November 2013

AEROSPACE AMERICA

China's bold lunar plan

THE INSPIRATION THE U.S. COULD DRAW

Airports, airlines brace for climate impacts
Reaching for unlimited (almost) flight

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AEROSPACE AMERICA

November 2013

DEPARTMENTS

FEATURES

BULLETIN

ON THE COVER

Photo by Masi Gianluca/Dreamstime.com

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AIAA
The World's Forum for Aerospace Leadership

Editor's Notebook

A fresh start

The most exciting thing about my new role as editor-in-chief of *Aerospace America* is that I'm joining AIAA at a critical juncture for the aerospace community and for the profession of journalism.

Today's aerospace professionals and educators need reliable information now more than ever. Government budgets are flagging and national economies are in transition. Innovation and creativity are the only factors that can keep the profession progressing. What's clear is that humanity is in no mood for excuses. People want to fly faster and more affordably. They expect to communicate effortlessly without wires. They need protection from terrorists and rogue states. They want answers to the big questions: Are we alone in the universe? Are we ruining our planet? Are humans in space to stay?

Well-read professionals and academics will do a better job of pushing societies forward on these and many other issues. Indeed, your appetite for ideas and your embrace of the digital media have sparked a fierce competition among media outlets. In this new media market, my goal is to make sure *Aerospace America* stays your go-to source for in-depth, non-sensationalized information about all things aerospace.

As the magazine of the AIAA, our coverage should serve members in two ways: It should inform you about the most critical developments in government, business, and research. But it also should enhance the national conversation about aerospace priorities and strategies, a conversation whose outcomes are critical to members and the broader society.

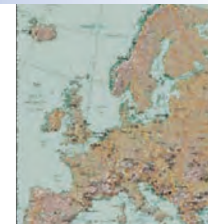
How will our team accomplish all this? First, by digging into topics with an independent spirit worthy of my predecessor, Elaine Camhi, who stayed on during the transition to help produce this edition of the magazine. Second, by modernizing *Aerospace America* to make it even more user-friendly and relevant to our readers.

I come to these challenges equipped with some core tenets from my years in online and print journalism, including my role as a long-time contributor to *Aerospace America*:

- High-quality journalism can be the glue that binds a community together. It can help solve problems, advance technologies, and dispel misperceptions.
- No topic relevant to the aerospace community should be out of bounds for thoughtful exploration and commentary.
- Print and online media products should work together to deliver unprecedented depth and choice to consumers.
- Content can be fun to read and still be intelligent and thought provoking.

These tenets are like the lines on a highway. They set us on the right path, but navigating the terrain beyond them will demand flexibility and fresh thinking. I invite you to join *Aerospace America* on a journey that will enrich your professional lives.

Ben Iannotta
Editor-in-Chief



Winners and losers in Europe's defense program cuts

European governments will meet in Brussels in December at the EU Council to discuss how defense capabilities can be enhanced, or at least maintained, during the current period of economic hardship. For military aircraft manufacturers, the meeting could go at least some way toward sorting out a major area of confusion in the European market.

Collectively, the European Union is committed to enhancing capabilities in areas such as maritime surveillance, air-to-air refueling (AAR), pilot training, and intelligence, surveillance, and reconnaissance, or ISR (which means new aircraft and systems will be required). However, individual national defense equipment budgets are in steep decline. So where will the cash come from for these new projects?

Severe reductions

Since the financial crisis of 2008, EU states have drastically reduced defense spending. In 2012, according to the London-based Institute for Strategic Studies, European NATO members' defense spending was, in real terms, around 11% lower than in 2006. Some of the smaller European states have slashed their defense budgets by huge amounts.

According to Christian Mölling, writing in a Brookings Institution report titled *The Implications of Military Spending Cuts for NATO's Largest Members*, "The largest budget cuts have been introduced in the smaller EU member states, with rates above 20%. Latvia notably reduced military spending by 21% in 2009. Lithuania cut 36% in 2010. The majority of middle-sized countries have implemented military spending cuts of 10 to 15%, on average. For example, the Czech Republic and Ireland reduced their defense budget by 10% in 2011 and 2010 respectively. Portugal cut 11% in 2010. Greek military spending dropped by 18% in 2010 and a further 19% in 2011. Romania introduced cuts of 13% in 2010."

In February 2011, before even more drastic cuts were announced, NATO Secretary General Anders Fogh Rasmussen said, "Over the past two years, defense spending by NATO's European member nations has shrunk by $45 billion dollars—that is the equivalent of Germany's entire annual defense budget."

According to recent figures from the Stockholm International Peace Research Institute (SIPRI), only Estonia, Poland, Slovenia, and Albania spent a larger portion of gross domestic product on defense than than they did 12 years ago.

The bigger picture

But these figures do not tell the whole story. Approximately 70% of all defense spending in Europe is concentrated on five states where the declines have been much less and have fallen, to a large part, on troop numbers rather than equipment. Even after the current round of cuts, Europe will still spend more than half its military budget on personnel. Both the U.K. and France, far and away the largest military spenders in Europe, have put in place strategic defense reviews aimed at safeguarding long-term acquisition programs, many of which are air- rather than ground- or sea-based.

This does not mean that further cuts or delays to aircraft acquisition programs are now out of the question—especially if economies do not improve as hoped. But it does mean that the impact of the cuts will continue to fall far more lightly on aviation than on other areas.

2012 EUROPEAN DEFENSE SPENDING BY FIVE KEY NATIONS

Country	*World ranking*	*Defense budget, €billions*
U.K.	4	60.8
France	6	58.9
Germany	9	45.8
Italy	10	34.0
Turkey	15	18.2

Source: SIPRI

EU defense ministers, meeting as members of the European Defense Agency (EDA) steering board in November 2011, agreed on a number of areas where European states needed to increase their capabilities through pooling and sharing national assets. These include helicopter training, maritime surveillance, satellite communications, AAR, ISR, pilot training, and smart munitions.

Recent conflicts in Afghanistan and Libya have starkly revealed Europe's continuing dependence on the U.S. for key capabilities. The need to develop ISR and AAR capabilities now has a new urgency.

At the Paris Air Show in June, Europe's EADS Cassidian, Dassault Aviation, and Alenia Aermacchi issued a joint statement calling for the launch of a joint European medium-altitude long-endurance (MALE) UAV program to help address the shortfall in ISR capabilities. In September the French and German governments asked for more details of these proposals. It is a market currently dominated by U.S. and Israeli unmanned air systems (UAS), and one of the key issues facing European defense departments is the need to ensure that, nationally and collectively, Europe retains an indigenous aerospace and defense capability even while new programs are being cut or delayed.

As France's defense department outlined in its *Livre Blanc* defense strategy, published this April, "The President of the Republic has chosen to preserve all the critical industrial sectors that make our industrial and technological base an instrument for preserving France's strategic auton-

The AAR shortfall is being met in part by a pan-European procurement program that included leasing Airbus A330 Multi-Role Tanker Transports.

omy and its sovereignty. It implies a continued priority…in favor of research and development spending and investment to equip our forces looking to 2025."

The AAR shortfall is being met partly by an increase in national capabilities and partly by a new pan-European procurement program managed by the EDA. By the end of 2013 the RAF will have taken delivery of six out of 14 Airbus A330 Multi-Role Tanker Transports (MRTT)—via the Future Strategic Tanker Aircraft program, which will see it lease the aircraft under a private finance initiative with the AirTanker consortium. In addition, Italy now has four Boeing KC767s. Further AAR capabilities will come on line as Europe's air forces take delivery of the Airbus Military A400M, which entered service with the French air force earlier this year.

U.K.: Ups as well as downs

Although the U.K.'s overall defense budget is set to remain more or less static next year, the government is committed to a 1% annual real growth in the equipment budget next year over 2013. Spending on the program to buy 48 Lockheed Martin F-35B aircraft for deployment aboard the Royal Navy's two aircraft carriers, in particular, is due to increase sharply from 2015 to 2016. The RAF has 232 Eurofighter Typhoon aircraft on order, and the first Tranche 3 aircraft is due for delivery by the end of this year. At the end of October, 109 aircraft had been delivered to the RAF.

Tranche 3 capability includes over 350 modified parts, including provision for conformal fuel tanks, extra electrical power, and cooling to cater for the E-Scan radar. The Tranche 3 contract has been signed and will deliver 40 aircraft. With the Tranche 1 aircraft fleet due to retire over the period 2015-2018, this will leave 107 Typhoons in RAF service until 2030.

If further reductions are needed, the number of Tranche 3 deliveries could be cut or deferred, or, more likely, the U.K. might cut its total planned buy of 138 F-35Bs. The country is also currently building two aircraft carriers—if one were to be canceled as a result of budget cuts, the number of F-35s required by the Royal Navy would fall by half.

Several countries have announced or are considering reducing their orders for F-35s.

The U.K. has already lost maritime patrol and long-range strike assets. In its May 2010 Strategic Defense and Security Review, the U.K. government announced that the Panavia Tornado would remain the RAF's main strike aircraft and the RAF and Royal Navy BAE Systems Harrier squadrons would be retired. The BAE Systems Nimrod MRA4 maritime patrol/intelligence-gathering program has been scrapped as a result of the defense review. The U.K. has also cut its order for A400M military transports from 25 to 22.

Another significant U.K. defense spending review is planned for 2015. By then it should be clear whether the country is out of the current recession and defense spending can return to pre-austerity levels.

The French plan

France's strategic defense plan has outlined a fall in the annual defense budget from 1.9% to 1.76% of the country's GDP. Some €364 billion has been allocated for 2014-2025, including €179 billion for 2014-2019. France has cut orders for the Dassault Rafale to 26 from a previously planned 60 deliveries over the period, with the total combat air force set to be cut to 225 aircraft by 2025, from a previous target of 300.

The review has also prioritized the acquisition of ISR MALEs, strategic air transports, and AAR aircraft. France has a total of 50 A400Ms on order, the first of which was delivered in August this year. But the delivery timetable for these platforms has been delayed under the latest draft proposals, due to be ratified by year's end. The spending plan covers the acquisition of 15 A400Ms between 2014 and 2019 and two Airbus Military A330 MRTTs out of a long-term proposal to acquire 12. France would also acquire 42 NH Industries NH90s and 16 Eurocopter Tigers. In June France concluded a deal with the Pentagon to purchase 16 General Atomics Aeronautical Systems MQ-9 Reaper UAS units.

Germany

Germany's defense department has plans to cut its budget by at least €2 billion to 2016, resulting in possible reductions in the procurement of helicopters, fighters, and military transport aircraft (60 A400Ms are on order).

Press reports at the start of this year suggested that the Bundeswehr is planning not to buy the last tranche of 37 Eurofighter aircraft it has ordered and was planning to cut long-standing commitments for NH90 naval helicop-

(Continued on page 9

Shutdown, sequestration, and the Silent Eagle

THE ANNUAL BUDGET PROCESS THAT has kept the government functioning for the past hundred years now seems to be a distant memory to many in Washington.

While the White House and House Republicans argued over the partial government shutdown, issues of grave importance, such as immigration reform and U.S. policy toward Iran, were pushed aside. President Obama's meeting with Israeli Prime Minister Benjamin Netanyahu was largely overshadowed. A CNN News poll showed that only 10% of the U.S. public approves of what Congress is doing. The executive branch fared little better, with a decline in President Barack Obama's approval rating and a sharp increase in citizen complaints about the functioning of cabinet departments.

During the partial shutdown, NASA said 98% of its employees would be furloughed, while the figure was just 33% for the Dept. of Transportation. Air traffic controllers were at work while air safety inspectors stayed home. Meat inspectors in the Dept. of Agriculture were on duty while meat inspectors in the Food and Drug Administration were not.

In spite of it all, as we entered autumn, much of the nation's business continued, including the business of aerospace.

Air Force secretary

Almost unnoticed amid the budget turmoil, the Senate quietly streamlined its process for considering nominees for high office. It appeared to be on the verge of confirming a new Secretary of the Air Force—when that, too, was sidetracked.

Thanks to an agreement reached by Democrats and Republicans last spring, executive branch nominees who require Senate confirmation can now expect a fairly prompt decision. Or at least in most cases: Among the first beneficiaries of the Senate's improved performance—or so it seemed—was Deborah Lee James, the defense contractor nominated to be the next Air Force Secretary. Little controversy was evident when James testified before the Senate Armed Services Committee September 19.

KC-46 air-refueling tanker

James gave predictable responses to questions about military programs. She said she supports the Air Force's current priorities: the KC-46 air-refueling tanker, F-35 Lightning II Joint Strike Fighter, and Long Range Bomber. She expressed concern about military operations being affected by possible retirement of the A-10 aircraft and agreed with Sen. Roy Blunt (R-Mo.) that if the service were to eliminate an entire class of aircraft, "we'd better be sure that we've got something else that will serve that mission in the interim until one of the futuristic programs comes online."

James almost certainly would have preferred to testify about aircraft, but senators grilled her repeatedly about two issues that have embarrassed the service in recent months, religious proselytizing in the workplace and sexual assault throughout the Air Force. James appeared to have overcome these concerns by calling for dignity and respect for all in the ranks.

Even as the nominee was testifying, the Air Force's uniformed leaders were saying that if the budget-cutting process known as sequestration remains in effect, the only way they can comply with the cuts is by eliminating an entire fleet of aircraft. At first, they considered the service's 59 KC-10A Extender tanker-transports or its 65 B-1B Lancer bombers. But it soon became clear that the Air Staff's real target is the inventory of 326 A-10C Thunderbolt II attack planes. "If the sequester continues, they'll have to go," said Gen. Mike Hostage, head of the Air Combat Command. "In a perfect world, I would like 1,000 A-10s, but with the sequester I can't afford any."

Enter Sen. Kelly Ayotte (R-N.H.).

Ayotte told James she had seen a PowerPoint slide from the Air Force saying the A-10 would be phased out by FY15. "That makes me concerned that there already has been a decision made about the A-10," when, in fact, no such decision has been announced, Ayotte said. The senator cited a recent incident in which 60 U.S. soldiers were saved in Afghanistan because of close air support provided by the A-10. James replied that no decision has been made.

Ayotte placed a hold on the James

Sen. Kelly Ayotte (R-N.H.)

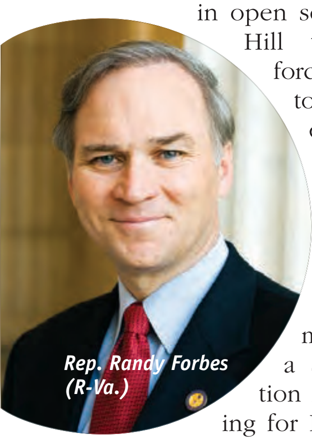
nomination—as any one senator is empowered to do—and called for a "substantial response" from the Air Force on the A-10's future. Days later, Sen. Martin Heinrich (D-N.M.) separately placed a hold on the nomination. Heinrich's office said his action was not related to the A-10 issue but would not give his reason.

Proponents for cutting the A-10 argue its close air support mission can be performed by other aircraft. But the plane is popular in the Army, where ground troops are said to love the support it provides, and also with some in Congress. James was expected to win Senate confirmation eventually as the Air Force's next civilian chief.


F-35C

Seeing sequestration

Before the October 1 shutdown, the nation's military service chiefs testified in open session on Capitol Hill that the armed forces will not be able to do their job if sequestration continues.


Rep. Randy Forbes (R-Va.)

And yet, the automatic spending cuts appeared to be the new normal. The measure mandates a $52-billion reduction in defense spending for FY14, and a $1.1-trillion cut over 10 years.

Speaking to the House Armed Services Committee, the flag officers in charge of the Air Force, Army, Marine Corps, and Navy were asked by Rep. Randy Forbes (R-Va.) whether they could carry out military requirements if sequestration—or anything similar—remained in place. One by one the three generals and one admiral said, simply, "No."

Gen. Mark Welsh, USAF chief of staff, told representatives during the September session that the Air Force may have to retire one of its current aircraft fleets to protect funding for its three top future priorities, the KC-46A air-refueling tanker, F-35A Lightning II, and Long Range Strike Bomber. All are in one stage of development or another, but none is anywhere near becoming operational. The Air Force wants 100 of the bombers, which are the farthest from completion. These are built with low observables, or 'stealth,' to make them hard to detect on radar. They also feature satellite-guided munitions, sophisticated sensors, and electronic jamming gear.

Critics say multimission aircraft like the F-35—in contrast to single-mission warplanes like the A-10—do not perform any single task well enough and are too costly to procure and operate. The F-35 or JSF program is now a $1.1-trillion effort aimed at providing 2,443 airplanes to U.S. squadrons over 55 years. Getting rid of a current aircraft in order to afford a new one is like burning the furniture to save the house, say critics, who for years have eyed the F-35 as a target for cancellation. While the plane is racking up some successes today, it has been plagued with delays and technical glitches. The latter have long included jittery images on the pilot's helmet-mounted cueing sight. Now a new problem has arisen: Officials say the tires on the Marine Corps F-35B short takeoff and landing model are wearing out too soon.


Gen. Mark Welsh, USAF chief of staff

Outside the U.S., the F-35 may see some defections by nations that originally were partners in the project. The Dutch announced in September that they would commit to 37 of the fighters, 48 fewer than their original total. Denmark, once committed to 30 planes, is now considering other fighters. Italy has reduced its order from 121 to 90. The governments of Canada and Turkey are now reconsidering their early commitments to the aircraft and could drop out of the program entirely.

F-35 progress

At Eglin AFB, Florida, the 33rd Fighter Wing is showing results after years of preparing to provide initial training to Air Force, Marine Corps, and Navy F-35 pilots. Although the aircraft's arrival and the training of pilots at the base began two years behind schedule, both are now in full swing.

The 33rd wing has one training squadron for each service branch and examples of all three JSF versions—the Air Force F-35A conventional takeoff version, the Marine Corps F-35B, and the Navy's carrier-capable F-35C. On August 13, the wing logged its 2,000th sortie by an F-35. Although Eglin remains the center of activity for the program, fully half a dozen bases are now operating the aircraft. At the end of September, planemaker Lockheed Martin was preparing to deliver the 100th F-35.

On September 24 the worldwide F-35 program received a boost it may not have earned when the South Korean government rejected a bid by Boeing to build 60 F-15SE Silent Eagle fighters, saying it needs a more advanced warplane. Seoul will reboot its fighter competition, known as Fighter Experimental Phase III or FX-3, from which it had earlier disqualified the F-35 and the Eurofighter Typhoon. The decision not to buy the F-15SE was unexpected—South Korea has been pleased with its fleet of 60 F-15K Slam Eagles.

South Korea is expected to formally reopen the FX-3 competition and officially reconsider the same three fighters: the F-35, Typhoon, and F-15SE. But at this juncture, and with Japan having recently done the same, Seoul isn't expected to seriously consider any aircraft other than the F-35. Leaders in the country's air force and acquisitions agency say privately that the F-35 is now the only contender.

Civil aviation issues

The FAA is telling Congress, the press, and the public that America's skies are safe despite a new FAA report that aircraft flew too close to each other fully 4,394 times last year—more than doubling the previous record from 2011.

"We run the safest and most efficient system in the world, and we have the most highly skilled controllers and technicians," said David Grizzle, FAA's chief operating officer, in a letter accompanying the report. Grizzle suggested that the increase in near misses may actually amount to nothing more than an increase in the reporting of incidents. Aircraft made almost 133 million takeoffs and landings last year, with rare mishaps.

Like some federal agencies but not all, the FAA began furloughing workers, including air traffic controllers, last spring. The move brought a quick response from Congress, with lawmakers such as Rep. Bill Shuster (R-Pa.) arguing the agency should find cost-saving measures that do not include temporary layoffs. At what should have been the start of the government's 2014 fiscal year, FAA Administrator Michael Huerta heeded Shuster's advice to find other ways to save. According to Shuster's office, the FAA spent $514 million on consultancy fees last year and could eliminate about half of these with almost no impact on daily operations.

Sen. Claire McCaskill (D-Mo.)

In other civil aviation developments, an FAA-sponsored government-industry panel recommended in September that the agency permit airline passengers to use email, texting, and web surfing as well as e-readers and MP3 players during takeoff and landing. The panel did not review the use of in-flight phone calls, which are banned by the FCC. Under current FAA guidelines, airlines prohibit the use of all electronic devices until an aircraft has climbed above 10,000 ft.

Sen. Claire McCaskill (D-Mo.) issued a statement saying she was "not breaking out my iPad in celebration just yet," and that if the FAA does not implement the panel's recommendations she will sponsor legislation to make it happen.

Some in Washington view the convening of the panel as a largely cosmetic measure, with the FAA unlikely to introduce change unless pressured by lawmakers. Experts disagree on whether electronic devices endanger aircraft systems. Many point out that the current prohibition has little meaning anyway, since passengers and even crewmembers often ignore the rule with impunity. **Robert F. Dorr**
robert.f.dorr@cox.net

(Continued from page 5)

ters and Eurocopter Tiger multirole attack helicopters. Germany had initially ordered 122 NH90 TTHs and 80 Tiger UHTs in separate deals, but decided in 2011 to cut these orders to 82 NH90s and 57 Tigers. The final shape of the budget cuts will not be known until the end of this year.

Other cuts

The Italian government announced in July that it would cut its planned purchase of Typhoons from 121 to 96, saving $2.6 billion, and has cut the number of F-35s it wants to buy from 131 to 90.

The NH90 may be another program to face cuts in orders.

Spain, whose government invested in a new facility to build both the NH90 and the Tiger, wants to reduce its NH90 order to 38 aircraft from 45. Its 2012 defense budget fell by 8% over 2011. Spain had initially bought 87 Typhoons but announced in August that it wanted to take delivery of just 73 and find customers for the other 14. It has 27 A400Ms on order but is now looking to offload 13 of these to other customers.

Elsewhere in Europe, the financial crisis forced Portugal in 2012 to cancel its order for all 10 NH90s it had on order, while the Netherlands has cut its original requirement for 85 Lockheed F-35As to 37. Denmark has postponed a decision on how to replace its F-16 fighter aircraft.

Is the era of defense cutting now over in Europe? Probably not.

Philip Butterworth-Hayes
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What about private enterprise?

In "Russian rocket engines forever?" (October **Commentary**), what is missing is reference to SpaceX and Blue Origin, companies in the U.S. that are developing rocket engines. It is quite possible that private enterprise will take over the technology developed by governments and provide better rocket engines in the future than any government.

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Hot and cold on "Weather or climate?"

Dr. [Jerry] Grey (September **Commentary**) has chosen to join the ranks of climate change deniers; those who dispute that anthropogenic climate change is leading to dire effects on the Earth. Dr. Grey takes the familiar tack of the climate change deniers by cherry picking the data and choosing outliers, instead of looking for trends.

Shalom Fisher
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That is the most level-headed, concise discussion of the topic that I have seen. The topic needs discussion not hyperbole and salesmanship. Thank you for broaching the issue.

Steven Howe
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Just a quick THANK YOU to Jerry Grey and his Commentary. About time we looked at this issue from a facts standpoint, not politics.

Jere Matty
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Helium or hydrogen?

The LZ-130 [Zeppelin] was not 'designed for helium,' but was rather extensively renovated so as to still carry about half its design load with promised American helium. (September **Out of the Past**)

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Corrections: The illustration on page 34 of **NEO Threats: Homeland security for planet Earth** (October) shows Japan's forthcoming Hayabusa-2 spacecraft preparing to take a sample from an asteroid.

In the September **Aircraft Update** column, Sikorsky's X2 demonstrator is pictured in the photo on the upper left side of page 20. Bell Helicopter's proposed V-280 Valor was not pictured and is not based on X2 technology, as was stated. The column also incorrectly stated that Bell Helicopter is not interested in the civil helicopter market.

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

Events Calendar

NOV. 3-7
Twenty-second International Congress of Mechanical Engineering. Ribeirao Preto, Brazil.
Contact: Joao Luiz F. Azevedo, joaoluiz.azevedo@gmail.com; www.abcm.org.br/cobem2013

NOV. 5-7
2013 Aircraft Survivability Technical Forum. Monterey, California.
Contact: Laura Yuska, 703/247-2596; www.ndia.org/meetings/4940

NOV. 5-7
Eighth International Conference Supply on the Wings. Frankfurt, Germany.
Contact: R. Degenhardt, +49 531 295 3059; www.airtec.aero

Military transports: Back to neglect

IN THEORY AND IN CONCEPT, MODERN militaries should be equipping themselves for rapid deployment as forces shrink and contingencies multiply. Political leaders play up the virtues of force mobility. However, the rhetoric of strategy is not being matched by the reality of the market, which remains quite flat.

For example, in September, Boeing delivered the USAF's last C-17, the 223rd to enter Air Force service. Within a few days, the company also announced that although it will still deliver 22 more C-17s, the line will shut in 2015. Meanwhile, in Europe, another round of budget cuts is threatening the viability of the A400M program. Aside from the C-130J, the market shows no signs of growth and too many players.

The end of an era?

The C-17, once a near-dead program that exemplified cost overruns and bad contracting, turned into a remarkable success story. Not only did costs come down to a level that represents good value even by civil aviation standards, it also scored the first export sales of any Western strategic transport.

As of September, Boeing had delivered 257 C-17s (223 to the USAF, 34 to international customers). Of the 22 remaining C-17s, seven will go to India (which has already taken three), and two are for an unnamed customer, probably Kuwait.

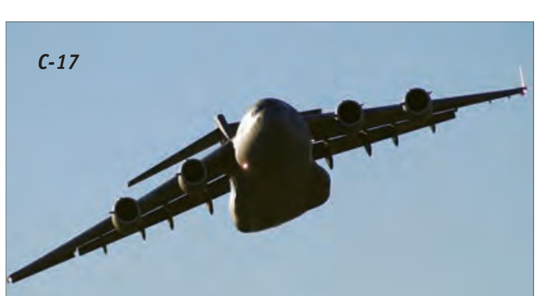
The remaining 13 are effectively being built on spec. Boeing's second quarter 2013 earnings report, filed with the Securities and Exchange Commission, indicated that $620 million is obligated in inventory and potential termination liabilities for these additional planes. While this 'white tail' build strategy carries risk, India has said it is interested in six more of the planes, and South Korea's defense budget calls for the purchase of four. Assuming those contracts are signed, the other three could go to one or more existing customers (Australia, Canada, NATO, Qatar, UAE, and the U.K.).

However, the two biggest potential new customers represent an upside for the program, if they move ahead with purchase plans in the next 12-24 months. The first is Saudi Arabia, which almost certainly has a requirement for a plane in this class and has a history of buying high-end defense products. Indeed, the country is conspicuously absent from the C-17 order book. It has been similarly absent from that of the C-130J as well, but it is now negotiating a contract for 20 C-130Js, against a total requirement for 70-80. Clearly, the country is interested in bolstering its military lift capabilities. Saudi Arabia alone would be good for 10-20 C-17s.

The second large possibility is Japan, which is developing its indigenous Kawasaki C-2, a twinjet transport smaller than the C-17 but at least as expensive. Progress on this program has been uncertain, and if it fails to go ahead (for technical or economic reasons), Japan would likely buy around 15-20 C-17s as an alternative.

Beyond these, Boeing has offered the Air Force a plan to buy 20 used USAF C-17s if the service in turn buys new ones. This would extend the line to 2016 or 2017. However, it is not clear that the service is interested, or that it is feasible for the Air Force to transfer cash generated from aircraft sales to the procurement account in order to buy new planes. A final complication concerns the market; it is not certain that any countries would be interested in used C-17s.

In short, unless Saudi Arabia comes through with an order in the next year or so, the U.S. will find itself in a few years with no strategic transport production line, and an aging fleet of 220 C-17s and 49 C-5Ms. There is also no R&D money to create a new strategic transport.



C-17

A400M: A strange story turns stranger

Assuming the C-17 dies and the U.S. fails to develop a follow-on in the next 10-20 years, Europe's A400M may have a good shot at the export market. Conceivably, there could even be U.S. demand for the plane. But its short-term prospects are rather difficult. Its hopes for long-term survival, like those of the C-17, are predicated on the arrival of export orders that may well fall through.

The A400M was created as a single-phase fixed-price procurement program. That is, the partner countries placed a single contract covering development of the plane and production of 180 aircraft. When this contract was renegotiated (after massive cost overruns) in March 2010, the total to be built was reduced to 170 for the home market, plus another four for Malaysia, the only firm export contract received so far.

Over the past year, however, several key partner countries have announced plans to reduce their commitments. Germany now says it will try to sell 13 of its 53 planes. France's latest defense white paper calls for cutting its 50 planes to 35-40 in the

A400M

2014 budget. Spain plans on reducing its 27-aircraft commitment to just 14 planes, with the remaining 13 to be resold to export customers.

The program is technically back on track. The first production A400M made its first flight in March, with first deliveries to France in August of this year. But it is not entirely clear how the economics will play out. Several of the countries involved, most notably France, seem unaware that under a fixed-price contract they will pay a set amount, regardless of whether or not they cut back on numbers of planes ordered. They will merely pay more per unit received. If they try to pay a smaller aggregate amount, Airbus may threaten to cancel the deal, a move they threatened just prior to the 2010 renegotiation.

In a further complication, the 2010 renegotiated agreement contained a €1.5-billion Export Levy Facility, essentially a lump payment to Airbus to be recouped by a tax on A400M exports. Basically, the two countries that now want to sell a total of 26 planes to export customers will be competing with Airbus Military to sell A400Ms on international markets. If these two countries sell their planes, they are effectively depriving themselves of revenue from the export levy.

Then there is the question of whether the plane will be competitive in export markets, an issue underlined by a near-absence of sales despite a decade of international campaigns (Malaysia's four-plane order is the only success; a South African order was canceled). The big question concerns the aircraft's price, which may well rise with home market procurement cuts. And if that export levy is applied over, say, 100 planes, that is a €15-million tax on each aircraft, not counting inflation and any interest charged by the governments behind the levy. The A400M may be economically problematic for much of the international market.

In short, while the A400M appears to have matured technologically, there are still major questions about its commercial viability both at home and in export markets.

The happier middle

The only true and enduring success story in the military transport market is Lockheed Martin's C-130J Hercules. The C-130, in fact, is the longest-running aircraft in production today. Indeed, it might be the longest-running aircraft production program ever, with the first planes delivered in the mid-1950s.

The current incarnation, the J Series, started slowly and almost turned into a disaster. Lockheed shot itself in the foot by trying to pass on massive cost overruns to customers. Just when it started to recover, the Pentagon made a somewhat incompetent effort to kill the DOD acquisition program, by canceling a multiyear procurement contract (these are written in a way that makes cancellation problematic). After that failed, this became a firm program again, although its salvation did not rescue it from the one-per-month doldrums. The years 2000-2007 saw just one export sale, a single plane follow-on for Denmark.

C-130J

But the past six years have been a remarkable turnaround story. Sales have included 17 for Canada and four for Norway, followed by most of the Middle East, including Israel, Iraq, Oman, and Qatar. More are in the pipeline, with India planning to

(Continued on page 23)

Composite tanks promise major savings

Rocket engineers have long been enthralled by the idea of storing liquid hydrogen in cryogenic tanks made from graphite composite. These would weigh an estimated 40% less than the cryogenic tanks used today, which are made of aluminum or higher strength aluminum lithium alloy. Automated manufacturing also could make the composite tanks 20% less expensive than metal versions.

The shift to composite cryogenic tanks has not happened yet, largely because of a composite tank failure that occurred at NASA Marshall over a decade ago. Late in the afternoon of November 3, 1999, a ragged crack of broken graphite fibers appeared along the circumference of a hydrogen tank that was in testing for use on NASA's X-33 reusable launch vehicle demonstrator. The tank broke the very first time it was subjected to external loads.

The failure was not very dramatic, producing no flames, explosions, or bursting. But the damage was real. The X-33 program was cancelled and NASA's rocket plans were thrown into years of disarray. The agency had been counting on the X-33 to pave the way for a space shuttle replacement.

Fast forward 14 years, and NASA is back in the composite tank business, ground testing versions specifically designed to avoid the X-33 pitfalls. NASA aims to use the new tank for expendable rockets, including the forthcoming Space Launch System to be used for launching astronauts to Mars or to asteroids. Boeing is making the tanks under NASA's Game Changing Technology Initiative, having beaten Lockheed Martin (the X-33 contractor) and Northrop Grumman for the $24-million contract in 2011.

The work is starting to get interesting, with a 2.4-m-diam. version passing pressure tests at Marshall, according to a preliminary report, and a 5.5-m version now in development at Boeing's Tukwila, Washington, facility. The bigger tank is supposed to prove the feasibility of making an 8.4-m composite tank for NASA's Space Launch System.

Changing the game

Liquid hydrogen propellant is typically stored inside cryogenic pressure vessels that are nearly spherical. In what's known as an integral tank design, the pressure vessels are bonded to a section of the launch vehicle's outer

A robotic arm applies composite laminate to Boeing's 2.4-m-diam. pressure vessel at Boeing's Tukwila, Washington, facility. Credit: Boeing.

shell—a cylinder in the case of an expandable rocket.

NASA thinks one of the X-33's two tanks broke because tiny amounts of hydrogen gas seeped into the honeycomb core of the tank wall. The wall was a sandwich composite consisting of a honeycomb core with facesheets bonded on the outside and inside of the core. Gas seeped in through microscopic cracks in the interior facesheet and produced "higher than expected core pressures" that caused the core to debond from the outer facesheet, according to the investigation report.

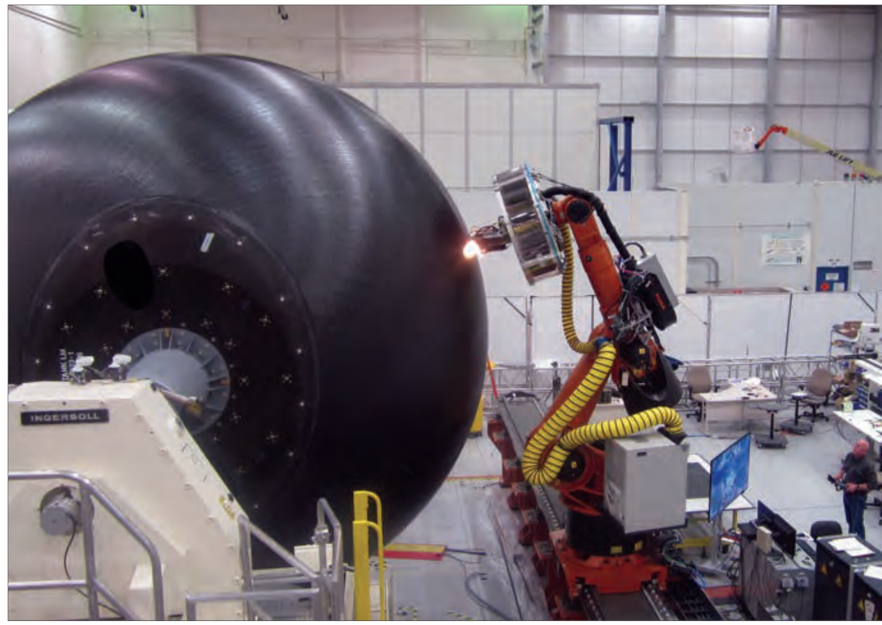
Boeing has come up with a tank design that shifts to an entirely new lamination technique for the pressure vessel and does away with the honeycombs in the core of the cylinder wall.

A 5.5-m tank assembly is scheduled to arrive at Marshall next April inside NASA's Super Guppy plane. Boeing and NASA engineers say the tank is big enough to test the design and manufacturing processes for the larger version that would be needed for the Space Launch System.

The first thing the new tank team did was to look closely at the history of the X-33 program, including a May 2000 investigative report describing the failure. The investigators cited not only technical flaws but also poor communications among engineers and managers: "A design of this complexity requires high levels of communication, both internal and external to the involved organizations; such communication did not occur in this case," the investigators said.

The Boeing-NASA team appears to have taken that criticism to heart. NASA project manager John Vickers says "a very close working relationship" has been established among engineers from Boeing and the Marshall, Glenn, and Langley centers. "We've got this small, passionate engineering team of government engineers and industry engineers working," he says.

Job number one was to address the permeation of hydrogen out of the pressure vessel. Boeing came up with



A robotic arm applies composite laminate to Boeing's 5.5-m-diam. composite propellant vessel at Boeing's Tukwila, Washington, facility. The light at the tip of the arm provides heat to soften the ribbon and make it adhere. Credit: Boeing.

a new lamination technique for the vessel wall. An undisclosed number of thin plies of graphite composite are surrounded by standard thickness plies. This hybrid laminate sounds like a small change but is supposed to have a big effect.

"We've incorporated thin composite plies into the laminate to not only mitigate, but the hope is to eliminate, permeability of the hydrogen from inside the tank," says Vickers. "The thin plies are the keys to eliminating the permeability, and they're really half the thickness of a typical ply material," he notes. Specifically, each layer is 2.5 mm wide, compared to the standard 5.5 mm.

What if the engineers are wrong about the impermeability of the new laminate? The Boeing-NASA team had to be sure that the tank's cylindrical outer wall would not soak up any hydrogen that might escape, so they found a way to eliminate the honeycombs in the core of the outer shell. For the X-33, those honeycombs were supposed to add strength when sandwiched between carbon-fiber facesheets, but they became the program's Achilles' heel. In the new design, "You don't get a trapped gas, and it's the trapped gas that contributed to X-33 failure," says mechanical engineer Dan Rivera, Boeing's project manager.

Instead of honeycombs, the core of the outer shell will be formed from hollow tubes called flutes. These run along the axis of the cylinder from end to end. "If you do have any sort of permeation from the tank wall, if it gets into the core, those flutes can very easily exhaust to the air, the ambient environment," Rivera explains.

Engineers know they must keep the voids of any composite sandwich empty and clean. Hydrogen from the tank is one threat, but so is moisture. It can freeze and expand, pulling the tips of the honeycomb away from the facesheet that forms the surface, weakening the whole sandwich structure. The flutes give engineers a way to address that problem too.

"The hollow tube provides the ability for us to very easily purge and vent the core. That is very challenging in a honeycomb structure. You have to machine in vent paths and things

Boeing's 2.4-m-diam. pressure vessel is bonded inside a composite cylinder that would form a segment of an expendable rocket. The tank assembly is pictured in a clean room in Marshall's advanced manufacturing facility. Credit: NASA.

like that," Rivera says. "Our core naturally provides those vent paths, so we can keep the air in those flutes very dry," he says.

An inert gas is run through the core, he explains.

Cue the robots

NASA and Boeing know that a stronger, lighter tank won't be a game changer if no one can afford it. Consider the pressure vessel. It requires wrapping ribbons of composite fiber material around a mandrel made from epoxy cured into the shape of the vessel. Doing the wrapping by hand would be time consuming and expensive, if it were possible at all. Engineers have chosen an intricate spiral application to maximize the strength of the vessel and minimize its weight. The job will be especially difficult for the 5.5-m pressure vessel or the 8.4-m version for the Space Launch System.

Instead of laying the ribbons by hand, Boeing took a commercially available, robotic manufacturing arm and designed a fiber placement head for it. The head provides heat to soften the ribbon and make it adhere. That's necessary because Boeing procures the ribbons as "pre-preg," a stiff material pre-impregnated with epoxy.

"The angle of that spiral wrap is key to the performance and weight savings of the tank, and so you can only really do that with this very sophisticated robotic, fiber placement capability," Vickers says. "It continually goes around the tank in this spiral pattern until it completely covers the tank, and then it'll do that for another layer."

Not everything is left to the robots, though. Once the vessel is done, the mandrel must be removed a section at a time. For a big vessel like the 5.5-m version, someone actually climbs in the mandrel and uses a crane and other lifting devices to remove the mandrel a section at a time. The mandrel is coated with a chemical release agent before the ribbons are applied, so that that they won't get stuck on it. "It's much like a wax," Vickers says.

First of a kind

Composite structures need to be cured, and doing that for a large structure like the 5.5-m tank posed what may be the biggest challenge for the team. Composite aerospace structures are typically cured in pressure chambers called autoclaves. As far as the Boeing-NASA team knows, there simply is no autoclave large enough to fit an 8.4-m-wide cylinder and pressure vessel. A structure that size will need to be cured in a giant oven—something that does exist, because it's easier to produce heat on that scale than pressure.

"The alternative would be you would have to go design, build, and purchase the world's largest autoclave to fit an 8.4-m tank," says Rivera.

The 5.5-m tank must prove the feasibility of oven curing for such a large structure. "It's the first time ever for a tank this large to be cured in an oven as opposed to an autoclave," Vickers says.

For the material, Boeing chose a commercial resin dubbed 5320, plus IM7 carbon fibers. "The 5320-IM7 has been developed for out of autoclave operations," Rivera explains.

NASA and Boeing conducted numerous tests to qualify the material for use in the 5.5-m tank. The real proof will come when the tank arrives at Marshall for installation on the test stand that the agency has begun setting up to accommodate it. The tank will be filled with liquid hydrogen and hooked up to a tank farm that adds pressure by pumping more liquid hydrogen into it. Those tests will simulate the pressures and structural loads the tank would experience inside a launch vehicle.

These tests will be tougher than those performed on the 2.4-m tank: "We did not test the 2.4-m with those structural loads," Vickers cautions. "The 5.5-m is really the biggest milestone we have for the project."

Space applications might not be all that's at stake in the composite tank program. If a giant, composite tank can be cured without an autoclave, engineers might be able to do the same with windmill parts or fuel storage tanks.

"Composites really are the materials of the future, and if we can build these structures outside the autoclave, that opens it up to many, many more companies" that otherwise could not produce the parts, "because autoclaves are very large capital investments," Vickers says.

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Strong ARM for seizing a space rock

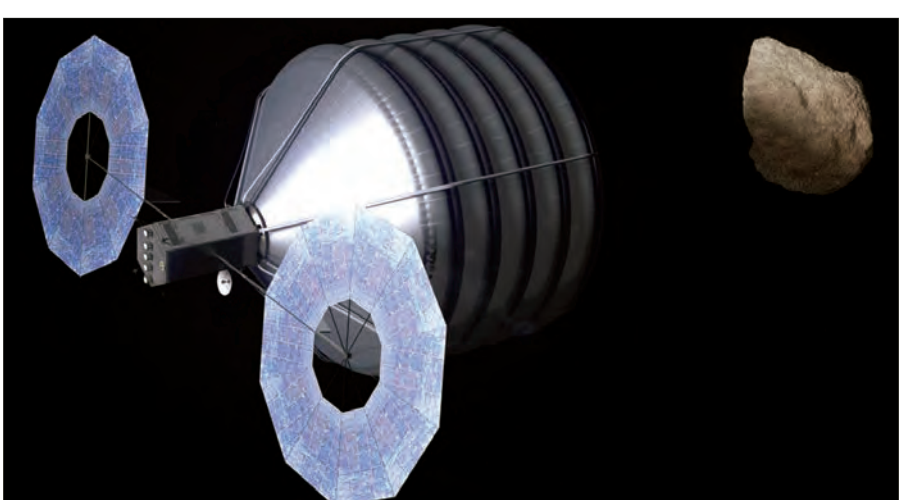
Bill Gerstenmaier, the top manager of NASA's Human Exploration and Operations Mission Directorate, is a master of the concise, technical language of engineering. Yet at AIAA's Space 2013 conference in September, the veteran space operator roused his audience with an uncharacteristic pep talk: "Turn off your logical side and turn on your touchy-feely side, the one you almost never use," he said. "Then jump up and down and do some break-dancing. We're going to grab a space rock and we're going to move it!"

Steve Stich, deputy director of engineering at NASA Johnson, was similarly fired up at breaking new exploration ground with the Asteroid Redirect Mission (ARM): "This is a bold mission," he said. "We are talking about sending two crew farther than we've ever been in space."

Capturing Congress

The ARM, first announced in April, is perhaps too bold for Congress. The House's proposed FY14 budget for NASA bars any spending on an asteroid capture mission. Back in July the chairman of the House Committee on Science, Space and Technology, Rep. Lamar Smith (R-Texas), argued that an asteroid mission would do little to advance science or planetary defense, and that it would not develop a lander, habitat, or other technologies necessary for long-duration missions into deep space. Committee members much preferred that NASA focus again on returning humans to the Moon. The best the Senate could manage was a legislative 'no comment.'

Because the continuing resolution expected to fund NASA through FY14 will likely say nothing about the ARM, NASA will keep studying the concept internally while readying it for next year's budget proposal. The agency will further develop the mission's technical approach and try to prepare a compelling, attractive sales pitch to Congress. At stake are U.S. prospects for getting astronauts into deep space in the coming decade, or for decades to come.



The ARM capture mechanism must cope with target asteroids of up to 1,000 tons, spinning at up to twice a minute, with a long dimension of up to 14 m. Even small asteroids might retain a significant dust layer, or consist of a rubble pile of small fragments held together only by molecular Van der Waals forces. Credit: NASA.

Mars is too far, too expensive. The Moon was ruled out as a destination when the White House canceled Constellation in 2010. Now, with NASA directed toward the asteroids, its deep space plans are being squeezed both by House antipathy to administration proposals and the latter's failure to deliver promised budget support.

The SLS and Orion vehicles are NASA's only option for travel beyond LEO, but if the White House accepts a budget hovering near $16 billion for its remaining three years, both booster and spacecraft may go on the chopping block. The situation is eerily similar to that described by the Augustine Committee in 2009, when Constellation's lunar goal was dismissed as unaffordable. Now the president's own 2025 asteroid goal seems to be outstripping the resources available. Delays to 2030 or beyond seem likely.

What, then, could NASA do for the next 17 years? Circumlunar and Lagrange point missions would exercise Orion and SLS but deliver little in the way of scientific or commercial payoff. Spending 17 years 'getting ready' to go someplace meaningful is a sure way to ensure one will go nowhere at all. A cash-strapped Congress or a president beset by more pressing priorities could cancel SLS and Orion altogether. Even a looming Chinese lunar landing may not be enough to revive NASA's fortunes. When in the late 2020s the ISS is retired, U.S. human spaceflight could well be decommissioned, too.

Something different

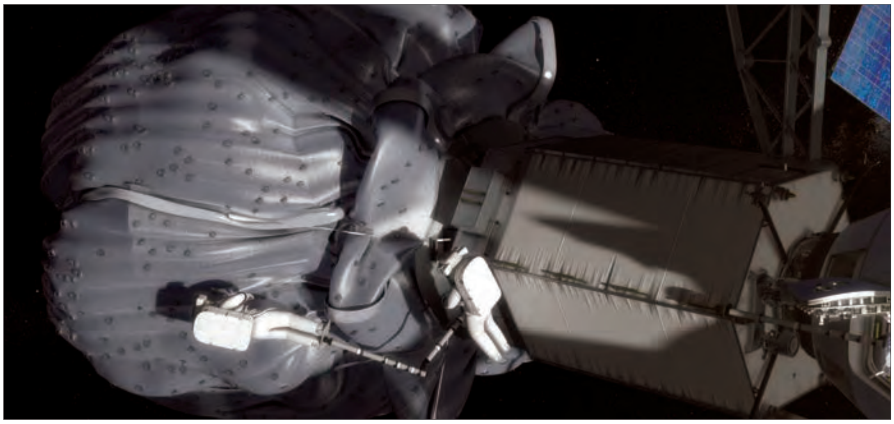
Confronting those barren prospects, NASA proposed in April the asteroid initiative, a broad effort pairing increased planetary defense activity with the ambitious ARM. In the latter mission, a robot spacecraft boosted by a single Atlas V launch would spiral outward under solar electric propulsion (SEP) from LEO, heading for a small near-Earth asteroid (NEA) in an Earth-like orbit around the Sun.

After matching orbits and spin rates, the asteroid redirect vehicle, or ARV, would position the open mouth of a fabric capture bag over an asteroid measuring 7 or 8 m across with a mass of up to 1,000 tons. Securing the asteroid, the ARV would despin its prize and begin thrusting toward the Earth-Moon system.

The 40-kW, xenon-fueled SEP system would nudge the asteroid's orbit just enough so that lunar gravity would capture the object into a distant, retrograde orbit of the Moon. There, Orion astronauts on a 3- to 4-week mission would dock with the robotic craft, gather an array of asteroid samples totaling a few tens of kilograms, and return them to Earth for analysis. The robotic vehicle would then maintain the asteroid's orbit and attitude for future astronaut follow-up or robotic exploitation by international and commercial partners.

The optimum target asteroid for capture is a low-albedo (dark) object with a C-type spectral classification, analogous to carbonaceous chondrite meteorites. These meteorites are black, low-density, organic-rich rocks little altered since their formation nearly 4.6 billion years ago. Some carbonaceous chondrites, like the Tagish Lake meteorite recovered after it fell in Canada in 2000, are as fragile as a charcoal briquette and contain as much as 20% water. Because of their fragility and susceptibility to rapid weathering, most of these asteroids break up on atmospheric entry, and few fragments survive on the surface long enough to be collected.

Water-rich, C-type asteroids are attractive targets, but they are difficult to find and characterize. Their low reflectivity means a 10-m asteroid is visible for only a few days near its Earth approach. After a detection, astronomers must quickly nail down the object's orbit through multiple observations, juggling precious telescope time to get the infrared spectra needed to confirm its composition. If the object is within range, radar from Arecibo or Goldstone can confirm its orbit, shape, and spin. Within two or three days of discovery, the potential target vanishes, unseen until its orbit carries it close to Earth again, as many as 10 years later.



The ARM mission would end with two Orion astronauts exploring the captured asteroid on several EVAs over the course of a week. The crew would conduct extensive sampling and emplace long-lived science and resource prospecting instruments. Credit: NASA.

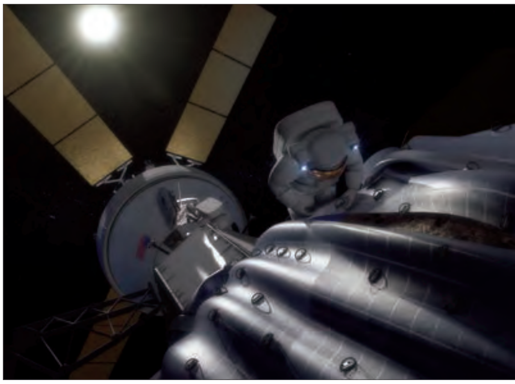
To enable ARM launch opportunities before 2020, NASA's first priority should be detection and characterization. In September, JPL asteroid dynamicist Paul Chodas said that three of 14 catalogued small asteroids had orbits favorable for robotic retrieval (requiring less than 2.5 km/sec of delta-V from the SEP system). With NASA-funded upgrades, ground-based observing programs could sift another five targets annually from the roughly 10,000 potential ARM candidates.

The best candidates will have C-type composition, a spin rate of less than 2 rpm, a mass under 1,000 tons, and a diameter smaller than 14 m in the long dimension. The search will be tedious and hard, but ground-based telescope time is relatively cheap. If NASA gets its $20 million in augmented search funding, it should discover 15-20 asteroid targets by 2018.

Brand new bag

Recent NASA studies show that several candidate capture mechanisms can cope with the challenges of corralling a small NEA. JPL has proposed a fabric bag held open by inflatable struts. With spin rates matched and the bag flown slowly over the asteroid, a cluster of 'Mars rover'-style airbags would inflate, stabilizing and gripping the asteroid inside. By triggering the inflation precisely, the craft can remove any minor axis rotations (tumbling). Retracting cables then close the bag around the asteroid, nestling it against the vehicle. Reaction control jets can then despin the spacecraft/asteroid stack.

An alternative capture design envisions a spidery set of lightweight arms holding open a wide-mouthed membrane; the arms fold inward to grasp the asteroid. Other despinning techniques under investigation include using the spacecraft's ion thruster plume to slow the asteroid's rotation, or lin-



The first Orion crew visit to the asteroid would be followed by robotic prospecting or science craft from commercial or international partners. Subsequent crew visits might follow if resource extraction techniques can benefit from astronaut assistance. Credit: NASA.

This fragment of the Tagish Lake meteorite, recovered after its fall in Canada in 2000, contains a variety of exotic amino acids whose formation was influenced by water percolating in the parent asteroid. Credit: Michael Holly, Creative Services, University of Alberta.

ing the capture bag with flexible bristles that apply passive retarding force across the asteroid's surface.

NASA is confident that ground-based simulations and mechanical testing can yield a capable, robust capture design, able to handle asteroid masses of up to 1,000 tons. More concepts could emerge at NASA's Asteroid Initiative Idea Synthesis Workshop, which was delayed by the partial government shutdown.

With the asteroid nestled safely in the capture enclosure, the redirect vehicle would begin the multiyear process of nudging the orbit toward a close encounter with the Moon. Once the asteroid is captured by lunar gravity, several months of SEP thrusting should suffice to park it in a very stable, distant retrograde orbit around the Moon. There is no chance of Earth impact from there, even without an active shepherding spacecraft: It would take more than a century for the asteroid to slam harmlessly into the lunar surface. Earth's atmosphere provides another layer of safety, as asteroids smaller than about 30 m in diameter break up and incinerate upon entry.

The capture in context

The deep-space experience and hardware needed for visiting a large NEA on a voyage of six months or more, as the president envisioned in 2010, are unlikely to be available before 2030. Without an improved budget picture, the ARM is the only way U.S. astronauts can reach an asteroid surface by the mid-2020s. However, the mission is not just about meeting some technical or political deadline. An asteroid encounter in lunar orbit would have real importance for conducting future expeditions to distant asteroids, the Moon's surface, and the Mars system.

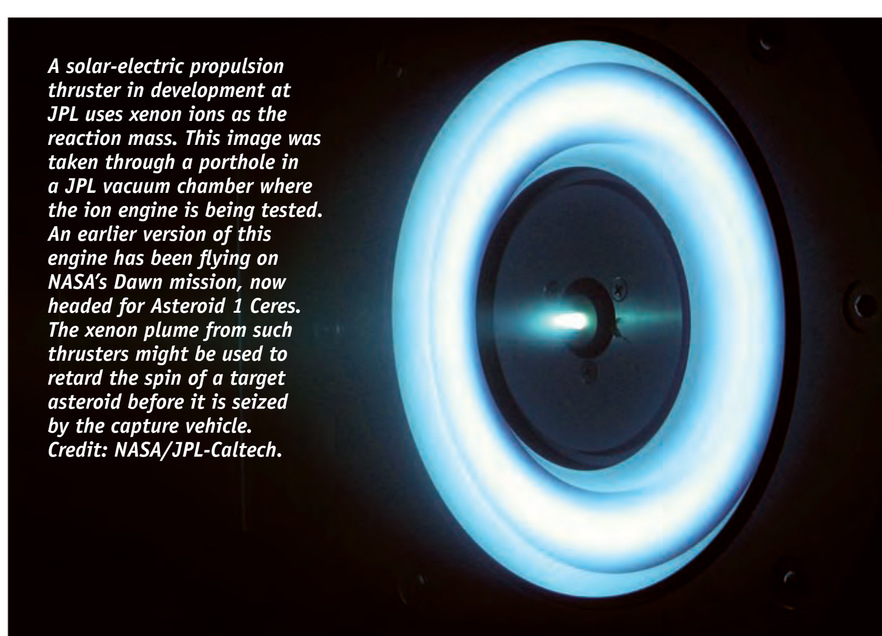
In the near term, the ARM would put U.S. explorers beyond the Moon about 10 years from now, with astronauts traveling well beyond Earth's protective magnetosphere, surpassing all Apollo benchmarks. The mission would be an affordable way to wring the kinks out of SLS and Orion systems, building deep-space operations experience for ground teams and astronaut field explorers.

The mission will not have a revolutionary impact on planetary science—a pair of asteroid sampling missions, Hayabusa 2 and OSIRIS-REx, may have succeeded in returning a few grams each from C-type NEAs by the early 2020s. But it will enable trained scientist-astronauts to return tens of kilograms of samples from an intriguing, previously unexplored class of small asteroids.

They are made of exotic stuff. Carbonaceous chondrites preserve material nearly unchanged since the formation of the solar system, including interstellar dust granules that predate the solar nebula. Using handheld coring instruments, the crew will penetrate a few tens of centimeters into the asteroid and retrieve pristine samples of its interior.

By emplacing long-lived science instruments on the NEA, the crew will gather important planetary defense information, too. Asteroids this small are not a threat to Earth, but do represent the building blocks of larger, hazardous rubble-pile asteroids. We should be able to sound the asteroid's interior structure, measure its thermal profile with depth, examine its optical properties to refine remote sensing methods, and assess the object's cohesion, porosity, and mechanical strength.

The mission's greatest potential is opening a new era of space exploration: using space-generated raw materials to supplant expensive propellants and consumables hauled from Earth. Investigators should feed some of the returned samples into processors at the ISS, working out practical methods to extract water, volatile elements, and valuable metals in a free-fall environment. NASA should also assess using the bulk mass of the asteroid as ready-made shielding against



A solar-electric propulsion thruster in development at JPL uses xenon ions as the reaction mass. This image was taken through a porthole in a JPL vacuum chamber where the ion engine is being tested. An earlier version of this engine has been flying on NASA's Dawn mission, now headed for Asteroid 1 Ceres. The xenon plume from such thrusters might be used to retard the spin of a target asteroid before it is seized by the capture vehicle. Credit: NASA/JPL-Caltech.

solar storms and galactic cosmic rays.

In the decade following an initial astronaut visit, NASA should partner with other space agencies and commercial firms in using the captured NEA as a testbed for mining and extraction technologies. By putting 500 tons of water-rich rock just outside the gravity wells of the Earth and Moon, the ARM may represent the first step on a long road to in-space propellant production, eliminating the need to ship cryogenic propellants from Earth.

Many advances must follow up the initial ARM: gathering asteroidal rocks, gravel, and dust in free fall; preparing them for processing; extracting water and separating it from organic material and other noxious volatiles; and finally, storing hydrogen and oxygen in a conveniently located free-fall facility. NASA, though, can take that most important first step—making raw space 'stuff' available to inventive users. Commercial innovators may then find ways to use in-space propellants, fluids, and industrial materials to address the logistical demands of industry and exploration.

The goal of the Asteroid Redirect Mission is not just putting a couple of astronauts in physical contact with a thousand-ton asteroid. It is instead to be the first in a series of incremental human spaceflight milestones aimed at reaching the Moon, more distant asteroids, and Mars. As budgets and experience permit, the ARM could be followed by visits to the Sun-Earth Lagrange points, then multimonth asteroid expeditions, or sorties down to the lunar surface. These options will depend upon the readiness of heavy-lift launch, reliable life support, and deep-space-qualified habitats.

The ARM provides a near-term astronaut target in deep space, beyond the Moon, within the coming decade. Even its critics recognize that under current policy and budgets, NASA lacks practical, affordable alternatives. This nontraditional yet promising mission may recapture for NASA and the nation some of the excitement missing in our recent space efforts.

ARM will be tough to sell, tougher to execute. NASA must answer crucial questions like those raised in July by veteran JPL engineer Gentry Lee: "Can we make it work? Can we make it useful?" If so, NASA will advance our scientific knowledge of asteroids, improve our planetary defense skills, and unlock a promising combination of human exploration, commercial innovation, and unlimited resources from space.

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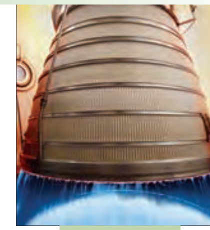


The new meaning of additive value

NASA Glenn's successful hot-fire testing of an injector assembly designed and made by Aerojet Rocketdyne may well prove to be a significant milestone in the development of rocket engine manufacturing. In creating the assembly, the company had used an innovative 3D additive manufacturing technique.

The test demonstrated that one of the most critical and expensive components of a rocket engine could be built to the required standard much more quickly, simply, and cheaply with the additive manufacturing technique than with traditional methods.

By using selective laser melting and 3D fusing of a metallic-powder bed (in an inert gas environment to minimize the potential for oxidation of the powder), Aerojet Rocketdyne was able to manufacture two separate subassemblies. When joined, these structures created the entire center-core section of a full-scale injector that would represent a liquid oxygen-hydrogen RL10 engine.

Reducing complexity

With most conventional manufacturing techniques, the company would have to make more than 100 parts and then turn them into a finished injector using a combination of forging, plating, brazing, welding, and five-axis milling. Hundreds of holes and ports would have to be machined into the injector assembly to ensure that it would function as designed.

Tyler Hickman, NASA Glenn's hot-fire task lead for the Manufacturing Innovation Project (MIP), says a variety of "complicated flow passages" inside the RL10 injector "make it difficult to machine conventionally."

In a sizable rocket engine, the injector assembly usually is among the most expensive components, because its manufacture is extremely time- and labor-intensive. However, 3D additive manufacturing took no more than six days each for the test injector's two parts, says Jeff Haynes, Aerojet Rocketdyne's additive manufacturing program manager. The company paid for the manufacturing project entirely with internal funding.

Task lead Tyler Hickman, in red shirt, and technicians inspect the additively manufactured rocket injector assembly as it is installed in the Rocket Combustion Laboratory at NASA Glenn. Courtesy NASA.

Although each part required some postprocessing and heat treatment (both parts were treated at the same time), the finished injector core was available no more than eight weeks after manufacture began. Fabricating the injector core conventionally would have taken a year or more, says Haynes. For some parts of the injector, such as closed-die forgings, it would normally take six months of manufacturing lead time before they could be incorporated into a subassembly.

"We struggle to quantify the support cost" of labor and all the other factors implicit in a six-month lead time, says Haynes. "But if we can print a part in six days, we don't have that support cost."

That is one reason why Aerojet Rocketdyne selected the RL10 injector for its first major experiment, aimed at determining if additive manufacturing could cut the time and cost involved in rocket engine production.

In service for more than 50 years, the RL10 is one of the most widely used upper-stage engines in the history of space propulsion. It has helped place many military, government, and commercial satellites into orbit, and has powered space probe missions to nearly every planet in the solar system. RL10 missions included Juno to explore Jupiter; New Horizons, now en route to Pluto and the Kuiper Belt; the Solar Dynamic Observatory; Radiation Belt storm probes; and the Lunar Reconnaissance Orbiter.

More than 435 RL10 engines have flown in space. Today the engine continues as a reliable workhorse in the form of the RL10A-4-2, delivering 22,300 lb of thrust to power the upper stage of the Atlas V rocket; and the RL10B-2, with 24,750 lb of thrust powering the upper stage of the Delta IV.

The company sees the RL10 "as a good pull for this [additive manufacturing] technology and probably one of the lead programs to pull it in." If the experimental RL10-equivalent injector core's success is replicated in similar cost savings in future tests, then Aerojet could eventually use additive manufacturing routinely to fabricate complex RL10 assemblies.

The RL10-like injector center core tested by NASA used full-scale RL10 features "as a baseline," says Haynes.

However, the 3D manufacturing machine for which Aerojet Rocketdyne designed the part could produce parts measuring up to just 10 in. in any dimension. Since the production RL10 injector is 12 in. in maximum dimension, "we truncated" the design of the 3D part so it could be contained within a 10-in. cube, he says. However, its design faithfully replicated the LO_X post features of the RL10 injector.

In an RL10 engine, notes Haynes, "there is a very complex series of parts that bring the fluids together efficiently." If the injector is not manufactured or assembled to the sufficient standard, mixing of the fluids can create "very bad instability" when they are ignited in the combustor. The size, shape, and density of the spray cone of LO_X released into the combustor are particularly important.

Testing at Glenn

Before the full injector center-core assembly was sent to Glenn for testing (which NASA paid for under a nonreimbursable Space Act agreement as part of its MIP), the AFRL at Edwards AFB provided Aerojet Rocketdyne with pretest data on the LO_X-spray pattern of the test RL10 injector. AFRL tested the LO_X injector from the additively manufactured injector core in its high-pressure cold flow test facility, which is able to generate much higher fluid flow pressures than the company's own facilities, according to Haynes.

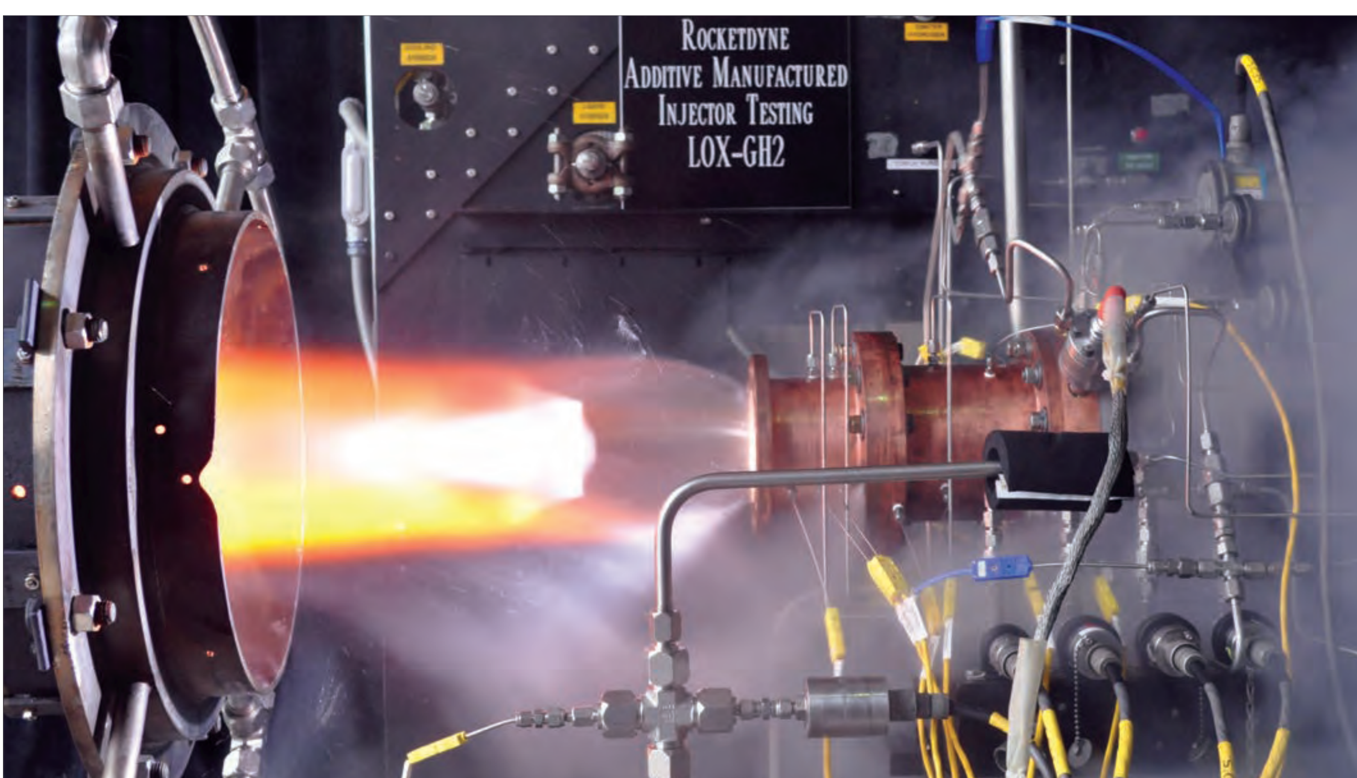
Reviewing the AFRL data gave the company "a lot of confidence" that the LO_X spray from the specially made injector would be "within the variability" needed to perform like a production RL10 in NASA Glenn's hot-fire testing, according to Haynes.

AFRL's offer to participate provided an "excellent" opportunity for Aerojet Rocketdyne and NASA to extend the government-industry partnership and the cost-sharing collaboration associated with the tests. Carol Tolbert, project manager for the MIP at Glenn, says AFRL funded the cold flow pretesting of the LO_X injector, maximizing the benefit of the funds that Aerojet Rocketdyne and NASA had made available for their parts of the effort. (NASA Langley and NASA Marshall are also involved in the MIP, each with its own research projects.)

Hickman coordinated the test activities at Glenn and led the design team that produced the supporting hardware for the injector test. He says Glenn first performed a series of cold-flow tests using nonreacting fluids to characterize the pressure drop in the system, refine the abort limits, and perfect the valve timing for the first ignition attempt.

Valuable data

Although the injector Glenn tested was not quite a full-size RL10 injector, Hickman says the hot-fire test data NASA obtained was significant. The exercise demonstrated that the addi-



A liquid oxygen/gaseous hydrogen rocket injector assembly built by Aerojet Rocketdyne using additive manufacturing technology is hot-fire tested at NASA Glenn's Rocket Combustion Laboratory in Cleveland, Ohio. Courtesy NASA.

tively manufactured assembly was able to withstand intense cold (in the form of LO_X); intense heat from combustion in the chamber, just downstream of the injector; and high pressures, since the pressure of the thrust chamber was significantly higher than the pressure of the external environment.

The test data will help NASA and Aerojet Rocketdyne to scale additive manufacturing and testing of components to a larger engine. Indeed, both groups are already looking ahead to more tests. The RL10 injector-core test was "the first of many hot-fire tests" NASA is planning "for infusing this technology," says Hickman.

A production RL10 engine awaits testing. Courtesy: Aerojet Rocketdyne.

The organizations continue to look at other engine parts that might benefit from additive manufacturing. "It may not be the whole engine, but it could be some of the most expensive parts," says Tolbert.

Other possibilities

NASA and Aerojet Rocketdyne have already tested two components of the J-2X engine for the Earth departure stage of NASA's planned Space Launch System: a workhorse gas generator duct in a rig test, and a fuel maintenance port cover in a full engine test. Neither has the complexity of an injector, but both tests provided exposure to combustion environments. Tolbert says NASA is also looking at how—in the longer term—astronauts might additively manufacture components and equipment in space, or on the surface of Mars.

Haynes notes powder-bed melting would not be a suitable additive manufacturing technique for space, because "zero *g* would wreak havoc on the powder." Laser melting of metal powder beds may also be a challenging technique for very large engine parts: A machine capable of making a part eight times the volume of a 10-in. cube would have to manipulate more than a ton of metal powder, a very difficult task. This machine exists today, but it is still being evaluated for the larger scale capability.

Other additive manufacturing techniques might be able to take up the slack. For instance, electron beam freeform fabrication (EBF3) uses a wire feed rather than powder. A potential disadvantage is that to be effective, the electron beams that melt the metal need a vacuum in order to operate. For in-space applications, however, EBF3 is ideal.

Additive manufacturing potentially could be used to 'print' an entire in-space thruster that is small, pressure-fed, and has no turbomachinery, according to Haynes. He says that the approach would be particularly suitable for rocket engine parts that require no postprocessing.

Haynes says such techniques would not be applicable to building an entire large engine like the space shuttle main engine, which would be "too big and complex." They could, however, be used to manufacture complex subassemblies quickly and cheaply. Now that a powder-bed additive manufacturing machine is available that can 3D manufacture a component the size of a 15-in. cube, this could "potentially support [production of] an entire injector."

Future outlook

Haynes and Hickman believe that routine production of small, simple rocket engine parts such as brackets and fittings might be only a couple of years away. Hickman estimates that the hot-fire test of the RL10 injector assembly took the technology readiness level (TRL) of additive manufacturing for rocket engine parts from TRL3 to TRL4 or even TRL5 (TRL6 represents a wholly production-ready technology).

However, routine use of this technology for production of complex rocket engine assemblies is still four or five years away, in their opinion. The reason is that although an additively manufactured part may appear to be exactly the same as an identical-looking part made using traditional methods, it is not the same.

"We're treating [additive manufacturing] as a new product," Haynes says. "We're having to define that and get the data we need" to show adequate manufacturing repeatability, to define and maintain the range of acceptable variability among parts, and to discover the limits of the process.

Theoretically, a component manufactured additively using powder-metal melting and deposition should demonstrate more repeatability and less variability in its properties than a part made by working sheet metal. First, however, manufacturers such as Aerojet Rocketdyne must do a lot of design, manufacturing, and testing work to demonstrate that this is indeed the case. This requires development of new design data that takes the new manufacturing method into account. That in turn means creating a new design and product definition process.

"We spent over a year building and developing design data," Haynes says. "To print out highly valuable equipment such as rocket engines, it is key to have specific design data for it in order to have your customers recognize it as production-ready technology."

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(Continued from page 11)

buy another six, and the UAE still negotiating for up to 12. Israel is also placing a follow-on. Best of all are the likely orders from Saudi Arabia, as mentioned above. Outside the Middle East, South Korea's recent buy also will lead to higher numbers.

Better still, the Pentagon suddenly realized it has an aging C-130 problem, with no possible replacement and with uncertain upgrade plans. The HC/MC-130 recapitalization effort put some serious numbers behind a revitalized procurement program. Another 16 planes were added via the AC-130 recapitalization. The Marine Corps continues to buy KC-130J tankers as well.

It is likely that the C-130 can count on home market orders for at least 12-16 planes per year, more than enough to guarantee the production line and keep unit costs reasonable while the company continues selling copies abroad. In fact, in September Lockheed Martin executives stated that they were working toward a five-year (FY14-FY18) deal that would cover 79 C-130Js for the Pentagon in a new multiyear procurement contract.

Overcapacity at the low end

Unfortunately, compared with the C-130J's prospects, a look at the bottom segment of the market shows much less success. For the past 10 years or so, Alenia Finmeccanica's C-27J has gone head-to-head with Airbus Military's C-235/-295 series. While the Airbus product has had its ups and downs, it has seen about 120 sales. By contrast, the C-27J has seen just half as many.

Alenia's big break came with the Army/Air Force Joint Cargo Aircraft program win. Originally, this called for 145 planes, but that number was later reduced to 38. However, the FY13 budget killed the entire program. A total of 21 planes were ordered, with 13 delivered. The eight remaining orders have been canceled, and the 13 delivered planes will be sold. In the meantime, Alenia has only one outstanding order, 10 planes for Australia. These will be delivered in 2015.

Clearly, the low end of the military lift market is good for only about 15-25 planes a year at best. Mindful of this, the latest market entrant, Embraer, has decided to aim at a slightly higher segment, closer to the C-130J. The company's KC-390, a twin turbofan transport design that can also serve as a tanker, complicates life for both Lockheed Martin and the two bottom segment players. Embraer has proposed selling it for about $50 million, which makes it a rather good value given its expected range and payload.

Whether Embraer can deliver at that price remains an open question, but the company has scored letters of interest from industrial partner countries (Chile, the Czech Republic, Portugal, and others), and from France (as an offset, if Brazil buys the Rafale fighter). The first KC-390 prototype will be delivered in late 2014, followed by a first flight. The airplane is scheduled to enter service in Brazil's air force in 2016.

Whether the KC-390 succeeds as a new entrant or not, its potential is limited by the market itself. The total market for all military airlifters over the past 10 years was $54.8 billion. The market's recent history shows scant evidence of growth, and we project deliveries to stay at about the same level.

In all, this market is best viewed as a zero-sum game. The A400M will merely take up the dying C-17's market position. The bottom half continues to suffer from overcapacity. And militaries will continue to be hobbled by relatively inadequate air mobility.

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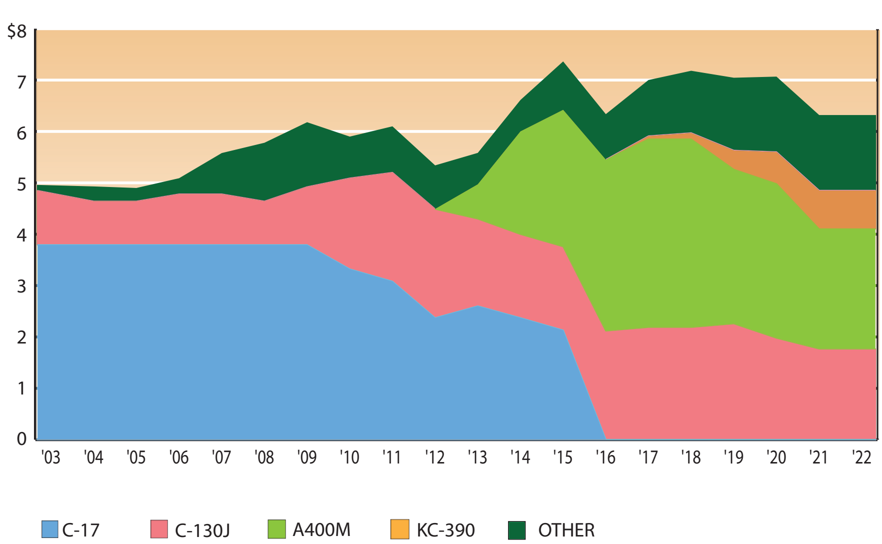
MILITARY TRANSPORT DELIVERIES BY VALUE
(Value in 2013 $billions)



China's bold lunar plan

by Craig Covault
Contributing writer

Astronauts Buzz Aldrin of Apollo 11 and Eugene Cernan of Apollo 17 tell *Aerospace America* that engineering details emerging from China's first robotic Moon lander suggest it is a formal precursor to a manned lunar module that would carry Chinese astronauts to the surface of the Moon around 2030. In their view, the time may be right for NASA to begin direct cooperation with China on the return of humans—both Chinese and American—to the Moon as a prelude to international manned missions to Mars.

The 308-lb Chinese rover, seen in images circulated online, appears to be inspired by U.S. work on another celestial body: Mars. The rover sitting atop the lander has major components that look identical to those developed and flown a decade ago by NASA's Mars Exploration Rover program. "It's remarkable that from a robotic rover design standpoint China wants to duplicate, with a lookalike on the Moon, what Spirit and Opportunity did on Mars," notes historian and author Andrew Chaikin.

Designated Chang'e 3, the mission's potential science return is already being questioned, at least outside of China. "Except for a ground-penetrating radar on the rover, none of many science instruments on the lander/rover are expected to discover much new on the Moon," says a U.S. lunar scientist who worked on Apollo and other lunar programs but is not authorized to speak on the record about the Chinese space program.

"The Chinese are carrying instruments that are a lot like instruments flown on the Soviet Luna and the U.S. Surveyor lander

Information from previously secret photos and documents reveals intriguing details about Chang'e 3, the new Chinese robotic lunar lander. Experts in China and the U.S. say the craft is a precursor to a scaled-up vehicle designed to carry human crews to the Moon. Other countries will be joining what has turned into a surge in lunar space plans. But if nothing changes, the U.S. will be contributing very little; a fact that two luminaries of the American lunar program suggest NASA should change.

program," he says. "I do not think they are going to find anything beyond what both U.S. and Soviet scientists already knew 45 years ago, even before Apollo 11."

Succeed or fail, the Chinese Communist party appears determined to reap the same kind of public adulation that accompanied the NASA Spirit and Opportunity rovers that landed on Mars in 2004. The government has begun a public contest to name the rover just as NASA did for all four U.S. Mars rovers launched since 1997. And the Chinese government has begun speaking in lofty terms about the project. Zhao Xiaojin, director of aerospace for the China Aerospace Science and Technology Corp., describes the rover as "a high altitude patrolman carrying the dreams of Asia."

The lander/rover combination is sched-

"The Chang'e 3 details tell me that the U.S. now absolutely must start communicating with the Chinese about lunar cooperation," says Aldrin.

uled for liftoff from the Xichang launch site December 1 on a Long March 3B, China's most powerful rocket. The unmanned Chang'e 3 is then to land on the Moon using a large descent stage with a powerful new throttling rocket engine—just as six NASA/Grumman lunar modules began doing nearly 45 years ago when they carried 12 U.S. astronauts to the lunar surface. Now it's China's turn.

"Seeing the Chinese lander and rover reveals major breakthroughs in Chinese space engineering," says Aldrin, "and also in what the U.S. knows about the Chinese lunar program." Aldrin copiloted the lunar module Eagle with the late Neil Armstrong on July 20, 1969, during the first manned landing on the Moon.

"This unmanned lander is specifically designed to be scaled up for addition of an ascent stage and crew cabin," Aldrin tells *Aerospace America*.

Ma Xingrui, head of China's space exploration body and chief commander of the lunar program, has hinted cryptically at future applications. "The Chang'e 3 mission makes use of a plethora of innovative technologies, 'secret weapons.' It is an extremely difficult mission that carries great risk," Ma said in Beijing.

The Nuclear-powered China Chang'e 3 Moon lander descent stage carrying the piggyback solar array-powered rover is lowered into Beijing vacuum chamber. The Chinese rover appears to copy many NASA Mars rover features and instruments. Credit: China Space News/ NASASpaceflight.com/ Planetary Society.

The underside of the lander has a nozzle for a large, new throttleable rocket engine and landing gear similar to Apollo lunar modules. The Chinese lander scales to about 40% of an Apollo descent stage and appears to be a formal prototype for eventual scale-up to a manned configuration. Credit: China Space News/NASASpaceflight.com/ Planetary Society.

"The Chinese robotic lander is much larger than what is needed for the small rover being carried," notes Cernan, who commanded the Apollo 17 lunar module in December 1972 and was the final Apollo astronaut to leave footprints on the Moon. "It is obvious this thing is a genuine precursor to a Chinese manned version with a scaled-up descent stage," he says.

The Chinese robotic flights are part of a multinational lunar mission surge with as many as a dozen robotic Moon missions, mostly landers, planned for launch by China, Russia, and India by 2020.

JOINING THE SURGE?

There may be a couple of fragile U.S. commercial landers in the mix as well. But while the Chinese and Russians are carrying out landings and surface operations, the only U.S. contributions will be the rich science data that continues to flow from the $500-million, 4,000-lb Lunar Reconnaissance Orbiter. Launched in 2009, it is one of NASA's most productive science and exploration spacecraft.

Russia, however, is also working to rebuild its once highly successful Soviet lunar robotic capability by planning as many as five lunar missions, four of them landers, between 2015 and 2020. How many will actually fly by 2020 is still being determined. All of the landers would aim at the Moon's south pole to plumb for volatiles like water and other ices, possibly returning cryogenically preserved samples to Earth.

What Aldrin would like to see develop out of the lunar interest spawned by China's program is a U.S. role in establishing a manned lunar capability at the L1 and L2 Lagrangian points near the Moon. Those locations would help the U.S. build a base efficiently at the resource-rich lunar south pole as a development facility for in-situ resource utilization to make Mars habitation viable in the future.

The U.S. will have scant participation in the lunar surge, although, ironically, it was NASA Ames' LADEE (Lunar Atmosphere and Dust Environment Explorer) that initiated it. LADEE was launched from the Wallops Flight Center in Virginia on a Minotaur on September 6. Weighing 844 lb, the spacecraft now orbits the Moon in a retrograde trajectory, flying east to west at an altitude of only 31 mi. LADEE is only the seventh NASA robotic lunar orbit mission since Apollo 17.

Technicians show the overall scale of the Chinese lander and the boxy design similar to the Apollo lunar module. But unlike Apollo, the plutonium 238 RTG-powered Chinese lander is to survive for an Earth year and carries science instruments including a drill and telescope. Rover is designed to drive up to 6 mi. during three Earth months of operation. Credit: China Space News/ NASASpaceflight.com/Planetary Society.

LADEE is designed to capture and analyze lunar dust to determine if rays of light seen by orbiting Apollo astronauts above the Moon's horizon at lunar twilight were caused by a glow from sodium atoms or suspended dust.

India, too, plans to launch a lunar rover sometime during the same period, as part of its own space race with China. India had earlier teamed with Russia on an orbiter/ rover plan that Russia scrapped after the loss of its Mars Phobos mission.

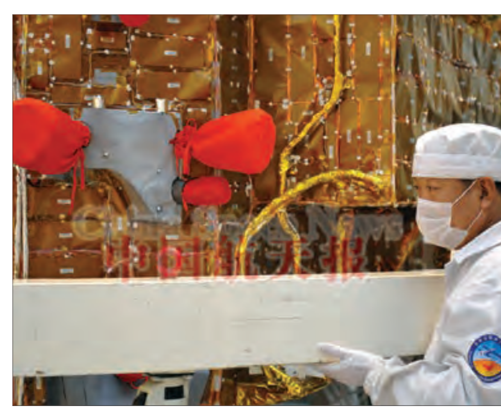
THE SECRET IS OUT

Direct proof of China's ambitious lunar surface program comes in the form of previously secret images sent out of China via the Internet.

The images, of the Chang'e 3 lander and rover, first appeared in the restricted Chinese government print publication *China Space News*. A Chinese web user in Hong Kong identified only as 'Galactic Penguin' then sent the pictures to a Chinese space thread on NASAspaceflight.com. From there they were picked up by Planetary Society blogger Emily Lakdawalla in Pasadena, California.

Back when the U.S. was pioneering human lunar exploration, Aldrin and Cernan spent thousands of hours at what was then the Grumman facility in Bethpage, N.Y., understanding the design of the Apollo lunar modules, and at the Manned Spacecraft Center in Houston, where their components were tested and crews were trained. They're sure they know what goes into building a lunar module—and they see one in the Chang'e 3 hardware and supporting documents.

"The Chang'e 3 details tell me that the U.S. now absolutely must start communicating with the Chinese about lunar cooperation," says Aldrin. "The U.S. knows more about the Moon than anyone else, and we know more about bringing together foreign partners, as we did for the International Space Station," he adds.



A technician inspects the area around thrusters covered in protective red covers. Credit: China Space News/ NASASpaceflight.com/ Planetary Society.

"With all this experience, why aren't we the ones to form something like a 'manned international lunar outpost authority,' where countries can begin to coordinate and demonstrate on the Moon operations needed on Mars, rather than doing it on an asteroid?" asks Aldrin.

"We are going to need cooperation for any mission to Mars, and lunar cooperation with China is a nice thought," says Cernan, "but we have nothing to deal with, we have no bargaining chips." Aldrin, however, believes the United States and its partners would have leverage if they invited China to participate in the ISS program.

The U.S. has rejected Chinese station overtures for more than a decade, because all of China's manned space operations are

The circular 146-mi.-diam. Sinus Iridium is the landing zone for the Chang'e 3. It is easily visible with binoculars at the northwest corner of the Imbrium Basin, the left eye of the 'Man in the Moon' viewed from Earth. Credit: Peter Rosén.

tightly controlled by the People's Liberation Army. Also, the vote must be unanimous among the ISS partners, and Japan and Russia especially may oppose it.

The lander spacecraft is more than 40% the size of a NASA Apollo lunar module descent stage, and the Chinese are building them on an assembly line basis. "This thing is huge!" exclaimed Lakdawalla, a planetary spacecraft expert, in her initial Chang'e 3 blog when she first saw the images.

As many as six Chang'e landers are being designed and built—two landers each with rovers, and as many as four other landers to complete two missions that would each bring back to Earth 4.6 lb (2 kg) of lunar rock and regolith. According to the Chinese, a duplicate lander and rover have been built in tandem with Chang'e 3 to act as a backup or fly as Chang'e 4 in 2015.

"The Chinese will be the next on the Moon, and they are going to be there for a long time, with significant staying power," says Cernan. He and Aldrin believe Chinese manned lunar landings will be possible on larger versions of the Chang'e 3 design within 10 years.

As with U.S. programs, a big challenge will be launch vehicle development. Liang Xiaohong, the deputy director and Communist Party chief of China's Academy of Launch Vehicle Technology, said early this year that China is beginning formal development of a Saturn-V-class Moon rocket with 11 million lb of liftoff thrust—3.5 million more than the Apollo Saturn V. It is designated the Long March 9.

According to the Chinese, the unfueled descent stage mass of Chang'e 3 is 2,646 lb, which is 42% of the mass and scale of an unfueled Apollo lunar module descent stage that, according to Grumman documents, weighed 6,100 lb. The launch mass of the entire Chinese vehicle will be up to 8,377 lb including a propulsion bus.

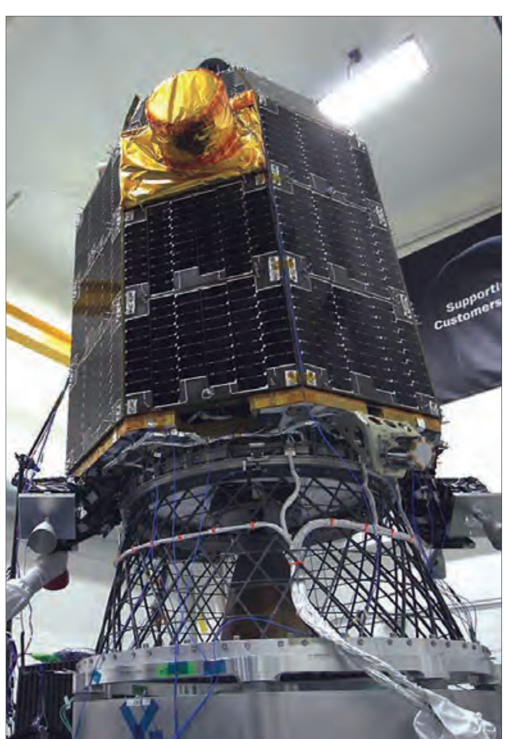
The development of a boxy-sided descent stage in which to package descent rocket engine propellant is under way early in the lunar program. This is directly tied to practicing toward creation of a manned landing vehicle, Cernan and Aldrin believe. New technologies evident in the lander and in fact necessary for it to survive on the lunar surface illustrate a breakout capability for China in several areas. These include thermal control, system integration, electrical system design, software, command and control, and propulsion, the two agree.

ROVER REDUX?

A notable feature of the Chang'e 3 lander and its piggyback rover, say Cernan and Aldrin, is that advanced Chinese technology is divided between the two. The lander is packed with it; the six-wheeled, 308-lb rover, by contrast, appears to duplicate the design and engineering of NASA JPL's 400-lb Spirit and Opportunity Mars rovers.

There is solid evidence that the Chinese have done just that with the Chang'e 3 rover, says Aldrin. But it is something you would expect them to do, he notes. Mars mission engineers believe the Chinese saved hundreds or thousands of man-hours in their lunar rover design and testing by using U.S. rover designs, and they wonder how the Chinese got them.

The solar-array-powered rover, like the NASA Mars rovers, has a small extendable arm equipped with an alpha particle X-ray spectrometer, and also an infrared spectrometer that will be placed atop specific rocks for detailed study. Also like NASA's vehicles, the Chang'e 3 rover has two mast-mounted navigation and two panoramic cameras, along with small engineering cameras placed at critical locations.



The 844-lb $100-million Lunar Atmosphere and Dust Environment Explorer (LADEE) is shown in testing before its September launch to the Moon to collect and analyze lunar dust from a 31-mi. orbit. LADEE is the first to use a Modular Common Spacecraft Bus and the first Ames-designed and developed spacecraft, but it may be the last NASA spacecraft to visit the Moon until the 2020s. Credit: NASA.

LANDING AND EXPLORATION

Once at the Moon the Chang'e 3 will be placed in a 62-mi. equatorial orbit. On touchdown day, the lander, with the rover, will separate from the bus and descend first into a 62x9.6-mi. orbit from which the final descent will be made.

The target landing area is a basaltic lava plain in the northwest corner of the giant Imbrium Basin—the left eye of the 'man in the Moon.' In the northwest corner of the basin is a 146-mi.-diam. circular bay that extends the Imbrium Mare farther northwest. The lander will be targeted to this location, called Sinus Iridium, for potential geologic discoveries.

To map the spot, the Chinese have used the Chang'e 1 and 2 orbiters and probably data released by NASA from the Lunar Reconnaissance Orbiter, as well.

The lander will hover at 328 ft for up to 90 sec while it uses hazard avoidance sensors and software to find a boulder-free area, moving laterally until it does so.

Chang'e 3 will then begin a slow descent to 10 ft. There, the large descent engine will be shut down and only small attitude control thrusters left on through the landing, according to a translation of Chang'e 3 project charts.

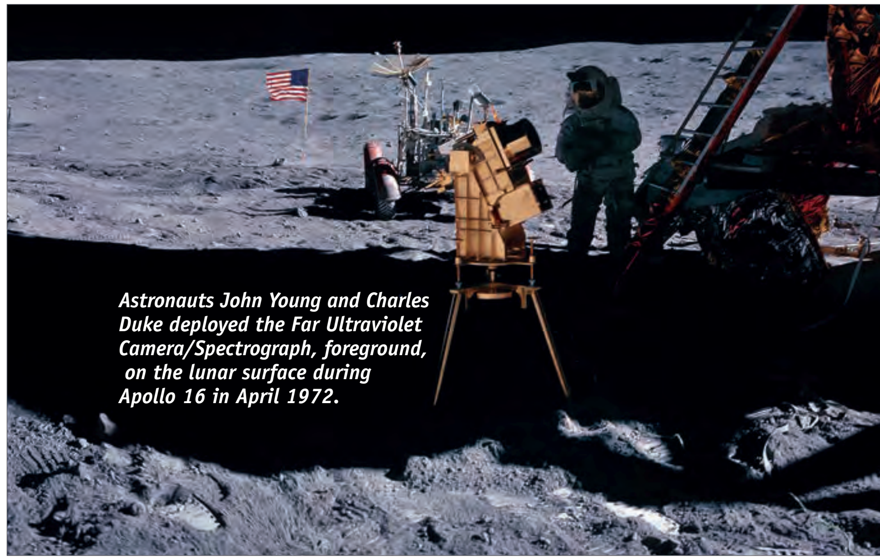
Powering the craft will be solar arrays and a plutonium 238 radioisotope thermoelectric generator (RTG) to provide heat during month-long lunar nights. The lander is designed to survive at least one Earth year as a science platform of its own.

Translated Chinese documents say the science instruments on the lander include:

• An optical ultraviolet telescope to observe binary stars, active galactic nuclei, and short-period variable stars. Some informal UV cooperation will be done by the Hawaii-based International Lunar Observatory Association, says Steve Durst, its founding director.

• A second ultraviolet camera to observe the 30.4-nm band radiation from the Earth's ionosphere to monitor the effect of space weather and solar activity on Earth's geomagnetic field. China says that means Chang'e 3, if successful, will be the first observatory on the Moon, although Apollo 16 carried a UV camera.

• A descent camera to watch the landing from the viewpoint of the rover, three panoramic cameras, an extendable lunar regolith probe or drill, and a lander engineering package.



Astronauts John Young and Charles Duke deployed the Far Ultraviolet Camera/Spectrograph, foreground, on the lunar surface during Apollo 16 in April 1972.

The documents say the rover carries:

• Two panoramic cameras, two navigation and engineering camera sets, an arm-mounted alpha particle X-ray spectrometer, plus an infrared spectrometer, the rover engineering package, and a data controller.

• Its most significant instrument is its belly-mounted ground-penetrating radar, designed to show detailed regolith structure down to 90 ft and basic lunar crust structures down to several hundred feet. "Unlike the other instruments, the radar could show 'very meaningful' fine scale information on the depth and structure of the regolith, especially around craters," said the U.S. lunar scientist.

The rover will reach the ground after being lowered on a platform that intersects two ramps on which it will drive down to the surface. Its six metal spoke-type wheels are very similar in design to those used on the two Soviet Lunokhod rovers.

The Chinese rover is designed to survive at least three months (three lunar days and nights). It is equipped with solar arrays and, probably, small plutonium 238 radioisotope heater units like those used on Spirit and Opportunity. Although lighter than these U.S. rovers, it is roughly the same size. It is also designed to travel up to 6 mi. during its mission, under both ground and autonomous control.

The mission will mark the first attempt in 37 years to achieve a robotic lunar landing. Chang'e also will be the first robotic lunar rover sent to the Moon in 40 years. The last one was the Soviets' Lunokhod 2, launched in 1973; the last lander was their Luna 24 sample return in 1976.

How climate change is likely to affect aviation operations, both in the air and on the

elsewhere have begun to take the issue seriously. Some nations view themselves as

bodies such as the EU have begun pumping sharply increased funding into devising

CLIMATE CHANGE AND AVIATION

Increasingly turbulent weather events and their impact on aviation—especially airlines and airports—are subjects now being taken very seriously by North American and European aviation research organizations, infrastructure providers, and governments.

Brussels-based air traffic management agency Eurocontrol, in its fourth *Challenges of Growth* study, looked at some of the emerging trends that it expects will impact civil aviation in Europe over the next 20 years. The study, published in June, predicted that stormier weather, rising tides, heavier rains, and changes in prevailing wind directions will impact airliner flight routes, where travelers choose to vacation, the length and placement of runways, and investments in drainage infrastructure.

Meanwhile, the U.S. will be a much hotter place, precipitation patterns will shift, and climate extremes will increase by the end of the 21st century. These are the findings reported in January by the National Oceanic and Atmospheric Administration in support of the National Climate Assessment. Temperatures have generally been higher in most areas, apart from the Southeast, says the report. It notes also that the country has seen increases in overall annual precipitation and rises in potentially dangerous extreme weather events such as heat waves and heavy rains.

Politicians and some scientists may question the precise role of fossil fuel emissions and jet contrails in the planet's warming, but some airport authorities and airlines are beginning to accept that the climate will warm for whatever reasons, and they are starting to write the potential impacts into their strategic plans.

Projected challenges

The Eurocontrol report lists a range of challenges that climate change could bring, from having to deal with more torrential rain at airports to shifting patterns of air travel demand within Europe. The study builds on other Eurocontrol research that in 2011 reported, "With over 30 European airports potentially at risk of loss of runway ca-

ground, is a matter of controversy. But many decision-makers in Europe, the U.S., and

less vulnerable to the problem than others, but all are likely to notice that governing

adaptive strategies.

by Philip Butterworth-Hayes
Contributing writer

FORECASTING THE EFFECTS

pacity through such impacts as sea-level rise and storm surges, the future impact on runway operations could be very significant for the European ATM system. Of particular significance is the number of secondary or diversionary airports which may also be closed if the main airport were closed."

In North America, a small but growing number of major hubs are beginning to look seriously at increasing their protection against more frequent and more extreme weather events. According to *Airport Climate Adaptation and Resilience*, a 2012 report prepared by the Transport Research Board and sponsored by the FAA, around 70% of airport delays are the result of extreme weather events, and these are on the increase.

"In 2011, the United States witnessed a record 12 weather/climate disasters, each costing $1 billion or more," says the report. "Quite often, how airports respond to these events influences future planning. By defining and more explicitly addressing the risks that climate change now presents to air travel, airports can extend and enhance the benefits from present day investments in maintenance, data collection, and capital improvements. For example, in 2011 Tropical Storm Irene closed all major New York airports. Although not a hurricane, but recording 5 to 8 inches of rain, the storm generated news that certain categories of hurricanes would put JFK International Airport under more than 15 ft of water."

According to research by the U.S. Global Change Research Program: "Recent hot summers have seen flights cancelled due to heat, especially in high altitude locations. Economic losses are expected at affected airports. A recent illustrative analysis projects a 17% reduction in freight carrying capacity for a single Boeing 747 at the Denver airport by 2030 and a 9% reduction at the Phoenix airport due to increased temperature and water vapor."

This is not the only research that points the way to possible changing weather patterns increasing disruption of air travel.

According to the U.K.'s Manchester Metropolitan University Centre for Aviation Transport and the Environment (CATE), "Global sea-levels are projected to rise by between 0.2 and 0.5 m by 2100. This, especially when combined with an increase in storminess, would result in more frequent flooding and storm surges causing coastal erosion and land subsidence."

In 2011 'Berit,' considered a 100-year storm, hit a helipad at Vaeroy, Norway. Climate models predict that storms of Berit's magnitude could occur as often as every 10 years from 2100. Photo by Leif-Rune Kristiansen, Avinor.

In addition, says the CATE study, "Rising temperatures reduce aircraft lift, thereby requiring longer take off runs, which could result in the need for longer runways at some airports, or changes in aircraft type or maximum payload, and potentially airspace changes and local community impacts. Precipitation changes will impact on airport operations and design requirements. A number of airports have already reported incidences of extreme rainfall and the operational disruptions that this has caused…. Investment in drainage infrastructure will be required if operational disruptions are to be avoided."

And it is not just on the ground where problems will occur, many forecasters say. In the U.K., Paul Williams from the University of Reading and Manoj Joshi from the University of East Anglia have analyzed supercomputer simulations of the atmospheric jet stream over the North Atlantic Ocean. They conclude that by the middle of this century, the chances of encountering significant turbulence will increase by between 40% and 170% as a result of climate change. The amount of airspace containing significant turbulence at any time will most likely double. The average strength of turbulence will also increase, by 10-40%.

According to Williams, "Air turbulence does more than just interrupt the service of in-flight drinks….The total cost to society is about £100 million [$150 million] each year."

Need for more data

How bad will it get? The data are, to say the least, contradictory. In its 2011 *Climate Change Adaptation Report*, the U.K. National Air Traffic Services company, known as NATS, set out its view of the risks that rising sea levels and more extreme weather phenomena pose to its aviation infrastructure.

According to its study, "Measurement of sea levels over the past century has shown that levels have been rising at a mean rate of 1.8 mm per year. More recent sea level measurement by satellite has estimated rates of 2.8 ±0.4 to 3.1 ±0.7 mm per year between 1993–2003. However from 2006 to 2010 the rate of sea level rise dropped back to levels approaching zero. Values for predicted sea level rise over the course of this century typically range from 90 to 880 mm (3.54 inches – 2.89 ft), with a central value of 480 mm (1.57 ft)."

On the other hand, the sheer number of climate change phenomena identified by ICAO (International Civil Aviation Organization) as likely to impact aviation gives much greater cause for concern.

Planning for resilience

In the U.S., only a relatively small number of airports have actively developed climate change resilience strategies. In May, at the Environmental Affairs Conference held by Airports Council International North America, only 4% of the airports contacted had developed such strategies. A small percentage said climate change is considered too challenging a political topic, but most did not anticipate being negatively impacted by such change, or did not have sufficicient resources to address the issue.

The picture is complex, because an increase in temperatures—predicted by many climatologists—is likely to benefit as many airports and airlines as it disrupts. For example, some would benefit from a reduction in the cost of snow and ice removal and reduced requirements for salt and chemical uses.

But overall, the impact on aviation facilities of changing weather patterns, according to the latest National Climate Assessment for the U.S., is not promising: "More frequent interruptions in air service and airport closures can be expected. Airport facilities including terminals, navigational equipment, perimeter fencing, and signs are likely to sustain increased wind damage. Airports are frequently located in low-lying areas and can be expected to flood with more intense storms. As a response to this vulnerability, some airports, such as LaGuardia in New York City, are already protected by levees. Eight airports in the Gulf Coast region of Louisiana and Texas are located in historical 100-year flood plains; the 100-year flood events will be more frequent in the future, creating the likelihood of serious costs and disruption."

Over the next few years there are likely to be new guidelines for aviation infrastructure providers in many countries, with climate change resilience issues included. For example, Norway's airport company, Avinor, has revised its airport design handbook to include new requirements for erosion protection and a stipulation that new runways should not be built lower than 7 m above sea level. This is a relatively high margin: Brisbane's new parallel runway in Australia is being built 4.1 m above sea level (exceeding the minimum level recommended by engineering consultants, 3.5 m).

Differing perspectives

Nations tend to view the challenges of climate change in terms of their own perceived vulnerabilities. The impact of rising sea levels is of more or less academic interest in Switzerland, under constant review in Norway—where 20 of the nation's 51 airports with regular commercial civil air traffic are situated between 2.5 and 15 m above sea level—and of urgent interest in the Netherlands, whose the main hub, Amsterdam/Schiphol, lies 4.5 m below sea level.

At the Netherlands facility, a two-themed 'Climate Proof Schiphol' program is under way. One strand is concerned with spatial design—issues such as drainage, salinization, and water level management. The other is operations based—improved predictions of weather conditions and noise, and better methods for preventing water pollution caused by deicing chemicals.

Six challenges identified by Eurocontrol

- *Europe should prepare for higher temperatures and an increase in precipitation. An exception is Southern Europe, where precipitation will diminish. Increased summer heat and humidity in the Mediterranean Basin may influence the amount and location of demand as traditional destinations could become uncomfortably hot during the summer season. This would lead to both a temporal and geographic shift in demand. Higher temperatures would also reduce aircraft climb performance, which in turn would affect the distribution of local noise.*
- *Heavy precipitation events will reduce airport throughput and challenge an aerodrome's surface drainage capacity.*
- *Snowfall will generally decrease throughout Europe, although there may be heavy snow events in new areas and an increase in more challenging wet snow conditions. In locations that seldom experience snow and are relatively unprepared for it, its effects on airport operations are greatest. Overall, more snow clearing and deicing equipment may be required.*
- *The strongest storms are expected to become larger and more powerful. Convective weather can impact flight predictability and punctuality while having implications for flying predetermined 4D trajectories.*
- *An increase in larger and more intense convective systems may affect multiple hub airports in a region.*
- *Changes in prevailing wind direction are also expected, leading to an increase in crosswinds. Associated changes in procedure may have an environmental impact, while capacity will be reduced at airports with no crosswind runway.*

Source: Eurocontrol.

EUROPEAN AIRPORTS AND THE RISKS FROM CLIMATE CHANGE

Climatic pressures	*Risks*	*Timeframe of expected event*	*Regions mainly affected*
Summer heat	• Greater need for ground cooling • Degradation of runways and runway foundations • Higher density altitudes causing reduced engine combustion efficiency • Decreased airport lift and increased runway lengths	Medium negative (2025-2080) to high negative (2080)	Southern Europe (2025), west, east, and central Europe (2080)
Heavy precipitation events	• Flood damage to runways and other infrastructure • Water runoff exceeds capacity of drainage system	Medium negative (2025) to high negative (2080)	European wide
Extreme storms	• Wind damage to terminals, navigation, equipment, signage	No information	No information
Sea-level rise	• Flooding of runways, outbuildings, and access roads	Medium negative (2080)	European wide
General	• Interruption and disruption to services supplied and to ground access • Periodic airport closures • Higher maintenance costs		

Source: European Commission.

POTENTIAL NEED FOR ADAPTATION MEASURES

	Level of uncertainty	*Probability of occurrence*
Sea-level rise	Virtually certain	≥99%
Temperature changes		
Decreases in very cold days	Virtually certain	≥99%
Increases in Arctic temperatures	Virtually certain	≥99%
Later onset of seasonal freeze, earlier onset of seasonal thaw	Virtually certain	≥99%
Increases in very hot days and heat waves	Very likely	≥90%
Precipitation changes		
Increases in intense precipitation events	Very likely	≥90%
Increases in drought conditions for some regions	Likely	≥66%
Changes in seasonal precipitation and flooding patterns	Likely	≥66%
Storms		
Increases in hurricane intensity	Likely	≥66%
Increased intensity of cold-season storms, with increases in winds, waves, and storm surges	Likely	≥66%

Source: IPCC 2007 Summary for Policymakers in Climate Change 2007.

"Schiphol airport and the surrounding area are very vulnerable to climate change," according to the Knowledge for Climate Research Program consortium, a group of private and government research agencies cofinanced by the Ministry of Infrastructure and the Environment. "The airport is situated, from a hydrology point of view, in one of the most complex and fragile urban areas in the world. There is no doubt that continued land subsidence, coupled with more intense periods of precipitation and drought and with an accelerated rise in sea levels, will force fundamental changes to take place in the design and use of the whole of the Schiphol region."

In general—and putting aside local considerations—consensus among most North American and European aviation organizations seems to be that climate change adaptation is a challenge but a long-term one that can be accommodated by relatively simple changes to current development plans. Such measures could include expanding drainage capacity, increasing training, and improving forecasting and communications among airports, airlines, and ATM agencies.

A key element of the FAA's NextGen ATM program is its Network Enabled Weather, which will provide common, universal access to aviation weather data. "This tool will allow ATM to more easily adapt to changing weather scenarios by distributing a single, comprehensive picture of current weather to a wide variety of users and systems. It will also be integrated into other NextGen-related systems in the future," according to the DOT.

The power of money

The biggest impacts are not expected to unfold rapidly. According to other Eurocontrol research, significant flooding risk to coastal airports will probably occur around 2099, and significant changes to travel patterns as a result of soaring temperatures in traditional vacation destinations will not occur before 2030.

Even so, climate change resilience is now high on the political agendas of both European and North American governments. According to an April 2013 EC report, *Adapting infrastructure to climate change*: "The European Union will step up its efforts in financing climate-resilient infrastructures in the 2014-2020 budgetary period. It is foreseen that a minimum of 20% of the overall 2014-2020 EU budget will go in climate-related investments. This is expected to have significant impact on infrastructure in Europe's less developed regions…where most EU funding will be allocated."

According to one European air navigation service provider with a long coastline and several major airports with runways fairly close to the waves, insurance costs to protect these facilities have fallen over the past 12 months, with insurers apparently unconcerned about the short-term impacts of climate change. But EU bodies responsible for supporting aviation infrastructure developments now need to see climate resilience plans built into the airport or ATM agency long-term business strategies.

In February, federal agencies in the U.S. released their first-ever climate change adaptation plans. The FAA has begun "analyzing aviation facility, service, and equipment profile data for vulnerability to a combination of storm surge impacts that climate change might bring. The assessment process involves overlaying outputs of publicly available climate models to FAA assets and operations to identify those most affected by storm surge under projected climate scenarios, evaluating mean high water mark in relation to the existing elevation," according to the agency.

Time will tell how appropriate these responses to the challenges really are.

Unmanned

Budget shortfalls and a crash haven't stopped work on long-endurance flight

U.S. aerospace firms are trying to develop unmanned planes or airships that would stay aloft for days at a time. DARPA and others are aiming for endurance that would be measured in years. If they succeed, ultra-persistent unmanned planes would be a new option for military commanders.

Unmanned air systems have changed the way war is waged, allowing military forces to spy on enemies without putting themselves in harm's way. But although some UAVs can stay aloft longer than manned aircraft, their endurance is still limited, usually measured in hours.

"Current UAVs provide valuable intelligence, surveillance, and reconnaissance [ISR] coverage for troops deployed overseas," says DARPA. "However, UAVs cannot stay airborne for extended periods of time before needing to be refueled or serviced." Moreover, the Air Force's current high-altitude, long-endurance (HALE) craft, the Northrop Grumman-built Global Hawk, is expensive to buy and operate.

Flying UAVs for days or weeks at a time has strong appeal, because it would provide continuous presence over areas of interest. In addition, such aircraft would generally operate at high altitudes that offer a wide view of the Earth and are largely devoid of other traffic.

Current efforts to make ultrapersistent UAVs a reality include Boeing's Phantom Eye and AeroVironment's Global Observer.

"There are different threats fueling these programs," says aviation analyst Larry Dickerson of Forecast International. These include "the ability to linger for hours or even days over a suspicious site, such as the nuclear facilities in North Korea or Iran, or to monitor the area surrounding a mili-

marathoners

Boeing's Phantom Eye flew for the first time in June 2012. Credit: Boeing.

tary base in a foreign country, or to keep an eye on a border or infiltration route."

Turning test planes into operational versions will not be easy, however. Besides facing a federal budget environment that is difficult at best for new programs, these aircraft still have to show that they will deliver as promised.

"Lower cost HALE concepts do have a potential market if they prove to be technologically feasible," says Philip Finnegan, director of corporate analysis at the Teal Group consulting firm. "Affordability is an issue for Global Hawk, the current system that dominates the market."

Another challenge for new HALE aircraft is that the Defense Department is already developing other, unspecified long-endurance capabilities that may weaken the case for a Phantom Eye or Global Observer. At an April hearing of the House Armed Services Committee, Lt. Gen. Charles Davis, military deputy to the Air Force acquisition chief, alluded to "classified platforms" that could do the mission of a Block 30 Global Hawk.

These classified platforms "might be the Pentagon's alternative, for now, to these persistent surveillance aircraft design programs," says Dickerson.

Phantom Eye

Boeing has pumped millions of its own dollars into designing, building, and testing its Phantom Eye demonstrator. The aircraft is designed to perform ISR and communications missions for up to four days without refueling, at altitudes of up to 65,000 ft. For fuel it uses environmentally friendly, energy-efficient liquid hydrogen cooled at -420 F in a well-insulated tank. The only byproduct is water vapor released into the atmosphere through exhaust ducts.

Although satellites already can provide persistent coverage for ISR and communications, putting this capability on an airborne platform is attractive for several reasons: An aircraft, at least theoretically, could be assigned a new mission more easily, would cost less to build, and would provide higher resolution imagery.

"It's exciting, because you're on the cusp of the next big thing in aerospace," says Keith 'Monty' Monteith, Boeing's business development lead for Phantom Eye. "You can deliver satellite-like capabilities from an airplane, which raises the bar in terms of affordability."

Liquid hydrogen contains three times more energy per pound than conventional aviation fuel. Boeing therefore believes that Phantom Eye not only could far outlast Global Hawk's roughly 30-hr endurance but also could provide its high-altitude capability at the operating cost of a medium-altitude Predator UAV.

"What enables that low cost of operations is the use of liquid hydrogen as a fuel," Monteith says. "It reduces the amount

by Marc Selinger
Contributing writer

of weight of the vehicle that's dedicated to-carrying fuel," so there is "more payload available, and you can keep that payload aloft for a lot longer."

Boeing launched the Phantom Eye demonstrator program in 2008 and unveiled the craft to the public in 2010. The first medium-speed taxi test took place in March 2012. Flight testing began in June 2012, and Boeing has gradually increased the altitude and duration. By mid-September, Phantom Eye had completed five flight tests, all at Edwards AFB, California.

During the first flight, the aircraft stayed airborne for 28 min and reached 4,080 ft. In an apparently temporary setback, the landing gear was damaged when Phantom Eye touched down, prompting Boeing to install an upgrade. On the second flight, in February of this year, the aircraft remained aloft for 66 min and exceeded 8,000 ft. For the third flight, in April, Phantom Eye flew for 2 hr 15 min and climbed to 10,000 ft.

The third test "was a very good flight," and the vehicle remained "well controlled" despite encountering air turbulence, says Brad Shaw, Boeing's Phantom Eye program manager.

During the fourth flight, on June 14, the UAV climbed to 20,000 ft and remained aloft for about 3 hr. At this writing, the program had not set a specific date for reaching the 65,000-ft altitude milestone. "We're going to do it as quickly as our flight test processes and safety will allow," Shaw says.

A timeframe for reaching the four-day endurance maximum is yet to be determined as well, he adds.

First customer, future outlook

Shortly before the UAV's fourth flight, Boeing lined up its first payload customer. The Pentagon announced June 5 that the Missile Defense Agency awarded the company $6.8 million to fly a vibration-sensing payload aboard the aircraft starting with the fifth flight, which took place Sept. 14. Phantom Eye climbed to 28,000 ft and remained aloft for nearly four and a half hours. The payload collected "vibration disturbance data," which could lay groundwork for a new airborne laser system someday, says agency spokeswoman Debra Christman.

"A long-endurance platform operating in a quiet environment would benefit both sensor and laser performance," Christman says. The agency "will use the data to anchor models and define requirements for future systems."

MDA does not envision Phantom Eye as a successor to the cancelled Airborne Laser, a modified Boeing 747 designed to shoot down ballistic missiles. Derailed by cost and performance concerns, the plane never made it past the test bed stage. "There are no plans for an airborne laser as a weapon system—that went away with ABL—and there are no plans to resurrect it as an interceptor technology," says agency spokesman Richard Lehner. "The current initiative is to determine if directed energy has a place as a sensor."

Phantom Eye is smaller than the operational version Boeing envisions building. The company is doing conceptual design work on the operational aircraft, which would look similar to the demonstrator but would have a larger wingspan—250 ft vs. 150 ft—and more fuel capacity to give it increased endurance, up to 10 days. It would also be able to carry a larger payload. Outside aviation experts are closely watching the demonstrator's performance.

"Phantom Eye appears to be promising at this point," Finnegan says. "It has considerable corporate support from Boeing and, if the technology proves itself, it could satisfy customer requirements for a longer endurance, lower cost system. The Phantom Eye could cut costs by enabling up to 10 days of endurance by a UAV. That would mean fewer UAVs would have to be purchased to cover an area. It would also mean that less would be spent getting to and from the target. With its greater autonomy, it potentially could reduce the manpower costs of operation."

Next Global Observer takes shape

Boeing is not alone in developing ultra-persistent unmanned planes. AeroVironment has been working on HALE systems since the late 1980s and has flown a series of solar-powered craft, including Centurion, Helios, Pathfinder, and Pathfinder Plus.

Pathfinder Plus, which had 10 flight tests in the 1990s, is on display at the Smithsonian Air and Space Museum's Steven F. Udvar-Hazy Center in Chantilly, Virginia. In 2001, Helios set a world record for aircraft by reaching an altitude of almost 97,000 ft.

But for an energy source that would be sufficient even in winter, AeroVironment eventually turned away from the Sun. Working with internal funds, it built a liquid-hydrogen-fueled, one-third scale Global Observer and flew it in 2005.

The company then built a full-scale version under a $140-million Joint Capability Technology Demonstration program sponsored by the Pentagon and the Dept. of Homeland Security. That version of Global Observer was designed to fly at 65,000 ft for up to a week and provide persistent communications and surveillance. The liquid-hydrogen-fueled aircraft, which carried government payloads, racked up eight successful flight tests in 2010 and 2011.

"Global Observer has moved quickly from development and testing toward demonstrating mission-ready, affordable persistence," AeroVironment Chairman and CEO Tim Conver said at the time. But in April 2011, disaster struck. About 18 hr into Global Observer's ninth flight test, the plane was destroyed in a crash at Edwards AFB. Having run out of money, the Pentagon demonstration project came to an end.

"Flight testing an innovative new solution like Global Observer involves pushing the frontiers of technology and convention," Conver said after the accident. "Risk is a component of every flight test program, and the learning that results from a mishap enables us to improve system reliability and performance. One benefit of testing an unmanned aircraft system is that pilots and crew are not in harm's way when a mishap occurs."

Exactly what happened remains a mystery, at least to outside observers. The Air Force says it did not investigate the accident because it did not own the aircraft. It referred questions about the accident to AeroVironment, which declined to reveal the cause of the crash.

"We identified and resolved the cause of the mishap, which was unrelated to the numerous critical innovations we developed to enable Global Observer's satellite-like capabilities," says Steve Gitlin, AeroVironment's vice president of marketing strategy and communications.

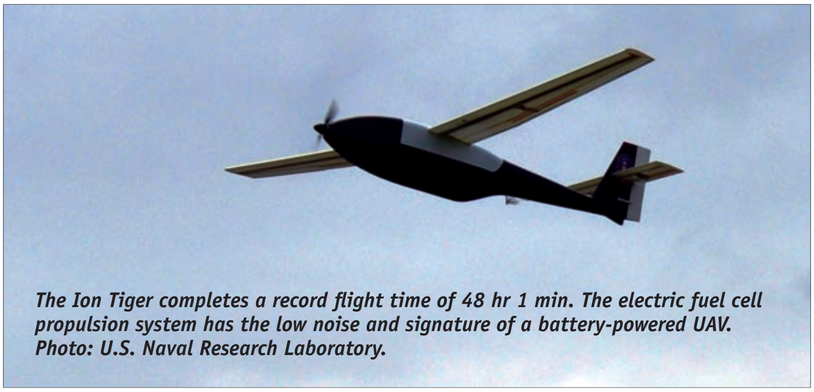
Despite the crash and the disappearance of government backing, AeroVironment continues to see a future for Global Observer. In March, the company announced it had paid $3 million to buy back the program's remaining assets, including the second aircraft and the fixtures to produce and support it.

The second Global Observer now sits at AeroVironment's factory in Ventura County, where it is 80-90% complete, Gitlin says. The craft has a 175-ft wingspan, making it slightly larger than a 767. The company is talking to interested parties in hopes of securing funding to finish the plane and move it into production.

"The capability is ready to go, from our perspective," Gitlin says.

Skeptics abound, but some analysts are not writing off Global Observer just yet.

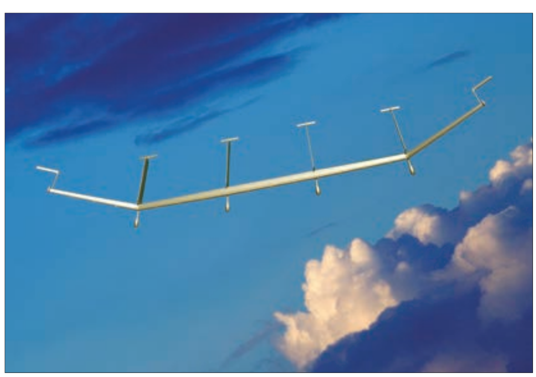
AeroVironment's second Global Observer sits in a company factory in California. Credit: AeroVironment.



The Ion Tiger completes a record flight time of 48 hr 1 min. The electric fuel cell propulsion system has the low noise and signature of a battery-powered UAV. Photo: U.S. Naval Research Laboratory.

Finnegan says the company can bounce back from the crash if the relatively small firm can line up external funding.

"The Global Observer, which is a competitive system to the Phantom Eye, is also promising," Finnegan says. "The difficulty that AeroVironment faces is its size and the resources it can devote to the program compared to Boeing. It needs customers to help fund development but does not have them in place yet. Boeing can move ahead on its own to prove the concept."



Originally a full-scale flight demonstration effort, DARPA's Vulture program now focuses on advancing critical energy management technologies—solar collection (photovoltaics) and fuel cells (energy storage systems).

Ion Tiger, Solara, Vulture, X-56A

There are other entities working on long-endurance UAVs as well. The Naval Research Laboratory, for example, is developing Ion Tiger, a small, low-altitude liquid-hydrogen-powered demonstrator. In April, the 35-lb UAV flew for 48 hr 1 min, almost double its previous record, set in 2009.

In contrast to Phantom Eye and Global Observer, which are large craft designed for high altitudes and hundreds of pounds of payload, Ion Tiger would be capable of carrying a payload in the 5-15-lb range.

"The challenge now is to make the leap from a demonstrator vehicle to a tactical system," says Karen Swider-Lyons, head of the alternative energy section in the NRL chemistry division. "Opportunities include robustness and simplification of the hydrogen fueling and logistics."

In August, Titan Aerospace announced at an unmanned systems conference in Washington, D.C., that it is developing the Solara, an "atmospheric satellite" that is actually a solar-powered, high-altitude unmanned aircraft. Titan envisions that the Solara could stay aloft for months or years at a time for communications, reconnaissance, and other missions.

"The Solara promises to open the door for stationing payloads near the edge of Earth's atmosphere," Titan says. "Unlike space satellites, the Solara is far less expensive to buy and launch, has a larger launch window, and most importantly, can easily be brought back for maintenance or payload upgrades. This allows the flexibility of flying different missions with the same serviceable airframe."

The X-56A takes off on its inaugural flight July 26 at Edwards AFB. NASA photo by Kenneth E. Ulbrich.

DARPA's Vulture project has backed away from its original goal of producing a full-scale flight demonstration. The program is now developing technologies to collect and store enough solar energy to allow a solar-powered unmanned aircraft to stay airborne for five years.

"These technologies are the least mature and are vital for enabling ultra-persistent HALE flights lasting multiple years," a DARPA statement says. "By narrowing the program's focus, DARPA seeks to advance energy management technologies that would benefit a number of future HALE aircraft applications and should reduce risk for development of future very long endurance aircraft programs."

Boeing is working on the program at several of its U.S. locations, including both Huntington Beach and St. Louis, according to Army Lt. Col. Joseph Hitt, DARPA's Vulture program manager. In August the company was testing solar panels in its laboratories and developing components for the aircraft's energy storage system, said Hitt.

"Vulture's advanced energy storage system technologies ultimately could enable a retaskable, persistent pseudosatellite capability in an aircraft package," the agency says. "Such a system would combine key benefits of an aircraft—flexibility and responsiveness, sensor resolution, reduced transmit/receive power, [and] affordability—with the benefits of space assets: on-station persistence, no logistics tail, energy independence, fleet size, [and an] absence of in-country footprint."

Another initiative, the X-56A unmanned flight research vehicle, is exploring technologies that could advance HALE flight. Chief among these is controlling lightweight, aerodynamically efficient aircraft configurations. The X-56A arrived at Edwards AFB in late April and was flight-tested for the first time on July 26, 2013. The program is a joint effort of the Air Force Research Laboratory, NASA Dryden, and Lockheed Martin.

Airships vs. fixed wing

Fixed-wing aircraft have not always monopolized long-endurance flight. Recent years have seen attempts to equip unmanned airships with ultra-persistent ISR capabilities. Such efforts have run into serious problems, however, and the U.S. military's interest seems to have waned.

The Army's Long Endurance Multi-intelligence Vehicle (LEMV), a helium-filled prototype with an advertised endurance of 21 days, was meant to carry intelligence and communications payloads in Afghanistan. But in April the service announced that it was canceling the effort, citing "technical and performance challenges" and "the limitations imposed by constrained resources." At one point, LEMV was at least 10 months behind schedule and about 12,000 lb overweight, the Government Accountability Office wrote in a November 2012 report on airships and aerostats.

The Air Force pursued a similar effort, Blue Devil Block 2, but terminated it in June 2012 after it "experienced significant technical problems resulting in cost overruns and schedule delays," according to the GAO. The Pentagon's inspector general concluded in a Sept. 19 report that the Air Force ignored warnings that the development schedule was too ambitious.

"At the time of project cancellation, the Blue Devil Block 2 airship was more than 10,000 lb overweight, which limited the airship's estimated endurance," said a GAO report. "The weight issue contributed to other design concerns, the tail fins were too heavy and were damaged during testing, and the flight control software experienced problems related to scaling to a larger airship."

Fixed-wing aircraft proponents are not surprised that their systems have outlived the airship programs."We believe the technology is much nearer term" for fixed-wing aircraft than for airships, Monteith says. "Airships may eventually have their day, but at least for the high-altitude market with robust payloads, we believe fixed wing is the way to go."

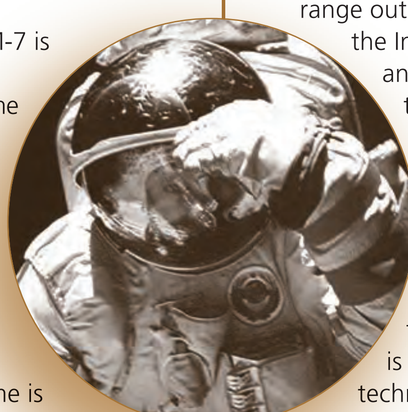
The LEMV, a helium-filled craft from Northrop Grumman, was meant to carry ISR and communications payloads.

Out of the

25 Years Ago, November 1988

Nov. 6 The DOD launches a classified satellite into orbit on a Titan 34D booster. NASA, *Astronautics and Aeronautics, 1986-1990*, p. 195.

Nov. 15 The USSR finally launches its space shuttle, the Buran (Snow Storm). It greatly resembles the U.S. shuttle but is unmanned and entirely automatic. An Energia rocket boosts the craft, which does not have main engines. Buran can be fitted with jet engines for landing assistance. It completes two orbits and lands successfully. It makes no other flights. NASA, *Astronautics and Aeronautics, 1986-1990*, p. 196.



Nov. 26 A Soyuz TM-7 is launched from the Baikonur Cosmodrome for a rendezvous with the Soviet Union's Mir space station. The flight carries three cosmonauts, including Jean-Loup Chretien of France. Watching from the cosmodrome is French President François Mitterand. During the long mission, Chretien will conduct the first spacewalk by a Western European. NASA, *Astronautics and Aeronautics, 1986-1990*, p. 196.

50 Years Ago, November 1963

Nov. 1 Arecibo Ionospheric Observatory, the world's largest radar-radio telescope, is dedicated in Arecibo, Puerto Rico. The 1,000-ft-diam. bowl greatly exceeds the capabilities of earlier telescopes, detecting radiation from far more distant galactic sources. *New York Times*, Nov. 2, 1963, p. 63.

Nov. 7 At the White Sands Missile Range in New Mexico, the Apollo escape system undergoes successful testing on an unmanned Apollo boilerplate command module space capsule. The main solid-propellant four-canted-nozzle escape rocket, built by Lockheed Propulsion, burns for 8 sec with 155,000 lb of thrust, up to more than 5,000 ft. A small solid-propellant pitch motor controls the direction of the flight. Three parachutes are then deployed and safely deposit the capsule back to the ground. *Aviation Week*, Nov. 25, 1963, pp. 52-53.

Nov. 21 The solid-propellant, two-stage Nike-Apache becomes the first modern rocket launched in India. Boosted from the Thumba launch range outside Trivandrum near the Indian Ocean, it reaches an altitude of 106 mi. It then deploys scientific experiments in which sodium-vapor ejections measure the speed and direction of upper atmospheric winds. The rocket, furnished by the U.S., is assembled by Indian technicians. France also contributes to the effort. NASA Press Release 63-105; *Flight International*, Dec. 5, 1963, p. 935; *Aviation Week*, Dec. 2, 1963, p. 34.

Nov. 22 President John F. Kennedy is assassinated in Dallas, Texas. Within 2 hr Vice President Lyndon B. Johnson takes the oath of office as the 36th president of the United States aboard the presidential jet, Air Force One. *New York Times*, Nov. 24, 1963, p. E1.

Nov. 22 The Relay 1 communications satellite conducts the first live transmission of TV signals across the Pacific Ocean. However, a previously taped message of greeting from President Kennedy is deleted from the broadcast when word of his assassination is received. NASA Press Release 63-256.

Nov. 25 A Sikorsky S-61N helicopter takes off from Dacca Airport in East Pakistan to inaugurate what will be "the most comprehensive helicopter service ever operated," according to a Pakistan International Airways statement. The S-61N carries 24 passengers, a flight and cabin crew of four, and 1,800 lb of cargo. *Flight International*, Dec. 5, 1963, p. 911.

Nov. 27 Boosted by an Atlas vehicle, the Centaur upper stage is successfully orbited and burns for 380 sec. This is the world's first flight of a hydrogen-oxygen rocket, a milestone in space exploration. (This is the Centaur's second test flight; the first ended in an explosion soon after liftoff in 1962.) It consists of two Pratt & Whitney RL10A-3 rocket engines and is capable of being shut down and restarted in space. Development began in 1956, but the use of LOX/hydrogen was theoretically proposed in the early 1900s by Russian rocket pioneer Konstantin Tsiolkovsky. Centaur opens the way to a new era of larger payloads and more ambitious missions into interplanetary space. It will later serve as the upper stage on launch vehicles for Viking flights to Mars and Voyager missions to the outer planets. *Aviation Week*, Dec. 9,

Past

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

1963, p. 21; *Flight International*, Dec. 5, 1963, p. 935.

Nov. 29 President Johnson signs an order that renames the NASA Launch Operations Center at Cape Canaveral, Fla., the John F. Kennedy Space Center, in honor of the late president. Cape Canaveral is also renamed Cape Kennedy. D. Baker, *Spaceflight and Rocketry*, p. 159.

75 Years Ago, November 1938

Nov. 5 Three RAF Vickers Wellesley monoplane bombers set a world nonstop distance record of 7,162 mi., flying from Ismalia, Egypt, to Darwin, Australia, in 48 hr 5 min. Portions of the flight encounter extremely bad weather, making radio reception impossible and forcing the crew to navigate by dead reckoning. The commanding pilot is Sqn. Ldr. Richard Kellett. *Aircraft Year Book, 1939*, pp. 163, 469; *The Aeroplane*, Nov. 9, 1938, pp. 547-549.

Nov. 10 The founder of modern Turkey, Mustafa Kemal (also known as Kemal Ataturk), dies in Istanbul. During WW I, most of the aviators in Turkey were Germans or Austrians, and there was no effort to build up the flying corps. After 1918, however, Kemal began rebuilding his nation's air force. Turkish officers were sent to England for training, and Turkey began buying British planes, including Bristol Blenheims. *The Aeroplane*, Nov. 23, 1938, p. 634.

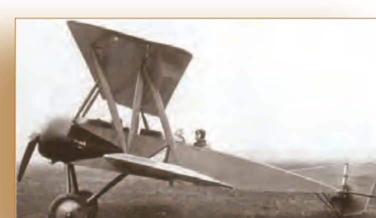
Nov. 25-Dec. 11 At the Paris Air Show, eight nations display 47 airplanes. All but 19 are military types and include fighters, bombers, reconnaissance aircraft, and trainers. Most of the planes are capable of 310 mph or more. Britain's Supermarine Spitfire, rated at more than 355 mph, is the fastest aircraft on exhibit. *The Aeroplane*, Dec. 14, 1938, p. 779.

Nov. 29-30 Pilot Johnny Jones sets a record for aircraft weighing less than 700 lb, flying a 50-hp Aeronca nonstop from Los Angeles to Roosevelt Field in New York. The flight, which lasts 30 hr 37 min, uses 123 gal of gasoline and a quart of oil, costing a total of $31. W. Shrader, *Fifty Years of Flight*, p. 66; *Aircraft Year Book, 1939*, p. 162.

Nov. 30 On a goodwill visit in return for the Japanese Divine Wind flight from Tokyo to Berlin in April 1937, a German four-engined Focke-Wulf Condor named Brandenburg completes an 8,375-mi. flight from Berlin to Tokyo. This is also the fastest flight ever made between Europe and Japan. The Brandenburg makes four stops during the trip, whose total flying time is 41 hr. It carries a goodwill message from Field Marshal Hermann Goering to the Japanese people. *Aero Digest*, January 1939, p. 40; *The Aeroplane*, Dec. 7, 1938, p. 732.

100 Years Ago, November 1913

Nov. 6 R.H. Carr wins the British Empire Michelin Trophy by flying his Grahame-White biplane a total distance of 300 mi., making stops every 60 mi. along the way. A van Hoorebeeck, *La Conquete de L'Air*, p. 101.



Nov. 10 The German dirigible LZ 21 completes its first flight. A. van Hoorebeeck, *La Conquete de L'Air*, p. 102.

Nov. 22 Charles A.H. Longcroft pilots his B.E.2a biplane 445 mi. between Montrose and Farnborough, England, in 7 hr 20 min, winning the first Britannia Trophy. A. van Hoorebeeck, *La Conquete de L'Air*, p. 102.

Massachusetts Institute of Technology

Come work with us!

Tenure-Track Faculty Positions

Department of Aeronautics and Astronautics

The Department of Aeronautics and Astronautics at Massachusetts Institute of Technology (MIT) invites applications for tenure-track faculty positions with a start date of September 1, 2014. The department is searching for exceptional candidates in any discipline related to our core competencies in Vehicles, Information, Computation, Humans and Automation, Atmosphere and Space, and Systems. We are particularly interested in candidates who can complement our strengths in the areas identified as strategic thrusts in our recent strategic plan – Air Transportation, Autonomous Systems and Small Satellites. Candidates are invited to visit the department's website http://aeroastro.mit.edu for more information. Faculty duties include teaching at the undergraduate and graduate levels, advising students, conducting original scholarly research, developing course materials at the graduate and undergraduate levels, and service to MIT and the profession.

Candidates should hold a Ph.D. in Aeronautics and Astronautics, or a related field, by the beginning of the appointment period. The search is for a candidate to be hired at the assistant professor level, however, qualified candidates at all levels will be considered.

Applications must include a cover letter, curriculum vitae, 2-3 page statement of research and teaching interests and goals, and names and contact information of at least three individuals who will provide letters of recommendation. Applications must be submitted as a pdf at https://facsearch.mit.edu. Letters of recommendation must be submitted directly by the recommenders at https://facsearch.mit.edu/letters.

To ensure full consideration, complete applications should be received by December 15, 2013. Note: Applications will be considered complete only when both the applicant materials and at least three letters of recommendation are received.

MIT is building a culturally diverse faculty and strongly encourages applications from minority candidates.

http://web.mit.edu

Tenure-Track/Tenured Faculty Position Aerospace Engineering

The Department of Mechanical and Aerospace Engineering at Rutgers University invites applications and nominations for a tenure-track/tenured aerospace engineering faculty position at the level of Assistant, Associate or Full Professor beginning in January 2014. Candidates with expertise in *Aerospace Engineering and Systems* including flight mechanics, aerospace vehicles, automated optimal design in aerospace systems, experimental diagnostics in high speed flows, satellite dynamics and control, unmanned aerial systems including micro- nano- air vehicles and morphing aerodynamics, aircraft and helicopter structures, air breathing propulsion, space propulsion, space structures, space robotics, spacecraft controls and dynamics, are highly encouraged to apply.

Candidates should demonstrate a capacity to develop a nationally recognized and externally funded scholarly research program. Excellence in teaching in Mechanical and Aerospace Engineering undergraduate and graduate programs is required. The candidate will be expected to develop both undergraduate and graduate level courses in aerospace engineering, and must hold an earned doctorate in Aerospace Engineering or a closely related field.

The Mechanical and Aerospace Engineering (MAE) Department has 28 full-time faculty with more than 600 undergraduate students and 170 graduate students. The MAE Department is one of seven within the School of Engineering at Rutgers-New Brunswick, a culturally and academically diverse environment with more than 4,000 full-time faculty, 6,000 graduate students and 41,000 undergraduate students.

Please submit your application at http://apply.interfolio.com/22403. Applications should include a detailed resume including the name and contact information of at least three references, and a statement of research and teaching interests. Applications will be reviewed until the position is filled. Questions concerning the position may be sent to maefsearch@jove.rutgers.edu

Rutgers University is an equal opportunity/affirmative action/Title IX employer. All persons are invited to apply regardless of race, color, gender, national origin, religion, disability, or sexual orientation.

SCITECH 2014

Gaylord National, National Harbor, Maryland (near Washington, DC)

Continuing Education Course and Workshops

Decision Analysis

Saturday & Sunday, 11–12 January 2014, 0815–1700 hrs

Summary: Decision analysis supports system life cycle development throughout all phases and system hierarchical levels. The course presents the trade study process as part of the systems engineering process, and introduces various decision analysis methods, including the traditional trade study methods, trade space for CAIV, AHV as part of the ANP, PAPRIKA, and Decision Analysis with Uncertain Information/Data.

1st AIAA Sonic Boom Prediction Workshop

Saturday, 11 January 2014, 0800–1700 hrs

Summary: The objective of the workshop is to assess the state of the art for predicting near field signatures needed for sonic boom propagation. Participants are requested to apply their best practices for computing solutions on the provided geometries.

Low Reynolds Number Workshop

Saturday, 11 January 2014, 0800–1700 hrs

Summary: The workshop aims to gather Industry, Academia and Government to assess new research directions and connection between the sciences and the applications. Outcomes aim to include an understanding of where the MAV community stands in 2014 relative to where we've been throughout the past 20 years, and how to begin bridging scientific/academic advances with the needs of industry and the user community.

For more information, visit: www.aiaa.org/scitech2014courses

Register TODAY!

AIAA

UtahState University
www.usu.edu

Assistant/Associate Professor

The Department of Mechanical and Aerospace Engineering (MAE) at Utah State University invites applications for multiple tenure-track faculty positions in 1) astronautical engineering; 2) aeronautical engineering; and 3) solid mechanics/structures. Preference will be given to candidates at the assistant professor level, although exceptionally qualified candidates may be considered at the associate professor level. The department is particularly interested in candidates with expertise and research experience in space systems, orbit determination, unmanned and micro-air vehicles, aerodynamics, and aerospace structures.

See **http://jobs.usu.edu** (Req. ID 054142) for more information and to apply online.

AA/EOE

UtahState University

FACULTY POSITION

The successful candidate will have a Ph.D. Aerospace Engineering or a closely related discipline, interest in developing a quality undergraduate educational program as well as, initiating sponsored research. The candidate has to demonstrate competence in some of the following areas:

a) Spacecraft dynamics, attitude estimation and control
b) Spacecraft structural analysis and design
c) Robotic system for space exploration
d) Spacecraft power and thermal management systems
e) Spacecraft system engineering and integration

The applicant should have excellent written and oral communication skill in English and Spanish. Also, the applicant should be authorized to work in the United States. Please send resume and academics credentials not later than December 15, 2013:

Inter-American University of Puerto Rico
Bayamón Campus
Human Resources Office
500 Road Dr. John Will Harris
Bayamón, PR 00957
Email: morti@bayamon.inter.edu

*Qualified individuals with any disability, who needs assistance for the interview, please contact the Human Resources Office at (787)279-1912, ext. 2015.

Women are encouraged to apply.
Inter American University of Puerto Rico is an Equal Employment Opportunity & Affirmative Action Employer (M/F/H/V)

UCLA Engineering

University of California, Los Angeles
Mechanical and Aerospace Engineering Department

The Mechanical and Aerospace Engineering Department is accepting applications to fill a full-time tenure track faculty position in ***thermal science and engineering*** at the Assistant Professor level in Mechanical and Aerospace Engineering (Tracking # 0205- 1314-01). Exceptional candidates at the Associate or Full Professor level may also be considered.

Applicants must hold a doctoral degree in engineering or a closely related discipline. The successful candidate will be responsible for teaching undergraduate and graduate courses and for developing a strong externally sponsored research program. We are interested in outstanding candidates who are committed to excellence in teaching and scholarship and to a diverse campus climate. The University of California is an affirmative action/equal opportunity employer.

Please apply by submitting your materials via our online application form, https://recruit.apo.ucla.edu/apply/JPF00091. Applications will be accepted online while the submission site is open until the position is filled. Do not send hard copies, as they will not be processed or returned.

BAYLOR UNIVERSITY 1845

Two Positions in Mechanical Engineering: (1) Assistant Professor and (1) Lecturer

The Department of Mechanical Engineering seeks dynamic scholars to fill one tenure-track faculty position and one lecturer position. The tenure track position is sought to fill the program area of *experimental or computational thermofluid sciences*. The lecturer position will be expected to teach thermofluids courses and laboratories, a measurements course, and/or basic mechanics courses. In light of Baylor's strong Christian mission, each successful applicant must have an active Christian faith.

The positions will begin in August 2014. For complete information, please visit:
www.ecs.baylor.edu/mechanicalengineering/.

Baylor is a Baptist university affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Employment Opportunity employer, Baylor encourages minorities, women, veterans, and persons with disabilities to apply.

USC University of Southern California

The Department of Aerospace and Mechanical Engineering at the University of Southern California is seeking applications and nominations for the position of Department Chair. The candidate must have an outstanding record of scholarly and technical achievements, a strong commitment to engineering education, effective management and interpersonal skills, and must be eligible for appointment at the full professor level. Exceptionally strong candidates will also be considered for appointment to an endowed professorship. A PhD degree in aerospace or mechanical engineering or a related field is required. Applications should be received preferably by December 2, 2013. Information about the department can be found at http://ame-www.usc.edu.

Interested candidates should prepare an application package consisting of their personal contact information; a curriculum vitae; a cover letter describing their technical qualifications, thoughts on leadership, and their vision of the field in the future; and contact information for at least four professional references. All material in the application package is to be submitted electronically at:
http://ame-www.usc.edu/facultypositions/

Inquiries should be directed to the Search Committee Chair, Prof. Lucio Soibelman at soibelman@usc.edu.

USC is an equal-opportunity/affirmative action employer. Women and under-represented minorities are especially encouraged to apply.

USC University of Southern California

The Department of Aerospace and Mechanical Engineering at USC is seeking applications and nominations for two tenure-track or tenured faculty positions in the area of thermo-fluids. Though we particularly encourage applications in the fields of combustion and fluid mechanics, consideration will be given to a broad spectrum of outstanding candidates. We also encourage special applications from more senior scholars who have a well-established academic record and whose accomplishments are leading/transforming their fields of study. Exceptionally strong candidates will also be considered for appointment to an endowed professorship.

Applicants must have earned a Ph.D. or the equivalent in a relevant field by the beginning of the appointment and have a strong research and publication record. Applications must include a letter clearly indicating area(s) of specialization, a detailed curriculum vitae, a concise statement of current and future research directions, a teaching statement, and contact information for at least four professional references. This material should be submitted electronically at http://ame-www.usc.edu/facultypositions/. Early submission is strongly advised and encouraged as the application review process will commence January 6, 2014.

The USC Viterbi School of Engineering is among the top engineering schools in the world. More than a third of its 177 tenured/tenure-track faculty members are fellows of their respective professional societies and 35 affiliated faculty members have been elected to the National Academy of Engineering. The School is home to over 45 research centers and institutes. USC Viterbi faculty conducts research in leading-edge technologies with annual research expenditures typically exceeding $180 million.

The University of Southern California values diversity and is committed to equal opportunity in employment. Men, women and members of all racial and ethnic groups are encouraged to apply.

AIAA Bulletin


On 18 September, Orbital Sciences' Antares rocket lifted off with the Cygnus commercial cargo resupply craft at NASA Wallops Flight Facility. (*Photo courtesy of Lauren Appleton, AIAA*)

NOVEMBER 2013

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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
2013			
3–7 Nov†	22nd International Congress of Mechanical Engineering – COBEM 2013	Ribeirao Preto, Brazil (Contact: Joao Luiz F. Azevedo, joaoluiz.azevedo@gmail.com, www.abcm.org.br/cobem2013)	
5–7 Nov†	8th International Conference Supply on the Wings	Frankfurt, Germany (Contact: R. Degenhardt, +49 531 295 3059, Richard.degenhardt@dlr.de, www.airtec.aero)	
2014			
11 Jan	1st AIAA Sonic Boom Prediction Workshop	National Harbor, MD	
11 Jan	Low Reynolds Number Workshop	National Harbor, MD	
11–12 Jan	Decision Analysis	National Harbor, MD	
13–17 Jan	AIAA SciTech 2014 (AIAA Science and Technology Forum and Exposition 2014) **Featuring:** 22nd AIAA/ASME/AHS Adaptive Structures Conference 52nd AIAA Aerospace Sciences Meeting AIAA Atmospheric Flight Mechanics Conference AIAA Guidance, Navigation, and Control Conference AIAA Modeling and Simulation Technologies Conference 10th AIAA Multidisciplinary Design Optimization Specialist Conference 16th AIAA Non-Deterministic Approaches Conference AIAA Spacecraft Structures Conference (formerly the AIAA Gossamer Systems Forum) 55th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference 7th Symposium on Space Resource Utilization 32nd ASME Wind Energy Symposium	National Harbor, MD	**5 Jun 13**
26–30 Jan†	24th AAS/AIAA Space Flight Mechanics Meeting	Santa Fe, NM Contact: http://www.space-flight.org/docs/2014_winter/2014_winter.html	**2 Oct 13**
27–30 Jan†	Annual Reliability and Maintainability Symposium (RAMS) 2014	Colorado Springs, CO (Contact: Jan Swider, 818.586.1412, jan.swider@pwr.utc.com)	
Feb–June	Advanced Computational Fluid Dynamics	Home Study	
Feb–June	Computational Fluid Turbulence	Home Study	
Feb–June	Introduction to Computational Fluid Dynamics	Home Study	
Feb–June	Missile Design and System Engineering	Home Study	
Feb–June	Spacecraft Design and Systems Engineering	Home Study	
2–6 Feb†	American Meteorological Society Annual Meeting	Atlanta, GA (Contact: Claudia Gorski, 617.226.3967, cgorski@ametsoc.org, http://annual.ametsoc.org/2014/)	
1–8 Mar†	2014 IEEE Aerospace Conference	Big Sky, MT (Contact: Erik Nilsen, 818.354.4441, erik.n.nilsen@jpl.nasa.gov, www.aeroconf.org)	
24–26 Mar†	49th International Symposium of Applied Aerodynamics	Lille, France (Contact: Anne Venables, 33 1 56 64 12 30, secr.exec@aaaf.asso.fr, www.3af-aerodynamics2014.com)	
30 Apr	2014 Aerospace Spotlight Awards Gala	Washington, DC	
5–9 May	SpaceOps 2014: 13th International Conference on Space Operations	Pasadena, CA	**5 Aug 13**
26–28 May	21st St. Petersburg International Conference on Integrated Navigation Systems	St. Petersburg, Russia (Contact: Prof. V. Peshekhonov, +7 812 238 8210, icins@eprib.ru, www.elektropribor.spb.ru)	
5 Jun	Aerospace Today ... and Tomorrow: An Executive Symposium	Williamsburg, VA	

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5 Jun	Aerospace Today ... and Tomorrow: An Executive Symposium	Williamsburg, VA	

DATE	MEETING (Issue of *AIAA Bulletin* in which program appears)	LOCATION	ABSTRACT DEADLINE
16–20 Jun	AVIATION 2014 (AIAA Aviation and Aeronautics Forum and Exposition) **Featuring:** 20th AIAA/CEAS Aeroacoustics Conference 30th AIAA Aerodynamic Measurement Technology and Ground Testing Conference AIAA/3AF Aircraft Noise and Emissions Reduction Symposium 32nd AIAA Applied Aerodynamics Conference AIAA Atmospheric Flight Mechanics Conference 6th AIAA Atmospheric and Space Environments Conference 14th AIAA Aviation Technology, Integration, and Operations Conference AIAA Balloon Systems Conference AIAA Flight Testing Conference 7th AIAA Flow Control Conference 44th AIAA Fluid Dynamics Conference 20th AIAA International Space Planes and Hypersonic Systems and Technologies Conference 11th AIAA/ASME Joint Thermophysics and Heat Transfer Conference 21st AIAA Lighter-Than-Air Systems Technology Conference 15th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference AIAA Modeling and Simulation Technologies Conference 45th AIAA Plasmadynamics and Lasers Conference 7th AIAA Theoretical Fluid Mechanics Conference	Atlanta, GA	**14 Nov 13**
22–27 Jun†	12th International Probabilistic Safety Assessment and Management Conference	Honolulu, HI (Contact: Todd Paulos, 949.809.8283, secretariat@psam12.org, www.psam12.org)	
15–18 Jul†	ICNPAA 2014 – Mathematical Problems in Engineering, Aerospace and Sciences	Narvik University, Norway (Contact: Seenith Sivasundaram, 386.761.9829, seenithi@aol.com, www.icnpaa.com)	
28–30 Jul	Propulsion and Energy 2014 (AIAA Propulsion and Energy Forum and Exposition) **Featuring:** 50th AIAA/ASME/SAE/ASEE Joint Propulsion Conference 12th International Energy Conversion Engineering Conference	Cleveland, OH	**14 Jan 14**
2–10 Aug†	40th Scientific Assembly of the Committee on Space Research (COSPAR) and Associated Events	Moscow, Russia http://www.cospar-assembly.org	
5–7 Aug	SPACE 2014 (AIAA Space and Astronautics Forum and Exposition) **Featuring:** AIAA/AAS Astrodynamics Specialist Conference AIAA Complex Aerospace Systems Exchange 32nd AIAA International Communications Satellite Systems Conference AIAA SPACE Conference	San Diego, CA	**21 Jan 14**
7–12 Sept†	29th Congress of the International Council of the Aeronautical Sciences (ICAS)	St. Petersburg, Russia (Contact: www.icas2014.com)	**15 Jul 13**

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.

DATE	MEETING (Issue of *AIAA Bulletin* in which program appears)	LOCATION	ABSTRACT DEADLINE
16–20 Jun	AVIATION 2014 (AIAA Aviation and Aeronautics Forum and Exposition) **Featuring:** 20th AIAA/CEAS Aeroacoustics Conference 30th AIAA Aerodynamic Measurement Technology and Ground Testing Conference AIAA/3AF Aircraft Noise and Emissions Reduction Symposium 32nd AIAA Applied Aerodynamics Conference AIAA Atmospheric Flight Mechanics Conference 6th AIAA Atmospheric and Space Environments Conference 14th AIAA Aviation Technology, Integration, and Operations Conference AIAA Balloon Systems Conference AIAA Flight Testing Conference 7th AIAA Flow Control Conference 44th AIAA Fluid Dynamics Conference 20th AIAA International Space Planes and Hypersonic Systems and Technologies Conference 11th AIAA/ASME Joint Thermophysics and Heat Transfer Conference 21st AIAA Lighter-Than-Air Systems Technology Conference 15th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference AIAA Modeling and Simulation Technologies Conference 45th AIAA Plasmadynamics and Lasers Conference 7th AIAA Theoretical Fluid Mechanics Conference	Atlanta, GA	**14 Nov 13**
22–27 Jun†	12th International Probabilistic Safety Assessment and Management Conference	Honolulu, HI (Contact: Todd Paulos, 949.809.8283, secretariat@psam12.org, www.psam12.org)	
15–18 Jul†	ICNPAA 2014 – Mathematical Problems in Engineering, Aerospace and Sciences	Narvik University, Norway (Contact: Seenith Sivasundaram, 386.761.9829, seenithi@aol.com, www.icnpaa.com)	
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AIAA Continuing Education courses.


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From the Corner Office

REFRESHING THE PIPELINE

Michael Griffin, AIAA President

Those of us who try to think of something useful to say in The Corner Office every month have, over the last year or so, commented quite frequently and in various ways on the changes that have taken place in our profession, and how we are trying to reshape our Institute to reflect and adapt to those changes. We hope we are getting it right. Whether we are or not, we won't know for awhile, and in the end the answers will be found in our membership statistics. I think by now we are all aware that our membership has been gradually declining over the last few years. While we are still by far the largest society of aerospace professionals in the world, we're going in the wrong direction, and the trend line is not starting from a position that is truly healthy. We are a society that has more members over 60 than under 40. If you care about the aerospace profession and about AIAA (and if you are reading this column, it is quite likely that you do), this one fact offers cause for real concern. There is just no way to look at that statistic and feel good about it.

I won't belabor the things we who presently manage the Institute are doing to reverse our declining membership trend. Some of us are volunteers and some of us are salaried professional staff, but we are united in our dedication to the Institute, the profession, and the future of both. We've talked about some of these initiatives in past columns and will be doing so again. In this column, I want to take a different course. I want to talk about what you, personally, can do to help. Protecting and growing the Institute cannot be a spectator sport. We need you on the playing field.

Whatever else might need to be done to refresh AIAA, to maintain our society's relevance to the profession (and people of good will do disagree about those things), we are united in our understanding that our demographics must change. We must attract, and then we must keep, both student members and the young professionals they become after they graduate and join the workforce. We simply are not doing it; indeed, the largest "jump" in our membership statistics occurs within a few years after graduation, when a typical young aerospace professional decides that he or she no longer needs to maintain membership in AIAA. With the cost of that membership being no more than a couple of tankfuls of gasoline, it is difficult to believe that a commitment to AIAA is unaffordable for a typical aerospace professional. It seems more likely that we're just not offering any real value to our younger members. We as members of the still-premiere aerospace professional society are simply not connecting with enough of them in their professional lives.

So what can you do to help? I can think of a bunch of things, and I have absolutely no doubt that you can think of more. But for starters, how about:

- Taking a few of the younger professionals where you work to lunch once a month, ask them about their commitment to AIAA, discuss with them the value you have seen over the years in being a part of the Institute, and listen and learn from them what they might like to find in their AIAA membership.
- Contacting your nearest AIAA Student Section, and asking them what sort of contribution you might be able to make to their next meeting or event.
- Reaching out to your local middle school or high school, find out when they do their unit on aeronautics and/or space, and offering a presentation on what you and your colleagues do at your company, laboratory, university, or government agency.
- If you're a pilot, or know a cooperative pilot (and a very large fraction of us either are or do), arranging with your local Student Section to meet at the airport and show them how the lessons in their textbooks are applied to real-world airplane design, and how there are a lot of things about airplanes that aren't written down in books!
- If you're in management, helping a young professional to get travel funds to attend an AIAA conference.

How about trying just one or two of these things, or an even better idea of your own, a couple of times a year? These are things you can do, things that can only help. If we all, each and every one of us, made a point of this, and if each effort added or retained only one AIAA member, we'd be headed to the future with our membership going in the right direction.

If you have other ideas on how to help, send them to Sandy (sandym@aiaa.org), so that we can share them with the other members in a future article.

New Lectureship in Aerospace Engineering Seeks Nominees!

The Yvonne C. Brill Lectureship in Aerospace Engineering has been established in the memory of Yvonne Brill, pioneering rocket scientist, AIAA Honorary Fellow, and NAE member. Nominations are now being solicited for the inaugural lectureship in September 2014. The ideal nominee should have a distinguished career involving significant contributions in aerospace research and/or engineering and will be selected based on technical expertise, originality, and influence on other important aerospace issues such as ensuring a diverse and robust engineering community. NAE or AIAA members are eligible to place a nomination. Contact carols@aiaa.org to request the nomination form. Nominations are due to AIAA on or before **15 December 2013**.

Prof. Joseph T. Verdeyen (right) of the University of Illinois at Urbana-Champaign receives the AIAA Plasmadynamics and Lasers Award from David L. Carroll (left). The award recognizes Prof. Verdeyen for major contributions in the fields of gas and semiconductor lasers, plasma discharge technologies, and the mentoring of young engineers and scientists.

AIAA LONG ISLAND SECTION VICE CHAIR VOLUNTEERS AT MAKER FAIRE

On 22 September, Gregory Homatas, AIAA Vice Chair of the AIAA Long Island Section, volunteered as part of the Engineers Without Borders NY Chapter representation at Maker Faire in Queens' Flushing Meadow Park at the Hall of Science. Engineers Without Borders is comprised of members from a number of societies such as ASCE, ASME, and AIAA who volunteer their time to develop and implement low-cost engineering solutions for real-world problems in third-world countries. Maker Faire is a national worldwide festival of innovators, tinkerers, and techno geeks that sell, display, and demonstrate their wares involving technologies such as robotics and 3D printing among many others. Other exhibits were compressed air rockets and rocket gliders developed by various firms. They had tables of youngsters building them, learning about assembly, and flying their creations using a compressed air piston arrangement.

Maker Faire is a great festival for youngsters who are interested in science or whom you want to encourage an interest in science, technology, engineering, and mathematics. IEEE Long Island Section had a display table and Microsoft and NASA Ames had exhibits at this festival which drew big crowds.

The project displayed by Engineers Without Borders at Maker Faire was a low-budget solution to aerial photography. The project was located in Balang, Cambodia, and they needed a low-cost solution for water planning in terms of building a new dam to provide irrigation water and therefore food in that third-world country after an earthen levee was destroyed during the 2000 rainy season. Helium for weather balloons was very expensive and not available, so a kite was rigged with a point-and-shoot camera and an off-the-shelf proportional remote control. This allowed the team to take photos and aerial map the area needed. The remote-controlled camera drew an interest from onlookers at Maker Faire when they realized its capability to solve a real-world problem where resources are scarce. See the following websites for additional information on the project: http://balang.ewbny.org and https://www.engineeringforchange.org/news/2011/07/04/do_it_yourself_aerial_photography_a_guided_tour.html

It was quite enjoyable chatting with visitors regarding engineering and the project and giving back to the community in the effort that there would be some youngsters that will be possibly interested in an engineering career.

AIAA NJIT GLIDER-BUILDING CHALLENGE

Rayon Williams, Student Branch Chair, NJIT, and Dr. Edward Dreizin, Chapter Advisor, NJIT

The AIAA New Jersey Institute of Technology (NJIT) Graduate Chapter, in conjunction with the AIAA Northern New Jersey Section, hosted a two-day glider-building event and competition at NJIT. This was the first event of this kind held on NJIT campus, aimed at stimulating the creative skills and ingenuity of our graduate and undergraduate students. Participants were required to register online for the event, after which they received a glider-building manual and rules of the competition prepared by the AIAA NJIT Graduate Chapter's executive board. The major limitation imposed was on the wing span of the gliders with the maximum allowable length of 18 inches. Teams consisting of a maximum of two students or individuals were allowed to enter the competition for two top prizes. Prizes were awarded for the best glider design and the glider traveling the longest distance.

The building of gliders by the participating students was conducted on 21 September. There was a 30-minute safety session held on the use of sharp instruments and tools used in the construction of the gliders. Participants were provided all the necessary materials: balsawood, craft knives, glue, markers, sand paper, rulers, and pencils for building their gliders. Participants received guidance from members of the AIAA NJIT Graduate Chapter's executive board. A total of 11 gliders were built by 8 individual participants and 3 teams.

To ensure that the glued components of the gilders had sufficient time to dry, the design and fly-off competition was held two days later on 23 September, at the upper green of NJIT campus with sufficient flying space. Raymond Trohanowsky (Chair, NNJ Section), Professor Ravindra (NJIT Physics Department), and Professor Mani (NJIT Department of Mechanical and Industrial Engineering) were invited as guest judges for the design competition. They assessed the gliders based on several criteria with a maximum possible score of 100. The majority of the points were awarded based on creativity, ingenuity, and quality of finishing. The winning glider for the design portion of the competition was built by Gustavo Alvarez and Toha Poveda (Mechanical Engineering graduate students) and the runner-up in the design challenge was Nellone Reid (Chemical Engineering graduate student). Winners received a gift card ($50) and certificate and the runner-up was presented an AIAA NJIT T-shirt.

NJIT Executive Board (top), and students at work during the building session on 21 September.

Judges at work (top left); Raymond Trohanowsky accepting certificate of appreciation on behalf of AIAA North New Jersey Section (top right); competition winners, chapter advisor, and chapter president (center); and students participating during the flyoff (bottom).

After the competition of the design section, we transitioned into the fly-off. Each team/individual was given three attempts at launching the gliders with the maximum distance of the three being recorded. The winning glider travelled a distance of 62 ft, again built by Gustavo Alvarez and Toha Poveda, travelling only 6 inches farther than the second place glider that was built by Kevin Nyamangorora (Mechanical Engineering graduate student). The publicity from this event is expected to encourage enrollment of students to the AIAA NJIT student chapter.

Overall, the glider-building challenge conducted by the students of the AIAA Graduate Chapter was well attended and well received by the NJIT community. This event showcased the individual talents of the participating students and their success in the glider fly-off event is a testament to their skills. This event provided the chapter with a platform to communicate the message of the AIAA community. Based on the success of the event, the NJIT AIAA Graduate Chapter is proud to host an annual glider-building challenge in the years to come.

Call for Nominations!

The AIAA Foundation Board of Trustees invites you to nominate your colleagues, teams, programs, or organization for the highest award presented by the AIAA Foundation Board of Trustees to recognize excellence within the aerospace community. The 2014 award will be presented on 30 April 2014 during the AIAA Aerospace Spotlight Awards Gala. For further details, see page **15**.

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2013 BEST PAPERS

During 2013, the following papers were selected as a "Best Paper." Authors were presented with a certificate of merit at a technical conference. Congratulations to each author for achieving technical and scientific excellence!

Aerodynamic Measurement Technology Best Paper
AIAA 2013-0033, "NO PLIF Visualization of the Orion capsule in LENS-I," Chris Combs and Noel Clemens, The University of Texas at Austin; Paul M Danehy and Brett Bathel, NASA Langley Research Center; Ronald Parker, Tim Wadhams, Michael Holden, CUBRC; and Benjamin Kirk, NASA Johnson Space Center.

Aerospace Power Systems Best Paper
AIAA 2012-3892, "Long-Lived Venus Lander Thermal Management System Design," Rebecca Hay, Andrew Slippey, Calin Tarau, and William Anderson, Advanced Cooling Technologies.

Aerospace Power Systems Best Student Paper
AIAA 2012-4048, "Carbon Nanotube Arrays for Enhanced Thermal Interfaces to Thermoelectric Modules" Kimberly Saviers, Stephen Hodson, and Timothy S. Fisher, Purdue University; James R. Salvador, General Motors Research and Development Center; and Linda Kasten, Air Force Research Laboratory.

Air Breathing Propulsion Systems Integration Best Paper
AIAA 2012-0275, "Addressing Corner Interactions Generated by Oblique Shock-Waves In Unswept Right-Angle Corners and Implications for High-Speed Inlets," Dan Baruzzini, Daniel Miller, and Neal Domel, Lockheed Martin Aeronautics Company.

American Society for Composites Student Paper in Composites Award
AIAA 2013-1879, "Fatigue of Metal-Composite Joints with Penetrative Reinforcement," Philip N. Parkes, Richard Butler, and Darryl Almond, University of Bath.

ASME/Boeing Best Paper
AIAA 2012-1464, "Wind Tunnel Test of a Very Flexible Aircraft Wing," Robert T. Britt and Daniel Ortega, Boeing Research & Technology; John McTigue, Boeing Defense, Space & Security; and Matthew J Scott, NextGen Aeronautics Inc.

ASME Propulsion Best Paper
AIAA 2012-4004, "A Novel High Temperature Non-Contact Dynamic Seal," Pete Crudgington, Rodney Cross, and Edward Cross, Cross Manufacturing Company

Atmospheric Flight Mechanics Best Paper
AIAA 2013-0332, "Wing Velocity Control System for Testing Body Motion Control Methods for Flapping Wing MAVs," Michael Oppenheimer, David Doman, & Ben Perseghetti, Air Force Research Laboratory; David Sigthorsson, General Dynamics Corporation; and Isaac Weintraub, General Dynamics Information Technology.

Atmospheric Flight Mechanics Best Student Paper
AIAA 4013-4509, "Impact Point Model Predictive Control of a Spin-Stabilized Projectile with Instability Protection," Matthew Gross and Mark Costello, Georgia Institute of Technology; and Frank Fresconi, Army Research Laboratory.

Collier Research HyperSizer/AIAA Structures Best Paper
AIAA 2012-1462, "Nonlinear Analysis of Prandtl Plane Joined Wings. Part II-Effects of Anisotropy," Rauno Cavallaro, Luciano Demasi, and Andrea Passariello, San Diego State University.

David Weaver Thermophysics Best Student Paper
AIAA 2012-3311, "Large Eddy Simulations of the Hydrodynamic and Thermal Fields from a Cylindrical Film Cooling Hole," Lucky Tran, Perry Johnson, and Jayanta Kapat, University of Central Florida.

Electric Propulsion Best Paper
AIAA 2012-3789, "Design of a Laboratory Hall Thruster with Magnetically Shielded Channel Walls, Phase III: Comparison of Theory with Experiment," Ioannis Mikellides, Ira Katz, Richard Hofer, and Dan Goebel, Jet Propulsion Laboratory.

Fluid Dynamics Best Paper
AIAA 2012-0086, "Investigation Of Aspect Ratio And Dynamic Effects Due To Rotation For A Revolving Wing Using High-Fidelity Simulation," Daniel Garmann and Miguel Visbal, ARFL; and Paul Orkwis, University of Cincinnati.

Gossamer Systems Best Paper
AIAA 2012-1746, "Heliogyro Blade Twist Control via Reflectivity Modulation," Daniel Vernon Guerrant and Dale A. Lawrence, University of Colorado-Boulder; and William Keats Wilkie, NASA Langley Research Center.

Ground Testing Best Paper
AIAA 2012-3318, "High Reynolds Number Active Blowing Semi-Span Force Measurement System Development," Keith Lynn, Ray Rhew, Michael Acheson, Gregory Jones, William Milholen, and Scott Goodliff, NASA Langley Research Center.

Guidance, Navigation, and Control Best Paper
AIAA Paper 2012-4622, "Experimental Demonstration of Multi-Agent Learning and Planning under Uncertainty for Persistent Missions with Automated Battery Management," N. Kemal Ure, Tuna Toksoz, Joshua Redding, Jonathan How, Massachusetts Institute of Technology; Girish Chowdhary, Oklahoma State University; Matthew Vavrina & John Vian, The Boeing Company.

Guidance, Navigation, & Control Graduate Student Best Paper
AIAA 2013-5173, "Adaptive Model-Independent Tracking of Rigid Body Position and Attitude Motion with Mass and Inertia Matrix Identification using Dual Quaternions," Nuno Filipe, Georgia Institute of Technology; and Panagiotis Tsiotras, Georgia Institute of Technology.

Harry H. and Lois G. Hilton Student Paper in Structures
AIAA 2013-1619, "Quantifying Effects of Voids in Woven Ceramic Matrix Composites," Marlana B. Goldsmith, Bhavani V. Sankar, and Raphael T. Haftka, University of Florida, Gainesville; and Robert K. Goldberg, NASA Glenn Research Center.

High Speed Air Breathing Propulsion Best Paper
AIAA 2012-4263, "Low-Dissipation Advection Schemes Designed for Large Eddy Simulations of Hypersonic Propulsion Systems," Jeffery White and Robert Baurle, NASA Langley Research Center; Travis Fischer, Sandia National Laboratories; Jesse Quinlan, National Institute of Aerospace; and William Black, Purdue University.

Space History, Society, and Policy Student Paper
AIAA 2013-5304, "Review of Recent U.S. Human Space Exploration Plans Beyond Low Earth Orbit," Patrick Chai, Sean R. Currey, & Christopher A. Jones, Georgia Institute of Technology.

Hybrid Rockets Best Paper
AIAA 2012-4199, "Development and Testing of the Regeneratively Cooled Multiple Use Plug Hybrid (for) Nanosats (MUPHyN) Motor," Shannon Eilers, Stephen Whitmore, and Zachary Peterson, Utah State University.

Hybrid Rockets Best Student Paper
AIAA 2012-4310, "Design and Development of a Thrust Vector Controlled Paraffin/Nytrox Hybrid Rocket," Laura Simurda, Keith Stober, Adrien Boiron, Katrina Rachel Hornstein, Elizabeth Jens, and Alex Fletcher, Stanford University.

Intelligent Systems Student Paper
AIAA 2013-5045, "Sensitivity of Trajectory Prediction Accuracy to Aircraft Performance Uncertainty," Enrique Casado and Colin Goodchild, University of Glasgow; and Miguel Vilaplana, The Boeing Company.

Intelligent Systems Best Paper
AIAA 2012-2431, "A Uniprocessor Scheduling Policy for Non-Preemptive Task Sets with Precedence and Temporal Constraints," Matthew Gombolay and Julie Shah, Massachusetts Institute of Technology.

Jefferson Goblet Student Paper
AIAA 2013-1595, "Fold Line Based on Mechanical Properties of Crease in Wrapping Fold Membrane," Yasutaka Satou and Hiroshi Furuya, Tokyo Institute of Technology.

Liquid Propulsion Best Paper
AIAA 2012-3867, "Investigation of the API-Injection Concept in a LOX/LH2 Combustion Chamber at GG/PB Operation Conditions," Dimitry Suslov and Jan Deeken, German Aerospace Center (DLR); and Oskar Haidn, Technical University Munich.

Lockheed Martin Student Paper in Structures
AIAA 2013-1612, "Interlaminar Fracture Toughness of Laminated Woven Composites Reinforced with Aligned Nanoscale Fibers: Mechanisms at the Macro, Micro, and Nano Scales," Sunny S. Wicks and Brian L. Wardle, Massachusetts Institute of Technology.

Modeling and Simulation Best Papers
AIAA 2012-4947, "Development and Testing of an Adaptive Motion Drive Algorithm for Upset Recovery Training," Shuk Fai (Eska) Ko and Peter Grant, University of Toronto Institute for Aerospace Studies.

AIAA 2012-5012, "A Multi-Scale Simulation Methodology for the Samarai Monocopter UAV," Borna Josip Obradovic, Gregory Ho, Rick Barto, Kingsley Fregene, and David Sharp, Lockheed Martin Advanced Technology Labs.

Nuclear and Future Flight Propulsion Best Paper
AIAA 2012-3860, "Faster-Than-Light Space Warps, Status and Next Steps," Eric W. Davis, Institute for Advanced Studies at Austin.

Plasmadynamics and Lasers Best Paper
AIAA 2013-0922, "Flame Propagation Enhancement of Ethylene by Addition of Ozone," Matthew Pinchak and Ephraim Gutmark, University of Cincinnati; Timothy Ombrello and Campbell Carter, Air Force Research Laboratory; and Viswanath Katta, Innovative Scientific Solutions, Inc.

Plasmadynamics and Lasers Best Student Paper
AIAA 2012-0822, "Fundamental Processes of DBD Plasma Actuators Operating at High Altitude," Alexander Duchmann, Bernhard Simon, Philip Magin, Cameron Tropea, and Sven Grundmann, Technical University of Darmstadt.

Propulsion and Combustion Best Paper
AIAA 2012-1272, "Influence of Steam Dilution on NOx Forma-tion in Premixed Natural Gas and Hydrogen Flames," Sebastian Goke and Christian Paschereit, Hermann-Fottinger Institute.

Shahyar Pirzadeh Memorial Award for Outstanding Paper in Meshing Visualization and Computational Environments
AIAA 2012-0160, "An Automated Adaptive Mesh Refinement Scheme for Unsteady Aerodynamic Wakes," Sean Kamkar & Andrew Wissink, Army Research, Development and Engineering Command.

Solid Rockets Best Paper
AIAA 2012-3825, "Theoretical Investigation of Parietal Vortex Shedding in Solid Rocket Motors," Germain Boyer, Gregoire Casalis, and Jean-luc Estivalezes, ONERA.

Space Architecture Best Paper
AIAA 2012-5153, "Mockups 101: Code and Standard Research for Space Habitat Analogues," Marc Cohen, Palo Alto, California.

Terrestrial Energy Best Paper
AIAA 2013-0736, "Tangential Velocity Effects and Correlations for Blow-Off and Flashback in a Generic Swirl Burner and the Effect of a Hydrogen Containing Fuel," Nicholas Syred, Anthony Giles, Jonathan Lewis, Augustin Valera-Medina, Philip Bowen, and Anthony Griffiths.

Thermophysics Best Paper
AIAA 2013-0304, "An Equilibrium Ablation Boundary Condition for the Data-Parallel Line-Relaxation Code," Matthew MacLean, CUBRC.

OBITUARIES

AIAA Senior Member Johnson Died in October 2012

Ralph P. Johnson, Jr. died 20 October 2012. He was 80 years old.

Mr. Johnson was with the Boeing Airplane Company for 38 years after graduating from the Civil Engineering Dept. of University of New Mexico in 1955. He was Chief Engineer at Boeing Los Angeles for five years.

AIAA Fellow Stollery Died in June

John L. Stollery, age 83, died on 28 June. He contributed to the understanding of high speed flight and inspired three generations of students to follow careers in aerospace.

Mr. Stollery attended Imperial College London to study aeronautical engineering. After gaining a BSc and an MSc, he joined the aerodynamics department at the De Havilland aircraft company in 1952. Stollery was a pioneer of the "gun tunnel," a device in which very high pressure air drives a piston down a long tube to force a small amount of test gas to accelerate to very high speeds. He built a machine that could deliver a speed of 3km/sec for about 10 milliseconds. His team made important contributions to the understanding of high Mach number flows and provided practical design information for missiles and aircraft intended for flight at more than 5 times the speed of sound.

In 1956 he returned to Imperial College as Lecturer in Aerodynamics. Promoted to Reader in Aerodynamics at Imperial in 1962, he was awarded a DSc for his collective research work in 1972. The following year, he moved to the College of Aeronautics, Cranfield University, as Professor of Aerodynamics, becoming Head of the College in 1976, a position that he held until 1986 and again from 1992 until 1995. He was also Dean of the Faculty of Engineering (1976–1979) and Pro-Vice-Chancellor of Cranfield University (1982–1985).

Outside Cranfield, he was chairman of the Defence Technology Board at the Ministry of Defence (1986–1989), chairman of the Aviation Committee at the Department of Trade and Industry (1986–1994) and a member of the Airworthiness Requirements Board at the Civil Aviation Authority (1990–2000). A Fellow of the Royal Academy of Engineering, AIAA, the City and Guilds Institute of London, and an Honorary Fellow of the Royal Aeronautical Society, he was President of the Royal Aeronautical Society in 1987. In 1994, he was made a CBE for services to the aerospace profession. He retired from Cranfield in 1995, but continued working with students.

AIAA Associate Fellow Kraemer Died in August

Robert S. Kraemer, NASA's former director of planetary exploration who was also an expert in rocket engines, died 20 August. He was 84 years old.

Mr. Kraemer received a bachelor's degree in aeronautical engineering from the University of Notre Dame in 1950. After receiving a master's degree in aeronautics and rocket propulsion from the California Institute of Technology in 1951, he worked for North American Aviation's Rocketdyne Division on rocket propulsion for a secret intercontinental cruise missile called Navaho. Mr. Kraemer then worked as chief engineer for space systems at Ford Aeronutronic until he joined NASA in 1967.

In an early assignment at NASA, Kraemer managed the development of a Mars surface laboratory mission at NASA Headquarters. After that project was cancelled, he was appointed manager of advanced planetary programs and technology and in 1970 was named director of planetary programs. He oversaw the successful completion of 12 missions to launch spacecraft into the solar system to study its planets, moons, and more before he retired in 1990.

Mr. Kraemer wrote several books, including *Rocketdyne: Powering Humans into Space* and *Beyond the Moon: A Golden Age of Planetary Exploration 1971–1981*. He received the NASA Distinguished Service Medal.

AIAA Associate Fellow Murray Died in August

Bruce C. Murray, a former director of the Jet Propulsion Laboratory (JPL), who was a proponent of space exploration and among the first to emphasize the use of photography of other planets, died 29 August. He was 81.

Dr. Murray received three degrees from M.I.T., including a Ph.D. in geology in 1955. He was a petroleum geologist in Louisiana before serving as a scientist with the Air Force in the late 1950s.

He began working for the JPL in 1960, while serving as a geology professor at the California Institute of Technology. As part of the scientific team that launched the Mariner series of missions to Mars and other planets in the 1960s and 1970s, Dr. Murray highlighted the use of photography in space science. Mariner 4 transmitted pictures of the terrain of Mars back to Earth in 1965, the first time images of the surface of another planet had been seen. Dr. Murray used the images to develop a geological history of Mars. In the early 1970s he was the top scientist of the Mariner 10 mission, which photographed Venus and Mercury.

In 1979 Dr. Murray and Carl Sagan founded the Planetary Society, which seeks to raise awareness of space science. Dr. Murray was president of the organization for five years after Sagan's death in 1996.

Dr. Murray was director of JPL from 1976 to 1982. After leaving JPL, he returned to Caltech, where he taught until 2002. He also worked on joint U.S. space ventures with the Soviet Union, Japan, and China.

Dr. Murray was the author of several books, including *Journey Into Space: The First Thirty Years of Space Exploration* (1989). In 1977, he received the AIAA Space Science Award and he gave the von Kármán Lectureship in Astronautics ("Exploring the Planets: Where Next?") in 1981.

AIAA Fellow Oskar M. Essenwanger Died in September

Dr. Oskar M. Essenwanger, age 93, passed away on 14 September.

Dr. Oskar Essenwanger, a native of Germany, was a well-known scientist. He received numerous prestigious awards over his lifetime. He was a fellow of AMS and AIAA.

AIAA Fellow Holloway Died in September

Paul F. Holloway, 75, passed away on 15 September.

After graduation from Virginia Tech, Mr. Holloway joined the staff of NASA Langley Research Center as an aeronautical engineer conducting research into hypersonic flight. From this start as a researcher, Mr. Holloway had a distinguished career with significant technical and management contributions, retiring as the Director of Langley Research Center in 2002.

In recognition for his many contributions to the national aerospace effort, Mr. Holloway was an active participant in this community of experts and was the recipient of many peer awards. He was an AIAA Fellow, a member of the International Academy of Astronautics, and National Editor of the *AIAA Journal of Spacecraft and Rockets*. One of his more significant accomplishments was his leadership of the national team that certified the Space Shuttle thermal protection system prior to the first flight.

CALL FOR AWARD NOMINATIONS

Recognize the achievements of your colleagues by nominating them for an award! Nominations are now being accepted for the following awards, and must be received at AIAA Headquarters no later than **1 February**. Awards are presented annually, unless other indicated. However AIAA accepts nomination on a daily basis and applies to the appropriate year. Any AIAA member in good standing may serve as a nominator and are urged to read award guidelines to view nominee eligibility, page limits, letters of endorsement. All nominations must comply with the limit of 7 pages for the nomination package; see details on the webpage (**https://www.aiaa.org/secondary.aspx?id=230**).

Aerospace Communications Award is presented for an outstanding contribution in the field of aerospace communications.

Aerospace Power Systems Award is presented for a significant contribution in the broad field of aerospace power systems, specifically as related to the application of engineering sciences and systems engineering to the production, storage, distribution, and processing of aerospace power.

Air Breathing Propulsion Award is presented for meritorious accomplishment in the science of air breathing propulsion, including turbomachinery or any other technical approach dependent on atmospheric air to develop thrust, or other aerodynamic forces for propulsion, or other purposes for aircraft or other vehicles in the atmosphere or on land or sea.

The industry-renowned **Daniel Guggenheim Medal** was established in 1929 for the purpose of honoring persons who make notable achievements in the advancement of aeronautics. AIAA, ASME, SAE, and AHS sponsor the award.

Energy Systems is presented for a significant contribution in the broad field of energy systems, specifically as related to the application of engineering sciences and systems engineering to the production, storage, distribution, and conservation of energy.

George M. Low Space Transportation Award honors the achievements in space transportation by Dr. George M. Low, who played a leading role in planning and executing all of the Apollo missions, and originated the plans for the first manned lunar orbital flight, Apollo 8. (Presented even years)

Haley Space Flight Award is presented for outstanding contributions by an astronaut or flight test personnel to the advancement of the art, science, or technology of astronautics. (Presented even years)

J. Leland Atwood Award recognizes an aerospace engineering educator for outstanding contributions to the profession. AIAA and ASEE sponsor the award. *Note*: Nominations due to ASEE by **14 January**.

Jeffries Aerospace Medicine & Life Sciences Research Award is presented for outstanding research accomplishments in aerospace medicine and space life sciences.

Missile Systems Award—Technical Award is presented for a significant accomplishment in developing or using technology that is required for missile systems.

Missile Systems Award—Management Award is presented for a significant accomplishment in the management of missile systems programs.

Propellants and Combustion Award is presented for outstanding technical contributions to aeronautical or astronautical combustion engineering.

Space Automation and Robotics Award is given for leadership and technical contributions by individuals and teams in the field of space automation and robotics. (Presented odd years)

Space Science Award is presented to an individual for demonstrated leadership of innovative scientific investigations associated with space science missions. (Presented even years)

Space Operations and Support Award is presented for outstanding efforts in overcoming space operations problems and assuring success, and recognizes those teams or individuals whose exceptional contributions were critical to an anomaly recovery, crew rescue, or space failure. (Presented odd years)

Space Processing Award is presented for significant contributions in space processing or in furthering the use of microgravity for space processing. (Presented odd years)

Space Systems Award recognizes outstanding achievements in the architecture, analysis, design, and implementation of space systems.

von Braun Award for Excellence in Space Program Management recognizes outstanding contributions in the management of a significant space or space-related program or project.

Theodor W. Knacke Aerodynamic Decelerator Systems Award recognizes significant contributions to the effectiveness and/or safety of aeronautical or aerospace systems through development or application of the art and science of aerodynamic decelerator technology. (Presented odd years)

The **William Littlewood Memorial Lecture**, sponsored by AIAA and SAE, perpetuates the memory of William Littlewood, who was renowned for the many significant contributions he made to the design of operational requirements for civil transport aircraft. Lecture topics focus on a broad phase of civil air transportation considered of current interest and major importance.

Wyld Propulsion Award is presented for outstanding achievement in the development or application of rocket propulsion systems.

For further information on AIAA's awards program, please contact Carol Stewart, Manager, AIAA Honors and Awards, carols@aiaa.org or 703.264.7623.

Upcoming AIAA Continuing Education Courses

Courses at AIAA Science and Technology Forum and Exposition 2014 (AIAA SciTech 2014)
www.aiaa.org/scitech2014

11–12 January 2014

Decision Analysis

Instructor: John C Hsu

Decision analysis supports system life cycle development throughout all phases and system hierarchical levels. The course presents the trade study process as part of the systems engineering process, and introduces various decision analysis methods, including the traditional trade study methods, trade space for Cost as Independent Variable (CAIV), Analytic Hierarchy Process (AHV) as a part of the Analytic Network Process (ANP), Potentially All Pairwise Rankings of All Possible Alternatives (PAPRIKA), and Decision Analysis with Uncertain Information/Data.

Sunday, 12 January

Introduction to Integrated Computational Materials Engineering

Instructor: David Furrer

Designed to provide an overview of integrated computational materials engineering (ICME), this course offers a primer on the various types of models and simulation methods involved in ICME. It is aimed at providing a general understanding of the critical issues relative to ICME, with the goal of increasing participants' knowledge of materials and process modeling capabilities and limitations. The important aspects of linking materials models with process models and subsequently to component design and behavior analysis models will be reviewed.

Saturday, 11 January 2014
Workshops at AIAA Science and Technology Forum and Exposition 2014 (AIAA SciTech 2014)
www.aiaa.org/scitech2014

1st AIAA Sonic Boom Prediction Workshop

Sponsored by the Applied Aerodynamics Technical Committee

The objective of the First Sonic Boom Prediction Workshop is to assess the state of the art for predicting near field signatures needed for sonic boom propagation. Comparisons will be made between participant solutions on workshop-provided grids. Participants are requested to apply their best practices for computing solutions on the provided geometries. There is particular interest in exploring refinement techniques including grid adaptation and alignment with flow characteristics. Impartial comparisons will be made between different solution schemes as well as with wind tunnel validation data for assessing the state of the art and identifying areas requiring additional research and further development. For more information, please visit the Sonic Boom Prediction Workshop website (**http://lbpw.larc.nasa.gov**).

Low Reynolds Number Workshop

Organized by Ming Chang, Lockheed Martin Aeronautics, and Michael OI, US Air Force Research Lab

Micro Air Vehicles (MAVs) are flight articles resembling natural flyers (birds, bats, insects) in size and functionality. While of extensive defense interest since at least the 1990s, scientific and engineering progress has been episodic, with principal advances more from trial and error than first-principles science. Pacing issues include the aerosciences as well as payloads/energy/materials. We aim to explore the state of the art in both the sciences and applications, examining research directions and interest for academia, industry, and government.

The workshop aims to gather industry, academia, and government to assess new research directions and connection between the sciences and the applications. By the end of the day, we intend to assemble a credible sight-picture of who is pursuing what research, and what might be the beginning of a business case. Outcomes aim to include an understanding of where the MAV community stands in 2014 relative to where we've been throughout the past 20 years, and how to begin bridging scientific/academic advances with the needs of industry and the user community. For questions, please contact Ming Change at 661.572.6228 or ming.chang@lmco.com, or Michael V. OL at 937.713.6650 or michael.ol@wpafb.af.mil.

To register for courses or workshops at AIAA SciTech 2014, visit www.aiaa.org/scitech2014 and select "Register Now".

February–June 2014
Home Study Courses

Introduction to Computational Fluid Dynamics

Instructor: Klaus Hoffmann

This introductory course is the first of the three-part series of courses that will prepare you for a career in the rapidly expanding field of computational fluid dynamics. Completion of these three courses will give you the equivalent of one semester of undergraduate and two semesters of graduate work. The courses are supported extensively with textbooks, computer programs, and user manuals.

Key Topics

- Classification of partial differential equations (PDEs)
- Finite-difference equations
- Parabolic equations

• Stability analysis
• Elliptic partial differential equations
• Hyperbolic partial differential equations
• Scalar representation of the Navier-Stokes equations
• Incompressible Navier-Stokes equations

Advanced Computational Fluid Dynamics

Instructor: Klaus Hoffmann

This advanced course is the second of the three-part series of courses that will prepare you for a career in the rapidly expanding field of computational fluid dynamics. Completion of these three courses will give you the equivalent of one semester of undergraduate and two semesters of graduate work. The courses are supported extensively with textbooks, computer programs, and user manuals.

Key Topics
• Grid-generation-structured grids
• Transformation of the equations of fluid motion from physical space to computational space
• Euler equations
• Parabolized Navier-Stokes equations
• Navier-Stokes equations
• Grid-generation-unstructured grids incompressible Navier-Stokes equations
• Finite volume schemes

Computational Fluid Turbulence

Instructor: Klaus Hoffmann

This advanced course is the third of the three-part series of courses that will prepare you for a career in the rapidly expanding field of computational fluid dynamics with emphasis in fluid turbulence. Completion of these three courses will give you the equivalent of one semester of undergraduate and two semesters of graduate work. The courses are supported extensively with textbooks, computer programs, and user manuals.

Key Topics
• Introduction to turbulence and turbulent flows
• Reynolds average Navier-Stokes equations
• Parabolic equations
• Turbulence models
• Compact finite difference formulations
• Boundary conditions
• Large eddy simulation
• Direct numerical simulation

Missile Design and System Engineering

Instructor: Gene Fleeman

This course provides the fundamentals of missile design, development, and system engineering. A system-level, integrated method is provided for missile configuration design and analysis. It addresses the broad range of alternatives in satisfying missile performance, cost, and risk requirements.

Key Topics
• Key drivers in the missile design process
• Critical trade-offs, methods, and technologies in aerodynamic, propulsion, structure, seeker, warhead, and subsystems sizing to meet flight performance and other requirements
• Launch platform-missile integration
• Robustness, lethality, guidance, navigation & control, accuracy, observables, survivability, reliability, and cost considerations
• Missile sizing examples for missile systems and missile technologies
• Missile system and technology development process

Spacecraft Design and Systems Engineering

Instructor: Don Edberg

This course presents an overview of factors that affect spacecraft design and operation.

Key Topics
• History
• Design drivers
• Orbital mechanics and trajectories
• Systems engineering
• Design considerations
• Estimation, testing, and failure prevention

To register for any of these Home Study courses, visit www.aiaa.org/homestudy and select “Register Now”.