAA associate administrator of research and acquisition. When he joined the FAA in 1994, there was no all-encompassing architecture for air traffic control system across the United States, he explains. The system at the time was a collection of component parts that had been added and plugged together over 40 years. By the time Donohue left the FAA in 2004, the initial blueprint for NextGen had been laid out. The new system was a modernization of older air traffic control systems, but with more automation and digital data networks.

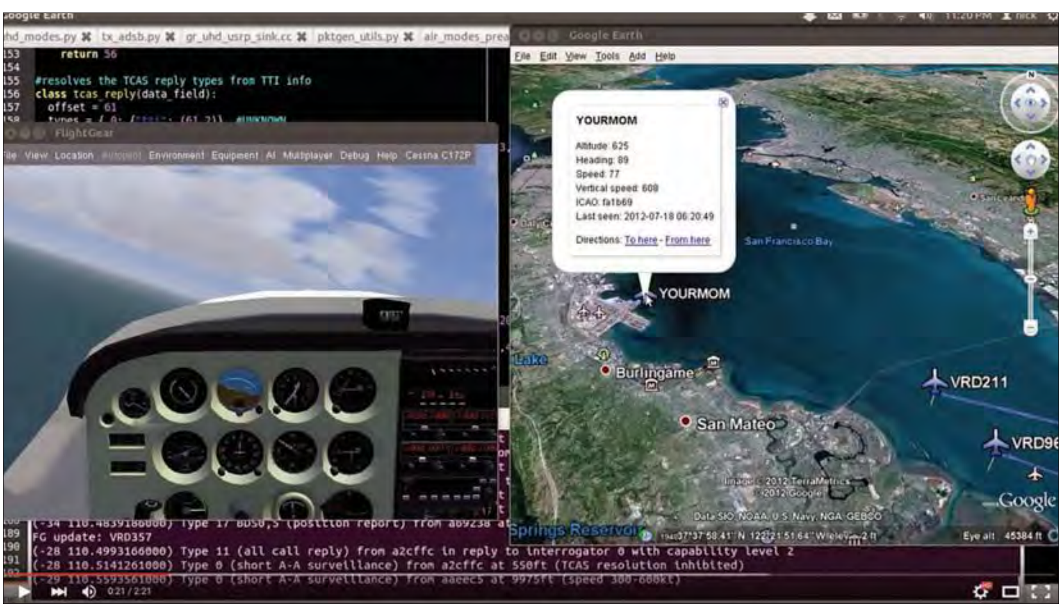
ADS-B transmissions are received by ground stations that retransmit the information to air traffic controllers and pilots. There are two types of ADS-B transponders, Out and In. ADS-B Out transponders transmit the aircraft's flight data only to the network. The FAA has mandated that all aircraft operating in U.S. airspace must be equipped with ADS-B Out systems by 2020. ADS-B In systems can receive data, allowing their pilots to see the locations of all similarly equipped aircraft in their vicinity as well as weather data on their flight displays. However, because the system was originally designed in the 1990s, at the dawn of the Internet age, cybersecurity was not a major consideration, Donohue explains. ADS-B and the other data links that make up NextGen are unencrypted. Part of this is due to international aviation protocols such as the Chicago Convention for Civil Aviation, which calls for participating nations to provide ubiquitous navigation and surveillance services for other nation's aircraft. Donohue noted that the need for openness trumped any security considerations.

As envisioned, ADS-B was a key part of

NextGen and the national aerospace architecture — the coast-to-coast air traffic control infrastructure. The FAA ran tests and pilot programs for ADS-B in Alaska from 1999 through 2006. There, its satellite-based GPS tracking capability proved very useful to monitor aircraft travelling over regions without ground-based radar coverage. There were some initial bugs in the system, but these were identified and fixed early in the testing process, Donohue says.

ADS-B's openness raises concerns that an aircraft's data links could be hacked or spoofed to accept or transmit incorrect data. Donohue cautions that although pilots and air traffic controllers may initially look out for any anomalies when a system is first deployed, over time, human operators will become complacent.

Brad Haines and Nick Foster, via YouTube



A pair of hackers created a ghost plane, "Yourmom," over San Francisco and transmitted fake automatic dependent surveillance-broadcast signals that could be indistinguishable from real flights to air traffic controllers. Cybersecurity consultants have warned that ADS-B signals, which are unencrypted and unauthenticated, are vulerable to spoofing.

"After the digital data link has sent correct information 100 or 1,000 times, the human actually becomes pretty lax in paying attention to what's in those data links. If something really bad was inserted, there's a very high probability that neither an air traffic controller nor pilot would notice it and just hit the 'accept' key," he says.

One reason the FAA is confident about the security of ADS-B is that the agency views the transponders as the third redundant leg of a triangle of surveillance systems that also include Mode S and ground based radar. Mode S transponders transmit an aircraft's identification data when the aircraft is detected by air traffic control radar. The official view is that even if an attacker completely shuts down ADS-B coverage across much of the U.S., there would still be airborne Mode C transponders (that provide altitude data) and primary radar tracking, Donohue says.

Belts and suspenders

Most of the physical infrastructure for NextGen — ADS-B towers and transponders, air traffic control software, servers and control room equipment — is now in place, with the final components going fully online in 2020. Reflecting its public safety role and culture, the FAA has always relied on multiple redundant technologies to keep air traffic safely on course in the event of any one system failing. This "belts and suspenders" approach has helped the administration through a number of equipment and software failures over the years. However, with the new [Internet Protocol]-based systems, any software-related failure would behave like a denial of service attack, Donohue says.

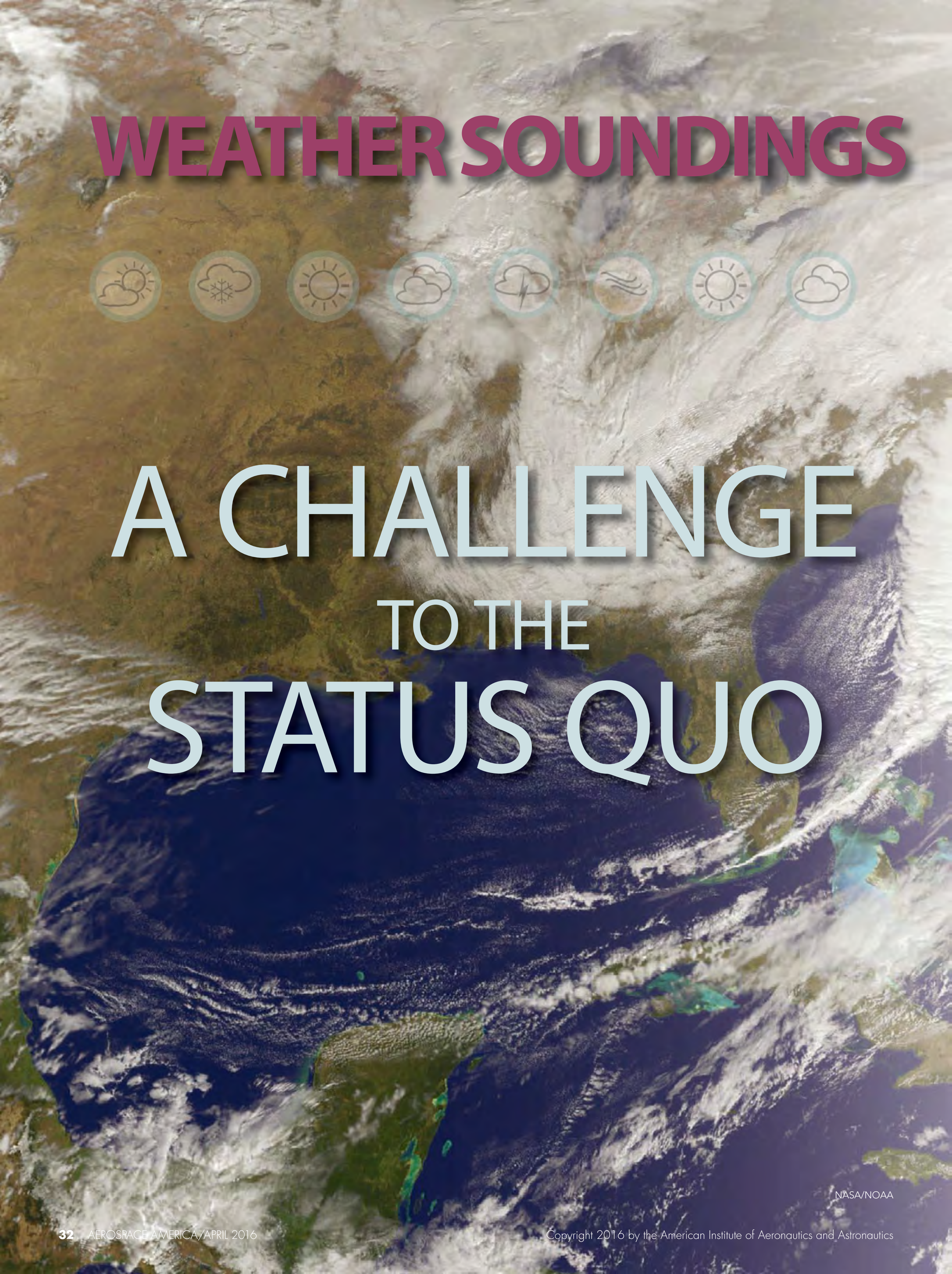
Because the FAA has weathered several software and equipment-related incidents and successfully relied on older backup systems, the agency is confident that it can deal with a denial of service type cyberattack.

"One upside of having '70s and '80s technologies is that they're not really vulnerable to cyber[attack] in particular," Bolton said in 2015. He added that this was perhaps the only advantage older technology offered in the event of a cyberattack.

"That's kind of what's going on with NextGen." Donohue says. "What if all this new stuff is corrupted and doesn't work? They [the FAA] say 'we've still got the suspenders and the rope that's holding up the pants,'" he says.

WEATHER SOUNDINGS

A CHALLENGE TO THE STATUS QUO



NASA/NOAA

NASA, NOAA and their partners have spent decades and hundreds of millions of dollars making instruments to measure the temperature and moisture of the atmosphere from space. No one disputes that these sensors have improved our weather forecasts, but NOAA is suddenly listening to those who say there might be another way. Ben Iannotta explains.

From orbit, the sky around a patch of clouds looks the same in a photo whether it is cool, dry and stable or warm, moist and about to explode into a string of tornadoes or grow into a hurricane. The first photos of weather from space were handy, but what weather forecasters really wanted were the factors they couldn't see, chief among them the temperature and moisture content of the atmosphere at different altitudes. NASA, NOAA and experts from academia got busy figuring out how to collect Earth's radiation from orbit and parse it into spectral channels that could profile the atmosphere vertically.

Conventional wisdom holds that gathering these atmospheric soundings from orbit is such a complex task that it's a job best left to the government with the help of universities and the industry. The first NOAA sounder, called HIRS, short for High Resolution Infrared Radiation Sounder, was built that way and launched in 1978. Versions of HIRS remain NOAA's sounding workhorses, and in 2011, those workhorses were joined in orbit by an instrument called CrIS, short for Cross-track Infrared Sounder. CrIS is intended to be the first in a new breed of vastly more precise sounders that will ride on NOAA's polar-orbiting satellites. Researchers had been struggling since the early 1990s to get its technology into orbit.

Both instruments are highly complex. On HIRS, a mirror reflects radiation to a rotating wheel made of germanium substrate, a metallic looking material that infrared wavelength can penetrate. The germanium is coated with materials to tune the wavelengths that can pass through. "It's actually quite a science to adjust the layers," explains physicist and sounding pioneer Hank Revercomb, director of the University of Wisconsin's Space Science and Engineering Center in Madison.

Harris Corp.

Cross-track Infrared Sounder: These sensors built by Harris Corp. measure the temperature and moisture content of the atmosphere by dividing incoming energy into 2,200 channels of wavelengths. The white cylinder partially visible in the center contains a scanning mirror.

CrIS is even more exotic. A beam splitter divides a ray of light into two, and one beam strikes a fixed mirror, while the other strikes a moving mirror. The beams are then recombined to create a pattern called an interferogram. The resulting spectrum must be "unscrambled" inside the instrument by a mathematical process called a Fourier transform, and then on the ground an inverse Fourier transform is performed, Revercomb says.

CrIS is now delivering 2,200 channels of infrared wavelengths, which is 100 times more channels than HIRS. More channels means more moisture and temperature readings at more altitudes. Interestingly, CrIS was supposed to deliver 1,300 channels, but after CrIS arrived in

The GOES-East satellite captured this image (opposite page) of a Nor'easter developing over North Carolina's Outer Banks in 2015. The first in new series of Geostationary Operational Environmental Satellites, GOES-R, is scheduled for launch in October.

by Ben Iannotta
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orbit aboard the Suomi National Polar-orbiting Partnership (SNPP) satellite, the team adjusted onboard software to send more mid- and short-wave infrared bands.

"The data rate has increased slightly, but the SNPP has sufficient data rate margin," says Harris Corp.'s Ron Glumb, who until last year was chief engineer for CrIS at the company's Environmental Solutions facility in Fort Wayne, Indiana. NOAA seems pleased, and in January Harris received an additional $316 million to its CrIS contract to deliver two more instruments.

Just as the CrIS technology is gaining momentum, however, members of Congress and NOAA are asking hard questions about the way ahead for atmospheric sounding. At issue is whether a simpler, commercial technology can supplement the sounding work planned for CrIS or even take over some of the duties. The outcome of these discussions and a NOAA pilot project that's about to begin could have a big impact on some satellite and instrument builders. That's because the new technique requires collecting GPS signals with many small cubesats, rather than the 3,000-kilogram polar orbiters that are to carry the next CrIS instruments.

Learning from Mars

All this discussion has been sparked by the advent of a technique called GPS-radio occultation, whose roots date to the Mariner 4 spacecraft's flyby of Mars in 1965. In addition to taking the first photos of another planet from space, Mariner 4 flew behind Mars and sent radio signals back toward Earth with Mars blocking, or occulting, the view. Just as scientists expected, the signals that went by the periphery of Mars were bent as they passed through the Martian atmosphere.

Until then, "the density of the Martian atmosphere wasn't known to within a factor of a thousand. That one measurement nailed it perfectly," says Thomas Yunck, a former NASA research scientist at the agency's Jet Propulsion Laboratory, and founder and chief technology officer of GeoOptics, a small company in Pasadena, California.

His firm is among those attempting to shake up the sounding world by applying the same basic principle used by Mariner 4. The company plans to test its concept in July by launching a single Pathfinder cubesat as a payload on a Soyuz rocket. That launch will be followed by four operational satellites on a Soyuz in November or December.

While working at JPL in 1988, Yunck wrote a research proposal outlining the concept he's now trying to turn into a viable business. The proposal noted that Earth's atmosphere bends GPS microwave signals. An instrument properly placed in orbit could receive those signals each time a GPS satellite rises or sets behind the curve of the Earth in occultation. Temperature, moisture, pressure and density could be deduced from the degree of signal bending. The technique was dubbed GPS-radio occultation or GPS-RO.

Each GPS signal received by an orbiting cubesat is called an occultation, and GeoOptics hopes to convince NOAA to buy a license to receive 100,000 of them a day and feed them into numerical weather forecasting models. The company faces competition from PlanetIQ of Boulder, Colorado, which plans to launch its first

Planning ahead

NOAA managers and weather scientists must wrestle with more than the here-and-now questions about atmospheric soundings. They know they must chart a long-term course for weather satellites and their instruments, so that the right budget and policy decisions can be made now.

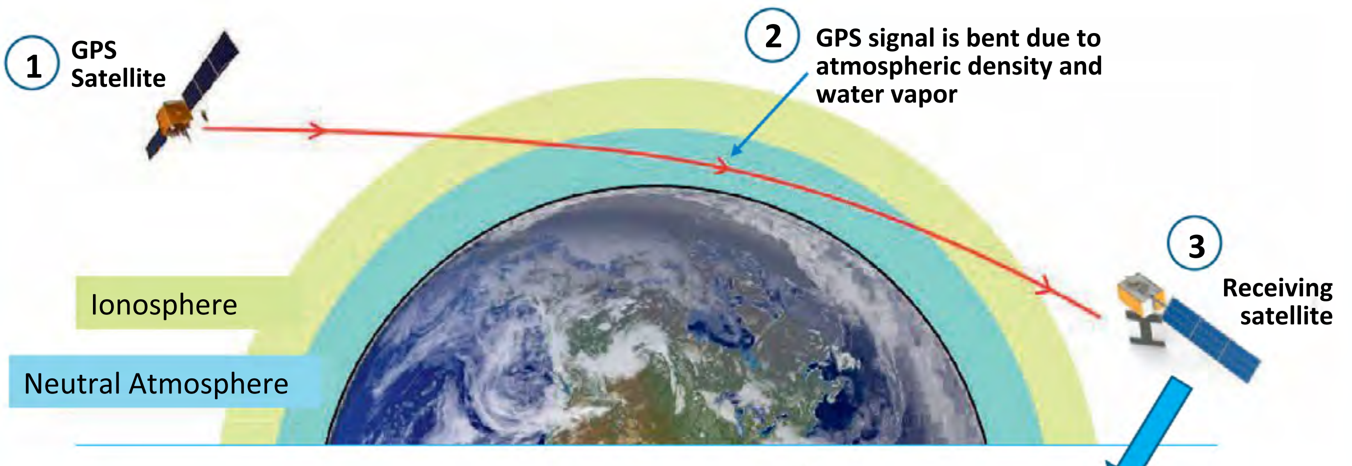
NOAA has assembled a Space Platform Requirements Working Group to consider the kinds and numbers of satellites that should provide weather data in 2030 and beyond. The team will look at what should come after the four Joint Polar Satellite System (JPSS) spacecraft that are slated to carry the Cross-track Infrared Sounder instruments and the next four Geostationary Operational Environmental Satellites (GOES), the first of which, the Lockheed Martin-built GOES-R, is scheduled for launch in October. NOAA says all options will be entertained. That includes a possible role for privately operated weather satellites and the possibility of shifting the agency's strategy away from 3,000-kilogram satellites like JPSS and GOES-R to numerous, small spacecraft, an approach that satellite experts call disaggregation. "Disaggregation is ONE among the many options being considered by the architecture study team," NOAA cautions in an email to me.

The topic of weather satellites and sensors also will be addressed in the next Decadal Survey of Earth Science and Applications from Space, which is to be published in July 2017 by the National Academies of Sciences, Engineering and Medicine. The decadal surveys give scientists and technologists an opportunity to recommend spending priorities. The new survey will cover the 10 years starting Oct. 1, 2017.

Ben Iannotta

How GPS aids weather forecasters

From the vantage point of space, a GPS satellite will periodically rise or set behind Earth's horizon. During these occultations, the radio signals that are normally received on the ground pass through the atmosphere and into space, where they can be collected by orbiting sensors. By measuring how far the atmosphere bends the signals, weather forecasters can deduce moisture and temperature. This graphic from PlanetIQ, one of the companies looking to turn GPS-radio occulation into a business, describes the process.



1. GPS satellite transmits a radio signal.
2. The signal is bent as it passes through the atmosphere.
3. The frequency of the signal shifts due to the Doppler effect, and the bending angle can be calculated from this shift.
4. The bending angles are fed into numerical weather models to refine estimates of temperature, pressure and water vapor, as well as electron density in the ionosphere.

4

Output: Temperature, pressure, water vapor and electron density by altitude; similar to weather balloon

PlanetIQ

two cubesats in early 2017, and Spire of San Francisco, Glasgow, Scotland, and Singapore, which has four operational satellites up and plans to deliver 100,000 occultations a day by next year.

The potential value of GPS-RO is well known to forecasters at the National Weather Service because of work by the University Corporation for Atmospheric Research in Boulder and partners in Taiwan. In 2006, UCAR and Taiwan launched six COSMIC satellites (short for Constellation Observing System for Meteorology, Ionosphere, and Climate). A year later, forecasters began incorporating occultations into their numerical weather models. These occultations have proved valuable, but there aren't enough COSMIC satellites or occultations for the readings to have a large impact.

"The long and the short is we can make use of more radio occultation data," says the National Weather Service's Jim Yoe, the chief administrative officer for the Joint Center for Satellite Data Assimilation.

Pilot project

A GPS-RO sensor is a GPS receiver that's been souped up to survive in space. Yunck says his company's version costs about $100,000 apiece. When construction of the cubesat and a ride to orbit are factored in, the total rises to about $1.5 million. The trick to making GPS-RO viable as a business will to be launch many of those satellites to deliver thousands of occultations a day. Each occultation provides highly accurate readings and excellent vertical resolution, but a single occultation covers only a narrow portion of the atmosphere horizontally. A CrIS instrument, by contrast, costs about $150 million but it scans from side to side, or cross track, as it orbits and covers about 2,200 kilometers. For severe-weather forecasting, a geostationary sounder would be much more useful because of its even broader view and its ability to watch the same features evolve, says the University of Wisconsin's Revercomb.

"The GPS-RO will never do that unless you darken the sky with [them or] something," he says.

That's pretty much what the commercial startups hope to do, but first things first. NOAA is preparing to invite the commercial companies to compete to have their weather observations assessed by the National Weather Service under a commercial weather data pilot project. The goal will be "to see how well those measurements meet NOAA's observing requirements," the agency says in written responses. NOAA plans to provide a report to Congress in 2017 with its initial findings.

The pilot was not NOAA's idea. Last year, U.S. Reps. James Bridenstine and Frank Lucas, two Oklahoma Republicans, wrote authorization language proposing a $9 million commercial data pilot. The language didn't become law, but Bridenstine worked with colleagues to include $3 million for a commercial pilot in the omnibus appropriation bill for 2016.

NOAA appears to be warming to the idea. "NOAA has been laying the groundwork for this effort since the day the omnibus appropriation was enacted," the agency says. In February, the agency surprised some observers by requesting an additional $5 million in the president's budget to continue the pilot in 2017.

Even so, Bridenstine hopes to see Congress pass authorization language this year that would spell out the intent of Congress for the pilot and require NOAA to follow it.

Trust

The pilot project will look at the technical aspects of GPS-RO, but the business model behind commercial services could prove to be the bigger sticking point. What if a commercial supplier goes out of business or a licensing or price dispute erupts? Can forecasters trust that the data will always be there?

"You don't want somebody to have to pay a bundle because they want to know if they're going to be hit by a tornado. This is a difficult political, sociological process here," Revercomb says.

Proponents of commercial data say NOAA can make sure that won't happen by negotiating wisely. Yunck of GeoOptics says it's just like NOAA purchasing a software license for a certain number of users.

"If they want to give the data away to the world, then we have a worldwide license price, which saves us the trouble of having to sell to everybody," he says. "We're not breaking ground here."

NOAA may have unwittingly created the bureaucratic and political opening for this proposed new way of doing business. The satellite that carries the first CrIS instrument, the SNPP, was launched in 2011, five years late, due in part to problems with development of its sensors. The satellite was originally intended to be an experimental pathfinder for a new constellation of spacecraft, but in 2009 slow development of NOAA's next polar-orbiting satellites prompted managers to declare it operational.

CrIS soundings today are fed into weather forecasting models. Members of Congress and the Government Accountability Office have been worried that Suomi NPP might not last until the first of four planned Joint Polar Satellite System spacecraft is launched. That's supposed to happen in early 2017.

Given this history, Bridenstine chafes at the argument that the private sector can't be trusted to meet weather data needs. He is among those concerned about a gap.

"Reliance on government satellites is not a guarantee of data availability," he says in a statement relayed by his staff. "Several companies are already seeking to partner with NOAA and, should the government send the signal that they are open to these data sources, there will undoubtedly be more."

Of course, all the discussions and politics could prove to be moot if the startups can get their GPS-RO constellations operating with broad enough coverage. "Once the data is out there and available, people are going to use it. The users don't care. They just want data," Yunck says.

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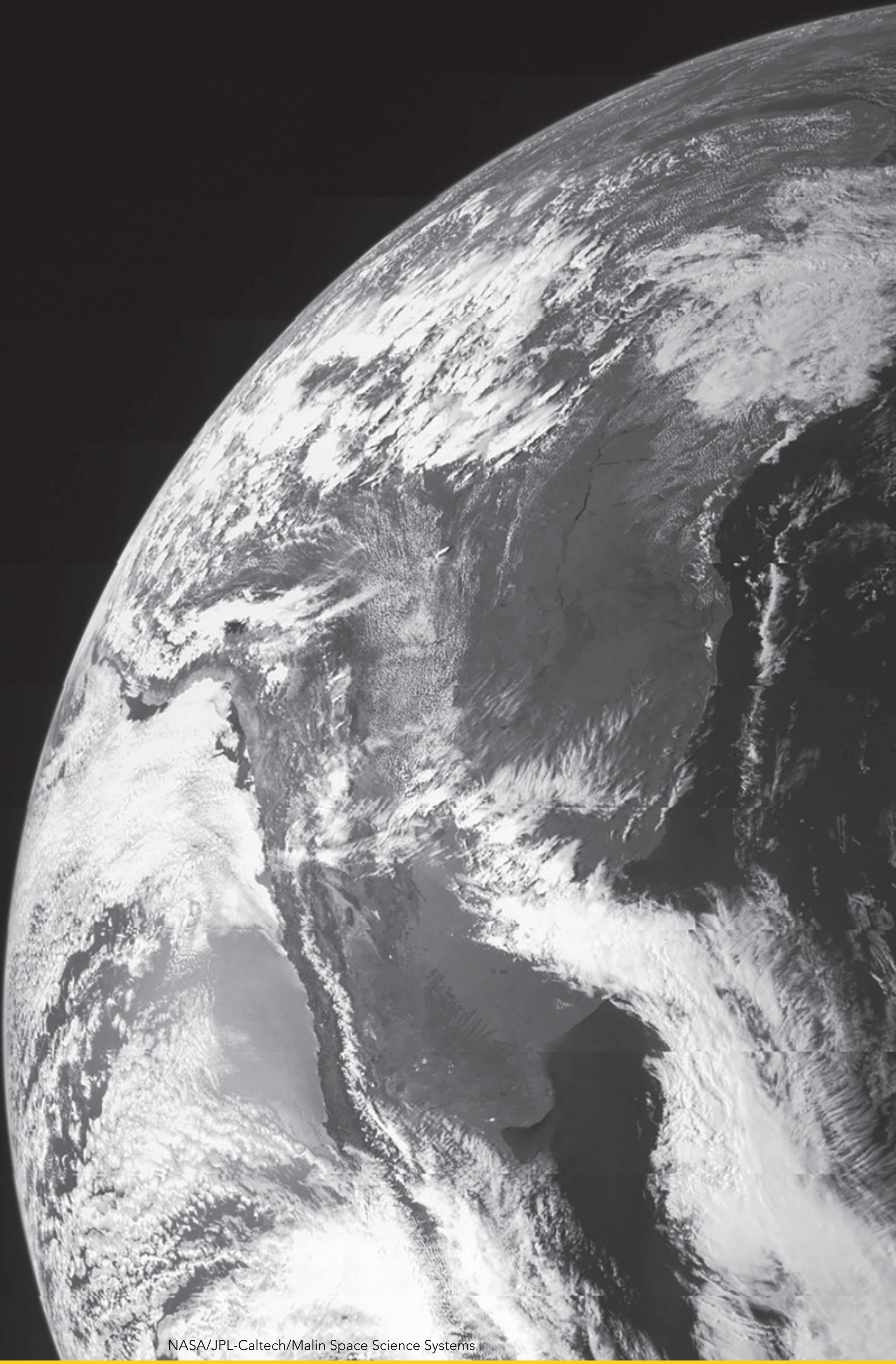


NASA/JPL-Caltech/Malin Space Science Systems

A pause button for MILITARIZING SPACE

by Theresa Hitchens
theresa.hitchens0@gmail.com

Earth, taken by the JunoCam color camera aboard NASA's Juno spacecraft, which is headed to Jupiter.

VIEWPOINT

The Obama administration's faith in diplomacy is well known. But when it comes to curbing the militarization of space, the administration's rhetoric has turned more bellicose than diplomatic. Defense analyst Theresa Hitchens says it's time for the administration to take a strategic pause to find a better course.

Through much of Barack Obama's presidency, strategic restraint was his administration's approach to maintaining security in space. The U.S. would restrain itself from introducing offensive capabilities in hopes of moderating the behavior of others, whether friends or potential foes. The Obama administration adopted this strategy early on despite, or perhaps because of, China's 2007 destruction of one of its own weather satellites by a ballistic missile. That was followed by the Bush administration's shootdown in 2008 of a malfunctioning American spy satellite. Within a year, China and the U.S. each had demonstrated an antisatellite weapon, though the U.S. maintains that Operation Burnt Frost was meant to protect people on the ground from debris. Regardless, the Obama administration decided that a better approach would be to establish norms of behavior in space that discourage such tests.

That, unfortunately, isn't what unfolded.

Since 2013, each of the leading space powers has conducted missions that the others consider provocative. Diplomatic efforts to rein in destabilizing conduct have foundered, and at last year's Space Symposium in Colorado Springs, the U.S. began pivoting away from strategic restraint. Air Force Secretary Deborah Lee James declared: "We must prepare for the potentiality of conflict that might extend from Earth one day into space."

This year, shortly after the Obama administration released its 2017 budget request, U.S. Defense Secretary Ashton Carter told an audience that "there are some in this world" who want to thwart U.S. technical "dominance" in space. "We're investing now so we stay ahead of them," he explained.

We are witnessing a drift toward the weaponization of space. If warfare were to break out in space, that would be uniquely dangerous because the environment of space is itself unique. Unlike ships on the high seas, another global commons, satellites when destroyed do not sink out of the way — instead they become uncontrolled and potentially lethal debris. Even tiny pieces of debris that cannot be detected with current space surveillance capabilities can kill an operational satellite because of the impact velocities. Further, because of the dual-use nature of space technologies, weapons placed in space would be difficult or impossible to differentiate from benign satellites, meaning everything would become a potential target. Civilians and the U.S. military each rely on commercially-operated communications satellites and the GPS constellation. Attacks on those spacecraft could cripple the global economy.

Rather than being goaded toward weaponization of space, the U.S. national security space community needs to take a strategic pause to consider whether there are alternatives. That does not mean that the U.S.'s concerns over China and Russia are unwarranted. Far from it.

Anti-satellite weapons

In May 2013, China launched a ballistic missile way beyond the 800-kilometer altitude where it destroyed its FY-1C weather satellite in 2007. The missile headed toward the geosynchronous satellite ring, which is home to most commercial communications satellites and many key U.S. intelligence and military satellites. The list includes the Advanced Extremely High Frequency comsats, which provide secure, jam-resistant communications for commanders and the president; the Wideband Global Satcom constellation, which provides broadband for troops and planners; and the Space Based Infrared System, the missile-warning satellites that are a key element of the country's nuclear deterrance and missile defense strategies.

Department of Defense

U.S. Secretary of Defense Ashton Carter told an audience in February that the Pentagon was working to maintain U.S. technical "dominance" in space.

A Chinese Academy of Sciences press release described the launch as a "scientific research mission" and noted that the altitude was 10,000 kilometers, considerably lower than the 36,000-kilometer GEO orbit. However, U.S. intelligence community and Pentagon officials concluded that the missile nearly reached GEO, and characterized it a test of a new ballistic missile-based anti-satellite, or ASAT, weapon. Space-policy wonks had long described GEO as a sanctuary from ASAT weapons given the distance and the unwillingness of governments to set a dangerous precedent. If the U.S. assessment of the Chinese launch is accurate, that sanctuary has now been violated.

The missile in the GEO test did not strike anything, and that was probably by intent. China's overt anti-satellite test in 2007 was the first such test in the world in two decades, and it sparked international opprobrium. The missile was most likely topped with a kinetic energy (hit-to-kill) kill vehicle. It created mass quantities of dangerous space debris. China has continued to experiment with non-destructive ballistic missile launches that garner less attention. The U.S. deems these as part of an ongoing Chinese ASAT testing program, but China has asserted they are missile-defense related.

Maneuverable satellites

In December 2013, Russia orbited a small maneuvering satellite in low Earth orbit and it did so again in May 2014. In each case, the Russian government at first announced that a Briz K-M rocket carried three military Cosmos satellites, but later, when registering these launches with the United Nations, Russia said there was a fourth satellite on each flight. Defense department officials and amateur observers tracked these small sats during the maneuvers. Some in the Pentagon suggested that Russia might have been practicing an offensive capability. Most worrisome was the September 2014 launch of another Russian maneuvering satellite, this one into geosynchronous orbit. After drifting back and forth for a few months, the satellite parked between two operational Intelsat communications satellites for about five months. Russia has not registered this satellite with the United Nations, as is required by the 1976 Registration Convention to which Russia is a signatory along with the United States and most satellite operating nations. Intelsat alleged that the Russian satellite came within 10 kilometers of one of its communications satellites, which is by no means standard operational procedure and certainly would represent a potential danger of collision. Intelsat sought an explanation from the Russian operator (through the U.S. Defense Department) to no avail.

"This is not normal behavior and we're concerned," Kay Sears, president of Intelsat General, the government services arm of Intelsat, said in an October 8 interview with Space News.

In a mission that seems similar in some respects to the Russian experiments, China in 2013 launched three small satellites into LEO, one of which was equipped with a robotic grappling arm. One of the satellites conducted close proximity operations around a companion satellite at least twice, once in 2013 and once in 2014. Just as with the Russian maneuvers, Pentagon officials voiced concerns that China may have been testing technologies for reaching out and touching another country's satellites. Chinese press reports said the satellites were testing capabilities to monitor orbital debris and conduct on-orbit maintenance operations related to potential debris removal or Chinese space station activities.

A troubling aspect of these episodes is a lack of transparency. Every nation has its secrets, but as noted, spacefaring nations are supposed to register a spacecraft's name and basic function with the United Nations. The United States typically registers even National Reconnaissance Office spy satellites, by providing the date of launch, the basic parameters of the initial orbit and the name of the agency that sponsored the launch. That said, the U.S. has at times played fast and loose with registration of secret satellites, either by registering years late or failing to provide accurate orbital data. Rarely are the final orbits of secret satellites provided. The Russian situation in GEO is particularly egregious, however, due to the satellite's behavior and Moscow's refusal to answer questions from either Intelsat or the U.S. government.

In early 2014, the U.S. stepped forward for a moment of transparency that it perhaps hoped would elicit a similar openness from China and Russia. At an Air Force conference in Florida, the service revealed the existence of a satellite development program called GSSAP, short for Geosynchronous Space Situational Awareness Program. Five months later, in July, the U.S. launched two GSSAPs to near geosynchronous orbit. Two more of these satellites are scheduled to launch sometime this year. These spacecraft drift along and look outward at other satellites with their electro-optical cameras. When commanded, a GSSAP can maneuver close to another satellite in a process the Pentagon calls RPO, short for rendezvous and proximity operations. None of this is a secret: "RPO allows for the space vehicle to maneuver near a resident space object of interest, enabling characterization for anomaly resolution and enhanced surveillance, while maintaining flight safety," the Air Force says in its GSSAP fact sheet. The U.S. has not released orbital parameters for GSSAP or its maneuvers; however, the satellites are watched closely by amateur satellite trackers around the world who have reported no maneuvers of concern regarding potential collisions — unlike the case of the Russian satellite in GEO.

Diplomacy runs aground

The Obama administration has pursued diplomatic solutions to improve space security more vigorously than any since the Jimmy Carter era. Those efforts have yielded some, but not nearly enough, rewards.

The U.S., working closely with Russia, led the way in achieving a consensus report in 2013 from the U.N. Group of Governmental Experts on Transparency and Confidence Building in Outer Space Activities.

The Bush administration portrayed its 2008 decision to shoot down an aging American spy satellite with a ballistic missile as a safety-related move. Many were skeptical of that rationale.

U.S. Navy

The group recommended voluntary, but significant, actions toward building trust and dampening risk perceptions. These recommendations included greater cooperation on space situational awareness, better compliance with and improvement of the Registration Convention to include reporting maneuvers, and information exchanges on national space security activities. But the Group of Governmental Experts report has been in limbo since its approval by the U.N. General Assembly, with no nation moving to establish a process for implementing its recommendations, even such basic ones as establishing points of contact for inquiries about space activities.

Washington also sought to aid the European Union's efforts to establish an International Code of Conduct designed to set norms of responsible behavior in space. The progress toward a Code of Conduct ended in July 2015, when Russia, China, Brazil, South Africa, India and the nations of the Non-Aligned Movement insisted that any negotiating process be placed under an open-ended U.N. mandate, meaning that discussions could go on for many years as there is no deadline or requirement to stick to the current text. That was exactly the process the European Union and the U.S. were trying to avoid.

The U.S. State Department has been a leading player in an initiative by the U.N.'s Committee for Peaceful Uses of Outer Space to establish best practices that would ensure the long-term sustainability of space for humans. This initiative, like the Code, is also being bogged down by a West vs. the Rest dynamic. In particular, many developing nations are suspicious of Western motives, thinking the U.S. and its allies might be trying to deny them parity in the space marketplace or seeking to keep military advantage.

But the key reason for the diplomatic molasses is the fallout of the Ukrainian crisis on Russian-Western relations. Russia has reversed course and become a serious roadblock to multilateral progress.

Underlying this lackluster diplomatic performance is a disconnect over the best way to keep war from ever breaking out in space. The U.S., as the leading space power, favors establishing politically binding norms. These would be voluntary codes of behavior that states would pledge to uphold. Washington is still not willing to pursue a legally binding treaty, as advocated by Russia and China and embodied in their proposal for a Treaty on the Prevention of the Placement of Weapons in Outer Space and of the Use of Force against Outer Space Objects. The PPWT, as it is called, is flawed in many respects, especially in the fact that it does not specifically cover ground-based ASATs and only vaguely defines what would constitute a weapon in space. That said, if the U.S. wanted a binding treaty, it could put forward a treaty proposal that it could accept.

It's tempting to argue that the Obama administration should have done more on the diplomatic front, but the reality has been that other geopolitical problems have sucked up most of the diplomatic bandwidth. Further, space arms control remains a contentious issue within the Republican-led Congress, with those who champion U.S. missile defense concerned that arms control initiatives could hamper their efforts. Pushing for space arms control would have taken political capital away from other high-priority issues such as health care reform.

What now?

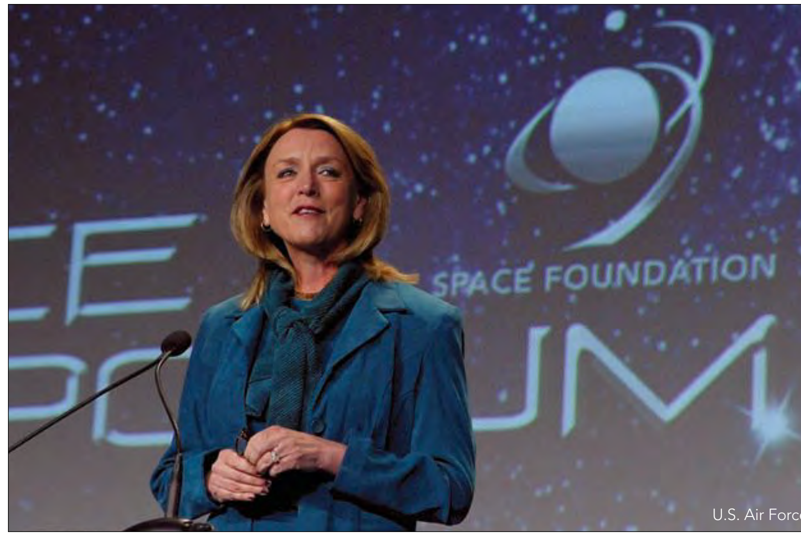
Today's difficult state of affairs could be exacerbated by Washington's shift away from a strategic restraint. As one senior national security space official told me privately, "strategic restraint has failed." That is debatable, but evidence suggests that the Obama admistration and Congress perceive it as so. The Pentagon in the summer of 2014 undertook a classified Space Portfolio Review that looked at threats, the survivability of satellites and the capabilities to respond to the threats. Congress jumped into the fray in the fiscal 2015 National Defense Authorization Act, ordering the Defense Secretary and the Director of National Intelligence to report on the role of "offensive space operations" in deterring and defeating threats to U.S. spacecraft, as well as mandating new spending on the development of "offensive space control and active defense strategies and capabilities."

According to an April 15, 2015 report in Breaking Defense, Deputy Defense Secretary Robert Work, in a classified session, invoked the need for the United States to emphasize "space control" — a military term of art that was all but eliminated from U.S. declaratory policy as too incendiary earlier in the Obama administration.

This was followed by the Pentagon's move in the summer of 2015 to reprogram between $5 billion and $8 billion (the exact figure remains unknown because some Pentagon spending and National Reconnaissance Office budgets are classified) in the 2016 to 2020 budget to "space protection." And now, Secretary Carter has pledged that the 2017 budget will target more spending on "negating" adversary counterspace capabilities. U.S. officials have not so far elucidated what types of offensive capabilities might be pursued, except to repeatedly stress that debris-creating weapons are still considered verboten because of their nondiscriminatory ability to do harm.

The U.S. should not allow fear or the actions of potential adversaries to dictate its national security space strategy. It is not in U.S. interest for space to become a potential battlefield. Despite advances in Russian and Chinese capabilities, the U.S. remains the country most reliant on satellites, both economically and militarily. It is also important to remember that the U.S. has demonstrated or deployed similar technologies to those now being tested by Russia and China. A "take-the-fight-to-the enemy" strategy is not a wise choice at this time.

A strategic pause would give time to decide how to passively protect both U.S. government and commercial satellites. This could include considering larger constellations of satellites to ensure greater redundancy and improving anti-jamming capabilities. Methods could be identified to ensure that missions or services enabled by satellites, such as positioning and timing services provided by GPS and communications, can be completed even in a degraded space environment. Perhaps some of these missions and services could be performed in an emergency by aircraft, blimps or by cellular communications. Diplomacy could be ramped up, via both more concrete discussions with Russia and China about what exactly they see as in their interests in space as well as greater efforts to find multilateral consensus on setting norms of behavior. A good place to start would be a commitment by all to forego debris-creating ASATs that would put all satellites at risk. Diplomacy will be particularly difficult as long as Russia is in its current mood as geopolitical spoiler, but that does not mean progress will be impossible in the long run. We should not forget Russia

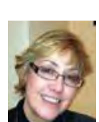


U.S. Air Force

At the 2015 Space Symposium in Colorado, Air Force Secretary Deborah Lee James signaled the Obama administration's pivot away from strategic restraint by saying, "We must prepare for the potentiality of conflict that might extend from Earth one day into space."

chaired the successful U.N. Group of Govermental Experts process. The U.S. could remind Moscow of that fact and challenge the Russians to again take the lead in implementing the 2013 report.

This does not mean that the U.S. should abandon research and development of technologies to defeat an adversary's offensive counterspace weapons. That said, it is not necessary to have tit-for-tat ASAT capabilities. There are other, cheaper airborne and terrestrial solutions, such as bombing ASAT launch pads and jamming. This is no time for the U.S. to toss up its collective hands in despair over Russia and Chinese technological developments and go on the offensive. That will not prove to be a winning move for the U.S. this early in the game. An arms race in space is to no one's benefit, and is not a race that the U.S. should allow itself to be dragged into easily.



Theresa Hitchens is a senior research scholar at the University of Maryland's Center for International and Security Studies at Maryland. She was director of the United Nations Institute for Disarmament Research in Geneva from 2009 to 2015 and director of the Center for Defense Information in Washington from 2000 to 2009, where she headed the Space Security Project. She is a former journalist, including a stint as editor of Defense News.

25 Years Ago, April 1991

April 23 After a lengthy fly-off, the U.S. Air Force names the Lockheed YF-22 as the winner of the advanced tactical fighter competition. Incorporating the latest in stealth technology, this highly advanced aircraft can supercruise—fly supersonically without the need of an afterburner for its two Pratt & Whitney F119 turbofan engines. David Baker, Flight and Flying: A Chronology, p. 484.

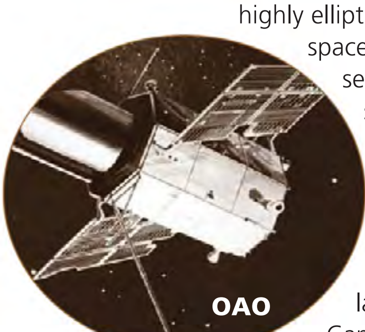
April 27 The Eurocopter Tiger attack helicopter completes it maiden flight from its factory in Marignane, France. Germany and France have already ordered Tigers that are equipped with anti-tank missiles and other ground support weapons. Each Tiger is fitted with two 1,285-equivalent-shaft-horsepower MTU/Rolls-Royce/Turbomeca turboshaft engines. David Baker, Flight and Flying: A Chronology, p. 484.

50 Years Ago, April 1966

April 4 NASA announces the selection of 19 pilots for astronaut training, bringing the number of its astronauts to 50. Some of these astronauts go on to serve in Apollo missions to the moon, and three of them, Charles Duke, James Irwin and Edgar Mitchell, later walk on the moon. Flight International, April 28, p. 733.

April 6 The first revenue service of a passenger hovercraft over an international route begins when a British Westland 38-passenger SR.N6 hovercraft, operated by the Swedish-owned, British-staffed Hoverlloyd Ltd., departs from Ramsgate, England, to Calais, France. The hovercraft, also known as an air-cushion vehicle, is a craft capable of traveling over land and is a hybrid vessel operated by a pilot as an aircraft rather than a captain as a marine vessel. Flight International, April 21, p. 47.

April 7 An Atlas-Centaur vehicle is launched from Cape Kennedy with a dummy Surveyor soft-landing lunar spacecraft. One purpose of this mission, designated Atlas-Centaur 8 (AC-8), is to demonstrate Centaur's capability to restart its high-energy engines in the space environment following a coast period in Earth orbit. Another goal is for the AC-8 vehicle to inject the dummy Surveyor into a simulated lunar transfer trajectory toward an "imaginary moon" following a 25-minute coast period in Earth orbit. The spacecraft then is to be placed in a highly elliptical Earth orbit, extending more than 804,650 km into space. But the Centaur stage fails to achieve a successful second ignition, leaving the dummy Surveyor stuck on Earth. Washington Post, April 8, p. A9; Atlas-Centaur 8 press kit, pp. 1-2.


OAO

April 8 The 1,769-kg Orbiting Astronomical Observatory (OAO), the first in a series of four U.S. space observatories, is launched by an Atlas-Agena vehicle from Cape Kennedy. But after two days in orbit, it ceases operation due an overheating battery and short circuit. The mission of the OAO spacecraft is to make the first high-quality observations of space objects in ultraviolet light. OAO-2 is not launched until Dec. 7, 1968. Aviation Week, April 18, p. 31.

April 10 Aviatrix Geraldine Mock sets a world nonstop record for a woman in a 4,550-km, 31-hour flight from Honolulu, Hawaii, to Columbus, Ohio, in a single-engine Cessna 206. Mock was the first woman to make a successful solo flight around the world in 1964 in a single-engine Cessna 180, taking 29 days, with 21 stopovers. New York Times, April 12, p. 25.

April 12 The Soviet Union celebrates Cosmonautics Day as the fifth anniversary of the world's first manned space flight, by Yuri Gagarin, that includes speeches by Gagarin and other cosmonauts at the Kremlin and at other events. Gagarin completed his 108-minute orbital flight in his Vostok 1 spacecraft in 1961. New York Times, April 14, p. 7.

April 13 Pan American World Airways, under the direction of Juan Trippe, places the first order for the new Boeing 747, the world's first widebody

Past

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

jetliner that is soon christened the "jumbo jet." The order is for 25 747s, including 23 490-seat passenger models and two cargo models. The $525 million order is the most expensive in airline history. New York Times, April 14, p. 1.

April 25 The Soviet Union launches its third Molniya 1 (Lightning) communications satellite in a highly elliptical orbit. Such orbits allow the satellites to remain visible to sites in polar regions for extended periods. This type of orbit is suited to high-latitude regions that are difficult or impossible to service with geostationary satellites. On April 26, the first long-range radio and TV transmissions via the satellite between Moscow and the Far East are made. On May 18 the satellite transmits TV pictures of clouds over the Earth to ground stations. Primarily, the early Molniya satellites serve government and military communications traffic. Later, they're also used to support the Russian civilian Orbita television network. Aviation Week, May 2, p. 26.

April 26 A NASA Convair 990 jet aircraft begins a series of flights to test new spacecraft sensors for weather measurements and to collect data at over 12,192 meters in support of the upcoming Nimbus C weather satellite scheduled for launch in May. NASA Release 66-107.

April 29 One of the world's largest and most sophisticated space tracking and telemetry antenna is officially dedicated in Goldstone, California. The 64-m diameter, $14 million dish antenna is later used to track Mariner and other spacecraft to Mars, Venus and even Pluto. NASA Release 66-88.

75 Years Ago, April 1941

April 2 The Heinkel He 280V-1 prototype, the first aircraft powered by two turbojet engines and the first intended to be a fighter, makes its inaugural flight. The He 280 uses two HeS 8 centrifugal-flow engines designed by Dr. Hans von Ohain, the inventor of the first jet engine to fly. While designed as a combat aircraft, the He 280 is not placed into production; the larger Messerschmitt Me 262 is produced instead. J.R. Smith and Antony Kay, German Aircraft of the Second World War, pp. 293-298.

April 6 The German Luftwaffe conducts its first air attacks on Yugoslavia. By April 17, Yugoslav forces capitulate. The Yugoslav air force is eliminated four days after hostilities begin. Interavia, April 24, p. 5.

April 15 For the first time in the Western Hemisphere, a single-rotor helicopter achieves a flight longer than an hour when Igor Sikorsky pilots his Vought-Sikorsky VS-300A for 1 hour, 5 minutes and 14.5 seconds at the Sikorsky plant in Stratford, Connecticut. That's a dramatic advance from his first helicopter flight of several seconds in 1939. E.M. Emme, ed., Aeronautics and Astronautics 1915-60, p. 41; D. Cochrane, V. Hardesty and R. Lee, The Aviation Careers of Igor Sikorsky, pp. 130, 132.

April 17 Igor Sikorsky's VS-300A helicopter, fitted with floats, makes the first helicopter water landings with Sikorsky himself piloting. Dorothy Cochrane, Von Hardesty, and Russell Lee, The Aviation Careers of Igor Sikorsky, p. 130.

100 Years Ago, April 1916

April 15-29 The Royal Flying Corps reinforces British troops besieged by the Turks at Kut el Amara. RFC aircraft from 30 Squadron deliver 13 tons of supplies to the troops in the first large scale aerial resupply. Despite these efforts, the approximately 12,000 British and Indian troops surrender after a four-month siege. A. van Hoorebeeck, La Conquete de L'Air, p. 117.

April 20 Elliott Cowdin II, a pilot for the newly formed Escadrille Americaine, receives the Medaille Militarie, the first American to receive the prestigious French award. A. van Hoorebeeck, La Conquête de L'Air, p. 117.

TEXAS A&M UNIVERSITY

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The Dwight Look College of Engineering at Texas A&M University is leading a multi-disciplinary search for scholarly talent in the area of unmanned autonomous systems. The goal of this effort is to position the Look College as the national leader in underwater, ground, air, and space autonomous systems research. The college is committed to providing the resources, facilities, equipment, and personnel to realize this goal. Applicants must have earned a doctorate in an engineering discipline or a closely related field. Applicants should submit a cover letter, curriculum vitae, teaching statement, research statement, and a list of five references (including postal addresses, phone numbers and email addresses) by applying for this specific position at www.tamengineeringjobs.com. Full consideration will be given to applications received by 1 June 2016. Applications received after that date may be considered until positions are filled. It is anticipated the appointment will begin fall 2016.

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AIAA Bulletin

In February, engineers from NASA Langley Research Center and Boeing dropped a full-scale test article of the company's CST-100 Starliner into Langley's 20-foot-deep Hydro Impact Basin. Boeing was testing the Starliner's systems in water to ensure astronaut safety in the unlikely event of an emergency during launch or ascent. The test was part of the qualification phase of testing and evaluation for the Starliner system to ensure it is ready to carry astronauts to and from the International Space Station. (*Image Credit: NASA/David C. Bowman*)

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

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

Event & Course Schedule

DATE	MEETING (Issue of *AIAA Bulletin* in which program appears)	LOCATION	ABSTRACT DEADLINE
2016			
4–6 Apr†	51st 3AF Conference on Applied Aerodynamics: "Thermal Effects and Aerodynamic"	Strasbourg, France (Contact: Anne Venables, secr.exec@aaaf.asso.fr; http://3af-aerodynamics2016.com)	
19–21 Apr†	16th Integrated Communications and Surveillance (ICNS) Conference	Herndon, VA (Contact: Denise Ponchak, 216.433.3465, denise.s.ponchak@nasa.gov, http://i-cns.org)	
16–20 May†	SpaceOps 2016: 14th International Conference on Space Operations	Daejeon, Korea (www.spaceops2016.org)	30 Jul 15
24–26 May†	The Fifth International Conference on Tethers in Space	Ann Arbor, MI (http://tethersinspace2016.com/)	
30 May–1 Jun†	22nd AIAA/CEAS Aeroacoustics Conference	Lyon, France (www.aeroacoustics2016.com)	
30 May–1 Jun†	23rd Saint Petersburg International Conference on Integrated Navigation Systems	Saint Petersburg, Russia (Contact: Ms. M. V. Grishina, +7 812 499 8181, icins@eprib.ru, www.elektropribor.spb.ru)	
11–12 Jun	Aircraft and Rotorcraft System Identification: Engineering Methods and Hands-On Training Using CIFER®	Washington, DC	
11–12 Jun	Concept in the Modern Design of Experiments	Washington, DC	
13–17 Jun	AIAA AVIATION 2016 (AIAA Aviation and Aeronautics Forum and Exposition) Featuring: 32nd AIAA Aerodynamic Measurement Technology and Ground Testing Conference 34th AIAA Applied Aerodynamics Conference AIAA Atmospheric Flight Mechanics Conference 8th AIAA Atmospheric and Space Environments Conference 16th AIAA Aviation Technology, Integration, and Operations Conference AIAA Flight Testing Conference 8th AIAA Flow Control Conference 46th AIAA Fluid Dynamics Conference 17th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference AIAA Modeling and Simulation Technologies Conference 47th AIAA Plasmadynamics and Lasers Conference 46th AIAA Thermophysics Conference	Washington, DC	5 Nov 15
15 Jun	Aerospace Spotlight Awards Gala	Washington, DC	
16–17 Jun	6th AIAA CFD Drag Prediction Workshop	Washington, DC	
5–8 Jul†	ICNPAA 2016 Mathematical Problems in Engineering, Aerospace and Sciences	University of La Rochelle, France (Contact: Prof. Seenith Sivasundaram, 386.761.9829, seenithi@gmail.com, www.icnpaa.com)	
23–24 Jul	3rd Propulsion Aerodynamics Workshop	Salt Lake City, UT	
23–24 Jul	Advanced High-Speed Air-Breathing Propulsion	Salt Lake City, UT	
23–24 Jul	Electric Propulsion for Space Systems	Salt Lake City, UT	
23–24 Jul	Hybrid Rocket Propulsion	Salt Lake City, UT	
24 Jul	Detonation-Based Combustors Tutorial	Salt Lake City, UT	
25–27 Jul	AIAA Propulsion and Energy 2016 (AIAA Propulsion and Energy Forum and Exposition) Featuring: 52nd AIAA/SAE/ASEE Joint Propulsion Conference 14th International Energy Conversion Engineering Conference	Salt Lake City, UT	12 Jan 16
5–7 Sept†	Advanced Satellite Multimedia Systems Conference	Palma de Mallorca, Spain (Contact: www.asmsconference.org)	
7–8 Sept†	20th Workshop of the Aeroacoustics Specialists Committee of the Council of European Aerospace Societies (CEAS): Measurement Techniques and Analysis Methods for Aircraft Noise	University of Southampton, United Kingdom (Contact: www.southampton.ac.uk/engineering/research/groups/acoustics-group/ceas-asc-workshop-2016)	
11–12 Sep	Introduction to Space Systems	Long Beach, CA	
11–12 Sep	Systems Engineering Fundamentals	Long Beach, CA	

DATE	MEETING (Issue of *AIAA Bulletin* in which program appears)	LOCATION	ABSTRACT DEADLINE
13–16 Sep	**AIAA SPACE 2016 (AIAA Space and Astronautics Forum and Exposition)** **Featuring:** AIAA SPACE Conference AIAA/AAS Astrodynamics Specialist Conference AIAA Complex Aerospace Systems Exchange	Long Beach, CA	**25 Feb 16**
25–30 Sep†	**30th Congress of the International Council of the Aeronautical Sciences (ICAS 2016)**	Daejeon, South Korea (Contact: www.icas.org)	**15 Jul 15**
25–30 Sep†	**35th Digital Avionics Systems Conference**	Sacramento, CA (Contact: Denise Ponchak, 216.433.3465, denise.s.ponchak@nasa.gov, www.dasconline.org)	
26–30 Sep†	**67th International Astronautical Congress**	Guadalajara, Mexico (Contact: www.iac2016.org)	
27–29 Sep†	**SAE/AIAA/RAeS/AHS International Powered Lift Conference**	Hartford, CT	**26 Feb 16**
17–20 Oct†	**22nd KA and Broadband Communications Conference and the 34th AIAA International Communications Satellite Systems Conference**	Cleveland, OH (Contact: Chuck Cynamon, 301.820.0002, chuck.cynamon@gmail.com)	
2017			
9–13 Jan	**AIAA SciTech 2017 (AIAA Science and Technology Forum and Exposition)** **Featuring:** 25th AIAA/AHS Adaptive Structures Conference 55th 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 19th AIAA Non-Deterministic Approaches Conference 58th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference 10th Symposium on Space Resource Utilization 4th AIAA Spacecraft Structures Conference 35th Wind Energy Symposium	Grapevine, TX	
4–11 Mar†	**IEEE Aerospace Conference**	Big Sky, MT (Contact: www.aeroconf.org)	
6–9 Mar†	**21st AIAA International Space Planes and Hypersonic Systems and Technology Conference (Hypersonics 2017)**	Xiamen, China	
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)	
5–9 Jun	**AIAA AVIATION 2017 (AIAA Aviation and Aeronautics Forum and Exposition)** **Featuring:** 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	

continued on page **B4**

Meeting Schedule

DATE	MEETING (Issue of *AIAA Bulletin* in which program appears)	LOCATION	ABSTRACT DEADLINE
10–12 Jul	**AIAA Propulsion and Energy 2017 (AIAA Propulsion and Energy Forum and Exposition)** **Featuring:** **53rd AIAA/SAE/ASEE Joint Propulsion Conference** **15th International Energy Conversion Engineering Conference**	Atlanta, GA	
12–14 Sep	**AIAA SPACE 2017 (AIAA Space and Astronautics Forum and Exposition)** **Featuring:** **AIAA SPACE Conference**	Orlando, FL	
25–29 Sept†	**68th International Astronautical Congress**	Adelaide, Australia	

For more information on meetings listed above, visit our website at www.aiaa.org/calendar or call 800.639.AIAA or 703.264.7500 (outside U.S.).
†Meetings cosponsored by AIAA. Cosponsorship forms can be found at https://www.aiaa.org/Co-SponsorshipOpportunities/.
AIAA Continuing Education courses.

From the **Corner** Office

DEMAND FOR UNMANNED – A CATALYST FOR THE MACHINE INTELLIGENCE REVOLUTION.

Thomas B. Irvine, AIAA Managing Director of Content Development

Each fall, *TIME* runs a review of the best new inventions. The roundup covers the latest innovations from all areas including home appliances, toys, transportation, computers, and other high-tech areas. From these categories, the editors normally select an Invention of the Year. In the November 12, 2007 edition, the Boeing X-48B blended wing body aircraft, a collaborative effort of The Boeing Company, NASA, and the Air Force Research Laboratory, was picked in the aircraft category for its innovative design and its potential to enable cleaner, quieter, and higher performance air transportation. The X-48B did not win the 2007 Invention of the Year award; that honor went to Apple's iPhone. Since then, the iPhone and other smartphones have become truly ubiquitous. And although your teenager would be the envy of the neighborhood were a X-48B to be parked in your driveway, blended wing body technology remains the purview of the research and development (R&D) engineers within the aeronautics industry. And while the aerospace industry went on to capture the 2009 *TIME* Invention of the Year award when the Ares-1 was selected following the Ares 1-X flight on October 28, 2009, we will only fully capture the public's imagination once we near the first crewed flight of the SLS, its successor vehicle.

However, within aerospace one technology is on the cusp of having a profound effect on society, the likes of which have not come out of our industry in quite some time. Unmanned Aerial Systems (UAS), and specifically, quadcopter drones, have captured the imagination of the public, government officials, and entrepreneurs, who aspire to use drones in a variety of ways for public safety, national defense and security, and business opportunities. Whether the use of drones for the variety of purposes currently envisioned becomes as ubiquitous as smartphones remains to be seen. Nevertheless, the potential uses, from retail package delivery, to medical deliveries and services, to public use where drones can aid in fire, rescue and safety, to performing aerial cinematography for the entertainment and sports industries, are limited only by our imaginations. From inside and outside of the aviation industry, it is hard to argue that UAS haven't already captured the public's attention and interest. Compare the explosion in the interest of drones, if not the actual operation of drones in both uncontrolled and controlled airspace, with the relatively dismal efforts over the past decade or more to revitalize general aviation. Proof that an idea whose time has come will always find an enthusiastic reception.

That brings us to AIAA and what is known as the Institute's "Growth Plan." The objective of the growth plan is to offer products and programming related to emerging trends and technologies in aerospace for the benefit of our members and aerospace professionals in general. As highlighted earlier UAS and their technology and application are a very important emerging area not only in aerospace but also in society. There are a plethora of frequently held events, conferences, and workshops that take place related to all aspects of the exploding UAS industry—business, policy, regulations, and technology.

AIAA, recognizing the impact that UAS will continue to have on society and the importance of the technologies involved, is creating the AIAA UAS-related symposium, DEMAND for UNMANNED—A Catalyst for the Machine Intelligence Revolution. Our members have been urging the Institute to engage in the topic of UAS and the Board has agreed. With so many people doing so many things regarding unmanned systems AIAA decided to focus on what we do best—technology. There are changes occurring in engineering and technology, that, while well known in the aerospace profession, are not apparent to the public as they engage with these systems. However, these technologies are likely to, or already are, causing monumental shifts in our society. Technologies that center around information technology and increases in computing capability (speed, storage, and bandwidth) have driven innovation in communication, manufacturing, and increasingly in operations. DEMAND for UNMANNED, to be held in conjunction with AIAA AVIATION 2016, will focus on UAS-related topics that primarily address the needs of the R&D community. Participants will discover how UAS are catalysts for autonomy, robotics, and machine intelligence; technologies that are changing the nature of civil and military aviation. As the world's premier aerospace R&D professional organization, we feel that AIAA is well situated to inform, educate, and provide a platform and a voice for the profession and ultimately the industry as we venture into the coming machine intelligence epoch. Come join us at AIAA AVIATION 2016, engage, and be a part of defining your own future and that of the aerospace profession and industry.

15 STUDENT MEMBERS NAMED TO 20 TWENTIES LIST

Fifteen 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 59th Annual Laureate Awards on March 3 at the National Building Museum, in Washington, D.C. (Full details can be found at: **http://www.aiaa.org/AIAA20TwentiesList2016**)

GREATER HUNTSVILLE SECTION RALLIES ENGINEERING COMMUNITY TO WATTS FOR TOTS

Daniel Cavender

The Watts for Tots idea originated because of my wife, Laura, who is an occupational therapist (OT) who works with children with special needs at United Cerebral Palsy of Huntsville (UCP). I saw the parallels between an engineer and OT, namely the end goal of making something useful to bring meaning and purpose to someone. Many of the children she works with have difficulty playing with toys because they lack fine motor skills or the strength to "activate" the toy. Engineers are problem solvers.

Plush toys are the easiest to adapt; consider a plush tiger that sings a certain Alma Mater's fight song when you squeeze a paw. That takes 1–2 pounds of force to activate, and a child diagnosed with extreme muscle weakness or poor neurological motor control may not be able to muster the control or strength to make Aubie sing. An adapted toy will either add in parallel or completely bypass the paw switch with a 3.5 mm mono jack female that can connect to an AT switch device. The most commonly used AT switch device is a large, brightly colored button the size of a coaster that has a very low activation force of 50–100 g. With a light press-of-a-button, Aubie can sing all day.

In December 2014, we decided to adapt the toys to give as Christmas gifts for the children at UCP of Huntsville. We hosted a get-together with engineering and non-engineering friends where they adapted nearly 50 toys. The whole event was immensely satisfying. All year, we heard stories of kids playing with their specially adapted toy. They had given their selves meaning and purpose by helping to improve the quality of life for those kids.

As Christmas 2015 approached Laura and her co-workers at UCP wanted to know if we would do another Watts for Tots event. Most of the engineers from the first Watts for Tots were members of the AIAA Greater Huntsville Section and we saw an opportunity to make Watts for Tots bigger. We held the event at a local brewery and had 40 volunteers that night and adapted 80 toys!

This is a need for this all over the country and people want to replicate our success. Since we began Watts for Tots, we've been contacted by occupational therapists from Philadelphia to Albuquerque asking, "How do we do this here? How can we get in touch with some engineers for help?" Some have asked how to get in touch with a local AIAA section for support. Watts for Tots revealed a fun way to connect with people in the community and to do something special by improving the quality of life of children in Huntsville.

The 2014 Watts for Tots crew adapting toys.

The 2015 Watts for Tots crew.

OBITUARIES

AIAA Fellow Born Died in January

Pioneering space researcher **George Born** passed away on 21 January 2016.

Born led a distinguished career at NASA, playing major roles in the Mariner and Viking missions to Mars, and serving as manager of the Seasat Geophysical Evaluation Team.

Following his service at NASA, he spent 30 years at the University of Colorado Boulder, teaching graduate classes and conducting groundbreaking research in oceanography. He revolutionized the field by developing a suite of tools that demonstrated the power of studying the ocean from space. Born founded the Colorado Center for Astrodynamics Research and is the primary author of the textbook *Statistical Orbit Determination*.

Born was a member of the National Academy of Engineering and the recipient of nine NASA awards and medals. He was a Fellow of the American Astronautical Society as well as AIAA, and a recipient of the 1999 AIAA Mechanics and Control of Flight Award.

AIAA Fellow Maurice Died in February

Dr. Mark S. Maurice passed away on 26 February 2016.

Dr. Maurice earned a Bachelor of Science in Mechanical Engineering in 1982, his Master's in Aerospace Engineering in 1986, and his Ph.D. in Aerospace Engineering in 1992, all at the University of Dayton. It was in calculus class at Dayton that he met his wife, Lourdes, also an AIAA Fellow.

While attending Dayton he began working at the U.S. Air Force Research Laboratory in Dayton, then in London, England, and finally in Arlington, VA. Over 35 years his job with the Air Force Office of Scientific Research (AFOSR) took him all over the world. As the director of the AFOSR's International Office Dr. Maurice coordinated research work with other countries, allowing U.S. scientists to conduct research overseas; promoted international cooperation in R&D; and connected with international researchers who came to the U.S. as visiting scientists.

Dr. Maurice and his wife, Lourdes, were very involved in AIAA over the years. He had been a member of the Ground Testing Technical Committee (1993–1996); a member of the Emerging Technologies Committee (2008); a member of the Institute Development Committee (2009–2011); a member of the International Activities Committee (2009–2016) and Chair (2009–2012); and Vice President–International on the Board of Directors (2009–2012). He received an AIAA Special Service Citation in 1998.

His friend Mark Lewis, former AIAA president, said, "Mark Maurice's sudden passing was an incredible shock. Mark was a valued member of our aerospace community, a scholar and a gentleman who was as smart and capable as he was fundamentally decent and kind. Those of us who had the privilege of working with Mark knew him as absolutely imperturbable and unflappable, thoroughly dedicated to advancing aerospace research as a collaborative international endeavor. Mark and his wife, Lourdes, who is herself an accomplished leader in our community and a dedicated AIAA member, were an amazing team. I would ask all of our members to join me in expressing sincerest condolences to Lourdes and their son Anthony, as well as to their entire family and circle of friends."

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 Washington Hilton Hotel, Washington, DC, on Thursday, 16 June 2016, at 10:20 AM.

William Seymore, AIAA Corporate Secretary/Treasurer

Introducing the New Faces of Engineering 2016!

AUGUST BOSCHERT, P.E.
Systems Planning and Analysis, Inc.

Boschert, 30, helps the Department of Defense deliver effective natural disaster and humanitarian aid.

ANNE DARE, PH.D., EIT
Purdue University

Dare, 29, solves international development challenges such as land water management, food security and rural sanitation.

TOBY DEEN, P.E.
Devon Energy

Dee, 29, works to increase our living standards and quality of life by improving the management and production of oil wells.

BRYONY DUPONT, PH.D.
Oregon State University

DuPont, 30, is researching how advanced computation systems can make sustainable environmental solutions more feasible.

ROSE FAGHIH, PH.D.
Massachusetts Institute of Technology

Faghih, 30, mixes engineering and physiology to tackle health problems related to challenging hormone issues.

DARVIN GRIFFIN
Cornell University

Griffin, 29, is on the cutting edge of developing cartilage repair mechanisms for those suffering from osteoarthritis.

THANKS TO OUR 2016 CO-CHAIRS.

DISCOVERE NEW FACES

WWW.DISCOVERE.ORG

RAJAN JHA (M.S, EIT, AM, ASCE)

ARCADIS

Jha, 28, works to solve challenging water infrastructure problems related to storm-water and stream rehabilitation.

TASHA KAMEGAI-KARADI

Geosyntec Consultants

Kamegai-Karadi, 28, designs and manages groundwater treatment plants to treat contaminated groundwater.

BRIDGET OSBORN, P.E.

HR Green, Inc

Osborn, 30, designs water reuse irrigation systems that reduce pollution in our waterways.

AMRIKA RAMJEWAN

Ministry of Public Administration

Ramjewan, 26, oversees a diverse portfolio of public sector projects in trade, transportation, education and healthcare in Trinidad and Tobago.

RACHEL ROMERO

National Renewable Energy Laboratory (NREL)

Romero, 29, worked on the creation of the National Standard Work Specifications for residential building professionals to ensure quality outcomes for the home energy industry.

KAYLEY SEAWRIGHT

The Boeing Company

Seawright, 23, works to ensure our astronauts travel safely to and from the International Space Station.

UNIVERSITY OF MICHIGAN'S AEROSPACE DAY

At the University of Michigan, it seems like a normal Saturday morning in December: the weather is getting colder, students are studying for finals, and campus is, for the most part, quiet.

At the Francois-Xavier Bagnoud building, the home of Michigan's aerospace engineering department, the hundreds of middle school students, parents, current engineering students, and faculty make it obvious that this is not, in fact, a normal Saturday. ... It's the morning of Aerospace Day.

Hosted each semester by the outreach committee of the AIAA student chapter at the University of Michigan, Aerospace Day gives students—generally in middle school, though all ages are welcome—the opportunity to learn about aerospace engineering through a series of activities, from designing part of a blimp gondola to watching rocket launches to building physical models of constellations. Parents and students are encouraged to ask questions of the current students, faculty, and alumni, and the exchange has proven beneficial to both the volunteers and the visiting students.

In November 2014, at the first-ever Aerospace Day, the AIAA student chapter hosted about 70 students with the help of 50 volunteers. Last semester, the outreach committee made its mark once again with the third biannual Aerospace Day. Registration opened in early November—and was full within 36 hours as 120 students registered. Those students, ages 6–16, joined 90 volunteers from across Michigan's College of Engineering, where they spent the day exploring the department's facilities, learning about the groups and activities on campus, and discovering what it means to be an aerospace engineer.

The importance of an event like Aerospace Day isn't lost on the students, parents, or volunteers. Feedback from parents each semester repeatedly emphasized how both the parents and students enjoyed learning about aerospace engineering, and how they plan to return for future events. Students leave with a newfound understanding of aerospace, an interest in everything from blimps to rockets, and often a desire to study aerospace engineering when attend college. The volunteers almost universally explained that they were eager to introduce the visiting students to their work and their department at an event they would have loved to participate in when they were younger.

In 18 months, Aerospace Day has grown into the department's largest outreach event, with more students interested than the facilities can currently handle. Accommodating more students is currently the biggest challenge for the AIAA outreach committee, but it's a good problem to have. And the Michigan AIAA student chapter is excited to brainstorm new solutions and activities for future events. The next Aerospace Day is on 9 April 2016, and Michigan's students are ready to introduce even more people to the world of aerospace engineering.

CONGRATULATIONS TO OUR STUDENT PAPER COMPETITION WINNERS!

AIAA congratulates the following winners of student paper competitions that were held during the AIAA Science and Technology Forum (AIAA SciTech 2016).

American Society for Composites Best Student Paper Award
Geoffrey Knott and Andrew Viquerat University of Surrey, AIAA-2016-1499, "Modeling the Bistability of Laminated Composite Toroidal Slit Tubes"

Guidance Navigation and Control Best Student Paper
Max Spetzler & Ansau Narang Siddarth, University of Washington, AIAA 2016-0080, "Local Linear Controllability and Observability Analysis of Nonlinear Systems with Continuation Methods"

Harry H. and Lois G. Hilton Student Paper Award in Structures
Tishun Peng and Yongming Liu, Arizona State University, AIAA-2016-0724, "3D Delamination Profile Reconstruction For Composite Laminates Using Inverse Heat Conduction"

Intelligent Systems Best Student Paper
Jayaprakash Suraj Nandiganahalli, Sangjin Lee, and Inseok Hwang, Purdue University, AIAA-2016-0129, "Intent-based Abstraction for Formal Verification of Flight Deck Mode Confusion"

Jefferson Goblet
Eric Eckstein and Paul Weaver, University of Bristol; Michael Halbig, NASA Glenn Research Center, AIAA-2016-1241, "Thermally-Driven Morphing with High Temperature Composites"

Lockheed Martin Student Paper Award in Structures
Phillip Deierling and Olesya Zhupanska, University of Iowa; Crystal Pasiliao, Air Force Research Laboratory, AIAA-2016-0490, "Thermal Response of a Spatially Graded Metal-Ceramic Structural Panel to Non-Uniform Heating in Hypersonic Flow"

Southwest Research Institute Student Paper Award in Non-Deterministic Approaches
Chenzhao Li and Sankaran Mahadeven, Vanderbilt University, AIAA-2016-0952, "Robust Test Resource Allocation using Global Sensitivity Analysis"

RECENT AIAA ORANGE COUNTY SECTION ACTIVITIES

During the past months, the AIAA Orange County (OC) Section has been involved in many different activities in Southern California, including popular speaker events and STEM activities pursued by AIAA OC council members. Moreover, the popular Annual AIAA Southern California Aerospace Systems and Technology (ASAT) Conference and Banquet is being planned for Saturday, 30 April 2016.

AIAA OC Speaker Programs

The speaker programs are recurring, popular events spearheaded by Dr. Jim Martin. With goals of networking, spreading knowledge, and stimulating discussions that could benefit the aerospace sector as a whole, the AIAA OC Section regularly hosts the AIAA OC speaker program series. Most of these programs are dinner meetings with pizza and soft drinks provided. An overarching goal of the speaker programs has been to include speakers from a wide range of aerospace topics. Since June 2015, the following topics have been presented as part of the AIAA OC speaker program series:


Dr. Jim Martin, AIAA OC Council member, hosting a presentation.

- "Our Changing Climate: Past, Present, and Future," Speaker: Dr. Jere H. Lipps
- "Flight of the Lynx," Speakers: Dave Dressler and Dale Amon
- "Flying the Feathered Edge: The Bob Hoover Project," Speaker: Kim Furst
- "The New Mooney Aviation Company," Speaker: Ron Blum
- "STEM Crisis in American School," Speaker: Bethany Orozco
- "USC Design-Build-Fly Championship," Speakers: USC DBF Team

Selected STEM Activities

The AIAA OC section supports a variety of STEM events. These events are primarily headed by Jann Koepke and Bob Koepke, who with the occasional support of other council members, actively pursue new STEM challenges to enable hands-on experiences for students and learners of all ages. The AIAA OC section typically provides publicity and donations to the local Team America Rocketry Challenge (TARC) teams. TARC is an international hands-on competition and every year student TARC teams present their work during the annual ASAT conference.

The section also supports the AIAA OC Rocketry Club. The club is primarily aimed at involving youth with science, engineering and technology through rocketry. The club meets once monthly and has at least one launch outing each month. Students begin by building commercial kits and progressively advance to design and build rockets using a Computer Aided Design program. Many students participate in the TARC contest and the Student Payload and Rocketry Challenge (SPARC).


AIAA OC Council members Jann Koepke and Bob Koepke speaking during a rocketry session at the AIAA OC ASAT 2014 conference.

The AIAA OC Section also regularly supports after-school programs that encourage the involvement of aerospace professionals. The Section also provides judges for the Orange County Science and Technology Fair, and invites winners to present their work during the ASAT Conference. The Orange County Engineering Council and local Design/Build/Fly teams have also been supported by the Section in the past.

ASAT 2016

The AIAA OC Section will host the 13th Annual AIAA Southern California Aerospace Systems and Technology Conference and Banquet, the premier event of the Section, on 30 April 2016. This conference brings together Southern California engineers, researchers, educators, students, leaders, and enthusiasts. The one-day program consists of presentations in a number of parallel tracks. Each session is initiated by a highly regarded keynote speaker. The 2016 ASAT keynote speakers are Dr. Garrett Reisman, former NASA astronaut, and Dr. Karl Garman, chair, AIAA Flight Test Technical Committee. The banquet speaker is Tom Longsdon of the Applied Technology Institute.

Similar to previous years, ASAT 2016 accepts unclassified presentations on all aspects of aerospace systems, technology, vehicle design, program management, policy, economics and education structured in three major categories:

- Aircraft Systems and Technology
- Space Systems and Technology
- Aerospace Public Policy and Education

During ASAT 2016, the Gohardani Presentation Award in Aeronautics and Aerospace, sponsored by the Springs of Dreams Corporation, will be presented. This award includes a monetary prize and a Certificate of Excellence and will be presented to the speaker with the most thought-provoking and exceptional all-around presentation during ASAT. The winner will be judged on content, organization, and delivery.

Co-chaired by Dino Roman and John Rose, ASAT 2016 will be held at the Doubletree Club Hotel, Orange County Airport in Southern California. The registration deadline is 26 April.

For more information on Section events, please visit: **https://info.aiaa.org/Regions/Western/Orange_County**.

GREATER HUNTSVILLE SECTION MEMBER EARL PEARCE HONORED IN EMERITUS MEMBER CEREMONY

On 6 February, the AIAA Greater Huntsville Section held a ceremony at the Southern Museum of Flight in Birmingham, AL, to honor Commander Earl H. Pearce, U.S. Navy (retired), in recognition of his attainment of Emeritus Member status. Over 55 AIAA members and guests gathered in a historic aviation venue to laud a man who lived much of that history.

CDR Pearce's contributions to AIAA and aviation span seven decades. He earned his Bachelor of Science in Mechanical Engineering degree from Auburn University in 1952; his Bachelor of Science in Aeronautical Engineering from the Naval Postgraduate School where he joined the Institute of the Aeronautical Sciences; and an MBA from the University of Alabama in Birmingham, where he was the Fiscal Officer from 1973 to 1980, and was on the faculty of the Mechanical Engineering Department from 1980 to 1990. CDR Pearce served as a fighter pilot in the U.S. Navy, accomplishing over 500 landings on 11 different aircraft carriers. He survived ejection from his F3 Demon fighter after an engine failure.

CDR Pearce is an AIAA Senior Member Emeritus, having been a member for over 50 continuous years. He served as the Supernumerary of the Greater Huntsville Section for many years, routinely making the two-hour drive from his home in Birmingham to Huntsville to attend council meetings. In 2011, the Section named its Professional of the Year Award for him. The Earl Pearce Professional of the Year Award is given annually to a Section member in recognition of extraordinary dedication, creativity, and leadership within the aerospace community.

After an AIAA group tour of the Southern Museum of Flight, including a behind-the-scenes look at the museum's restoration facilities, a luncheon and emeritus recognition ceremony followed. Guests included AIAA Section members; AIAA Student Members from the University of Alabama, Tuskegee University, and Auburn University; members of the Association of Naval Aviators; and friends and family members. The colors of the United States and the State of Alabama were presented by members of the Homewood High School AFJROTC honor guard, followed by the playing of the National Anthem. Past Section Chair Lt Col Ken Philippart, USAF (ret.) served as the master of ceremonies.

CDR Pearce cut the cake using his military dress sword, after which he was honored by various groups. He was presented with an Emeritus Certificate by Section Chair Dr. Kurt Polzin. Past Section Chairs Alan Lowrey, Dr. Arloe Mayne, and Ken Philippart gave him an AIAA Emeritus clock, followed by the presentation of the Section Coin by past recipients of the Pearce Professional of the Year Award, John Dankanich, Richard Jozefiak, and Tim Pickens. The Section's Young Professional members presented him with a framed print of the well-known aviation poem "High Flight" superimposed on a picture of a soaring gull donated by Lisa Philippart. Finally, on behalf of Air Force Association (AFA) Tennessee Valley Chapter 335, Ken Philippart presented CDR Pearce with an AFA coin along with an Air Force coin depicting an F-4 Phantom, one of the many aircraft types he flew during his military service.

Students from Tuskegee University with CDR Pearce

Left: Section Chair Dr. Kurt Polzin present Emeritus Certificate to CDR Pearce. Right: CDR Pearce speaks about his career and AIAA.

CDR Pearce then spoke about his career, including being an instructor pilot and using afterburner to boost F-4 Phantoms to fly over 100,000 feet in altitude, where the curvature of the earth could be seen, and the value of being an AIAA member. After the event was adjourned attendees visited with CDR Pearce, with many staying well after the conclusion of the event to talk with CDR Pearce and each other.

While this was the first dedicated emeritus recognition ceremony conducted by the Greater Huntsville Section, it was an unqualified success, bringing together multiple generations of AIAA members to share in the Section's proud history and carry on the legacy of excellence. The Greater Huntsville Section intends to institutionalize an emeritus recognition program to ensure that its longest serving members are publicly recognized for their devoted service in a timely manner and to pass on their achievements to the Institute's younger members.

Presentation of the AIAA Emeritus clock.

AIAA Young Professionals presented CDR Pearce with a gift.

AIAA K–12 STEM ACTIVITIES

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).

NASA IV&V Robotics STEM Programs

Science and technology education programs, such as the West Virginia Robotics Alliance Project (**http://wvroboticsalliance.org**) offered through NASA's Independent Verification and Validation (IV&V) Educator Resource Center (ERC), provide tremendous STEM experiences for K–12 students from across the region. In partnership with Fairmont State University, the West Virginia Robotics Alliance Project supports robotic competitions, off-season events, and trainings in-state. Other local sponsors include the NASA West Virginia Space Grant Consortium, the NASA IV&V Program Robotics Alliance Project, CSRA Inc., Southwestern Energy, West Virginia Governor's STEM Initiative, and various individual contributors.

It's an all-hands on deck approach with students, educators, coaches, mentors, and volunteers all engaged in supporting the various robotics projects. FIRST LEGO League (FLL) Jr. (grades K–3) and FLL (grades 4–8) focus on developing and applying STEM concepts using the fun and familiar LEGO® platform. Students build motorized models or robots for competition on a tabletop playing field. Development of STEM capabilities continues in the FIRST Tech Challenge where teams design, build, program, and operate robots to compete as a two-team alliance. FIRST Robotics high school teams work to build and program an "industrial-size" robot capable of completing difficult tasks in competition with other FIRST participants.

The VEX program also offers exciting STEM education opportunities using the VEX robot platform, including the VEX IQ Challenge for elementary and middle school students, the VEX Robotics Competition for middle and high school students and VEX U for university-level students. During the challenging tasks

VEX teams learn the importance of teamwork, critical thinking, project management, and developing communication skills which are required to not only complete the project, but be well positioned for success in the local, state, national, and worldwide tournaments.

The Zero Robotics Program involves writing code to control robotic spheres on the International Space Station and has both middle school and high school level participants.

AIAA is committed to supporting ERC and their efforts leading various robotics programs. AIAA members such as Sam Brown, an Associate Fellow and member of the Space Automation and Robotics Technical Committee, and Jeff Jones, an Associate Fellow and member of the K–12 STEM Committee, serve as mentors, judges, and supporters of these critical STEM activities for our future science and technology leaders.

For more information about how you as an AIAA member can help, contact: Jeff.Jones@csra.com. For more information on the Robotics programs contact: todd.ensign@ivv.nasa.gov.

AIAA ENGINEERING EVENT HELD AT A-MAN CENTER

On 20 February, the AIAA Los Angeles/Las Vegas Section organized a STEM event at the A-MAN Center to educate and entertain a group of 5th–8th grade students. Members Dan Carlock, Bob Friend, Robert Norcross, and Dana Puschell and John Anderson from Harbor Soaring Society of Costa Mesa were welcomed by Jessica Anderson, lead facilitator at the A-MAN, Inc. STEM International, Science Discovery & Learning Center in Inglewood, CA. Volunteers helped students make paper airplanes and helicopters, and Mr. Anderson did a presentation on the Design/Build/Fly program. The students also designed and built gliders using everyday materials, and played with a simulator of radio-controlled model planes provided by John Anderson.

Announcement

AIAA Journal (*AIAAJ*), covering pioneering theoretical developments and experimental results across a far-reaching range of aerospace topics, will be moving to an online-only format in 2017.

AIAAJ was launched along with AIAA in 1963 and is once again leading the way. Print customers transitioning to the online format will be able to maximize the user experience with research tools and access to the most up-to-date versions of articles in Aerospace Research Central.

CALL FOR NOMINATIONS

Nominations are now being accepted for the following awards, and must be received at AIAA Headquarters no later than **1 July** unless indicated otherwise.

Any AIAA member in good standing may serve as a nominator and are urged to read award guidelines carefully. AIAA members may submit nominations online after logging into **www.aiaa.org** with their user name and password. You will be guided through the nomination entry. If preferred, a nominator may submit a nomination by completing the AIAA nomination form, which can be downloaded from **http://www.aiaa.org/OpenNominations/**.

Awards are presented annually, unless otherwise indicated. However AIAA accepts nomination on a daily basis and applies to the appropriate award year.

Nomination Deadline 1 June 2016

AIAA-ASC James H. Starnes, Jr. Award presented In honor of James H. Starnes, Jr., a leader in structures and materials, to recognize continued significant contribution to, and demonstrated promotion of, the field of structural mechanics over an extended period of time emphasizing practical solutions, to acknowledge high professionalism, and to acknowledge the strong mentoring of and influence on colleagues, especially younger colleagues. Nomination form and instructions are located at **http://www.aiaa.org/starnesaward**/.

Nomination Deadline 1 July 2016

Aerospace Design Engineering Award recognizes design engineers who have made outstanding technical, educational or creative achievements that exemplifies the quality and elements of design engineering. (Presented even years)

Aerospace Guidance, Navigation, and Control Award recognizes important contributions in the field of guidance, navigation and control. (Presented even years)

Aerospace Software Engineering Award presented for outstanding technical and/or management contributions to aeronautical or astronautical software engineering. (Presented odd years)

Ashley Award for Aeroelasticity recognizes outstanding contributions to the understanding and application of aeroelastic phenomena. It commemorates the accomplishments of Prof. Holt Ashley, who dedicated his professional life to the advancement of aerospace sciences and engineering and had a profound impact on the fields of aeroelasticity, unsteady aerodynamics, aeroservoelasticity and multidisciplinary optimization. (Presented every 4 years, next presentation 2017)

Children's Literature Award presented for an outstanding, significant, and original contribution in aeronautics and astronautics. (Presented odd years)

de Florez Award for Flight Simulation is named in honor of the late Admiral Luis de Florez and is presented for an outstanding individual achievement in the application of flight simulation to aerospace training, research, and development.

Excellence in Aerospace Standardization Award recognizes contributions by individuals that advance the health of the aerospace community by enabling cooperation, competition, and growth through the standardization process. (Presented odd years)

Gardner-Lasser History Literature Award presented for the best original contribution to the field of aeronautical or astronautical historical nonfiction literature published in the last five years dealing with the science, technology, and/or impact of aeronautics and astronautics on society.

History Manuscript Award presented for the best historical manuscript dealing with the science, technology, and/or impact or aeronautics and astronautics on society.

Information Systems Award presented for technical and/or management contributions in space and aeronautics computer and sensing aspects of information technology and science. (Presented odd years)

Intelligent Systems Award recognizes important fundamental contributions to intelligent systems technologies and applications that advance the capabilities of aerospace systems. (Presented even years)

Lawrence Sperry Award presented for a notable contribution made by a young person to the advancement of aeronautics or astronautics. The nominee must be under 35 years of age on **31 December** of the year preceding the presentation.

Losey Atmospheric Sciences Award presented for recognition of outstanding contributions to the atmospheric sciences as applied to the advancement of aeronautics and astronautics.

Mechanics and Control of Flight Award presented for an outstanding recent technical or scientific contribution by an individual in the mechanics, guidance, or control of flight in space or the atmosphere.

Pendray Aerospace Literature Award presented for an outstanding contribution or contributions to aeronautical and astronautical literature in the relatively recent past. The emphasis should be on the high quality or major influence of the piece rather than, for example, the importance of the underlying technological contribution. The award is an incentive for aerospace professionals to write eloquently and persuasively about their field and should encompass editorials as well as papers or books.

Structures, Structural Dynamics and Materials Award presented for an outstanding sustained technical or scientific contribution in aerospace structures, structural dynamics, or materials. (Presented even years)

Survivability Award recognizes outstanding achievement or contribution in design, analysis implementation, and/or education of survivability in an aerospace system. (Presented even years)

Summerfield Book Award is named in honor of Dr. Martin Summerfield, founder and initial editor of the Progress in Astronautics and Aeronautics Series of books published by AIAA. The award is presented to the author of the best book recently published by AIAA. Criteria for the selection include quality and professional acceptance as evidenced by impact on the field, citations, classroom adoptions and sales.

Sustained Service Award recognizes sustained, significant service and contributions to AIAA by members of the Institute. A maximum of 20 awards are presented each year. A special nomination form and scoresheet is required; contact AIAA for details.

James Van Allen Space Environments Award recognizes outstanding contributions to space and planetary environment knowledge and interactions as applied to the advancement of aeronautics and astronautics. The award honors Prof. James A. Van Allen, an outstanding internationally recognized scientist, who is credited with the early discovery of the Earth's "Van Allen Radiation Belts." (Presented even years)

For further information on AIAA's awards program, please contact Carol Stewart, Manager, AIAA Honors and Awards, carols@aiaa.org or 703.264.7538.

Upcoming AIAA Continuing Education Courses

Courses at AIAA Aviation and Aeronautics Forum 2016 (AIAA AVIATION 2016)
www.aiaa-aviation.org/CoursesWorkshops
11–12 June 2016

Aircraft and Rotorcraft System Identification: Engineering Methods and Hands-on Training Using CIFER® (Instructor: Dr. Mark B. Tischler)

The objectives of this two-day short course is to 1) review the fundamental methods of aircraft and rotorcraft system identification and illustrate the benefits of their broad application throughout the flight vehicle development process and 2) provide the attendees with an intensive hands-on training of the CIFER® system identification, using flight test data and 10 extensive lab exercises. Students work on comprehensive laboratory assignments using a student version of software provided to course participants (requires student to bring a PC laptop running Windows 7 (preferred) or above, or a Mac laptop capable of dual-booting to Windows OS or running Windows virtual machine using VMware Fusion or Parallels Desktop). The many examples from recent aircraft programs illustrate the effectiveness of this technology for rapidly solving difficult integration problems. The course will review key methods and computational tools, but will not be overly mathematical in content. The course is highly recommended for graduate students, practicing engineers and managers. Course includes the AIAA book, *Aircraft and Rotorcraft System Identification*.

Key Topics
- Overview of system identification methods and applications
- Flight testing and instrumentation for handling-qualities and manned/unmanned control system development
- Simulation model fidelity analysis and design model extraction from prototype flight testing
- Flight test validation and optimization of aircraft dynamics and control
- Hands-on training in system identification training using CIFER®
- Students work ten comprehensive labs on model identification and verification using flight test data

Courses and Workshop at AIAA Propulsion and Energy Forum 2016 (AIAA Propulsion and Energy 2016)
www.aiaa-propulsionenergy.org/CoursesWorkshops
23–24 July 2016

3rd AIAA Propulsion Aerodynamics Workshop (Organized by the AIAA Air Breathing Propulsion System Integration Technical Committee)

The focus of the workshop will be on assessing the accuracy of CFD in obtaining multi-stream air breathing system performance and flow structure to include nozzle force, vector and moment; nozzle thrust (Cv) and discharge (Cd) coefficients; and surface pressure prediction accuracy. Experimental data are available for the test cases; however, the CFD studies will be performed as a blind trial and compared with the experimental data during the PAW02 workshop. Models will be provided for multiple cases featuring isolated inlets, isolated nozzles, and nozzles with or without a ground plane. A statistical framework will be used to assess the CFD results. Baseline computational grids will be provided for structured solvers. Geometry will also be available to those interested in developing their own meshes or employing an unstructured grid. Participants may run one or more cases if the required example grid solution is completed. The workshop provides an impartial forum to present findings, discuss results, exchange ideas, and evaluate the effectiveness of existing computer codes and modeling techniques.

Topics include:

- Analysis of flow in a diffusing S-duct with and without AIP instrumentation, and with and without flow control
  – Comparisons of AIP total pressure recovery and distortion both steady-state and dynamic
  – Comparisons of steady-state surface static pressure distributions
- Analysis of flow in a Dual Separate Flow Reference Nozzle (DSRN) and Dual Mixed Flow Reference Nozzle (DMFR)
  – Comparisons of thrust coefficient

Advanced High-Speed Air-Breathing Propulsion (Instructors: Dr. Dora E. Musielak, Dr. Tomasz Drozda, Mr. Robert Moehlenkamp, Dr. Steven Russell, Dr. Venkat Tangirala)

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

Key Topics
- Aerothermodynamics and engine performance analysis
- Flow path analysis
- Ramjet and scramjet multidisciplinary design optimization
- Fuels and combustion
- Structures and materials
- High-speed combined cycle propulsion

Electric Propulsion for Space Systems (Instructor: Dan M. Goebel, Ph.D.)

Over 120 spacecraft presently use electric thruster systems for primary or auxiliary propulsion. Electric thrusters are now being used to provide most of the post-LEO propulsion demands for both geosynchronous and deep space missions. The availability of practical, high-specific-impulse electric thrusters with long life, and the development of electrical power-systems required to sustain them, has resulted in extremely rapid growth in the applications of this technology. This course describes the fundamental operating principles, performance characteristics and design features of state-of-the-art systems in each of the three classes of electric thrusters (electrothermal, electromagnetic and electrostatic). The impacts of the thruster performance and life on mission planning; mission analysis techniques; and on-board spacecraft systems will be addressed. The extension of spacecraft capabilities afforded by electric propulsion and issues associated with its integration into spacecraft will also be discussed.

Key Topics
- Learn principles of operation of electric thrusters
- Understand when and why electric thrusters should be used
- Understand lessons learned from mission studies and flight experience

Hybrid Rocket Propulsion (Instructors: Dr. Joe Majdalani and Dr. Arif Karabeyoglu)
This short course is quintessential for all professionals specializing in chemical propulsion. The mechanisms associated with hybrid combustion and propulsion are diverse and affect our abilities to successfully advance and sustain the development of hybrid technology. It is our penultimate goal to promote the science of hybrid rocketry, which is safe enough to be used in both academia and the private sector. A historical demonstration of hybrid rocket capability is the 2004 X-prize winner SpaceShipOne. This technology can also be used in outreach activities when used in conjunction with hands-on design projects and payload launches that involve student teams. Interest in hybrid rocketry can thus be translated into increased awareness in science and technology, helping to alleviate the persistent attrition in our technical workforce. This course reviews the fundamentals of hybrid rocket propulsion with special emphasis on application-based design and system integration, propellant selection, flow field and regression rate modeling, solid fuel pyrolysis, scaling effects, transient behavior, and combustion instability. Advantages and disadvantages of both conventional and unconventional vortex hybrid configurations are examined and discussed.

Key Topics
- Introduction, classification, challenges, and advantages of hybrids
- Similarity and scaling effects in hybrid rocket motors
- Flowfield modeling of classical and non-classical hybrid rockets
- Solid fuel pyrolysis phenomena and regression rate: mechanisms & measurement techniques
- Combustion instability and transient behavior in hybrid rocket motors
- Metals, other energetic additives, and special binders used in solid fuels for hybrid rocket applications

Courses at AIAA Space and Astronautics Forum 2016 (AIAA SPACE 2016)
www.aiaa-space.org/CoursesWorkshops
11–12 September 2016

Introduction to Space Systems (Instructor: Prof. Mike Gruntman, Ph.D.)
This course provides an introduction to the concepts and technologies of modern space systems. Space systems combine engineering, science, and external phenomena. We concentrate on scientific and engineering foundations of spacecraft systems and interactions among various subsystems. These fundamentals of subsystem technologies provide an indispensable basis for system engineering. The basic nomenclature, vocabulary, and concepts will make it possible to converse with understanding with subsystem specialists. This introductory course is designed for engineers and managers – of diverse background and varying levels of experience – who are involved in planning, designing, building, launching, and operating space systems and spacecraft subsystems and components. The course will facilitate integration of engineers and managers new to the space field into space-related projects.

Key Topics
- Space environment and interactions
- Orbital mechanics and space mission geometry
- Overview of space mission design and applications
- Space propulsion and launch systems
- Attitude determination and control
- Communications, power, and thermal control subsystems

Systems Engineering Fundamentals (Instructor: John C. Hsu, Ph.D., P.E., AIAA Fellow, INCOSE ESEP)
In today's globalized environment, manufacturing and designing companies compete for business. To be successful, companies need to practice strategies that minimize the possibility of degradation of product quality, cost overrun, schedule slippage, customer dissatisfaction and system development failures. In this course you will learn why do we need systems engineering, the systems engineering fundamentals including Requirements Analysis and Development, Functional Analysis and Allocation, Design Decision Analysis based on requirements; Risk Management throughout the development and design cycle; Integrated Master Plan/Integrated Master Schedule and Work Breakdown Structure for development and design management; Technical Performance Measurement for measuring, tracking and validating design; Interface Management across in-house disciplines, supplier, and customer; and Verification and Validation to prove the right system was built and the system was built right.

Key Topics
- Requirements development and management
- Functional analysis and allocation
- Risk, opportunity and issue management
- Decision analysis
- Work breakdown structure and integrated master plan/schedule
- Interface management and verification and validation


WHEN THIS IS YOUR BACKYARD, YOU CAN'T HELP BUT EXPLORE.
When you've been in space long enough, you start to feel at home. We've been pushing the limits of what's possible out here since the dawn of the space age. For over 60 years, we at Northrop Grumman have been igniting the flame for space exploration—inspiring generations to stop and look up. From building the lunar module that led to one small step for man, to realizing the global dream that is NASA's James Webb Space Telescope, the Great Pyramid of our generation. We've been here all along, and we aren't going anywhere but up.
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