July-August 2011

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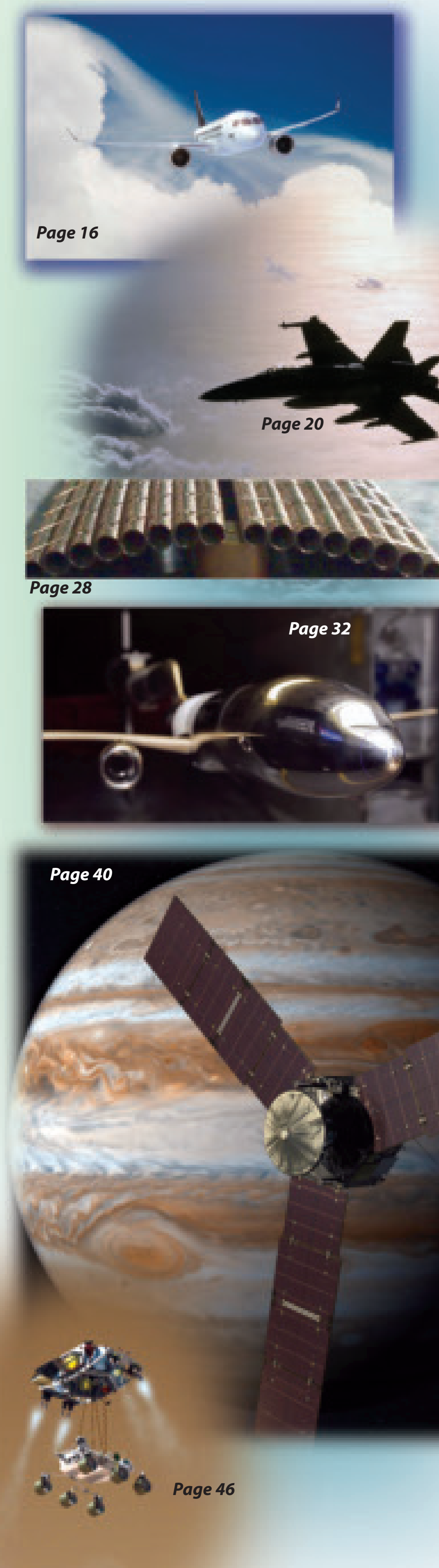
DEPARTMENTS

FEATURES

BULLETIN



COVER

NASA is working with industry to develop more fuel-efficient engines, like the P&W PurePower 1000G undergoing testing. To learn more about this NASA initiative, turn to page 32.

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Editorial

All dressed up with nowhere to go?

NASA is hard at work trying to develop a new, congressionally mandated heavy-lift launch vehicle. It seems that almost weekly we are issued updates on the progress of their efforts. At the same time, the press is receiving up-to-the-minute accounts and photographs of a new 'multipurpose crew vehicle,' which looks remarkably like the Orion crew vehicle of Constellation fame. This Apollo-like capsule is designed "to safely fly astronauts through all the harsh environments of deep space exploration missions."

But where exactly would that be?

The citizens of this nation, despite what seem to be NASA's best efforts otherwise, are still excited about space exploration—witness the thousands who entered the lottery for an opportunity to view the final launch of the space shuttle.

However, it will be very difficult to drum up excitement for the next-generation system without a destination that seems worthy of the time and treasure, both human and monetary, that will have to be expended to see it to completion. The Obama administration has suggested that astronauts should visit an asteroid. Even during the glory days of the Apollo missions to the Moon, commitment to the program seemed to wane after the stirring of national pride over watching astronauts plant an American flag, then skip across the lunar surface collecting samples to bring back to Earth.

The space shuttle program allowed us to launch satellites of massive size and weight, and to repair the invaluable Hubble Space Telescope, which provided us a magnificent new window on the universe. The shuttle then took on extra meaning as the space station began to take shape. Even those who railed against the station's expense and lack of what appeared to be a specific mission could pause with wonder at the mastery of its engineering accomplishments. What seems lacking now is only a catalog of accomplishments, to show all that we have learned from this massive endeavor, and how that knowledge can pay off in our daily lives.

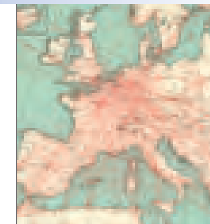
The Apollo program was at least as much a political race, driven by the Cold War and played out on a global stage, as it was a scientific and technological one. In its own way, construction of the space station became an international effort, as 16 nations played a role in its construction, and astronauts from several countries form part of each expedition crew.

But what's next? Are we building this new heavy-lift vehicle, and a new crew capsule, to visit a rock?

In challenging economic times, a case needs to be made for endeavors of this magnitude. Will a visit to an asteroid be a stepping-stone to some farther destination? Is it a waypoint to Mars? What can we learn from such a voyage, and does it play into a larger vision for further exploration of space? What are the accomplishments that require human, rather than robotic, visits? Surely such a case can be made, or this work would have stopped a long time ago.

But until the administration, and NASA, make that case, we may well be stuck between that rock and a hard place.

Elaine Camhi
Editor-in-Chief



Ups and downs for EU aviation projects

In May of this year the European Commission (EC) announced that the first two European Union Galileo navigation satellites will be launched via a Soyuz rocket from French Guiana on October 20. Initial satellite navigation services will be provided by 2014, and Galileo is expected to deliver €60 billion to the European economy over 20 years, according to Antonio Tajani, vice president of the EC.

There was further good news about the project: According to Tajani, the estimated €3.4-billion price tag for implementing Galileo would be reduced as the final two contracts of the program, which were scheduled to be announced at the Paris Air Show in June, would be worth less than originally planned.

Prospering amid turmoil

Galileo is one of three huge aviation infrastructure programs under development by the commission, funded partly from EU sources and partly by industry. Because these projects are planned and funded over long periods, the economic turmoil engulfing half the continent has yet to impact their progress.

Europe's major aviation infrastructure program management organizations have not just escaped the worst of the economic crisis, it seems, but have actually prospered. For example, 14 of ESA's 18 member nations agreed to raise their 2011 contributions despite the parlous state of many national government debt burdens. As a result, the agency has received a 7% budget increase this year to €2.975 billion. Also swelling ESA's coffers are EC funds for the Galileo program and GMES (global monitoring for environment and security) Earth observation project, as well as funds from other European bodies and 'cooperating' states (see "Space industry takes root in central and eastern Europe," June, page 3), which will give ESA €3.99 billion this year, 6.7% more than in 2010.

The EC has continued to fund the Galileo project at a healthy rate.

Will the euro survive?

The contrast between the well-funded European aviation infrastructure programs and the fiscal problems facing national government aviation organizations, especially in Southern Europe, is startling.

In May new fears arose about government debt levels in Greece, Italy, and Spain, leading many economists to ask whether the Eurozone will survive in its current form. Many believe that the euro's survival will mean either moving much faster toward fiscal union—with EU organizations taking tighter controls over the budgets of euro members—or forcing some countries to drop the euro altogether.

"There is no modern history of falling living standards in peacetime on the scale necessary to keep the euro in its current form," says Douglas McWilliams, chief executive of the Center for Economics and Business Research, a U.K. financial forecasting organization. "Indeed, the scale of the cuts necessary was only just achieved in wartime. This is why I think there is at best a one in five chance that the euro will survive as it is."

Austerity measures

These economic and politically turbulent forces are having an impact on aviation organizations in Spain, Portugal, and Greece. In Spain the government has decided to privatize airports and part of the nation's air traffic management system; earlier this year it announced its intention of offering up to 49% of the airport and air traffic control company Aena Aeropuertos to private companies for around €9 billion.

Greece has decided to privatize up to 40 facilities—the government will create joint stock companies for each major airport, in which the state will own 100% of the shares and then sell off various numbers of them to private investors.

Greece is looking to privatize up to 40 of its airport facilities.

In Portugal the government is looking to offload its stakes in the national airline TAP Portugal, airport and air navigation service provider ANA Aeroportos de Portugal, and other state-owned defense and industrial companies.

The austerity measures are not confined to southern Europe. As part of its drive to cut spending and raise taxes, the U.K. government has heavily increased the tax it imposes on U.K. air travelers, the air passenger duty tax, so a family of four flying from the U.K. to Australia must now pay £340 in tax. The APD rises are one reason why passenger numbers in the U.K. remain depressed, according to some air transport analyses, resulting in the closure of U.K. airports such as Coventry, Bristol Filton, and Plymouth.

Border issues

Between the nation states of Europe and the EU bodies, there are growing tensions that will have consequences for aviation and aerospace organizations throughout the continent.

In early May, Denmark announced it would be setting up new security checks for people and goods crossing between Denmark, Sweden, and Germany. The move is part of a plan to cut down on the number of smuggled goods and illegal immigrants entering the country.

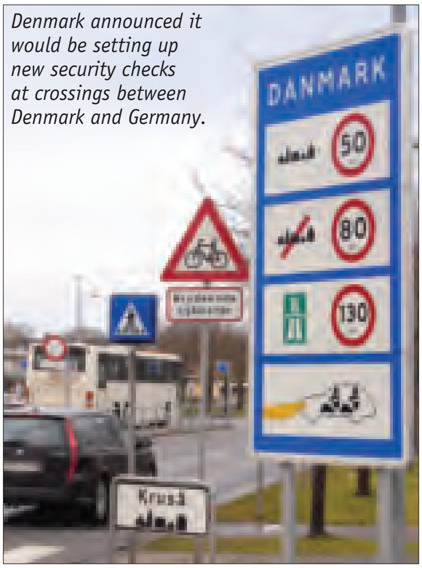

Portugal is looking to sell off its stake in its national airline.

So far the reintroduction of new security controls for intra-EU travel has yet to impact European airports in the same way it has affected land crossings. But with different countries starting to impose unilateral border security measures, the picture is confusing and, for EU bodies, frustrating. After all, the free movement of people and goods across Europe is a founding principle of the EU, but its viability has come under increasing pressure in recent months since Italy gave residence permits to more than 25,000 North Africans in April, allowing them free access to the rest of the EU. The EU's vision is for a strong border security force to protect the EU's external borders; but once inside the union, passengers should be allowed to travel freely between countries the same way they travel between U.S. states.

At the European Union interior ministers' May meeting in Brussels, it was agreed: "...control of the EU's external borders to be strengthened and for increased cooperation with third countries in the Southern Neighbourhood Region as well as in the Eastern Partnership Region."

While the political turbulence in North Africa has created refugee problems for southern European countries, it has also boosted tourism there, as passengers have sought Mediterranean holiday resorts away from politically volatile areas on the African shoreline.

In the first quarter of this year European passenger traffic was up 5.4% over the same period in 2010, boosted by tourism to Barcelona (where passenger numbers have risen by 13.4%) and Istanbul (rises of 9.3%).



Denmark announced it would be setting up new security checks at crossings between Denmark and Germany.

Trimming budgets

Despite the austerity measures in the south of the continent, the 17 Eurozone countries managed to grow their economies by 0.8% in January-March, up from 0.3% in the previous quarter, with Germany reporting growth of 1.5% in the period and France 1%.

However, there is growing unease among some European states at the rising amounts of money that EU entities are asking for. In April the commission stated that to meet its existing spending commitments, there would have to be a 4.9% increase in the EU's annual budget, to €132.7 billion; the U.K., France, and Germany had suggested freezing this year's budget, but eventually an increase of 2.9 percent was agreed.

The EC has frozen administrative expenditure for 2012 at 2011 levels and trimmed costs on several major projects, including a €24.9-million reduction in support to Galileo.

Then in May, a request to increase the External Action Service—the EU's own diplomatic corps—by 5.8% was roundly rejected by several countries worried not just by the money but by what many see as the EU usurping rather than supporting the activities of member states' foreign departments.

Rethinking research approaches

One of the inevitable consequences of current economic troubles will be a radical rethink of the way the EU sponsors, manages, and leads strategic research programs in areas such as aeronautics, to increase not just the amount of money available for new research but also the effectiveness of the work the EC is undertaking.

European states and companies generally support the EU's research work, not least because contributions to the budget invariably are rewarded with research work. And the sums available from the EC are substantial; the budget for the seventh framework program of research (2007-2013), for example, is €53 billion. The competitiveness and innovation framework program is €3.6 billion for 2007-2013, while the European Institute for Innovation and Technology has a €309-million budget for the same period.

The commission has already signalled that for its next round of major research spending, starting in 2014 it will take a new strategic and integrated approach to EC-funded research. It will do so by making it easier for research organizations to access programs, by reducing the time-to-market for the results of the research, and by more closely aligning research to the work of the EU's structural funding regional-aid programs (worth €86 billion between 2007 and 2013), which aim "to resolve structural economic and social problems" throughout the EU.

The commission has called this new research philosophy a "common strategic framework," and there will be a new emphasis on improving both the industrial competitiveness of EU industries and the percentage of national gross domestic product (GDP) dedicated to research. The EC is targeting a 3% figure for this, and aerospace has already been seen as a key area for investment by the EC.

"Securing a strong position in key enabling technologies such as ICT [information and communications technology], nanotechnology, advanced materials, manufacturing, space technology, or biotechnology is of vital

European aviation's grand projects

SESAR

How much?

The total estimated cost of the development phase (2008-2013) of SESAR (Single European Sky ATM Research) is €2.1 billion, to be shared equally between the EC, Eurocontrol, and industry. The deployment phase (2014-2020) will cost $20 billion and be funded entirely by industry.

Objectives

- *Triple air traffic management capacity in Europe.*
- *Halve the costs of providing ATM services.*
- *Reduce the environmental impact per flight by 10%.*
- *Increase safety levels by a factor of 10.*

Clean Sky

How much?

The Clean Sky joint technology initiative is a public-private partnership established and funded through the commission's €53-billion seventh framework program (2007-2013). The initiative was born in 2008 with a budget of €1.6 billion, based on a 50/50 split by the commission (in cash) and the aeronautical industry (in-kind contribution).

Objectives

Clean Sky will demonstrate and validate the technology breakthroughs outlined in the environmental goals set by ACARE (Advisory Council for Aeronautics Research in Europe), to be reached in 2020:

- *A 50% reduction of CO_2 emissions through drastic reduction of fuel consumption.*
- *An 80% reduction of NO_x emissions.*
- *A 50% reduction of external noise.*
- *A green product life cycle: design, manufacturing, maintenance, and disposal/recycling.*

Galileo

How much?

Slightly less than €3.4 billion, according to recent EC estimates.

Objectives

Providing autonomous navigation and positioning services and being interoperable with GPS and GLONASS. The fully deployed system will consist of 30 satellites and the associated ground infrastructure. Three initial services will be provided in 2014-2015: an initial Open Service, an initial Public Regulated Service, and an initial Search And Rescue Service. The Safety-of-Life Service and the Commercial Service will be tested as of 2014 and will be provided as the system reaches full operational capability with the 30 satellites.

importance to Europe's competitiveness and enables the development of innovative goods and services needed for addressing societal challenges," according to an EC position paper on its new approach to research.

If the EU does realize its target of ensuring that member states invest 3% of their GDP in research despite the huge debt problems many face, it will be a considerable achievement. The EC has set some very challenging targets within the three major aerospace programs it has led. But by committing states to supporting the programs over the long term, the EC has effectively ensured that no matter what the prevailing economic challenges individual countries may face, strategic aviation research will continue to grow steeply over the next 10 years.

Philip Butterworth-Hayes
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Correspondence

I have read with interest the letter of Ralph Barnes in the April **Correspondence** (page 6) concerning condensation around aircraft, and would like to make some comments.

I agree wholeheartedly with his comment that numerous photos are mislabelled that say an aircraft must be traveling at supersonic speeds to produce condensation around itself. But the real issue here is the plane must be traveling fast enough to bring the air flowing over and around it to a relative humidity of 100%. A combination of low static pressure and high ambient humidity is all that is required to produce a fog. This is what condensation shows us. NASA SP-514 (which I contributed to) describes the many interesting flow phenomena we can see on aircraft due to condensation, normal and oblique shocks being some of these phenomena.

I therefore disagree with Mr. Barnes, that shock waves can only be seen in a wind tunnel. There are numerous examples of pictures on the Internet (usually involving the Blue Angels, who fly in areas of high humidity, and have a predominantly dark blue color scheme providing good contrast to the condensation). Furthermore, natural shadowgraphs due to the Sun can visualize amazing shock patterns around parts of aircraft traveling at high subsonic speeds and above. I myself have seen shocks reach the ground from a supersonic SR-71. No doubt many of your readers have their own observations, some through an airliner window giving a view of the wing upper surface.

Stephen Wolf
Wind Tunnel Division
ONERA Centre de Palaiseau

✈✈✈

I recently read **Cyberscience and 21st-century education** (April, page 3) and would like to offer some comments, even though I do not have Prof. Long's credentials nor am I an expert on 'cyberscience' (as he describes some engineering fields) or in aerospace engineering education.

With all due respect, I consider that his piece was highly biased by his background and current teaching. Although I agree with many of his comments, especially on the importance of computer science knowledge for solving today`s engineering challenges, I consider that independent of the high level of complexity from the point of view of automation or systems integration involved in the latest aircraft programs. Knowledge, mastery, and continuous research in the 'old aerospace school' are still mandatory and necessary, as can be seen from the various calls for papers for the various AIAA conferences in fields such as structures and materials, since not all aircraft components are necessarily fully 'software' driven.

Notwithstanding the fact that, as a result of their conversion from aircraft manufacturers to system integrators, companies like Lockheed Martin seem nowadays to require more electrical or software engineers than design, structural, or power plant professionals for some positions, within such a multidisciplinary world as aerospace engineering, various levels of expertise are still required in other fields such as aerodynamics, damage tolerance, structural dynamics, and composites design and manufacturing, which do not necessarily belong only to 'cybersciences.'

The aerospace industry and its requirements are as diverse as the whole range of products involved, with an ever-growing demand for lighter, greener, and smarter air transport solutions. So exchanging the quantity of fundamental courses for more technology-like approaches would not only endanger the continuation of a whole body of knowledge that needs to be transmitted and improved but also eventually deter some future students who once joined the workforce solely for their love of mechanics, math, physics, fluid mechanics, and hardware (machines, engines, aircraft) instead of just computer sciences.

Though necessary, software-driven redefinition of the discipline should not be the sole approach to cover the future needs in aerospace engineering education. Subjects such as aeroelasticity, turbulence, combustion, and structural integrity are not yesterday's problems but active areas of research, where only with an open-minded, multidisciplinary yet physics-driven approach, can the fundamentals not only be understood but also exploited and improved so that better, lighter, smarter, yet reliable, designs can fly even higher, farther, or faster.

Julio C. Salazar
Montreal, Canada

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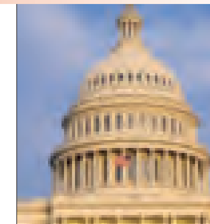


Questions abound about spaceflight and jet fighters

As the summer recess approached, lawmakers in Washington were still struggling with a future course for human spaceflight programs, a contentious defense authorization bill, and conflicts over an alternative engine for the F-35 JSF. Adding to the turmoil was a growing chorus of voices calling for an outright scrapping of the troubled fighter aircraft, which also has some powerful supporters in both Congress and the administration.

John D. Rockefeller IV

Uncharted course for human spaceflight

Three decades of space shuttle operations are ending with leaders in Washington offering little clarity on how, and how much, the nation's public coffers will pay for future journeys by U.S. astronauts.

The two-week STS-134 mission headed by Navy Capt. Mark Kelly ended June 1. Slated for July 8 is the last ever shuttle mission, STS-135 by Atlantis, to be commanded by Christopher Ferguson, also a Navy captain.

"Our nation's space program is undergoing a transition that has not been seen since the end of the Apollo era," wrote four senators in a May 18 letter to NASA Administrator Charles Bolden. The letter accuses Bolden and the agency of foot-dragging in the context of the NASA authorization act of 2010, which mandates developing a commercial space industry while "preserving and developing the Nation's capability for crewed missions beyond low Earth orbit." The legislation is specific about a crew vehicle but vague about a rocket to boost it aloft.

Sens. John D. Rockefeller IV (D-W.Va.), Bill Nelson (D-Fla.), John N. Boozman (R-Ark.), and Kay Bailey Hutchison (R-Texas) warned that without a NASA-developed launch program to follow the shuttle, the agency "is beginning to lose the unique and highly technical skills that NASA employees have developed over 50 years of human spaceflight." The senators blasted Bolden and NASA for "delaying the transition from Constellation-related work and contracts to the new human spaceflight program."

The reference to 50 years was a reminder that Soviet cosmonaut Yuri Gagarin made humankind's first space flight on April 12, 1961; the Obama administration is seeking to replace Constellation primarily with incentives for private-sector space vehicles.

In their letter, the four senators demanded a variety of documents and a series of testimonies by experts on the subjects cited. Without explicitly saying so, they want a return to Capitol Hill by Bolden, whom lawmakers criticized during a hearing on April 11. In that appearance, Bolden said NASA would comply with legislation requiring it to develop a multipurpose crew vehicle (MPCV) by exploiting technology from the Orion spacecraft, a part of the Constellation program.

After first stating it would have a major announcement about the future of human spaceflight, NASA disclosed on May 24 that Orion—the name has been revived and is now synonymous with MPCV—will be the vehicle to carry astronauts into deep space.

In fact, little about the craft is new. A capsule-type spacecraft reminiscent of Apollo vehicles, it is said to be capable of ferrying four astronauts on

Lockheed Martin is working on the MPCV test article.

21-day missions. It is expected to offer 316 ft^3 of "habitable space," as well as a pressurized volume of 690 ft^3. "It is designed to be 10 times safer during ascent and entry than its predecessor, the space shuttle," says NASA.


Sen. Richard Shelby

Missing from the equation is any explanation of what NASA and the private sector are doing to develop a rocket to boost Orion aloft. As Scott Powers wrote in the *Orlando Sentinel*, NASA "did not release estimates on when Orion will be ready, how much it will cost, where it will go, or even what rocket it will ride."

While entrepreneurial efforts to develop a private sector spacecraft are progressing, many in Washington believe that neither Congress nor the administration is enunciating a coherent policy. The sense of being rudderless is exacerbated by the failure of Congress to deliberate on and enact budgets in the traditional manner over the past few years. Some in Washington almost certainly agree with space observer David Hatch, who critiqued the letter from the four senators:

"This should solve all of our space gap problems," wrote Hatch sardonically. "Require NASA to do something. Don't fund it. If they do what they're told, they'll be breaking the law. If they don't, accuse them of dragging their feet."

Analyst Loren Thompson of the Lexington Institute worries that if NASA separates itself entirely from Constellation, the agency will "bet the future of the human spaceflight program on nontraditional and largely unknown launch providers."

Citing Elon Musk's SpaceX project as a private venture that receives more praise than scrutiny, Thompson points out that Sen. Richard Shelby (R-Ala.) "warned last year that NASA had no analytic foundation for its faith in commercial launch solutions and therefore was in danger of repeating the same overreliance on market sources in the civil space program that crippled military space plans in the 1990s." Thompson's institute receives funding from aerospace firms, which favor a government-sponsored spacecraft, but many in Washington share his skepticism about private sector spaceflight.

F-35 faces scrutiny

At a Senate Armed Services Committee hearing on May 19, key defense figures in Washington suggested that the F-35 Lightning II JSF program may have to be scrapped. Despite technical glitches, cost overruns, and four restructurings (meaning delays) over three years, the F-35 had previously been deemed too big to fail, and a series of modest successes were being notched up in its flight test program. Now, Sen. Carl Levin (D-Mich.), chairman of the committee and generally a supporter of the program, speaks for many on both sides of the aisle when he says "people should not conclude that we will be willing to continue ...support without regard to increased costs resulting from a lack of focus on affordability."

Says Sen. John McCain (R-Ariz.), "The facts about this program are truly troubling....After almost 10 years in development and four years in production, the aircraft's design is still not stable, manufacturing processes still need to improve, and the overall weapon system has not yet been proven to be reliable. No program should expect to be continued with that kind of track record—especially in our current fiscal climate."


Sen. Carl Levin

Just after Levin and McCain presided over a hearing that quizzed F-35 program bosses, a *New York Times* editorial lamented the "unhappy story" of the aircraft, "whose initial selling point was its relatively cheap cost of $62 million per plane (in today's dollars)." The *Times* said the nearly 2,500 F-35s the Pentagon plans to buy over the next two decades "are now projected to cost around $382 billion," or about $152 million per airplane.

Until recently, it has been scripture in Washington that no real alternative to the F-35 exists. The Air Force, as part of its preparation for a fleet of the planes, retired 250 older fighters that will not be replaced. The Navy has been permitted to buy a small number of F/A-18E/F Super Hornets to fill its 'fighter gap' on carrier decks caused by delays in fielding the carrier-based version of the F-35. But suggestions that the services might invest in upgraded versions of so-called fighters such as the F-15C Eagle and the F/A-18E/F have been, until now, roundly dismissed by administration supporters of the F-35.

Now, that is changing. "It seems to me [prudent that] we at least begin considering alternatives," says McCain.

With defense cuts certain in the near future and the congressional budget process in a perpetual state of uncertainty, even Undersecretary of Defense Ashton Carter says the F-35 could become "unaffordable" after delays in integrating sophisticated systems into the fighter.

F-35 supporters say that with its radar-evading stealth properties and its ability to deliver precision ordnance, the aircraft is essential as a replacement for aging fighter-bombers. Robert J. Stevens, Lockheed Martin's CEO, says the F-35 is being unfairly compared with the legacy fighters it will replace. Stevens points out that the company has grown lean in recent

Leon Panetta

years, reducing employee numbers from 146,000 to 126,000, and that Lockheed has embarked on a vigorous effort to bring down F-35 costs. He told reporters, "There will not be another rebaseline of this program. There will not be. We understand that." He also said there are "early signs that the program is stabilizing."

If a decision were made to forge ahead with alternatives to the F-35, the Air Force might well find itself purchasing Boeing's F-15SE Silent Eagle, which the company developed primarily for export but which is technologically far ahead of existing models, or Lockheed's F-16E block 60, currently used only by the UAE. The Navy would acquire additional F/A-18E/Fs. It is not clear what alternative, if any, might work for the Marine Corps, which uses no version of any of these fighters and has no obvious alternative to the short takeoff/vertical landing version of the F-35.

F-15SE

In a speech that coincided with F-35 debate on Capitol Hill, outgoing Defense Secretary Robert Gates reiterated the Obama administration's goal of paring $400 billion in defense spending over the next 12 years, said it will not be easy, and stressed that canceling the F-35 is not the answer.

"If we are going to reduce the resources and the size of the U.S. military, people need to make conscious choices about what the implications are for the security of the country," stated Gates. He said the F-35 and the KC-46A air refueling tanker are too important to take budgetary hits. But he warned that other, unspecified Pentagon equipment, roles, and missions must be reduced or eliminated to achieve the intended saving.

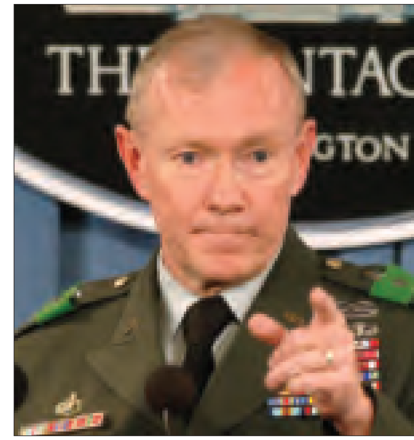
Gates' successor, CIA Director Leon Panetta, was expected to glide through Senate confirmation and to be in office at the Pentagon in early July. Panetta is credited with improving U.S. efforts in South Asia—eschewing a vaguely defined war on terror and sharpening the focus on a war waged directly against al-Qaeda. Panetta commanded the May 1 joint CIA/military operation that killed al-Qaeda boss Osama bin Laden. Panetta is also very much a budget expert with strong ties on Capitol Hill.

Obama named Army Chief of Staff Gen. Martin Dempsey as chairman of the Joint Chiefs of Staff, replacing Adm. Michael Mullen on October 1. Dempsey too should have an easy path through Senate confirmation.

FY12 defense budget

The Panetta/Dempsey team was expected to be formidable in pushing through the defense cuts that Obama wants and Gates cited. However, that does not necessarily mean Congress will enact an FY12 defense budget by the time the new fiscal year begins on October 1. Under both parties, under two presidents, Congress has not passed an annual budget on schedule for six years. Debate on the annual defense authorization bill—the measure that establishes policy without appropriating funds—is now under way but is clouded by the administration's threat to veto the bill unless some of the bill's provisions are changed.

The most contentious item in the bill would require DOD to test an alternate engine for the F-35. Even though the engine-making team of General Electric and Rolls-Royce USA is prepared to conduct the tests at no cost to the government, both the administration and many lawmakers want to drive a stake into the heart of the F136 engine, leaving the Pratt & Whitney F135 as the powerplant for all F-35s.



Gen. Martin Dempsey

Supporters of the alternate engine say that having a choice of two power plants worked well with the F-16 Fighting Falcon program of the 1970s, when it fostered competition, encouraged technological advances, and lowered costs. Opponents argue that a second engine costs too much and adds no new measure of reliability.

Whatever the merits, both sides thought this issue had gone away. In fact, the F136 keeps rising from the dead so often that one critic calls it 'the zombie engine.' But the alternate engine has strong supporters on Capitol Hill, including Rep. Howard P. 'Buck' McKeon (R-Calif.), chairman of the House Armed Services Committee, and senior lawmakers such as Rep. Roscoe Bartlett (R-Md.) and Rep. Robert Andrews (D-N.J.). So at press time the House committee version of the defense authorization bill prohibited the Pentagon from destroying or discarding engines made by GE for the F-35 and also encouraged further testing.

"If the final bill presented to the president includes funding or a legislative direction to continue an extra engine program, the president's senior advisors would recommend a veto," said a statement issued by the White House Office of Management and Budget.

Robert F. Dorr
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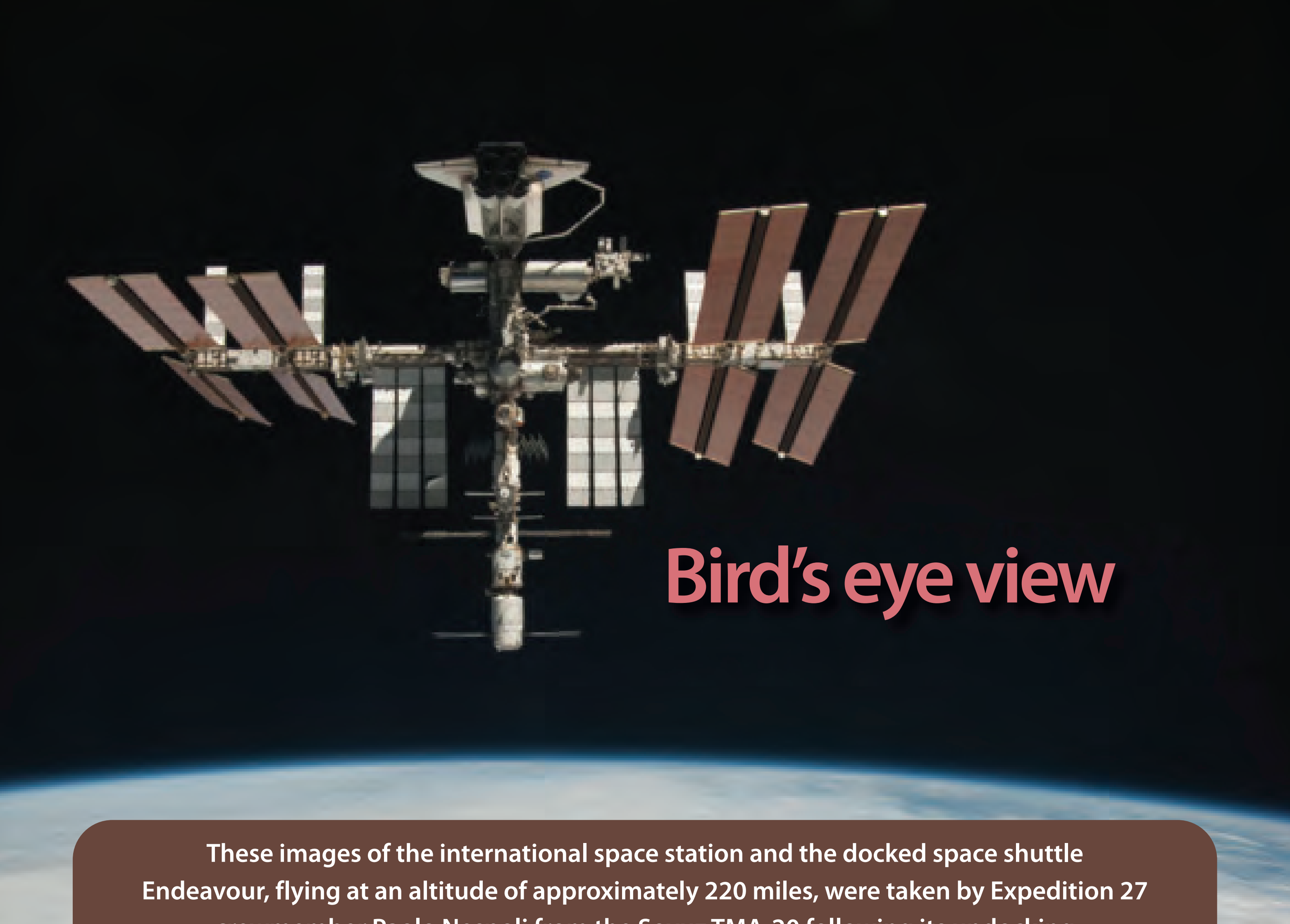
Bird's eye view



These images of the international space station and the docked space shuttle Endeavour, flying at an altitude of approximately 220 miles, were taken by Expedition 27 crewmember Paolo Nespoli from the Soyuz TMA-20 following its undocking on May 23, 2011. The pictures are the first taken of a shuttle docked to the station from the perspective of a Russian Soyuz spacecraft.

David Williams

The U.K. Space Agency was launched in March 2010 and is now responsible for all strategic decisions on the U.K. civil space program. How do you measure whether the agency has been successful in its aims?

We have some simple measures of success—the work we can win from the European Space Agency and how much we can reduce our internal costs, for example. But obviously we need to measure our success in other ways. We want to remain the recognized voice of the U.K. in the international space program community, to make sure that government has a higher view of space, understanding the value of the industry and its growing importance. We want to continue to be successful in developing our strengths in the academic world, in space exploration and Earth observation, and to promote the U.K.'s space capabilities in all other areas.

The objective of the agency is to improve the U.K. space sector's growth rate and to increase revenues by more than six times to £40 billion by 2030, at the same time increasing the U.K.'s share of the global industry to 10%. These are ambitious targets.

The targets have been set with the help of industry. Most of the space market is in 'downstream'—users of the space technology; we are also concerned with 'upstream' space systems—providers of space technology. This is already growing rapidly. When you consider that of the largest 100 FTSE [London Stock Exchange index] companies, two are space organizations, INMARSAT and BskyB—companies based entirely on space systems—that's not a bad representation.

The targets are ambitious but realistic. Currently we have around 6% of the global commercial space industry and a turnover of £7.5 billion, of which the upstream sector accounted for some £800 million. Direct government investment accounted for about £220 million.

For many years, successive U.K. governments have, it appears, been less than enthusiastic in their support for the space industry, especially when compared to neighbors in continental Europe. Has there been a real change in attitude from the government to space in recent years and, if so, why?

There has been a change—after all, we have a space agency now. Before the new agency was formed, we worked through the British National Space Centre. It was a partnership across government in which each department made its own decisions, which resulted in a lot of independent initiatives. But now, space is being viewed as much more of an integral part of life; we have a higher visibility at the senior levels of government than ever before.

"A world without satellites would be like a world without computers. We'd be back to the 1960s."

The new agency ups the game. It means that there are now government ministers making decisions on funding issues. It means we are also integrated within government thinking on issues such as security—which is different from defense—so, for example, government can now more easily address the challenges of coping with the security implications of protecting critical satellite systems.

In a recent government study, for the previous administration, we looked at the impact of losing GPS signals, in both the short term and long term, on the economy and wider society. We found that in the short term this would have a major impact on electricity supplies, for example, as energy suppliers now use GPS for synchronizing electricity grids when connecting them together.

The results of the study showed us just how much now society depends on space technology for communications and media. The public expects real-time broadcast from remote locations, for example, not just for news but for sport. A world without satellites would be like a world without computers. We'd be back to the 1960s.

The government has recognized that in at least four areas the U.K. has a very strong space sector. In Earth observation the U.K. is heavily involved in ESA programs. We have a very strong small satellite industry in the U.K. [see 'Conversations with Sir Martin Sweeting,' February, page 14] which is the envy of much of the world. We're strong in satellite navigation, with our involvement with the Galileo program, and we have a large slice of the space telecommunications business. I estimate the U.K. has about 25% of the global market in commercial telecoms and that, collectively, Europe has around half the market.

And we now have a broadband satellite flying—Avanti's HYLAS was launched in November 2010; we're also fairly strong both in space exploration and in space science.

But the U.K., unlike other countries, does not have an indigenous launch capability. Has the U.K. missed out because of that?

It's difficult to say. The original Ariane design envisaged a U.K.-derived second stage, but we pulled out early in the program. We subscribed to a policy of having access to a European launch capability, but not to the industrial policy of developing a production capability. It is not essential

Interview by Philip Butterworth-Hayes

for all European countries to be involved in all developments.

I have to say that we have never been in a position where we couldn't find a launcher.

The U.K. is now an integral part of ESA, but doesn't that make it more difficult to build industrial relationships with other space powers, in Brazil and China, for example?

We are currently a big player in the space science sector in Japan and the U.S., but through ESA. We have not yet moved into working with China because, among other factors, there are technology transfer issues to consider.

And one of the key questions you have to address is: How much capacity do you really need? We have taken the route of focusing in key areas rather than trying to spread ourselves too thin.

It hasn't handicapped us not to have this technology. And those that do now face new issues. For example, in the U.S., launcher service systems are now undergoing some radical changes with the introduction of commercial operators.

So do you see the role that commercial companies play in the global space market developing further, into areas that were previously the preserve of governments?

In the U.K. we have a thriving commercial sector throughout a range of different markets. From space science research, with projects like the Mars Explorer and the James Webb Space Telescope, the U.K. commercial space sector is highly active. We have very strong academic industry partnerships within the U.K., and even on the military side with Paradigm, which supplies military-hardened satellite communications—primarily to the U.K. armed forces, but also to other governments and organizations around the world.

One of the benefits of not having a huge government agency to oversee the development of the industry is that we have been able to develop some very strong joint ventures between academic institutes and commercial operations.

In my experience, establishing a center of excellence is one thing; maintaining that excellence is a bigger challenge. Centers create an almost self-generating institution; I think this is recognized in many countries. In the U.K. we maintain a system where we get business and research organizations to work directly with each other. And to a certain extent ESA has taken over the role of the strategic national industry institution, allowing industry to be more proactive.

The backbone to any successful national space program must be the link between research institutions and industry, so there's a well developed resource of scientific knowledge from which programs can be

"And one of the key questions you have to address is: How much capacity do you really need? We have taken the route of focusing in key areas rather than trying to spread ourselves too thin."

David Williams leads the U.K. Space Agency, which is responsible for all strategic decisions on the U.K. civil space program and provides a single voice for U.K. space ambitions. Launched in shadow form on April 1, 2010, it was established as a full executive agency of the Dept. for Business, Innovation and Skills on April 1 of this year. The new agency replaced the British National Space Centre (BNSC), where Williams served as director general from May 2006.

In taking up that post in 2006, Williams also became head of the U.K. delegation to ESA, and in June 2010 he was elected to serve as chairman to the ESA Council. Before his appointment as director general of BNSC, Williams spent 10 years as head of strategy and international relations with EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites) in Darmstadt, Germany. His earlier experience includes work in the U.K. with the Natural

Environment Research Council, which funds scientific research in universities and other centers.

Before entering industry Williams was a lecturer in the Dept. of Geography at the University of Reading, from which he earned a B.S. degree in 1974 and a Ph.D. in 1978.

launched and a pool of well qualified personnel from which companies can draw. How healthy is that link in the U.K., and is space still an attractive subject for undergraduates?

STEM subjects (science, technology, engineering, and mathematics) are still popular, and space still excites students. We have worked hard to support space within the national educational curriculum (for schools). About three or four years ago we started to introduce space subjects into the existing core areas of education—for example, using problems of how to put satellites into space, or using satellite images for geolocation lessons—rather than teaching space as a separate subject. We have some early indicative information that, from the schools where this has been introduced, we are starting to see the average grades of pupils rise, once space subjects are introduced.

But for further education, are we teaching the right subjects to the right people at the right places?

Universities are independent, so it's up to them what is taught. In the U.K. we have a number of universities where space science is taught at the undergraduate level. We've seen that many of these students do not always pursue their careers in space, preferring to become bankers for, example.

But the academic world is both global and mobile—which means we have a lot of foreign students now studying in our universities, and a lot of U.K. students studying abroad.

I think if there is an area where we need to increase our pool of talent, it is in the technology and engineering side. We need to build on the engineering production skills, especially in areas such as nanotechnology, to have people who understand the technology of how the computers, which actually build the space systems, really work. We need modern-day machine tool workers, the people who generations ago in motor factories used to build and engineer the tools that made the parts and understood how the various engineering elements of a motorcar worked together.

Are the essential programs now properly funded in the U.K.?

One of the benefits of the new agency is that it has secured the funding stream to meet our current commitments. One of my jobs has been to set out a stable budget, and that is something we now have, along with a clear agenda of programs.

If there are any areas where I think we need to develop our expertise further in the U.K., they are in the sectors of instrumentation for Earth observation and developing technologies for the assimilation of data.

We also need to look more closely at the next generation of launchers. From my understanding of the technology, we are getting fairly close to the limits of lift capability possible from solid or liquid propellant rockets. That means we need to look at new technologies. In the U.K., Reaction Engines has been working on the Skylon reusable space launcher, using air-breathing engines for some of the launch cycle. The key technology area here is in the heat exchanger, aimed at reducing the energy from high-speed air entering the engine. These advances in technology could represent a relative democratization of access to space, and it's something we are keen to support.

"If there are any areas where I think we need to develop our expertise further in the U.K., they are in the sectors of instrumentation for Earth observation and developing technologies for the assimilation of data."

"I believe in space we will have to see governments move further away as the industry becomes more integrated within society."

The other way to reduce launch costs is to develop new competitive business models, which is under way in the U.S.

We are also working on whether it could be sensible to apply nuclear propulsion systems to power vehicles in space, where you need a lot of consistent low-thrust power over long periods, and where you need to design power systems which won't fail because the chemicals run out or the solar panel collapses.

What's the size of the U.K. space workforce?

Around 25,000 jobs in the U.K. work directly in the space industry. We're finding more and more people now involved in developing software, which is the essential core of the business, and [the core] around which the hardware sits.

What's your biggest challenge now?

The biggest hurdle has been getting the agency into place. I'm concerned now about the next stage of how the space industry evolves, how you develop operational capacity from the continued research and development programs.

We are at the point where space needs to be more open and more integrated within society. It is very much like the television industry in the 1950s, or how the computer industry began, basically as government entities. But government exited these industries, and I believe in space we will have to see governments move further away as the industry becomes more integrated within society.

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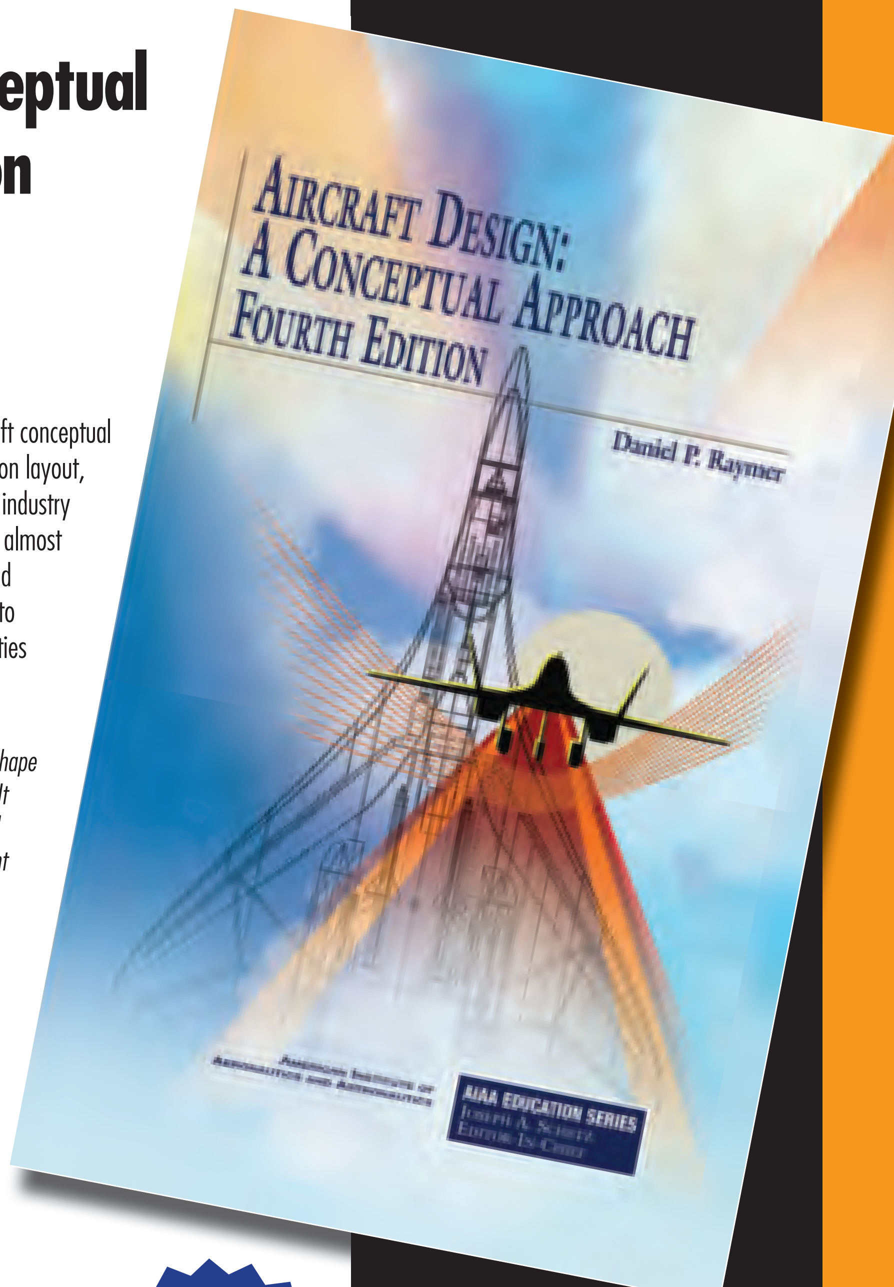

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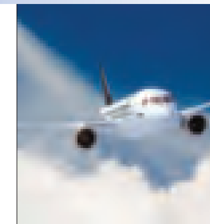


Single-aisle jets: The more things change…

THE SINGLE-AISLE JETLINER MARKET IS at record levels in terms of output. Not surprisingly, new players want a piece of it. Regional jetmaker Bombardier is trying to break into the mainline single-aisle market with its 110/130-seat CSeries. Bombardier's regional market competitor, Embraer, might follow them with a larger jet. China's COMAC wants to break into the market with its 150-seat C919. And Russia's United Aircraft wants to stage a comeback, after an absence of a decade or so, with its 150/200-seat MS-21.

Yet for the foreseeable future, this market will be dominated by the two current single-aisle manufacturers, Airbus and Boeing. The only change in this segment is at the propulsion level, providing the current manufacturers with an opportunity to maintain their duopoly position.

Much at stake

Last year, the two large jetliner primes delivered a total of 777 single-aisle jets—a record not only in volume but also in terms of output. In terms of value, these A320 and 737 series jets constituted 56% of the total jet market, a level not seen since the dawn of the twin-aisle era (45% is closer to the historical average). This strong output was driven by demand in emerging markets, particularly China and India, but also by the popularity of these two jet types as investments by lessors and financial houses.

With this much at stake, governments are playing a prominent role in supporting their national manufacturers. Bombardier is getting Canadian and provincial government launch aid to develop the CSeries. The Russian and Chinese jets, of course, are purely government-funded creations. And both Airbus and Boeing have relied increasingly over the past three years on customer financing support from export credit agencies (ECAs) such as the U.S. Export-Import Bank.

Notably, in May 2011 Ex-Im Bank announced that it would provide funding for 737 sales to U.S. carriers, a radical departure from the primary ECA mission of supporting exports. This change is largely due to the arrival of the CSeries as a force on the market.

Historically, ECA finance has only gone to carriers domiciled outside the U.S. and Airbus home countries. However, this informal 'home country agreement' does not appear to be standing up to the arrival of new players. Canada will likely use ECA finance for CSeries.

Bombardier CSeries

For the future, the two current manufacturers are planning to ramp up output, partly as a way of filling market demand before the new generation of products arrives. In May, Airbus announced that it would raise A320 production to a new record, 42 per month, by the fourth quarter of next year.

Boeing is also upping its output rates, although less aggressively. The current 31.5 per month rate is increasing to 38, and the company is also studying a 42-per-month rate after 2013, depending upon supply chain considerations.

Pioneer or martyr?

In theory, this market offers tremendous opportunities for new market players like Bombardier, whose 110/130-seat CSeries is the most promising new product. But in reality, the strong advantage afforded by their production volumes gives Airbus and Boeing an extremely strong defensive position. This is best illustrated by the problems facing the CSeries.

Launched in August of 2008, the CSeries was the first announced application for the new generation of single-aisle engines, in this case Pratt & Whitney's PurePower geared turbofan. But after almost three years, only two airlines, Lufthansa and Frontier, have placed orders, and neither has agreed to be the launch user. The CSeries is in the very unusual position of being just two years away from entering service with an unknown carrier.

The main problem for the CSeries has been Airbus's strong market position, and the production volumes that result. In December 2010, the company launched its A320neo (new engine option) series, offering a choice of Pratt & Whitney's PW1100G PurePower or CFM International's LEAP-X. The neo series has already attracted more airline customers than the C-Series, with well over 300 firm and option orders.

The problem for Bombardier is that it is not competing with the average cost of an Airbus single-aisle jet. It is competing with the marginal cost to Airbus of building additional A319/320neos on top of the hundreds of A320/321neos it will be building annually. Bombardier will be forced to offer very seriously discounted CSeries prices to match this volume.

Time will tell if Bombardier will be able to compete against seriously aggressive prices. If it fails as a pioneer, the CSeries will still have played a noble role, akin to martyrdom. As the first jet to be offered with new-generation engines, it guaranteed a response from Airbus—all the real and rumored CSeries buyers were Airbus customers.

Bombardier may have effectively kicked a hornets' nest. Over the past few months, Airbus has signed up both of the CSeries airlines as new neo customers. In March, Lufthansa ordered 30 A320/321neos. Republic Airways Holdings, parent company of Frontier Airlines, has also put down an $8 million deposit with Airbus for A320neo-family aircraft (the specific model is not known yet). Airbus has also prioritized its A319neo, moving its service entry from 2017 to 2016. This model directly competes with the CSeries' 130-seat CS300.


Airbus A320neo

The elephant in the corner

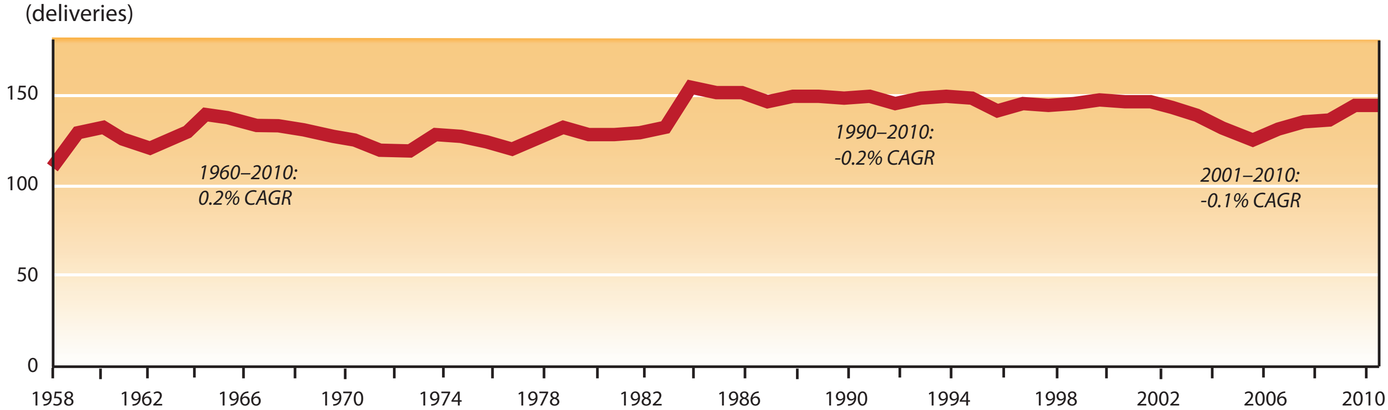
Boeing, the other half of the jetliner duopoly, is either in a tight corner or a strong position, depending upon your perspective. But as of right now, it looks like a tight corner.

On the one hand, the company insists that its current 737NG has always had a fuel-burn advantage over the A320 series, and the A320neo series merely helps Airbus play catch-up. Also, Boeing has historically enjoyed waiting to see what the competition was doing, rather than making the first move. This approach worked very well with the 777 relative to the MD-11 and A330/340.

Yet it is clear that in a time of high fuel prices, the A320neo series will continue to gain traction. It is likely as well that one or more key 737NG clients will defect to Airbus. They might conceivably defect to Bombardier as well. Southwest Airlines, the biggest 737 customer and the launch customer behind the 737 Classic and 737NG, has said that 2020 is too long to wait for a new Boeing jet. Delta, American, and several other important single-aisle customers will likely place new orders in the next few years. A discounted 737NG will be at a disadvantage, assuming fuel stays expensive.

This means that Boeing will have a limited menu of technological options

AVERAGE SEATS 70–220 PASSENGER JETS
(deliveries)



Source: Teal Group

for an all-new product. There are some promising technologies that will be available after 2020 (or 2025-2030, in Airbus's view), such as composites, advanced propulsion, and fly-by-light controls. But for a product launched in the next two years or so, new engines are about the only key enabler.

Thus, in its choice between a 737 reengine and a new jet, Boeing is constrained by time. But it is also constrained by size. Despite all the considerable discussion about single-aisle jets getting larger, there is absolutely no quantitative evidence that this is a long-term trend. Looking at the average seat count of all single-aisle 70/220-seat jets delivered since the dawn of the jet age, jet size has remained remarkably constant. According to the Teal Group's delivery database, there has been a 0.2% compound annual growth rate in seat count since 1960. Although the last five years have seen some growth, with average seat count going from 125 in 2005 to 144 last year, this has merely been a reversion to the long-term plateau. There is no evidence that seat size will continue to grow beyond this level.


ARJ21

Boeing, then, would not be able to rely on technologies that primarily contribute advantages to larger jets, such as composite primary structures. And of course it would not be able to use size as a rationale for doing a new jet. In May 2011 CEO Jim McNerney stated that any new Boeing aircraft would address the "heart of the market," or the 145/185-seat range.

In short, the company will likely need to launch some kind of new or reengined single-aisle product in the next 24 months. When it does, it will likely find that the additional cost premium of an all-new jet (about $4 billion-$5 billion above the cost of a 737 reengining) is not justified by the technology available in this time. A reengined 737, despite its drawbacks, is therefore the most likely solution.

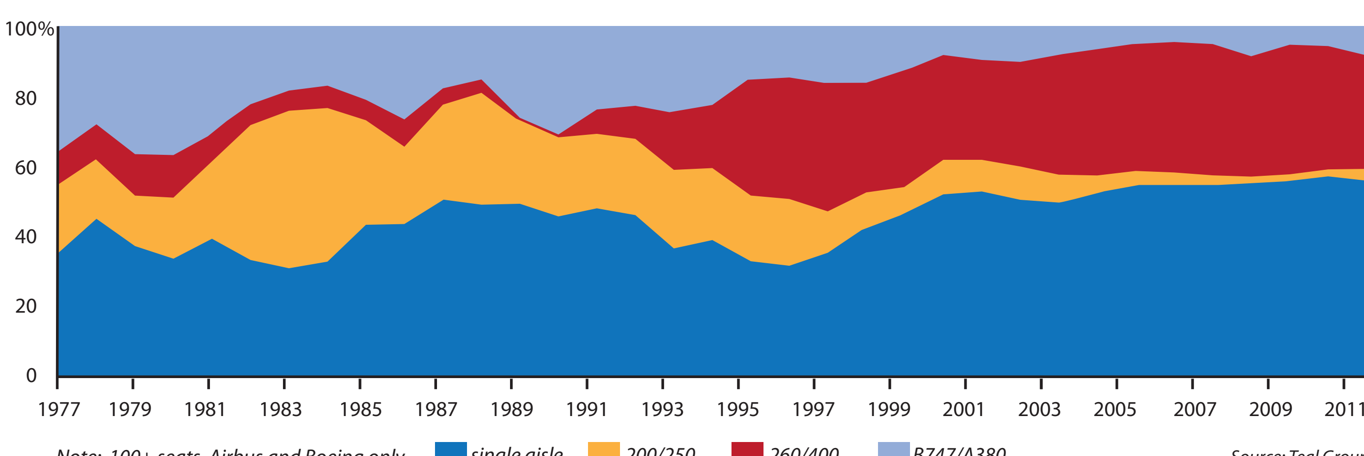
Of course, this problem also presents Boeing with an opportunity. Toward the end of the decade, there will be many more technological options, and Boeing will be in a better financial position to launch an all-new aircraft. It can move forward with a 180/230-seat 757/767-200 replacement, arriving around 2022-2024. While this would cannibalize some of the 737-reengined market, that would not be enough to undermine the overall success of the 737-Re program. And more important, Boeing would avoid losing a significant part of the 145/170-seat market over the next decade.

Embraer watches the watcher

If Boeing is taking a somewhat passive approach to this segment right now, Brazil's Embraer is even more calm about assessing its options. That is understandable, because Boeing's next move will provide considerable guidance. If Boeing launches a larger single-aisle product and abandons the sub-150-seat market, there is plenty of room for Embraer to expand with a new 140/150-seat jet. But with Boeing likely to stay in the 145/185-seat segment, a major derivative of Embraer's ERJ 190 would be a logical step, with a fuselage stretch allowing 120 seats in two classes. This derivative would feature new or improved wings and, of course, a new engine.

These two concepts are not mutually exclusive. Going with both would

A HEAVILY SINGLE-AISLE CYCLE
Jeliner segment deliveries (share of deliveries by value)



Note: 100+ seats, Airbus and Boeing only *Source: Teal Group* offer strong advantages. A short-term 120-seat ERJ 190 upgrade would harness new engine technology, while a larger jet, arriving after 2020, could take advantage of new airframe technology without completely displacing the ERJ 190 on the market. According to Embraer, a composite-based jet is one option for the all-new model. A wider fuselage would allow for three-two seating, as with the CSeries.

A two-track approach would also fit nicely with the company's current new product development obligations. Through 2016, much of Embraer's engineering workforce will be focused on the Legacy 450/500 business jets and KC-390 military transport. With a two-track approach, it will be able to develop a major ERJ 190 derivative in the same time frame as the other projects, followed by by an all-new larger jet just after the end of the decade.

Yet it is possible that they will fill a portion of domestic demand in their home countries. That prospect alone will encourage Airbus and Boeing to keep their products updated with improvements to the new engine families as they are made available. This ability to rapidly update and incrementally improve their products is another advantage held by the current two jetmakers.

All four current and potential new single-aisle-market entrants are enabled by one factor: the arrival of new engine technology. Without it, developing new airframes to play catch-up with the two established manufacturers would have few charms. With the new engines, there is the hope of being a first adapter, and perhaps even leapfrogging ahead of the established players while they focus on their expensive new twin-aisle jets.

Airbus has sensed this, and has quickly co-opted the new engines, putting the newcomers back in the position of playing catch-up. Boeing and Airbus have not yet moved in a similar direction. But it is difficult for any airframer to admit that it is not in the driver's seat in a particular segment of the market. Having new engines drive change makes single-aisle airframes more of a commodity than they are in the twin-aisle segment.

Having new engines drive change also gives the airframers fewer opportunities to affect the market with their own new technology. They will rise and fall by the usual metrics: salesmanship, product support, and the financial appeal of their products. And in these areas, Airbus and Boeing will always have a very strong advantage.

Other newcomers

The Chinese and Russian single-aisle offerings are both undermined by one crucial weakness: They are being designed, built, sold, and supported by government-owned companies. Historically, government-owned aerospace companies do an extremely poor job of meeting market needs.

It is also notable that these products are not first attempts to break into the jet market. COMAC's C919 is actually China's second recent attempt at civil jet design, and the ARJ21, which may enter service later this year, looks set to be instantly forgotten as an obsolete design with serious development problems.

As for the MS-21, it is an effort to return to the market Russia was forced to exit after the collapse of the Soviet Union. There is no reason to believe that the MS-21 will do better than all the other post-Soviet Russian jets that have been offered with modern engines, such as the Tupolev Tu-204 and Ilyushin Il-96.

Neither the C919 nor the MS-21 offers any promise in global markets.

Richard Aboulafia
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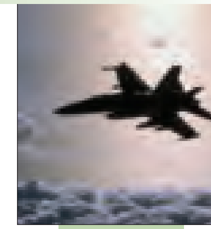
Green fuels for the wild blue yonder



ON MARCH 30 AT GEORGETOWN University, addressing the subject of energy security, President Barack Obama observed, "Our best opportunities to enhance our energy security can be found in our own back yard—because we boast one critical, renewable resource that the rest of the world can't match: American ingenuity…American know-how."

To illustrate the point, the president said, "Just last week, our Air Force…used an advanced biofuel blend to fly an F-22 Raptor faster than the speed of sound. Think about that. I mean, if an F-22 Raptor can fly faster than the speed of sound on biomass, then I know the old beater that you've got, that you're driving around in, can probably do so, too."

That F-22 flight is the result of a fast-paced effort by the military to help develop, test, evaluate, and certify alternative jet fuels for the Air Force and Navy aircraft fleets, fuel infrastructure, and ground support vehicles and equipment.

The Air Force is aiming to get half of its continental U.S. drop-in jet fuel, or 400 million gallons, from competitively priced alternative sources—typically a blend of alternative and conventional fuel—by 2016. Another goal is to develop a greener way of producing the new fuels, one that improves on the methods currently used for others such as the kerosene-based JP-8 (Jet Propellant 8) that powers the majority of the Air Force's manned aircraft and UAVs and the JP-5 fuel used in Navy aviation.

As the DOD's largest consumer of jet fuel, the Air Force uses roughly 2.6 billion gallons a year. That is about 10% of the entire domestic market, representing most of the service's energy costs of around $7 billion. Hence the rationale for looking seriously at alternatives to dependency on oil-based fuels, which are subject to severe price and supply swings.

Beyond its own needs, the Air Force is working closely on certifying new fuel blends for use in the civil aviation sector with the Commercial Aviation Alternative Fuels Initiative (CAAFI). A broad coalition established in 2006, it includes airlines, aircraft and engine manufacturers, energy producers, researchers, international participants, and U.S. government agencies, including NASA and the Defense, Transportation, and Energy Departments. CAAFI's goal is to promote the development of alternative jet fuel options that offer equivalent levels of safety and are cost competitive with petroleum-based fuel, while also offering environmental benefits and enhancing the security of our nation's energy supply for aviation.

An F-22 Raptor powered by biofuel takes off March 18, 2011, at Edwards AFB. The flight was the capstone of a series of ground and flight test events conducted by members of the 411th Flight Test Squadron for the F-22, using the biofuel blend. (USAF photo/Kevin North.)

Spearheading the Air Force's alternative jet fuels effort is the service's Alternative Fuels Certification Office in the AFRL (Air Force Research Laboratory) at Wright-Patterson AFB in Dayton, Ohio.

Tim Edwards, a senior chemical engineer with the Propulsion Directorate, says the alternative fuels work at Wright-Patterson builds on three-quarters of a century of fuels research at the base, beginning with "high-octane aviation gasoline for the engines that helped win WW II, and through the jet age with advanced fuels like JP-7 for the SR-71 Blackbird and JP-10, the fuel for the cruise missile."

In the early 2000s, notes Edwards, "Bill Harrison, who's now the technical advisor for fuels and energy in the Propulsion Directorate here, had been working with the Dept. of Energy on small-scale fuels made from coal and biomass. It was a fairly low level of effort. In 2006 Harrison briefed Secretary of the Air Force Michael Wynne, who wanted to help get it moving, and pretty much said, 'What does it take to fly a plane on this by the end of the year. This is exciting work but you're going too slow.'"

After Harrison's group flew a B-52 on a fuel derived from natural gas in late 2006, the effort picked up: In 2007 the Air Force established the Alternative Fuel Certification Office, managed by Jeff Braun, and Harrison's group was tasked to continue fuels R&D. In addition, to improve and standardize the aviation fuel certification process, a team was established to develop a systems engineering-based approach to fuel and fuel additive certification.

Fischer-Tropsch and beyond

The first major advance in certification was to blend the JP-8 fuel with up to 50% of a synthetic paraffinic kerosene component derived from the Fischer-Tropsch process, the set of chemical reactions that convert a carbon monoxide and hydrogen mix into liquid hydrocarbons. The Air Force has already met this year's goal of testing and certifying all its aircraft for use of a 50/50 synthetic fuel blend.

One drawback of Fischer-Tropsch fuel, notes Jeff Braun, is that while the fuel "burns cleaner than petroleum, the manufacturing process creates more CO_2" than does the process for producing standard jet fuel in the specific case of Fischer-Tropsch synthetic fuel derived from coal without using carbon capture sequestration (CCS) methods. He adds, however, "Coal derived FT fuel that is cofired with biomass or that utilizes CCS could have a much lower CO_2 footprint than standard petroleum-based fuel. In fact, FT derived exclusively from biomass has the potential for having the lowest carbon footprint of all alternative fuels."

Turning to an alternative fuel that has very promising overall environmental characteristics, in 2009 the Air Force developed a new requirement to develop hydrotreated renewable jet fuels, or HRJs, which are made from biomass. "What we're looking at right now," states Braun, "is the conversion of animal fats—such as beef tallow, chicken greases, and chicken oil—and plant oils into aviation-grade kerosenes." Also being examined are algae as well as synthetic fuels derived from domestic coal and natural gas.

Braun emphasizes that his group is "feedstock agnostic. We don't care what feedstock is used, but the resulting fuel must meet JP-8 specification, and it must replicate JP-8 performance." Adds Edwards, "The HRJ fuel the F22 flew on, we call it hydroprocess renewable jet. An HRJ fuel made from algae grown in Arizona might make sense there. In other places, such as Florida, Montana, and Washington, you might grow camelina, which is a fairly hardy weed. Another fuel we're working on takes waste biomass like agricultural waste, or woody biomass like switchgrass, and makes a similar drop-in fuel. And that would make sense in the Midwest. The market is really going to determine which process makes the most sense in which parts of the country."

The reason for blending both HRJ and Fischer-Tropsch fuels with conventional jet fuel, says Braun, is that "we want to retain some of the qualities and some of the chemical characteristics of the JP-8." He notes that alternative fuels do not have natural aromatics, the jet fuel compound that promotes growth in the system's seals, such as O-rings.

"Initially, Braun says, "using 100% of the alternative fuels in testing, we were seeing leakage. We found when we blended with JP-8 at a 50% volume, we got enough aromatics to promote sufficient growth in the seals to prevent the leaks. Another reason why we go 50% is for density. These alternative fuels originally were a little bit less dense than their JP-8 counterparts. By blending them at 50%, we were able to bring the density back up to a more historically acceptable range."

While certification of the Fischer-Tropsch fuel involves fleet-wide testing, Braun says for HRJ fuels "we're not going to test every aircraft and every system. What we've done is identify different pathfinder systems, systems that are either fleet-wide representatives or considered the most technically challenging systems out there (for flight test).

"In addition, we are doing other various engine tests, auxiliary power unit tests, just trying to hit the critical points that were gleaned from the Fischer-Tropsch data." In this method, Braun explains, HRJ fuels are first tested on an A-10C Thunderbolt II aircraft "to get the fuel up in the air just to prove that, yes, in fact, we can power flight and we can get basic systems working with the fuel in a demonstration concept."

The fuels will then be tested on the three designated pathfinder aircraft. First is the C-17 Globemaster III military transport plane, "representing all the mobility aircraft," says Braun; it was certified for biofuel usage in Feb-

An A-10C Thunderbolt II from Eglin AFB, Florida, flies along the coast of Florida March 25, 2010, during the first flight of an aircraft powered solely by a biomass-derived jet fuel blend. The A-10 was fueled with a 50/50 blend of HRJ and JP-8. (USAF photo/Senior Master Sgt. Joy Josephson.)

ruary. Second is the F-22 Raptor, "the highest performance fighter aircraft we have, and the most technically complicated aircraft." Third is the Global Hawk UAV, "because of the environment it operates in," he says.

Comprehensive testing process

So how does the testing process work? As Braun explains, "The first thing that happens before any of these fuels touch an aircraft is that our laboratories analyze the fuel. That's where we get a lot of the chemical composition characteristics defined—the lubricity, the density. Then we'll go through a series of materials analyses. We'll subject common materials and not so common materials that are used in manufacturing processes and in aircraft, whether it is in the fuel system, somewhere in the engine, or even in the skin coatings. We'll subject those materials to soak tests with the fuel. I think we've looked at almost 100 materials thus far to see if there is any interaction with the fuel blend.

"We'll look at component testing, maybe just an APU, maybe just a gauging system, and then subsystem testing, to include full-up uninstalled engine tests. And finally, we'll do the end-to-end systems flights, where it's the actual flight test of the aircraft. We do a building block approach before we just go out and fly the airplane."

Alcohol to Jet

Braun cautions that to meet the Air Force's 2016 goal, replacing 50% of the current JP-8 fuel with an alternative blend (about 400 million gallons), they may need to look even beyond Fischer-Tropsch and HRJ fuels. "We're also interested in evaluating other technologies, other approaches, other processes. We're currently trying to gain approval to start certifying a third pathway, called Alcohol to Jet (ATJ), where you take cellulosic materials like woods, grains, and paper products and extract the sugars from the cells and ferment those sugars into hydrocarbons, which we can hydroprocess into aviation-grade kerosene.

Richard Strievich, with the University of Dayton Research Institute, runs lab tests on camelina oil at the AFRL. (USAF photo/Bonnie White.)

"The beauty about the ATJ pathway is that it significantly increases the available feedstock. In the HRJ effort, where we are using plant oils and animal fats, there's only so much beef fat available in the U.S. There are only so many chicken renderings available. Vegetables have other uses as well.

"When you start looking at cellulosic materials, you're looking at waste materials—agricultural waste, timber waste, papers. Theoretically you could start looking at garbage. So it significantly enhances our feedstock pool, which would enhance our ability to meet the 2016 goal."

Edwards is confident that a new industry will emerge to develop alternative jet fuels. He notes that because the plants that make renewable jet fuel can also make diesel fuel, there is no reason why the U.S. could not have plants that produce a couple of hundred million gallons a year.

"The feedstock is here," he says. "You'd just have to get your ducks in a row and make sure the farmers are growing the crops to make the feedstock, that they can get crop insurance, that the plants are being built, that there are ways to transport the stuff there, and then that we get the fuel processed and into the pipeline. It's more of an organizational and economic barrier than a technical barrier."

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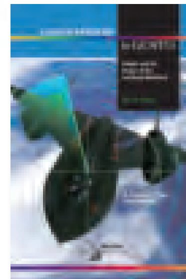

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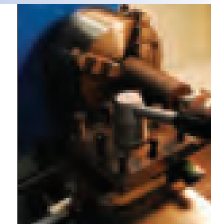


Microwave launch idea heats up

A credit-card-size piece of graphite in a lab at NASA Ames could be the start of something big in the world of rocketry.

The graphite is being tested as a potential linchpin in a concept called microwave thermal propulsion, which calls for focusing microwaves onto the belly of a rocket to heat hydrogen fuel coursing through its walls. The heat would increase the pressure of the hydrogen, and the resulting hot gas would shoot out a nozzle, generating thrust without combustion.

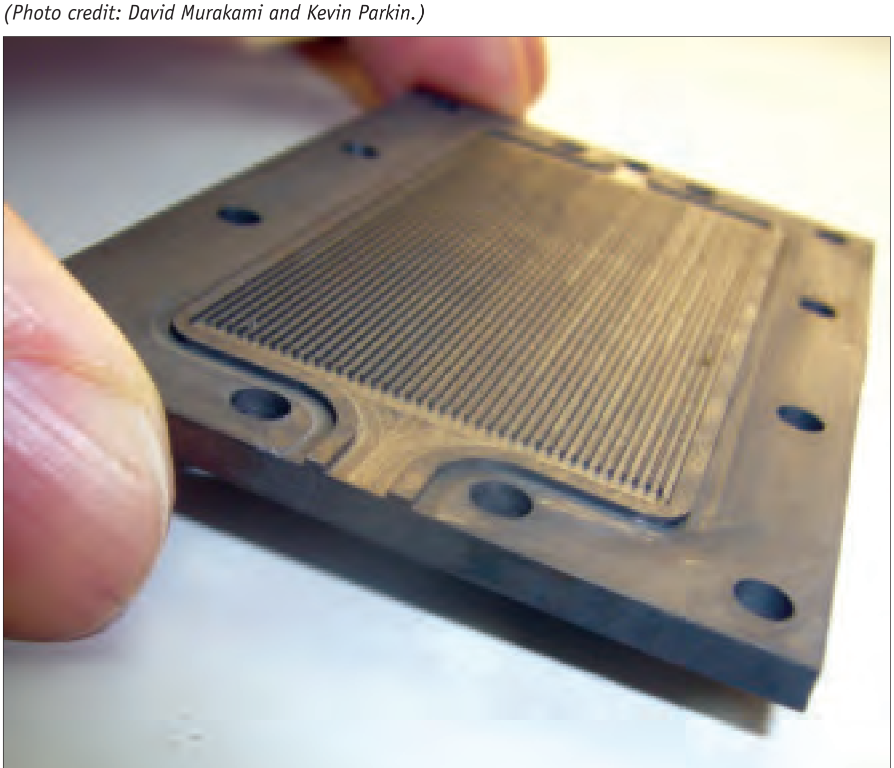
Exploring the concept is a loose alliance of physicists, students, and engineers from Stanford University, Carnegie Mellon, and the startup company Escape Dynamics, which is funded by one of the founders of the Quiznos restaurant empire.

However, if the rocket industry is about to witness a revolution, it is one at its earliest stages.

Uncomplicated, safe

David Murakami, a Ph.D. candidate at Stanford, is conducting thermal tests on the piece of graphite using a 20-kW theater lamp. Ceramic is another potential material for the device, called a heat exchanger. Whichever material is chosen, it must be able to withstand temperatures of 2,500 K to generate the required thrust. If graphite turns out to be the material of choice, Murakami or other engineers would have to figure out how to manufacture channels into it and fill them with helium as a surrogate for hydrogen. The subscale heat exchanger would have to prove the feasibility of transferring heat to hydrogen fuel with the required efficiency.

Channels are machined into a credit-card-size segment of graphite for subscale testing. (Photo credit: David Murakami and Kevin Parkin.)



For now, the name of the game is simplicity and safety. "We're using helium because that's almost as good a working fluid as hydrogen, with the benefit that it won't explode," explains Murakami.

While Murakami's tests are under way, officials at NASA and DARPA are discussing the concept's funding future. In January, advocates of microwave thermal propulsion finished contributing information to NASA Ames, which is working with DARPA on a review of options for externally powered rockets.

Microwaves and lasers are considered the most viable options. In the 1960s and early 1970s, engineers conducted ground tests to show how hydrogen could be heated by a nuclear reactor, in a project called NERVA (nuclear engine for rocket vehicle application). Linking the concepts is a desire to generate thrust without lugging oxygen aboard a rocket for combustion.

So far, NASA Ames has provided initial research funds for the microwave concept through a cooperative agreement with Murakami's mentor, physicist Kevin Parkin of Carnegie Mellon. As a graduate student at Caltech in 2002, Parkin had become convinced that microwaves were the best option for externally propelled rockets, and the idea was the subject of his 2006 Ph.D. thesis.

"I was looking at many different ways of getting to orbit and trying to pick something that had a big performance increase and was near term, and [I] arrived at microwave thermal rockets that way," he says. "We're trying to demonstrate all of the things we need to demonstrate at very low cost and small scale, and build things up incrementally that way."

A 'no brainer'

Parkin's microwave thermal research is funded by NASA, but the physicist is also a volunteer adviser to Escape Dynamics. The company was founded in 2010 by Dmitriy Tseliakhovich, a doctoral candidate at Caltech, and Richard Schaden, cofounder of Quiznos.

"Right now, we're all privately funded," says Tseliakhovich, but "we are looking for partners in research institutions and academia for 2012."

Tseliakhovich went to Canada from Belarus and now hopes to become a U.S. citizen. As an entrepreneur and scientist, he looked at the state of the technology and concluded that microwaves were the most promising option. He approached Parkin for help.

Tseliakhovich's opinion about microwaves came down to dollars and cents. After examining today's energy sources, the choice of microwaves was a "no brainer," he says. "Lasers require much more subtle and complicated control optics. Microwaves cost at least 100 times less than energy in the laser beam," he explains.

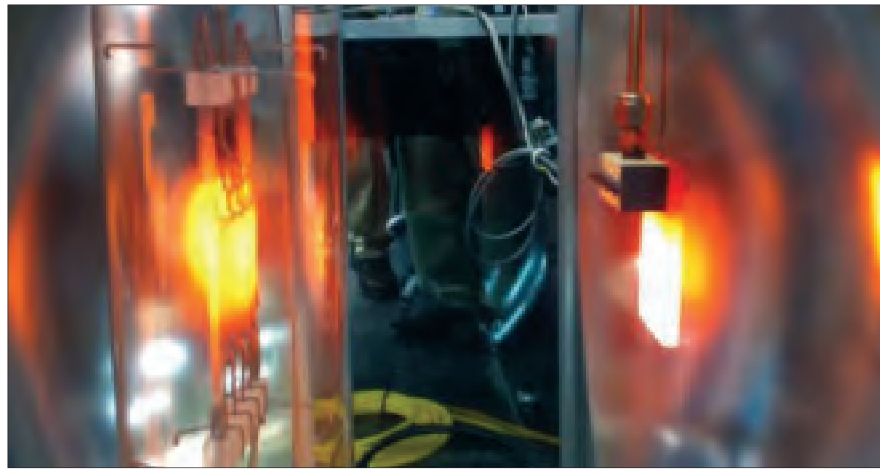
Which is not to say the system will be easy to develop. After years of studying and drafting papers on the physics of microwave thermal propulsion, the alliance knows it must prove the key elements of the system. "We need to show delivery of power from source to heat exchanger, and transferring this energy efficiently enough in the power of the jet," Tseliakhovich explains.

Keep it simple

The alliance's strategy is to remove as many technical challenges as it can from its proposed design. In the first iteration, a rocket would be air-dropped from an altitude of about 20 km to avoid the problem of heating the rocket at liftoff, says Parkin.

Projecting microwaves at low altitude would be difficult, because objects on the ground would reflect the energy. So, for the first stage of the ride to orbit, "We're looking at some sort of variation on Global Hawk or WhiteKnightTwo as a carrier vehicle," says Parkin.

The alliance has not given up on the idea of having a single-stage vehicle someday, but for now the rocket would be dropped into the path of microwaves beamed by about 100 ground-based dishes. These would be focused on the surface of the rocket.



A segment of graphite is heated to 2,000 K by a 20-kW light during a February test at NASA Ames. Later tests will add channels and helium to simulate hydrogen propellant. Photo credit: David Murakami and Kevin Parkin.

Tseliakhovich says the rocket's payload could be protected from the microwaves by a metal Faraday cage—the same technique used to contain microwave energy in a microwave oven. And even with precautions, he has no illusions about launching people or large payloads to space any time soon. "It will take a long time to go from small payloads to human flight—years and years," he says.

Enormous efficiency gains

If the concept works, the efficiency improvements could be enormous. Since the hydrogen would not be heated by combustion, there would be no need to carry liquid oxygen; that should make the microwave rocket more powerful pound-for-pound than a chemical rocket.

"A mix of hydrogen and oxygen is much less efficient than just hydrogen, because of the molecular weight," explains Tseliakhovich.

In conventional rockets, some of the energy released by the chemical reaction is wasted moving the oxygen atoms carried in an oxidizer tank and in the exhaust gas.

Parkin calculates that when hydrogen is burned with oxygen, about 16 MJ of energy are released per kilogram, versus 30-40 MJ for a pure hydrogen system.

On the specific impulse efficiency scale, the best a conventional rocket can do is about 450 sec, a unit that refers to the amount of time a given mass of propellant can produce a certain level of thrust. Calculations show that a pure hydrogen rocket could break 1,000 sec, Murakami says.

Choices ahead

It sounds great, but Parkin, Tseliakhovich, and Murakami acknowledge they are just at the beginning.

"There are two big challenges," Murakami explains by email. "Beaming large amounts of electromagnetic energy to a target many kilometers away, and a heat exchanger system that can transfer that energy to the working fluid."

Conducting a full-up microwave demo involving megawatts of energy will not be easy. So the first task is to find a material that can take the heat, since the hotter the fuel, the higher the pressure, and the faster it will shoot out the nozzle. Murakami is testing graphite, but Tseliakhovich also likes refractory ceramics.

Thermally testing materials is most important, and at this point, Murakami is agnostic about how that heat gets generated. "From the heat transfer and

Carbon fibers can be woven into hollow channels to conform to the curve of a rocket. Photo credit: Kevin Parkin.

fluid mechanics standpoint, the type of radiation you're using to heat it up (microwaves, millimeter waves, lasers, or our 20-kW light bulb) doesn't matter much as long as it gets absorbed and converted into heat," he says. "So we decided to go with the most cost-effective system we could find," which was a light bulb.

For the required thrust, Murakami needs to get the material to about 2,500 K; he has demonstrated 2,000 K so far.

"Success would be, after exploring the options and testing, being able to build (on a small scale) a heat exchanger system that actually produces the impressive values of specific impulse, thrust to weight, etc., that Kevin's analyses say should be possible," Murakami says, referring to Parkin of Carnegie Mellon.

In its strategy of not reaching too far, the microwave alliance is eschewing not just single-stage-to-orbit flight, but also reusable rockets and large payloads.

Parkin initially thought the rocket should have a flat surface to absorb the microwaves. He coauthored a paper proposing to use the lifting body shape of NASA's canceled X-33 single-stage-to-orbit spaceplane.

"We're not using X-33 aeroshell any more," he says emphatically.

He came to that conclusion after looking at materials for the heat exchanger. A flat surface would be unnecessary because of the advent of graphite fibers. "You can weave them into all kinds of strange shapes you never thought were possible. Wrapping it around the tank is no problem. You can do it in a conformal way," Parkin says.

That should help to simplify the aerodynamics. "Once you realize you could wrap the heat exchanger around the tank, there's no reason to go to a kind of aeroshell that requires strange tank configurations or winglets or anything like that," he says.

The latest version of the concept calls for a cylindrical rocket with a fuel tank 3 m in diameter and 6 m long. "That's the target," says Parkin.

Not to be underestimated is the challenge of beaming the microwaves to the rocket. Microwave sources can be ordered, but this would require building a large facility consisting of dishes capable of forming high-power microwave beams. There are microwave sources, "and there are various technologies to create high-powered microwaves. But the two have not yet been combined. So that's where the challenge is on the beam facility side," Parkin says.

If the microwave alliance can overcome these challenges, the payoff could be enormous. Today, when a rocket blasts off toward space, just 2% of its total mass consists of useful payoff, says Tseliakhovich. In theory, 20% of the microwave thermal rocket could consist of payload. The microwave alliance plans to prove it.

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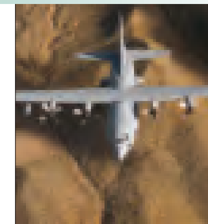

SIGINT: Manned systems still on top

SIGNALS INTELLIGENCE (SIGINT) HAS become the primary focus of electronic warfare today (along with infrared countermeasures systems), and it now garners genuine 'A-list' funding for both UAVs and manned airborne platforms. Because threats are constantly evolving, and detecting IEDs (improvised explosive devices) is so dependent on SIGINT, continuing RDT&E, production, and upgrade funding will be needed. There are several major ongoing manned SIGINT programs, in addition to other, more changeable, UAV efforts.

Four-engine supremacy

The Air Force's primary legacy manned SIGINT program is L-3 Communications' RC-135, with systems mounted on widebody Boeing 707s. Versions include Rivet Joint (about 17 aircraft), Combat Sent (two), and Cobra Ball (three), with development and integration managed by the Air Force Big Safari Systems Group. Some funding is publicly declared, but other funding and most program details are classified.

In February, FY12 upgrade budget plans showed enhanced air surveillance capabilities and antenna improvements for Rivet Joint, and geolocation improvements for Combat Sent and Cobra Ball. The budget plans also showed future EAN 105 antenna integration efforts and software improvements. Additional classified funding in all budget lines should be worth more than $200 million annually. Our funding forecasts are speculative, and include Teal Group's estimate of classified funding.

In March 2010, U.K. defense secretary Bob Ainsworth announced that the U.K. had finalized its agreement to buy three new Rivet Joint aircraft and related ground equipment, in a deal to be worth well over $1 billion. Later that year, the RAF sent 51 Squadron's Nimrod R.1 SIGINT airplanes to Afghanistan, as their last mission before retirement. Then, in October, the U.K. government unveiled a new Strategic Defence and Security Review. Many big-ticket programs were canceled in the punishing budget cuts—including the entire Harrier jumpjet fleet. Retained on schedule, however, were plans for purchasing Rivet Joint, due to enter service after 2014.

Another major USAF program is Compass Call, a suite of ECM (electronic countermeasures) systems designed primarily to disrupt voice and data communications. Although Compass Call has been a fielded, operational capability since 1983, it continues to evolve and adapt to counter constantly changing adversary tactical communications. Most recently, this has been reflected in a shift from countering traditional military communication systems to an increasing emphasis on commercial/civil countermeasures such as those used in Iraq and Afghanistan. A limited radar jamming capability has reportedly been added as well. Compass Call is now mounted aboard 14 EC-130H Hercules aircraft. A 15th reportedly will be added, and the system is expected to remain in service until 2025.

All aircraft were to be upgraded to Block 35 standard by 2008. In February, the Compass Call Baseline 1 (BL1) configuration was being fielded; eight aircraft will receive the BL1 upgrade. The BL2 configuration is projected to begin fielding in the first quarter of FY14; six Compass Call mission aircraft will receive BL2. A new mission equipment baseline is to be defined approximately every 24-36 months, with funding in FY12 planned to support development of BL3 upgrades. BAE Systems in Nashua, New Hampshire, is the primary subsystem developer and integrator, with Raytheon in El Segundo, California, also providing some subsystems. Obsolescence and diminishing manufacturing sources are addressed with each baseline upgrade, and annually as part of sustainment responsibilities.

Judging from the long list of planned Compass Call RDT&E projects—including the digital signal analy-

AIRBORNE SIGINT FUNDING FORECAST

RDT&E+Procurement (FY12 $Millions)

	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	Total
RC-135	214	352	394	413	388	336	280	258	270	259	3,164
Compass Call	110	132	71	102	85	84	70	79	70	66	867
EP-3	154	182	134	110	98	102	90	92	88	80	1,130
ACS/EMARSS	14	44	44	56	96	108	60	18	20	18	478
Guardrail/ARL*	46	34	28	38	36	76	102	49	60	58	527
ASIP	356	413	437	486	471	493	533	558	483	453	4,683
TSP	2	32	40	28	38	48	72	122	162	164	738
Other	117	134	151	164	196	208	223	237	237	243	1,910
Available	465	542	613	695	779	835	882	959	981	1,001	7,751
Total	1,509	1,866	1,911	2,092	2,187	2,290	2,311	2,372	2,370	2,342	21,250

*Not including ASIP.

Members of the 398th Air Expeditionary Group prepare an RC-135 Rivet Joint aircraft for a misson. USAF photo by Tech. Sgt. Robert J. Horstman.

sis and exciter subsystem, or AXE; the SPEAR (special purpose emitter array); the integrated modern communication receiver; the human-to-machine interface; and network-centric operations and phased-array transmit and receive apertures—we believe a large portion of Compass Call funding is also classified. We have broken out an estimate of SIGINT funding, though more than this will be devoted to ECM systems.

The Air Force also funds programs to develop new SIGINT technologies. Under the Compass Bright program, the FY12 budget this February funded projects including auto noise profiling, advanced wideband digital ELINT, cross cueing, spectral search, LPI search and copy, optimum audio extraction, hands-free audio processing, single-aircraft geolocation, and digital wideband pulse receiver. Projects are selected through a data call process whereby the USAF evaluates proposals from the labs and industry to select the most promising projects.

The Navy's primary legacy manned SIGINT program is the EP-3E Aries II. Based on the P-3 Orion platform, it has been in service for more than 30 years. In early 2007, the Navy had 12 EP-3Es operational at any one time, but they were scheduled for retirement from 2014 to 2017. Service life will now be extended, with substantial upgrades, following the 2006 (and later 2010) cancellation of the follow-on ACS/EP-X airborne SIGINT aircraft. Conversion of four more P-3Cs to EP-3Es was completed in 2007, giving the Navy a total of 16 EP-3Es.

Tempest in a teapot: ACS/EMARSS

The aerial common sensor (ACS) program was intended to replace both the ARL (airborne reconnaissance low) and Guardrail for Army SIGINT/SAR/EO/IR surveillance and reconnaissance. The Army envisioned a 38-aircraft procurement, with the entire program worth several billion dollars. The Navy also planned to buy 19-20 ACS aircraft as replacements for its EP-3E Aries II SIGINT planes.

Then, in January 2006, the Army and Navy terminated ACS, after the Embraer ERJ-145 aircraft proved to be too small to carry all the payloads the services required. But scheduled funding continued, with the Army and Navy both analyzing alternatives. The Army planned to restart ACS with a new technology development contract to two companies in late 2009, followed by single-developer EMD slated for the fourth quarter of FY14. This would delay initial operational capability until at least 2016. But in February 2010, the program was reformatted as a less gold-plated system and redesignated the enhanced medium altitude reconnaissance and surveillance system (EMARSS). Perhaps the Army figured two 'ACS' strikes were enough.

Finally, in November 2010, Army

Aries II is assigned to Fleet Air Reconnaissance Squadron One and operates from Kadena Air Base, Okinawa, Japan.

AIRBORNE SIGINT MARKET SHARE
RDT&E+Procurement (FY12 $Millions)

	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	Total
Northrop Grumman	356	413	437	486	471	493	533	558	483	453	4,683
L-3	325	464	449	440	408	371	314	298	304	287	3,661
BAE Systems	102	120	76	103	96	99	90	99	91	91	968
Raytheon	28	33	18	25	21	21	17	20	17	16	217
Other	106	118	132	143	169	184	200	204	207	210	1,673
Available	593	717	799	894	1021	1123	1156	1192	1268	1284	10,048
Total	1,509	1,866	1,911	2,092	2,187	2,290	2,311	2,372	2,370	2,342	21,250

CECOM (Communications-Electronics Command) awarded Boeing Phantom Works in St. Louis, Missouri, an initial $88-million contract toward a $323-million, 42-month EMD program for EMARSS. The $88-million contract includes orders for four EMD aircraft (with an option for two more) plus options for six LRIP (low-rate initial production) planes. About 36 production aircraft are expected eventually.

EMARSS will be based on the Hawker Beechcraft King Air 350ER turboprop, including a crew of four with two operator workstations (for an EO/IR operator and a communications intelligence, or COMINT, specialist). Its mission is to eavesdrop on signal and communications transmissions, and use an EO/IR sensor with full motion video to identify potential targets from standoff range. Endurance will be 5-7 hr at 25,000-ft altitude. Boeing's new Argon ST subsidiary, in Fairfax, Virginia, is expected to develop the SIGINT sensor.

Boeing is new to SIGINT, but used its mid-2010 acquisition of successful COMINT developer Argon ST and late-2008 acquisition of SIGINT manufacturer Digital Receiver Technology to beat off the competition, including Northrop Grumman, Lockheed Martin/Sierra Nevada, and the competition favorite—L-3 Communications, which is producing about 40 similar MC-12 Liberty ISR aircraft as a rapid response acquisition initiative for the Air Force. Raytheon and SAIC also made bids, both but were eliminated earlier in the year-long competition.

The Army hoped for an early operational capability within 18 months of contract award, or around October 2012, with EMD aircraft serving overseas under a forward operational assessment. But in December, EMARSS losers Northrop Grumman, Lockheed Martin/Sierra Nevada, and L-3 Communications filed protests with the Government Accountability Office protesting the Army's award to Boeing, and development work was frozen.

In March 2011, the GAO found missteps in the Army's source selection of Boeing. The Army announced that it "has agreed to reevaluate certain areas of the competition, and following those reevaluations, will make a new award decision in the near future." So, back to square one.

What makes all this much ado about very little, in market terms, is that despite the constant media attention, neither ACS nor EMARSS were planned to match funding of the bigger four-engine manned SIGINT programs such as Rivet Joint. Those have trundled along doing their jobs—and earning hundreds of millions of dollars of funding—since before ACS began. The Army's new EMARSS plan, whenever it goes ahead, is now a shrunken program even in relation to ACS, and Guardrail and ARL will continue as the Army's primary (and more effective) SIGINT platforms.

Guardrail and ARL

The AN/USD-9(V) Guardrail is still the Army's primary airborne SIGINT platform, carried on Hawker Beechcraft RC-12s. The principal version now in service is the USD-9B Guardrail/Common Sensor (GRCS), which added an ELINT (electromagnetic intelligence) capability to the earlier COMINT function. Production of new Guardrail aircraft ended in 2000, but the GRCS has seen a number of system upgrades and improvements. More than 50 aircraft have been built, and about 45 remain in service.

In September 2007, following the first cancellation of ACS aircraft, the Army announced the Guardrail modernization system integration program to upgrade 33 Guardrail aircraft (29 operational, four training) to a new RC-12X standard, with a potential value of $462 million over five years. Initial deliveries for testing occurred in 2010. The primary new sensor for

An Army RC-12 taxis down the runway at Balad Air Base. USAF photo by Airman First Class Andrew Oquendo.

the RC-12X is Northrop Grumman's ASIP (airborne signals intelligence payload) enhanced situational awareness (ESA) system.

In November 2010, due to (unwarranted) optimism about EMARSS, Army funding was shifted back from Guardrail, and the GRCS modernization program (ASIP ESA) was to end after the completion of 14 systems, versus the original plan to complete 33 systems. The Army announced, "This change is to assist the funding, force structure, and manning for the EMARSS program, without losing necessary capability to the force."

In January of this year, the first two ASIP-upgraded RC-12X Guardrail aircraft left Northrop Grumman's Sacramento, California, facility, deploying to Asia. Despite their deployment, an initial four systems were set to complete outfitting and testing during the first quarter of FY11 before receiving a 'fully operational' designation. An additional 10 RC-12Xs are to be fielded in 2011-2012.

The Army's ARL is also a militarized commercial aircraft, based on the De Havilland DHC-7. ARL came in two configurations, the ARL-C COMINT version, with a complete COMINT sensor package, and the ARL-M (multi-INT), which combines COMINT with synthetic aperture radar and EO/IR imagery capabilities. In total, there are eight DHC-7/ARL aircraft in service.

In February, Army procurement plans included nearly $300 million for ARL-M 'payload migration' in FY15 and FY16. The ARL modernization program will standardize payload systems, upgrading the COMINT subsystem for improved irregular warfare tactical collection and geolocation.

Unmanned future: ASIP and TSP

The Air Force's primary future UAV SIGINT program is Northrop Grumman's ASIP. Development of a pod-mounted ASIP began in 2003, for the U-2 Dragon Lady and Global Hawk. By August 2007, Global Hawk was to be the primary platform, and the USAF also planned to equip all Predator and Predator-B UAVs with the wiring necessary to receive the ASIP 1C (MQ-1 Predator—one electronics 'box') or 2C (MQ-9 Predator-B—two 'boxes'), beginning with UAVs leaving the production line in 2010. The Army's manned Guardrail aircraft will also get a version of ASIP for the RC-12X upgrade.

The Global Hawk Block 30 carries the ASIP, which will increase battlefield signal collection capabilities. The 452nd Flight Test Squadron began developmental flight tests on the aircraft earlier this year. Photo by Senior Airman Julius Delos Reyes.

Early this year the 452nd Flight Test Squadron began developmental flight tests on the first ASIP-equipped Block 30 Global Hawk aircraft.

In October 2009 the ASIP 1C for the smaller Predator was canceled, but in November 2010 the Air Force awarded Northrop Grumman a $23-million contract to design and build a pod-mounted ASIP-2C prototype for Reaper, along with a $5-million contract modification to support a limited flight demonstration.

For Army UAVs, a sources-sought solicitation was released in October 2010 to identify companies for TSP (tactical SIGINT payload) EMD and production, for a podded system for Grey Eagle (Predator) UAVs. The TSP cannot exceed 200 lb and 3 ft^3 in size, nor require more than 1,200 W of power. In February of this year, the Army released a draft RFP for an 18-month EMD contract to procure three production-representative systems for testing aboard RC-12 manned aircraft, with options for up to 97 full-rate production systems.

Our forecast is for the TSP competition to choose either a version of the ASIP or BAE Systems' earlier 'TSP' development. In either case, the winner stands a good chance of eventually seeing high-volume production, perhaps greater than ASIP, as the Grey Eagle program is just beginning. TSP will likely be offered for subsequent endurance and tactical UAV competitions, as we speculatively forecast.

Northrop and L-3 to lead

L-3 Communications and Northrop Grumman should stay firmly atop the airborne SIGINT market, because of L-3's control of large manned SIGINT aircraft such as the RC-135 and Northrop's dominance of future UAV systems with its modular, multiplatform ASIP. BAE Systems had previously been expected to maintain a strong presence with its TSP and other systems, but has had trouble bringing programs to production.

Aside from these firms and some work by Raytheon, nearly half of the future SIGINT market is still up for grabs, though the big players will undoubtedly earn a share of our 'available' forecast. Expect more opportunities for subcontractors in this processor- and software-driven market.

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PART THREE

Flying farther on less

Escalating jet fuel prices are bringing fresh interest in NASA-led research into technologies that promise to reduce the amount of fuel needed to fly an airliner from gate to gate. Whether conservation comes through increasing jet engine efficiency, minimizing drag on the aircraft, or using lighter materials for the airframe, NASA's aeronautical innovators are considering many options.

Their goal is to develop technology that would enable airplanes to burn only half as much fuel by 2020 and at least 70% less by 2025, compared to one of today's most fuel-efficient aircraft, a Boeing 777 with GE 90 engines. Such significant fuel savings are one of three ambitious goals of NASA's green aviation technology research.

Researchers are testing a wind tunnel model with specially designed wings in NASA Langley's National Transonic Facility. They are trying to see if they can test for natural laminar flow on an airliner wing at flight conditions in a wind tunnel. Credit: NASA/Sean Smith.

by Jim Banke
Public Affairs writer,
NASA Headquarters;
President, MILA Solutions,
a NASA subcontractor

The others are to minimize harmful emissions and attenuate noise. NASA expects to see simultaneous improvements in airplanes entering service in 2025 or later.

Realizing these outcomes is challenging, because they are not necessarily complementary. For example, fuel saving technologies should have a direct positive effect on emissions, because the less fuel an airplane burns, the less carbon dioxide, sulfur, and soot it releases. But one means of increasing energy efficiency—burning fuel at hotter temperatures in the engine—actually produces higher concentrations of nitrogen oxides, which degrade local air quality.

NASA is working to understand the physics behind these trades so it can develop methods for increasing fuel efficiency and decreasing emissions simultaneously, which would reduce carbon and emissions footprints and improve local air quality. While the environmental benefits remain a driver, the economic benefits of burning less fuel become more important with each increase in the price of petroleum.

"Fuel is a big part of the cost for an airline, and the price is not something they have much control over," says NASA Langley's Rich Wahls, project scientist for the agency's Subsonic Fixed Wing Project.

There are concerns that prices will return to record levels not seen since 2008. According to the DOT's Bureau of Transportation Statistics, in March of this year (the latest available data), jet fuel averaged $2.79 per gallon, $0.55 more than the annual average of $2.24 in 2010. At that rate, commercial carriers spent $38.8 billion on the 17.2 billion gallons of fuel they burned last year. The highest price on record was $3.83 per gallon in July 2008.

Although there are practices that save fuel now, the technical innovations that NASA and its partners are studying promise the greatest increases in fuel efficiency during the next few decades.

The power and the glory

Engine designers can approach the problem of reducing fuel consumption by improving either propulsive efficiency or thermal efficiency. Propulsive efficiency usually is enhanced by slowing the speed and increasing the mass of air moving through the engine. Thermal efficiency, how the energy in the fuel is converted into power, usually is enhanced by increasing the pressure of air entering the combustor, running the combustor at a hotter temperature, or using less air to cool the turbine.

The bypass ratio—the proportional relationship between the amounts of air moving either past the engine core or into it—is the key to improving propulsive efficiency. In a modern jet, a fan housed inside a nacelle draws air into the engine. Some air flows into the engine core and gets compressed, mixed with fuel, and burned. The resulting hot gas, which passes over turbines that provide mechanical energy to spin the fan blades and generate electricity for the plane, is then expelled out of the back of the engine. The higher the bypass ratio, the greater the amount of air that moves past the engine core, and the slower the speed of the exhaust. This all means, in theory, that less fuel is being consumed, because making a lot of air move slowly takes less work than making a smaller amount of air move fast.

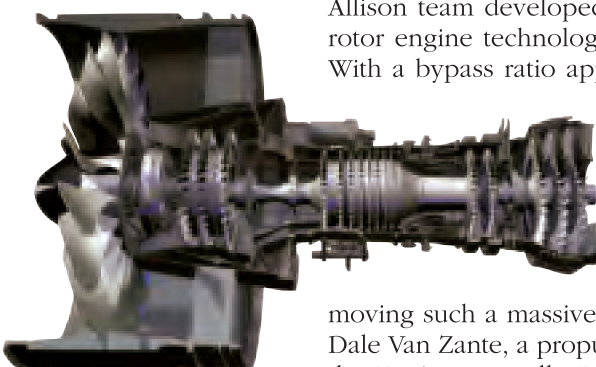
Ideally, a jet engine with an open rotor, characterized by fan blades so big that a nacelle becomes impractical, offers the greatest improvements in propulsion efficiency. But the associated noise and structural issues have made open rotors impractical.

The open rotor concept is problematic for three reasons. First, because the giant blades are not shielded inside a nacelle,

After more than a century of flight, it might seem that advances in aerodynamics have reached their practical limits. But researchers at NASA believe ambitious goals in areas such as reducing fuel consumption may still be achieved in tandem with limiting noise and pollution effects. From exotic new materials to greener manufacturing methods, intensified efforts are leading NASA into some futuristic technologies.

they are very noisy and would disturb people both inside the aircraft and on the ground. Also, the large open rotor systems envisioned, with blade lengths approaching 14 ft, will not fit any existing aircraft; a new vehicle must be designed to accommodate them. Finally, because of their propeller-like appearance, open rotors have been slow to gain the flying public's acceptance.

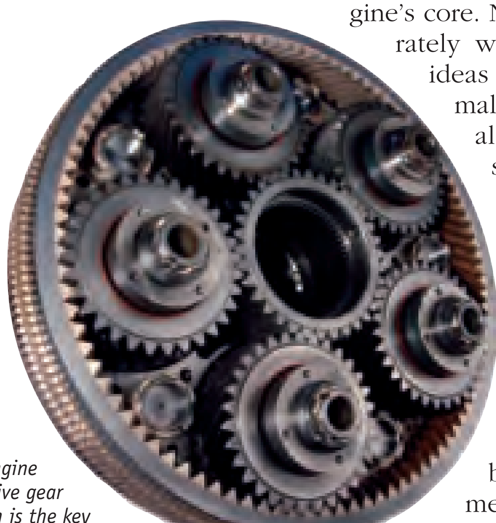
This cut-away view shows the Pratt & Whitney PW1000G PurePower engine. Image credit: Pratt & Whitney.



General Electric and a Pratt & Whitney/Allison team developed and studied open rotor engine technology in the late 1980s. With a bypass ratio approaching 30, open rotors proved that they could beat the fuel burn efficiency of other engines 'hands down,' because the blades were moving such a massive amount of air, says Dale Van Zante, a propulsion engineer with the Environmentally Responsible Aviation (ERA) Project at NASA Glenn. Recently, NASA and GE revived the investigation of open rotors with the aim of improving their practicality.

Thermal efficiency efforts

For researchers seeking to improve thermal efficiency, all the action is in the jet engine's core. NASA is working separately with GE and P&W on ideas that address the thermal efficiency of engines already in use or envisioned for the future.



The engine fan drive gear system is the key component that makes it possible for the P&W geared turbofan engine to work and thus to increase the engine's fuel efficiency. Image credit: Pratt & Whitney.

With GE, NASA is attempting to dramatically increase the pressure of air that passes through an engine compressor, but without adding too many rows of compressor blades. More blades mean a longer and thus larger engine, and can induce unwanted vibrations. The work is under way at the High Speed Multistage Compressor Facility at Glenn.

"The challenge we face with this idea is that the flow characteristics of the air moving through the core become difficult to manage at this higher aerodynamic loading. You have transonic flow with shock waves, and there is a tendency for the flow to separate from the compressor blades, which can result in loss of aerodynamic efficiency and potential compressor stall," says Jim Heidmann, chief of the Turbomachinery and Heat Transfer Branch at Glenn.

The potential short-term solution is the use of better 3D design tools; the long-term solution is using flow control in the compressor using suction and directed air to help keep the air moving through the engine as it is designed to do, Heidmann says.

One concept that addresses both propulsive and thermal efficiency is the geared turbofan, which NASA has teamed with Pratt & Whitney to investigate. In most turbofan engines a shaft connects the fan directly to the low-pressure turbine, which is part of the core engine. The fan turns at the same speed as the turbine. Slowing the fan speed, which has noise and propulsive efficiency benefits, requires an increase in the size of the turbine, because the turbine is most efficient at higher speeds. In the geared turbofan, a gearbox connects the fan to the turbine. The gearbox enables the turbine in the core engine to run efficiently at high speed while the fan runs efficiently and quietly at low speed.

This change in configuration enables an increase in fan diameter without increasing core engine size, so the bypass ratio increases. The higher bypass number allows for improvements in propulsion efficiency. At the same time, changes in design within the core allow it to burn the fuel at higher pressures and temperatures, improving the thermal efficiency. These characteristics and their contribution to improving overall fuel burn efficiency, along with the noise benefit offered by slower fan speeds and nacelle, are what excite researchers about the technology.

"This is a revolutionary technology," says Chris Hughes, manager of the ultrahigh bypass engine technology research at Glenn for ERA. "The question is, how far can we push the technology and grow it to fit an entire range of aircraft?"

Although the geared turbofan provides slightly less overall propulsion efficiency than an open rotor, it is much quieter. The thermal efficiency challenge in the core engine of an open rotor system is similar, if not identical, to that of a ducted propulsion system with a nacelle, so the developments in core engine technology benefit both ducted and open systems.

Going with the flow

Another way to improve fuel efficiency is to

A NASA experiment will be flown on this jet to test improving laminar flow over an aircraft wing. The marked area on the left wing shows the area where an experimental glove will be located. Image credit: NASA/Tony Landis.

reduce drag. The less drag, the less thrust engines must generate to maintain the aircraft at a given speed and altitude, so the less fuel they burn. The two major sources of drag confronting aircraft designers are skin friction—how smoothly air passes over the vehicle surface—and induced drag caused by the finite wingspan. NASA is focused on finding practical solutions to reduce skin friction drag. One approach is to control turbulent air near the surface of the aircraft; another is to reduce the size of aircraft surfaces.

No matter how aerodynamically smooth the surface of an aircraft is, after only a couple of flights the wing leading edge and cockpit windshield will be spattered with insects and debris that can trigger turbulent flow and increase drag. NASA researchers are working to quantify what they call the 'knock-down' factor—just how detrimental the insect accumulation can be to laminar flow in an operational environment.

"One of our goals is to find a way to treat the leading-edge surface with a coating, or some kind of surface modification that is self-cleaning, so that dirt doesn't accumulate very fast on it, insects also don't accumulate very fast, or the insect residue is reduced," says Langley's Tony Washburn, chief technologist for ERA.

Washburn says researchers have tried several commercially available products and have formulated new compounds with the desired nonstick properties.

System studies typically show that a 6-10% reduction in overall aircraft drag is possible with laminar flow technology, depending on the configuration and mission profile. The coatings work is intended to improve the odds for maintaining a high rate of return from laminar flow in an operational environment.

While one group looks at coatings, another is looking at what aerodynamic enhancements are possible when roughness is applied judiciously to a wing. NASA, with contractor Texas A&M University, plans a series of test flights in late 2012 or early 2013 with a Gulfstream III business jet. A portion of one aircraft wing will be fitted with a glove—a test article designed to demonstrate a relatively new idea for enabling laminar flow on commercial airliners.

This computer simulation shows what the wing glove looks like and how it will be placed on the testbed aircraft. Image credit: NASA/Ethan Baumann.

The leading edge of the glove is covered with microscopic bumps known as discrete roughness elements, which are 6-12 µm in height (about the thickness of plastic wrap) and spaced about 4 mm apart. Flight tests will determine whether such roughness elements can maintain laminar flow over a 6-ft section of wing. It seems counterintuitive, but without discretely spaced roughness elements, air flowing over a swept wing tends to develop small vortices that grow in intensity until the airflow over the wing is fully turbulent. This increases drag and reduces fuel efficiency. Vortices created by the roughness prevent the naturally occurring vortices from growing and destroying the laminar flow, thus reducing skin friction.

Wind tunnel tests have shown this approach to laminar flow works at laboratory conditions. The question is whether it works in the thinner boundary layers experienced in flight.

Another means of minimizing drag may be to make airplanes with smaller vertical tails. NASA and Boeing are pooling resources to investigate active flow control, which is a way to shrink the tails and still maintain control of the airplane during critical flight phases such as takeoff.

Designers think pulsing air along the rudder hinge line is one way to give the airplane full control over its yaw, even with an engine out and the tail smaller. The concept involves a series of small jets placed along the rudder hinge line. The jets would make the air better follow the contour of the rudder, causing the rudder to generate more force than it otherwise could. This allows for a smaller tail, with less surface area to create drag when the airplane is cruising. Recent wind tunnel tests indicate that it is possible to achieve a 40% improvement in the force created by the rudder.

The electron beam free form fabrication process was used to make this sample titanium part. NASA innovators are working on scaling up the process to build larger components. Image credit: NASA.

Weighty structural advances

The heavier an aircraft is, the more fuel it will need to get off the ground and stay aloft. One key to fuel efficiency is new materials that are as strong as anything used today but can do the same structural job with much less mass.

Electron beam free form fabrication, EBF^3, technology uses an electron beam, a computer, a moving base inside a vacuum chamber, and wire to create structures one layer at a time. Having progressed for several years, the technology is becoming available commercially, but its applications in aviation and in space are still being researched.

"You start with a CAD model of the part you want to build, you push a button, and out comes the part," explains Karen Taminger at Langley, the EBF^3 technology lead in the Fundamental Aeronautics Program.

Normally an aircraft builder might start with a 6,000-lb block of titanium and machine it down to a 300-lb part, using many gallons of cutting fluid in the process and leaving 5,700 lb of material to recycle. "With EBF^3 you can build up the same part using only 350 lb of titanium and machine away just 50 lb to get the part into its final configuration," says Taminger. "Because the part is built up layer by layer," she adds, "you also have flexibility in engineering the materials and shapes of the stiffeners to tailor the resulting structure, resulting in something that cannot be built with conventional manufacturing practices."

The weight savings comes through the freedom the EBF^3 process allows: to use less material while manufacturing parts that are more structurally efficient, meaning they weigh less and still meet or exceed the necessary strength and safety requirements.

Another weight-savings possibility is nanotubes, in theory 100 times stronger than steel. "These tubes are not just strong, they also are highly conductive," says Mia Siochi, a research scientist with NASA's Subsonic Fixed Wing and ERA projects. Could they be the next generation of aircraft structural composites?

"The promise of having it multiple times stronger than carbon fiber is not yet realized, [but] we're working on that," says Siochi. She adds that researchers are starting small, through nanoscale modeling of materials and research into the manufacturing of nanotubes, and are trying to make increasingly larger structures. It could take another 15-20 years for the technology to be ready for use on commercial airliners, either as large structures such as wings, or even as wiring for power within an airliner.

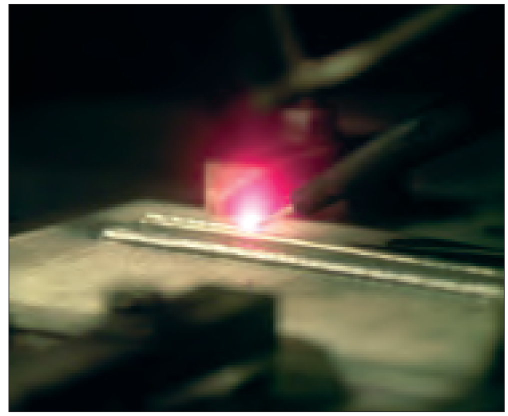
Another candidate technology for building large, lightweight structures for future aircraft is pultruded rod stitched efficient unitized structure, or PRSEUS. Layers of carbon-fiber composite materials are stitched together with a special thread to give the layers structural integrity. Once the stitching is done, the carbon fiber is infused with epoxy resin under vacuum pressure to pull the resin through, and then placed into an oven to bake.

Unlike using traditional composite fabrication techniques, making PRSEUS does not require the high pressure of an autoclave, so the material costs less to process. The stitching arrests damage and keeps a small puncture or crack from growing out of control. The key is that with stitching, one can achieve the fail-safe design load limits of metals, but with lighter weight. Carbon-epoxy systems are about half as dense as aluminum, so the resulting structure weighs less.

"We're trying to develop technology to make aircraft lighter, and we're doing that by looking at new ways to put together composite structures where they are lighter than metals and get rid of all those fasteners, all those rivets," says Langley's Dawn Jegley, PRSEUS lead for ERA.

The way ahead

Overcoming the many technical challenges of reducing the aviation industry's thirst for fuel while also meeting air traffic growth expected during the next few decades will keep NASA and its research partners busy for the foreseeable future. What is clear is that there is no single solution to the problem; boosting fuel efficiency will require a host of innovative ideas and in-depth efforts on multiple fronts.



An electron beam free form fabrication is shown at work laying down a metal part one layer at a time. The EBF^3 process allows for more intricate components to be manufactured using smaller amounts of raw materials than conventional methods use. Image credit: NASA.

Editor's note: *This is the third of four features describing the challenges associated with trying to invent a truly 'green' airplane. The first feature (March 2011) covered research into reducing nuisance noise around airports. The second (May 2011) concerned efforts in lowering aircraft emissions and improving air quality. The final feature will examine the nation's air traffic management system to find means to handle aircraft in a more environmentally responsible manner.* ▲

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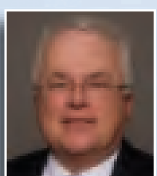

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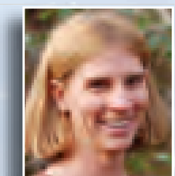
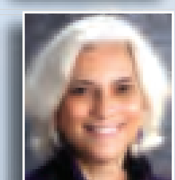


Christy Garvin
Vaughan Elementary School
Powder Springs, Georgia



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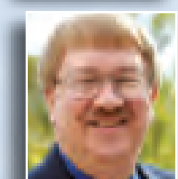
Merion Elementary School
Merion, Pennsylvania



Roger Kassebaum
Milken Community High School
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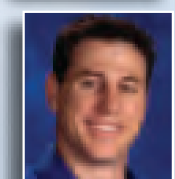

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Meadows Elementary School
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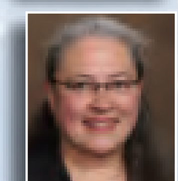
Linwood Holton Governor's School
Abington, Virginia



Jill Guisberg Wall
Farnsworth Aerospace PK–8 Magnet School
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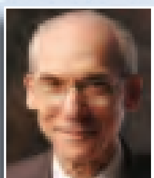

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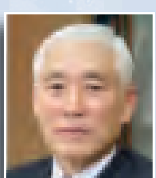
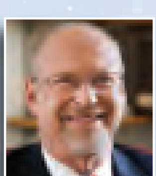
Smithsonian National Air and Space Museum
Washington, D.C.



AIAA Plasmadynamics and Lasers Award
Chul Park
Professor, Department of Aerospace Engineering
KAIST
Daejeon, South Korea

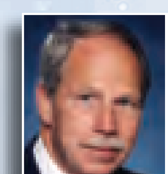
AIAA Public Service Award
Richard R. John
Director Emeritus
Volpe National Transportation Systems Center
Cambridge, Massachusetts



AIAA Reed Aeronautics Award
David A. Peters
McDonnell Douglas Professor of Engineering
Department of Mechanical Engineering and Materials Science
Washington University
St. Louis, Missouri

AIAA Theodor Knacke Aerodynamic Decelerator Award
Edwin Vickery
Consultant
Vice President Engineering (Retired)
Irvin Aerospace Inc.
Santa Ana, California

AIAA Thermophysics Award
Ramesh K. Agarwal
William Palm Professor of Engineering
Department of Mechanical Engineering and Materials Science
Washington University
St. Louis, Missouri



Daniel Guggenheim Medal
(Sponsored by AIAA, AHS, ASME, and SAE)
Robert H. Liebeck
Senior Technical Fellow
The Boeing Company
Huntington Beach, California

Walter J. and Angeline H. Crichlow Trust Prize
Chin-Teh (C. T.) Sun
Neil Armstrong Distinguished Professor of Aeronautics and Astronautics
Purdue University
West Lafayette, Indiana

AIAA

Thank You Nominators!

AIAA appreciates your time and effort in preparing the nomination package!

Rodney Bowersox
Charles Elachi
Feri Farassat
Sivaram Gogineni
Bruce Holmes
John Lineberry
R. Byron Pipes
J. David Powell
Donald Richardson
Steve Trejo
Kenrick Waithe

11-0505

Like its namesake, a goddess who peered through the clouds to discover the truth about the god Jupiter, NASA's Juno spacecraft will seek to answer burning questions about our solar system's largest planet. The probe will gather data that may rewrite the history not just of Jupiter and its formation but of the solar system itself, including our own planet.

Juno to Jupiter

by Leonard David
Contributing writer

A spacecraft mission to massive Jupiter promises unique insight into the planet's origins, structure, atmosphere, and magnetosphere. But it could also yield findings on the development of our solar system, including the Earth itself.

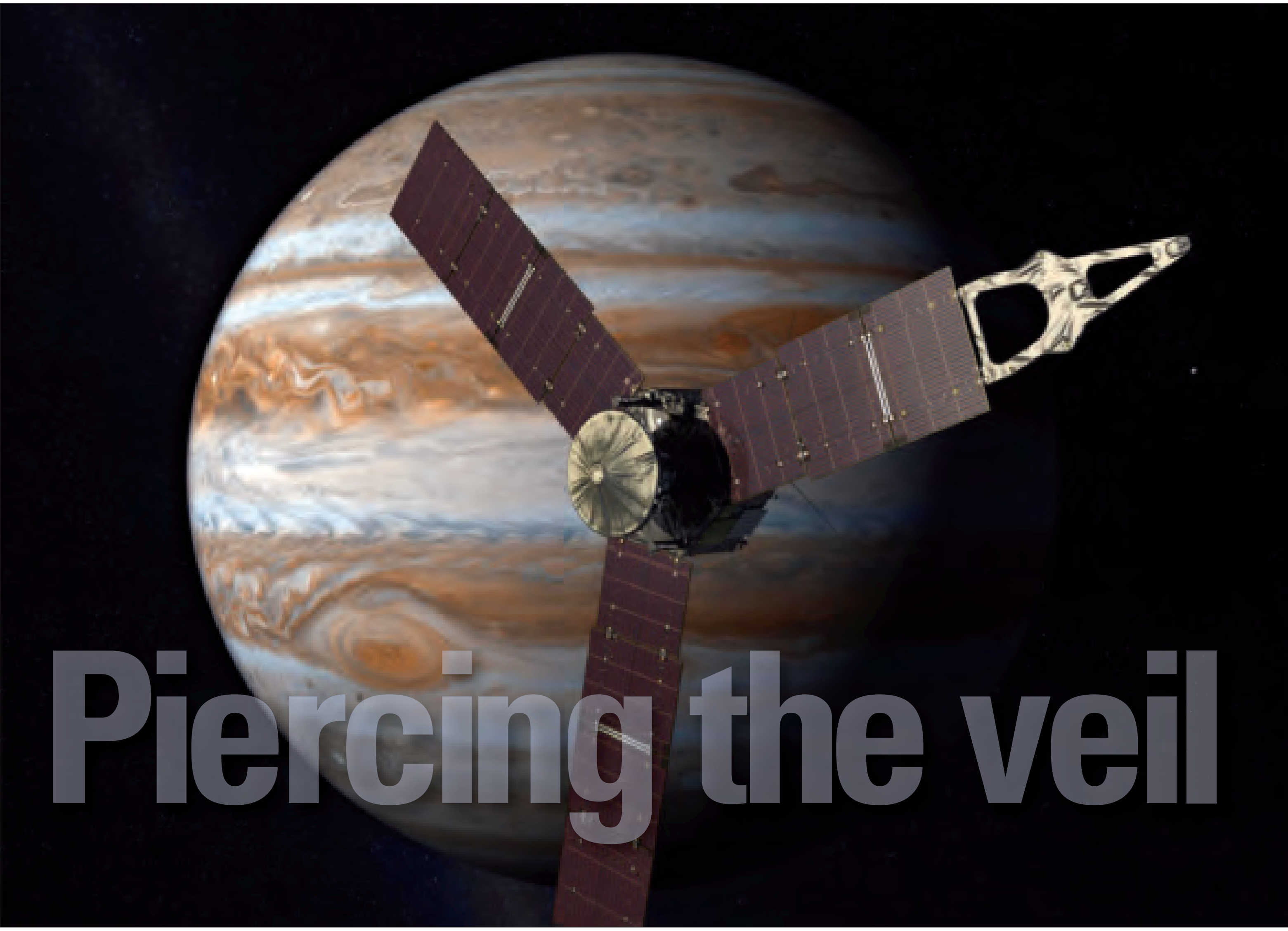
NASA's solar-powered Juno spacecraft, now ready for an early August sendoff to the giant planet, is built to endure hardware-crippling radiation and brutal thermal conditions. With an orbit five times farther from the Sun than Earth's, Jupiter receives 25 times less sunlight than does our planet.

Juno has a trio of solar wings that give it an overall span of more than 20 m. Its modern solar cells are 50% more efficient and radiation tolerant than the silicon versions that were available for space missions 20 years ago. Spin stabilization will keep the probe pointed toward the Sun, with no need for active control.

Early in the design process, radiation was flagged as one of the top risks to the spacecraft. Juno will avoid Jupiter's highest radiation regions by approaching over the north, dropping to an altitude below the radiation belts, and then exiting over the south. The probe's 11-day elliptical orbit drops under the belts to within 3,000 mi. of Jupiter—closer than any previous spacecraft. Vital to Juno's operation is the placement of sensitive electronics within the first radiation-shielded 'electronics vault'—a titanium chamber whose thickness is optimized for maximum protection.

Juno is the second spacecraft designed under NASA's New Frontiers program, fol-

Piercing the veil



Juno will explore Jupiter starting in 2016 from an elliptical, polar orbit. Image credit: NASA/JPL.

lowing Pluto New Horizons, a probe now en route to a 2015 flyby of Pluto and its moon Charon. JPL in Pasadena, California, manages Juno's mission; the spacecraft was built by Lockheed Martin Space Systems.

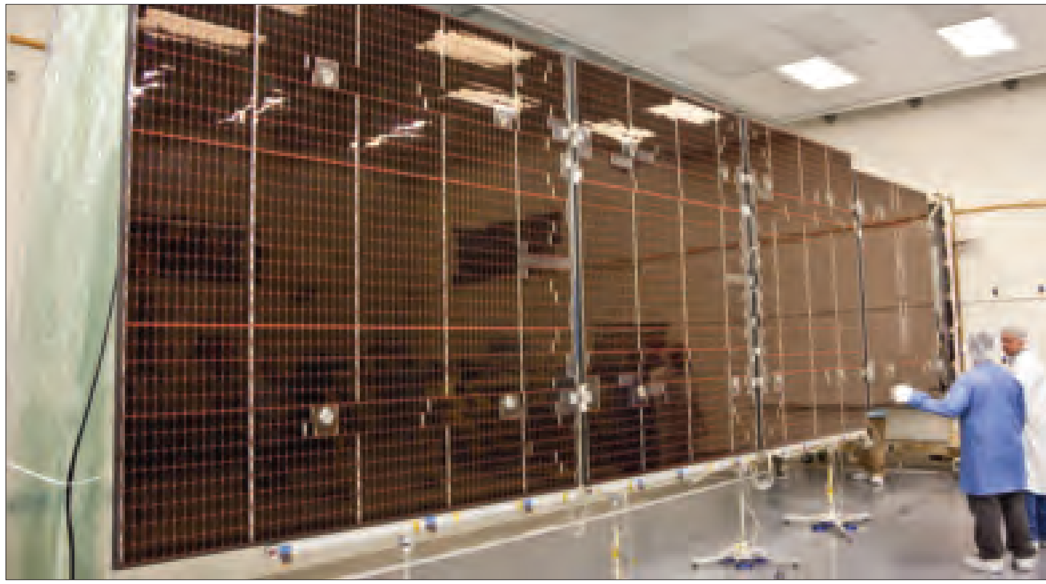
A United Launch Alliance Atlas V will hurl Juno into space from Launch Complex-41 at Cape Canaveral AFS in Florida. The launch window opens August 5 and extends through August 26.

Farthest solar-powered journey

Anyone who visited Lockheed Martin Space Systems while Juno was under construction could see that its elaborate design presented many challenges, particularly given the harsh conditions at Jupiter. The planet has a deadly radiation environment, along with an abundance of charged particles that also charge up the spacecraft. These conditions are much more relentless than those faced by Mars probes, says Tim Gasparrini, Lockheed Martin program manager for Juno. Thanks to the shuttle-launched Galileo spacecraft, which orbited Jupiter from December 1995 to September 2003, "the team has been able to leverage a lot of the experience gained about Jupiter as a place," Gasparrini tells *Aerospace America.*

The electronics of the nuclear-powered Galileo were shielded by special components designed to be radiation resistant. Its mission to Jupiter did not need to survive the harshest radiation regions where Juno will operate.

Without plutonium-fueled radioisotope thermoelectric generators, Juno features some 50 m^2 of solar arrays, meaning it will



Technicians test the deployment of one of the three massive solar arrays that will power NASA's Juno spacecraft. Image credit: NASA/JPL-Caltech/Lockheed Martin.

travel farther than any solar-powered spacecraft ever built, Gasparrini notes. Solar array fabrication was not easy, but the problems encountered early on were eventually solved. "We cherry-picked the solar cells…using thicker cover glasses than you might normally have. On the back of the arrays, there's a patchwork of conductive Kapton to dissipate charged particles."

Juno is equipped with 25 sensors and nine experiments. "So that's a lot of fields of view, and lots of things that you have to keep happy. Everybody wants to look a certain way and do a certain thing and operate at a certain time. And you want to make sure that the interplay of the instruments with the spacecraft isn't taken as science by one of the instruments," he adds.

Vaulting to an outer planet

The radiation belts are shaped like a huge doughnut around the planet's equatorial region and extend out past one of the many Jovian moons, Europa, about 650,000 km beyond the top of Jupiter's clouds.

Gasparrini says Juno's special radiation vault was an early idea. "You had two choices: Either shield the hardware from the radiation, or try and design the hardware to survive the radiation. Trying to go through a design process to screen all those parts to Jupiter's environment was judged

Inside a clean room, technicians installed a special radiation vault onto Juno's propulsion module. The vault has titanium walls to protect the spacecraft's electronic brain and heart from Jupiter's harsh radiation environment. The vault will dramatically slow the aging effect radiation has on the electronics for the duration of the mission. Image credit: NASA/JPL-Caltech/LMSS.

to be much more expensive and invasive into the hardware design," he says.

After lead turned out to be a poor structural metal for the vault, tantalum face sheets with honeycomb were assessed. Tantalum is a rare, hard, blue-gray, lustrous transition metal that is highly resistant to corrosion. It is one of the refractory group of metals widely used as minor components in alloys. While a tantalum sandwich structure offered a lightweight solution for radiation shielding, construction of the vault using the material proved more complicated than machining a piece of titanium.

The vault is not designed to foil every Jovian electron, ion, or proton from striking the system. Rather, it will significantly slow the radiation's aging effects on the electronics for the duration of Juno's explorations.

"For the 15 months Juno orbits Jupiter, the spacecraft will have to withstand the equivalent of more than 100 million dental X-rays," says Bill McAlpine, Juno's radiation control manager at JPL. "In the same way human beings need to protect their organs during an X-ray exam, we have to protect Juno's brain and heart."

The titanium vault is a centralized electronics hub. Parts of Juno's electronics were made from tantalum or tungsten, another radiation-resistant metal. Some assemblies also have their own minivaults for protection. "Virtually all of the spacecraft and instrument avionics are inside the vault," says Gasparrini. Each titanium wall of the vault measures nearly 1 m^2 in area, about 1 cm in thickness, and 18 kg in mass. The vault itself is roughly the size of an SUV's trunk and contains the command and data-handling box, the power and data distribution unit, and some 20 other electronic assemblies. The entire vault weighs about 200 kg.

"Juno is basically an armored tank going to Jupiter," says Scott Bolton, the project's principal investigator, based at Southwest Research Institute (SwRI) in San Antonio, Texas. "Without its protective shield, or radiation vault, Juno's brain would get fried on the very first pass near Jupiter."

Gasparrini says Juno receives roughly half its radiation dose in the first 24-26 orbits of Jupiter. The other half comes during the last eight orbits.

Boa constrictor-like cabling

A close-up look at Juno during its cleanroom assembly reveals a myriad of boa constrictor-like cabling and wiring harnesses that snake in, around, and throughout Juno. Those harnesses are specially treated with copper overwrap, which provides enough radiation shielding that the wires will survive the environment. But all that adds weight, explains Jack Farmerie, Lockheed Martin's lead spacecraft technician on the Juno project.

Farmerie says Juno is a complicated vehicle, not just because of the radiation safeguards but also because it carries so many science instruments. "You have to jam as much as possible, things that typically we would spread out over a whole spacecraft, into the small area of the vault," he tells *Aerospace America*. "Anything we could fit inside the vault, we did. It was definitely the toughest wiring job I've had so far. A huge degree of difficulty."

While there are 'out of the box' items that dot Juno's structure, they have their own built-in shielding. Germanium-coated blankets and conductive Kapton film wraps help offset whatever Jupiter spits at the spacecraft.

Science focus

In October 2013 Juno is to carry out an Earth flyby gravity assist, followed by arrival at Jupiter in July 2016. The 7,992-lb spacecraft carries more than 4,400 lb of propellant for the five-year voyage.

Juno's three large solar panels will be folded into four-hinged segments for launch. Once extended, they will soak up sunlight continuously throughout the mission, except for a few minutes during the

The Juno payload

Juno carries nine instrument suites comprising 26 separate sensors. The Italian Space Agency is contributing an infrared spectrometer instrument and a portion of the radio science experiment.

Gravity science: *X- and Ka-band Doppler gravity measurements will map Jupiter's interior structure (JPL).*

Magnetometer: *Fluxgate magnetometers guided by advanced stellar cameras map Jupiter's interior structure and magnetic dynamo (NASA Goddard and Danish Technical University).*

Microwave radiometer: *Multiple antennas map Jupiter's microwave brightness for deep atmosphere sounding and composition (JPL).*

Jupiter energetic-particle detector instrument: *Particle detectors map electron energy and ion energy/composition over both polar regions (APL/Johns Hopkins University).*

Jovian auroral distributions experiment: *Electron and ion detectors map electron energy and ion energy/composition over both polar regions (Southwest Research Institute).*

Electric and magnetic antennas: *These measure radio and plasma waves in Jupiter's polar magnetosphere (University of Iowa).*

Ultraviolet spectrometer: *This device characterizes spatial, spectral, and temporal auroral structure (Southwest Research Institute).*

Jupiter infrared auroral mapper: *An infrared camera will observe the auroral structure, troposphere structure, and atmospheric sounding (SolexGalileo).*

Junocam: *An education and public outreach visible-light camera provides the first pictures of Jupiter's poles (Malin Space Science Systems).*

Earth flyby. Each solar panel measures 2.6 x 9 m. End to end, the spacecraft and panels cover a circle about 20 m in diameter. Once in orbit at the giant planet, the three arrays will provide about 450 W of electricity. The high-gain antenna is attached to the center of Juno's main hexagonal body.

As a spinning spacecraft, at Jupiter Juno sweeps its instruments' fields of view through space once for each rotation. At three rotations a minute, the fields of view move across Jupiter about 400 times in the 2 hr it takes to fly from pole to pole.

Juno will orbit the immense planet 33 times. To meet planetary protection requirements, specifically to avoid running into any biologically promising Jovian moon, the spacecraft will purposely be aimed to crash into Jupiter in October 2017.

Juno's scientific agenda focuses on four themes:

- Origins: Determine the ratio of oxygen to hydrogen, a clue to the abundance of water on Jupiter. Obtain a better estimate of Jupiter's core mass.
- Interior: Precisely map Jupiter's gravitational and magnetic fields to assess the distribution of mass in its interior, including properties of the planet's structure and dynamics.
- Atmosphere: Map the variation in atmospheric composition, temperature structure, cloud opacity, and dynamics, to depths far greater than 100 bars at all latitudes.
- Magnetosphere: Characterize and explore the 3D structure of Jupiter's polar magnetosphere and its auroras.

Technicians at the Astrotech payload processing facility in Titusville, Florida, complete installation of Juno's high-gain antenna. Photo credit: NASA/Jack Pfaller.

In search of clues

"Juno was conceived by scientists who were very familiar with the hazards of the Jovian environment," says SwRI's Bolton, the lead scientist. "Working with engineers, they were able to put together a concept that simultaneously considered measurement, orbit, and spacecraft requirements that could accomplish our objectives without compromising our goals. The key was having the right people with the right expertise working together right from the start," he tells *Aerospace America*.

He underscores the likelihood not only that Juno will provide answers to the science questions on its agenda but also that these answers will lead to new questions.

"Juno is fully capable of addressing all of our science objectives. The trick is to get the special instruments onboard Juno observing from a very special place—our polar orbit," notes Bolton. "As with all scientific exploration, I expect Juno will allow us to make progress answering our questions and providing the knowledge we need to develop the next set of questions for the next mission. This is the key to learning about the Earth and our solar system origin, to make steady progress with each step—and sometimes we get lucky, with programs like Juno, and get a chance to make a giant leap."

The Juno mission will probe Jupiter's atmosphere for clues to how the largest (and probably oldest) planet in the solar system, and the solar system itself, were formed from a primordial cloud of gas.

"Jupiter contains more matter than all the other planets combined," says Bolton. "By determining how much water is in it, we complete our inventory of the key ingredients that make up Jupiter…to figure out the billion-year-old recipe [for] the first planets in our solar system."

Bolton sees Juno's mission of discovery as conceivably rewriting the books on how Jupiter was born, and possibly even on how our solar system came into being.

Beyond the 'frost line'

Holding a similar view is Juno coinvestigator Fran Bagenal, professor of astrophysical and planetary sciences at the University of Colorado, Boulder. She says that to understand how the solar system formed, scientists need to understand how much oxygen—most commonly found as water—is inside Jupiter.

Did Jupiter collapse from the original

cloud of gas? Or was the planet formed by the gravitational attraction of hydrogen gas onto a core of ice and rock? Or was more ice added later when large leftover ice balls collided with Jupiter? "These different ideas all predict different amounts of water in the outer layers of Jupiter. Unfortunately, scientists have been unable to measure the amount of water at the planet," she says.

Current ideas about the formation of the solar system, Bagenal says, suggest that the Earth was formed at about its present distance from the Sun, where it was too warm for ice to condense. "This means, we think, that Earth formed from balls of rock and metal that condensed out of the original cloud of gas close to the Sun. It means that the water was delivered to the Earth later, after the planet was formed," she says.

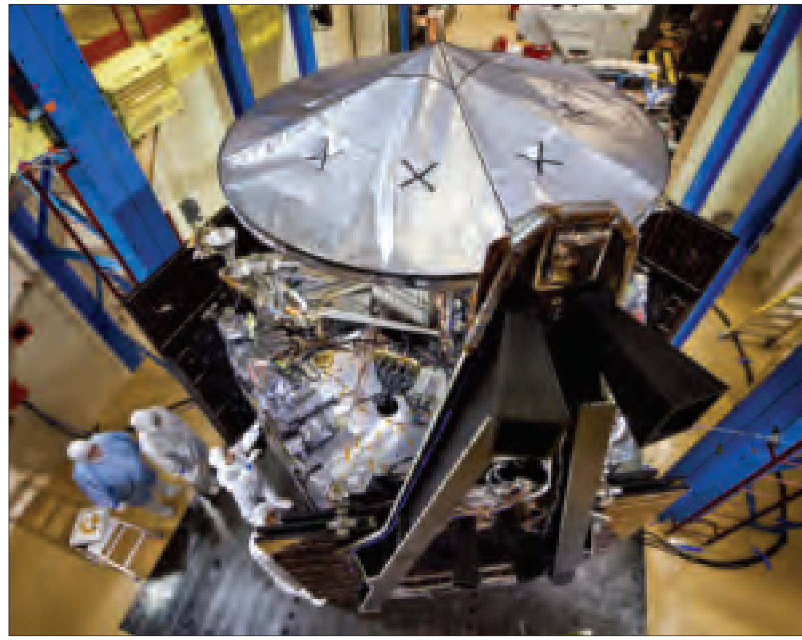
Bagenal says one possible source of Earth's water was a population of large ice balls that condensed out beyond the 'frost line'—likely beyond the asteroid belt. These ice balls were left over from the formation of the cores of Jupiter and the other giant planets. As the largest, most massive planet in the solar system, she adds, Jupiter is thought to have stirred up the leftover ice balls and sent them hurtling to the Earth. Some of them "may have been responsible for the large craters on the Moon. The early phases of the solar system were a dangerous time."

First glimpses

Juno's magnetometers will measure Jupiter's magnetic field with extraordinary precision and supply a detailed picture of what the field looks like, both around the planet and deep within, says NASA Goddard's Jack Connerney. He is the mission's deputy principal investigator and head of the magnetometer team. "This will be the first time we've mapped the magnetic field all around Jupiter…it will be the most complete map of its kind ever obtained about any planet with an active dynamo, except, of course, our Earth," he says.

The spacecraft also totes a color camera that will provide the closest ever images of Jupiter, including the first detailed glimpse of the planet's poles. This hardware, dubbed Junocam, will acquire three-color (red, green, blue) photos of Jupiter during Juno's first seven orbits around the giant planet. The data will be processed and studied by students as part of the Juno Education and Public Outreach program.

Built by Malin Space Science Systems, Junocam is derived from the Mars Science Laboratory's Mars descent imager instrument. The camera images, of approximately 9.3 mi./pixel resolution, will be used by students to create the first color images of the Jovian poles and high-resolution views of the planet's lower latitude cloud belts. After the required seven-orbit design life, Junocam will continue to operate as long as possible in the cruel Jovian environment.



The fully assembled spacecraft went through extensive testing at Lockheed Martin Space Systems near Denver. All three solar array wings can be seen installed and stowed, and the spacecraft's large high-gain antenna is in place on top. Image credit: NASA/JPL-Caltech/LMSS.

Looming line in the sand

Expectations are high that the Juno probe's principal goal of understanding the origin and evolution of Jupiter is attainable. In meeting this objective, Juno is likely to expose other secrets as well, not just about our solar system but also about planetary systems around distant stars.

After an extensive test program, Juno was shipped on April 8 from Lockheed Martin Space Systems, tucked within an environmentally controlled container on an Air Force C-17 Globemaster III. The spacecraft was then transported to Astrotech Space Operations in Titusville, Florida, where it went through final processing.

With the departure date looming, Lockheed Martin's Gasparrini notes, "You have constant tension between mission success and a 21-day launch window. So you're doing everything you can to make sure that the spacecraft operates 100% flawlessly when it gets into orbit....But you have this realization and this reality that you've got 21 days to get it off the planet." A

From visions to voyages

Fiscal austerity measures anticipated under the Obama administration will have a major impact on planetary science, including some high-priority NASA projects. New plans based on a decadal survey of potential missions call for trimming and realigning some programs to maximize science output. Greater international cooperation and scaled-back hardware are just a few of the belt-tightening measures proposed.

by Craig Covault
Contributing writer

Once every decade, the National Research Council (NRC) is asked to prioritize NASA's goals, looking 10 years out. This year's planetary decadal survey, recently released, has determined that NASA must reduce the size and complexity of its large ($2-billion-$3-billion) 'flagship' planetary missions. The decadal survey was undertaken to plan U.S. exploration strategy ahead of the NASA funding cuts expected under the Obama administration's austerity measures.

Employing a more open planning process, one with broad community involvement and a focus on science, will allow a smoother process for making the needed changes in post-2013 mission designs. (The entire report may be found here: http://solarsystem.nasa.gov/multimedia/download-detail.cfm?DL_ID=742.)

Mission priorities

The survey team, which included top NASA and university scientists and engineers, came up with 25 candidate missions for launch between 2013 and 2022, says Cornell University's Steve Squyres, who led the review.

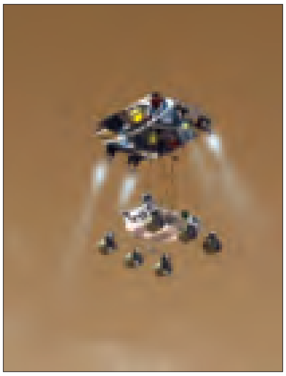
The sweeping document, formally titled *Vision and Voyages for Planetary Science in the Decade 2013-2022*, carries both the new recommendations and the reasons for them. Squyres took temporary leave as project scientist for NASA's Mars Exploration Rover program to head the survey.

A NASA/ESA twin-rover Mars sample return to search for evidence of life has the highest priority, but is slated for major changes, including the redesign of both rovers. And almost equally important, a planned 2016 flight to Jupiter to investigate a potentially habitable ocean on the Jovian moon Europa is also in for heavy cuts.

The changes to the Mars and Europa efforts will affect the European Space Agency's participation in both. The flight to Europa was to have followed NASA's Juno mission, set for launch this summer to investigate Jupiter's atmosphere for clues to early planetary formation.

Next in priority to the Mars and Europa missions is a Uranus orbiter/probe flight, which would be the first in-depth exploration of an 'ice giant' planet in the outer solar system.

Planets in the solar system imaged by previous NASA spacecraft show the breadth of targets covered in the decadal survey. The new strategy for 2013-2022 envisions the first missions to the 'ice giants' Neptune and Uranus.



The MAX-C, a new rover for collecting Mars samples, will be lowered by a rocket-powered Sky Crane just like the new Curiosity Mars Science Laboratory being launched in November for landing in late 2012. After MAX-C has completed its mission, another rover, possibly a European one, will also use a Sky Crane landing to collect and load samples into a return rocket.

If the Mars, Europa, or Uranus missions falter in their development, then either an Enceladus orbiter at Saturn, to sense that moon's subsurface ocean, or a Venus climate mission could be flown.

Sharp cuts, sharp responses

There is some sharp criticism in the planetary exploration community—not about the decadal survey findings trying to salvage exploration, but rather about the sharply reduced Obama administration budgets that are forcing the actions recommended by the survey. "The flow of scientific creativity and technical innovation cannot be turned on and off like a spigot. To make progress, there must be steady support," says Bill Nye, executive director of the Planetary Society. "NASA is charged with exploring and innovating, but the Congress and administration routinely turn the spigot on and off, and then seem outraged when NASA fails to meet their schedules and expectations."

In the proposed FY12 budget numbers, all science disciplines will take a hit, especially planetary science. No money has been allocated for a Mars mission in 2018. In fact, there is no money for any future Mars mission in this budget after 2016, including a Mars sample return. The high-priority Europa orbiter is not even in the budget, Nye points out.

"Just as the planetary science decadal survey presented its thoughtful recommendations, NASA is faced with reworking the whole thing to save as much science as possible within this new federal budget," he explains.

A Martian ascent vehicle lifts off from Mars with samples selected and picked up by the NASA MAX-C rover and then retrieved for launch by an ESA rover. That rover would place them in a U.S. launcher that will send them to a Mars orbiter, which would then place them in another vehicle for return to Earth.

Jim Green, the director of NASA's planetary science division, is working hand in hand with Squyres in the effort to preserve mission content and equality across different disciplines. Nonetheless, the Planetary Society is "deeply disappointed that there may well be no flagship mission to the outer planets," says a statement issued by the group.

Trimming costs

"Europa's probable ocean may be the best candidate in the solar system beyond Earth for a currently habitable environment," says Squyres. But an independent estimate from the Aerospace Corporation puts the cost for a full-up Jupiter Europa orbiter (JEO) mission at $4.7 billion—a level far too high under the new federal budget realities. The decadal committee thinks that even if the spacecraft's capabilities are reduced and ESA shares the expenses, it will not fit within a cost-constrained program.

Work on reducing JEO costs must begin now, says Squyres, adding, "JEO science would be enhanced by conducting the mission jointly with ESA's proposed Ganymede orbiter"—perhaps by launching them together to Jupiter.

Technology work on a Uranus or Neptune mission needs to begin now, and the mission, perhaps not to be flown until after 2022, would still open a whole new region of the solar system for exploration.

But Mars exploration is where major cuts must be made. This would kill ESA's 2018 ExoMars rover and replace it with a single NASA rover that could carry most of the ESA science instruments while fulfilling the primary U.S. objective of collecting samples for later pickup.

The proposed strategy would conduct sample return as a campaign with three separate elements:

• *A 'caching rover,' the Mars astrobiology explorer-cacher (MAX-C)*, which would select samples and position them for pickup.

• *A Mars sample return lander (MSR-L)*, likely an ESA rover to fetch the sample cache, and a U.S. ascent vehicle to loft it into Martian orbit.

• *Rendezvous and return by a Mars sample return orbiter (MSR-O)*. The Mars ascent vehicle, with the samples, would rendezvous with the MSR-O, which would fire the samples back to Earth.

The process could take many years, given that at each point the samples would be relatively safe from loss, unless the ascent vehicle failed. NASA must also keep the cost of MAX-C below $2.5 billion.

"This campaign would be scientifically robust, with the flexibility to return to a previously visited site (for example, if motivated by an MSL discovery), go to a new site, or fly a second MAX-C rover if the first mission was unsuccessful for any reason," says the decadal survey. "It would also be technically and programmatically robust, with a modular approach and multiple caches left on the surface by MAX-C to recover from a failure of either the MSR-L or MSR-O elements without requiring a reflight of MAX-C," adds the survey.

Missions already approved and funded for near-term launch would continue. Discovery, held to $500-million projects, is a good example of a program where the creativity of the mission's principal investigator will not be countered by decadal survey findings.

Discovery missions now in flight include Messenger, orbiting Mercury; Dawn, heading to orbit planetoid bodies in the asteroid belt; and Kepler, using its unique optics to spot planets around other stars.

A mission focusing on Europa could help determine whether it has a habitable ocean under just a 100-ft frozen surface. An artist's concept shows a notional spacecraft collecting radar data on the ocean and its frozen surface, which some future mission could penetrate to reach the water below.

Other candidates

NASA will pick one 2016 mission from among three science investigations it has selected: looking at Mars' interior for the first time; studying an extraterrestrial sea on one of Saturn's moons; or studying the surface of a comet's nucleus in unprecedented detail.

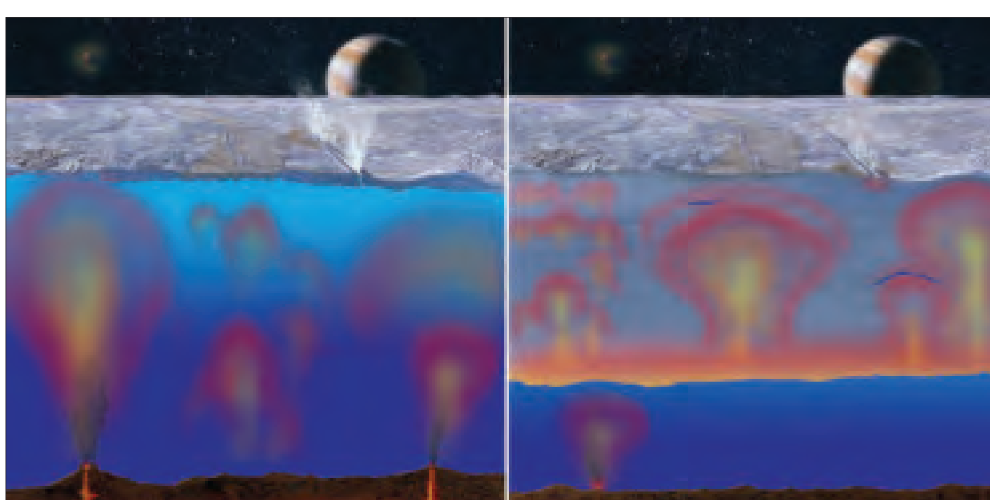
NASA scientists and engineers have just completed a major assessment of 28 new Discovery mission candidates. They picked three to receive $3 million each for the mission's concept phase or preliminary design studies. In 2012, after another detailed review of the concept studies, NASA will select one for continuing development efforts leading up to launch.

The selected mission will be cost-capped at $425 million, not including launcher funding. The missions selected for pursuit of preliminary design studies are:

• *Geophysical monitoring station*, or GEMS, would study the structure and composition of the interior of Mars and advance understanding of the formation and evolution of terrestrial planets. Bruce Banerdt of JPL in Pasadena, California, is principal investigator. JPL would manage the project.

• *Titan Mare explorer*, or TiME, would provide the first direct exploration of an ocean environment beyond Earth, by landing in and floating on a large methane-ethane sea on Saturn's moon Titan. Ellen Stofan of Proxemy Research in Gaithersburg, Maryland, is principal investigator. Johns Hopkins University's Applied Physics Laboratory would manage the project.

• *Comet hopper*, which would study cometary evolution by landing on a comet multiple times to observe its changes as it interacts with the Sun. Jessica Sunshine of



The Europa mission would study the subsurface ocean heating and thickness of the Jovian moon's icy surface. If the heat from below is intense and the surface ice is thin enough (left), the surface can directly melt, causing areas of broken, rotated, and tilted ice block, as seen in many Galileo spacecraft images. But if the surface ice is sufficiently thick (right), the less intense interior heat will be transferred to the warmer ice at the bottom of the shell, coupled with heat generated by tidal squeezing of the warmer ice. This warmer ice will slowly rise, flowing as glaciers do on Earth, and the slow but steady motion may also disrupt the extremely cold, brittle ice at the surface.

Water vents firing from Enceladus, discovered by the Saturn orbiter Cassini, indicate there is a warm water ocean under the surface. A mission to Enceladus, nearly 1 billion mi. from Earth, is cited in the survey as highly desirable and would investigate the tiny body, a moon where early microbial life could have formed.

A new $500-million Discovery mission candidate would be this proposed 2016 spacecraft that would fly to Saturn and drop into a large methane lake on the moon Titan. The spacecraft in this graphic uses a floodlight while moving along the surface. The lake lander, developed by Johns Hopkins Applied Physics Laboratory, would compare Titan's characteristics to the hydrological cycle on Earth.

the University of Maryland in College Park is principal investigator; NASA Goddard would manage the project.

"This is high science return at a price that's right," says Green. "The selected studies clearly demonstrate a new era, with missions that all touch their targets to perform unique and exciting science. NASA continues to do extraordinary science that is rewriting textbooks."

Explains NASA Administrator Charles Bolden, "Missions like these hold great promise to vastly increase our knowledge, extend our reach into the solar system."

New Frontiers

NASA's New Frontiers program carries the creative aspects of the Discovery program to missions costing $1.05 billion, a figure that includes launcher costs. But to give New Frontiers missions more funding margin, the decadal survey recommends that NASA lower the funding cap to an even $1 billion (in FY15 dollars), excluding launch vehicle costs, says Squyres.

"This change represents a modest increase in the effective cost cap and will allow a scientifically rich and diverse set of New Frontiers missions to be carried out," according to the survey. It will also help protect the science content of the program against increases and volatility in launch vehicle costs.

Two New Frontiers missions have been selected by NASA to date, and a third selection is under way now: "The committee recommends that NASA select two New Frontiers missions in the decade 2013-2022. These are referred to here as New Frontiers Mission 4 and New Frontiers Mission 5.

New Frontiers Mission 4 should be selected from among the following five candidates: a comet surface sample return, a high mission priority; lunar south pole-Aitken Basin sample return; a Saturn probe; a Trojan tour and rendezvous, to explore several of the 4,000 'Trojan asteroids' that orbit Jupiter ahead of and behind the giant planet; and a Venus in-situ explorer."

No relative priorities are assigned to these five candidates. Instead, the selection from among them should be made on the basis of competitive peer review, says the decadal survey.

For the New Frontiers Mission 5 selection, in addition to the list of candidates that lost out in the NF 4 selection, Squyres says, other options, such as an Io observer and a lunar geophysical network, should be considered.

The bigger picture

In a briefing at this year's Lunar and Planetary Science Conference in Houston, Texas, Squyres says the mission strategy selected by the NRC survey participants cross-cuts three main themes:

- **Building new worlds**: Missions to different planets can all add data to key questions asked in the survey, such as: What were the initial stages, conditions, and processes of solar system formation, and how did the giant planets and their satellite systems accrete? What governed the accretion, supply of water, chemistry, and internal differentiation of the inner planets and their atmospheres?
- **Searching for habitats**: Locations that could harbor life range from Saturn's moon Enceladus, where subsurface water is warmed, to the closer Jovian moon Europa, whose subsurface ocean is warmed by Jupiter's tidal forces. Mars is central to the search for habitats. And some survey questions that cut across all mission areas are: What were the primordial sources of organic matter? Where does organic synthesis continue today? Did Mars or Venus host ancient aqueous environments conducive to early life, and is there evidence that life emerged?
- **The workings of solar systems**: The study of planetary processes through time includes questions such as, how do the giant planets serve as laboratories for understanding Earth, the solar system, and extrasolar planetary systems being discovered by the Kepler spacecraft and Earth-based observatories?

Out of the

25 Years Ago, July 1986

July 10 In preparation for their first nonstop nonrefueled round-the-world flight attempt, pilots Dick Rutan and Jeana Yeager take off on a five-day test flight that covers 11,339 mi. *Voyager Curatorial File*, National Air and Space Museum.

50 Years Ago, July 1961

July 2 The USSR delivers the first batch of Tupolev Tu-16 twin-engine strategic jet bombers to the Indonesian air force. The aircraft (NATO code name Badger) is also used by the Iraqi and Egyptian air forces. It has a maximum range of 4,474 mi. F. Mason and M. Windrow, *Know Aviation*, p. 61; *Tu-16 file*, NASM.

July 5 The Comet II, a three-stage all-solid-fuel rocket developed and built in Israel, is launched from the Negev Desert to a height of 50 mi. and releases a cloud of sodium vapor to measure atmospheric phenomena. Preparations are under way for another rocket with instruments and radio telemetry equipment. *The Aeroplane*, July 13, 1961, p. 32.

July 9 The Soviet Union shows its new Myasishchyev M-50 bomber for the first time, in a Moscow flyby at the Tushino Airport. Later given the NATO code name Bounder, the M-50 is 187 ft 10 in. long with a wingspan of 121 ft 4 in. Four 28,600-40,000-lb-thrust Koliesov turbojet engines provide power, enabling a top speed of Mach 1.83. Also displayed is a full-scale replica of cosmonaut Yuri Gagarin's spacecraft, flown suspended from an Mi-6 transport helicopter. D. Baker, *Flight and Flying*, p. 376; *The Aeroplane*, July 13, 1961, p. 31.

July 12 Making its first launch, the Atlas-Agena B lofts the Midas-3 infrared missile early warning satellite into a polar orbit from Vandenberg AFB at Point Arguello, Calif. *The Aeroplane*, July 20, 1961, p. 63; D. Baker, *Spaceflight and Rocketry*, pp. 121-122.

July 19 In London, before the Air Ministry, England's prime minister and the archbishop of Canterbury unveil a large statue of Hugh Montague, Lord Trenchard, who helped establish the RAF; he became its first marshal in 1927. *The Aeroplane*, July 27, 1961, p. 92; *Hugh Trenchard file*, NASM.

July 21 Astronaut Virgil I. Grissom is successfully launched as the second American in space, in the second suborbital flight aboard the Project Mercury Liberty Bell 7 spacecraft. Boosting the craft is a Mercury-Redstone (MR-4) vehicle from the Atlantic Missile Range at Cape Canaveral. Grissom reaches a peak altitude of 118.26 mi. and a speed of 5,168 mph. His flight lasts 15 min 37 sec, and his landing is made 302 mi. downrange from the launching point. The Liberty Bell 7 unfortunately sinks in the water as it is picked up by a Marine helicopter, but Grissom is rescued and reported in excellent condition. I. Ertel and M. Morse, *The Apollo Spacecraft, Vol. I*, p. 100.

July 28 About a week after the U.S. launches Virgil Grissom into space, NASA chooses a dozen U.S. aerospace companies to prepare bids for the design and development of the Apollo spacecraft for manned flights to the Moon. D. Baker, *Spaceflight and Rocketry*, p. 123.

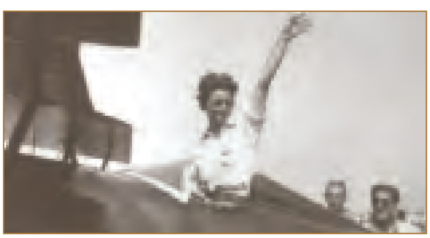
75 Years Ago, July 1936

July 5 Australian pilot James Melrose and A.G. Campbell, his passenger, are killed when their Heston Phoenix airplane breaks up near Melbourne. The 22-year-old Melrose attained fame in 1934 when he flew around Australia, a distance of 7,500 mi., in record time. He then flew to England in 8 days 9 hr, beating the previous official record by 13 hr. He was the first solo

competitor to finish in the MacRobertson Race between England and Australia, in October 1934. *The Aeroplane*, July 8, 1936, p. 46.

July 5 Philip A. Wills sets a new British long-distance record for sail-planes by flying 102 mi. from Dunstable to Pakefield, on the Suffolk coast, in 4.5 hr in the British-built sailplane Hjordis. The previous British record was 95 mi., set by Eric Collins. *The Aeroplane*, July 8, 1936, p. 73.

July 8-10 British newspapers reveal that the German airship Hindenburg narrowly escaped being rammed by an RAF plane on June 26. Famed airship commander Hugo Eckener corroborates this and relates that the near-collision was caused by fog as the airship left Manchester. Eckener urges that British aviators henceforth be informed of which days the airship will cross Britain, and of its precise course. *The Aeroplane*, July 15, 1936, pp. 79-80.

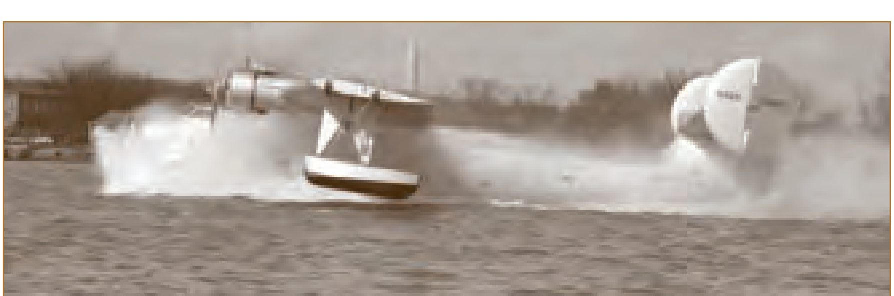


July 12 Louise Thaden sets a new women's speed record of 109.58 mph when she flies a 90-hp Monocoupe over a 100-km course in 34 min. at Endless Caverns, Va. *Aero Digest*, Aug. 1936, p. 76.

July 18 The Spanish Civil War begins. It is to involve German, Italian, and Soviet air units as well as French and U.S. aircraft. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 34.

July 18 In a 63-min ascent over Moscow, a Soviet flyer reaches a record altitude of 36,089 ft in a two-place plane of Soviet construction with a payload of 1,102.311 lb. The pilot, Vladimir Kokkinaki, establishes a new record for planes of this type. *Aero Digest*, Aug. 1936, p. 76.

July 23 The Navy awards a contract for the XPB2Y-1 flying boat to Consolidated Aircraft. The plane subsequently becomes the prototype for the Coronado series of four-engined flying boats used throughout WW II. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 34.



And During July 1936

—The first of the big, four-engined Short Brothers Empire flying boats, meant for long-distance Imperial Airways passenger routes, undergoes trial runs at Rochester, England, where it was built. Imperial has purchased 28 of the machines. With a length of 88 ft, a wingspan of 114 ft, and a normal gross weight of about 40,000 lb, the boat will accommodate 24 passengers by day and 16 by night. It cruises at 160 mph. *Flight*, July 9, 1936.

100 Years Ago, July 1911

July 1 Glenn Curtiss completes the maiden flight of his A-1, the first of a long series of Curtiss seaplanes. The flight takes 5 min and reaches an altitude of 9 m. A. van Hoorebeeck, *La Conquete de L'Air*, p. 91.

July 1 U.S. pilot Charles Weymann wins the coveted Gordon Bennett Cup, flying his Farman aircraft 150 km in 1 hr 11 min. His average speed is 78 mph. A. van Hoorebeeck, *La Conquete de L'Air*, p. 91.

25 Years Ago, August 1986

Aug. 12 Japan launches its first Mitsubishi H-1 rocket. The two-stage vehicle features a license-built Thor-ELT first stage built in Japan and a completely Japanese designed and built second stage. The rocket places a geodetic satellite into LEO. *New Scientist*, Oct. 23, 1986, p. 50.

50 Years Ago, August 1961

Aug. 6-7 Maj. Hermann Titov becomes the USSR's second man in space, after Yuri Gagarin, when he completes a 17-orbit flight in the Vostok 2 spacecraft and is successfully recovered. The aims of the mission include determining the effects of a prolonged orbital flight on human organisms and studying man's working capacity during weightlessness. Another goal is to measure the effects of cosmic rays on living organisms, of which there are several specimens on board. *Flight*, Aug. 17, 1961, p. 208; *The Aeroplane*, Aug. 17, 1961, p. 188.

Aug. 10 The European-built Lockheed F-10G, the first of 210 to be built, makes its first flight. Built by German manufacturer ARGE Sud, the fighter is to be used by the German and Spanish air forces. *Flight*, Aug. 17, 1961, p. 207.

Aug. 12 Sir Victor Sassoon, the British aviation pioneer, dies in the Bahamas at 79. He had an early interest in aviation and in 1911 put up money to start the journal *The Aeroplane.* In 1912 he participated in the Grand Prix of the Aero Club of France. *The Aeroplane*, Aug. 17, 1961, p. 170.

Aug. 12 Echo 1, the world's first passive communications satellite, reenters the atmosphere and burns up after completing 4,480 orbits around the Earth and carrying out about 150 communications experiments. Its most notable included relaying a voice message from President Eisenhower back to Earth during its first orbit, the transmission of music and messages across the Atlantic, and sending facsimile photos transmitted by the Post Office. *Flight*, Aug. 24, 1961, p. 249.

Aug. 16 A magnetometer aboard Explorer 12 provides the first clear picture of Earth's magnetosphere, which was discovered in 1958 by Explorer 1 during the International Geophysical Year. Magnetospheres are a mix of free ions and electrons from both the solar and Earth winds, or from other planets' ionospheres, and are formed when a stream of charged particles such as the solar wind interacts with the magnetic field of a planet. R. Zimmerman, *The Chronological Encyclopedia of Discoveries in Space*, p. 17.

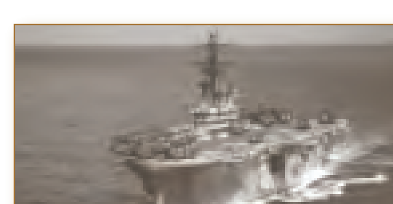
Aug. 17 The Handley Page H.P. 115, the world's first slim-delta research aircraft, makes its maiden flight at the Royal Aircraft Establishment at Bedford, England. The plane is designed for low-speed flight tests but is to play a very important part in the British supersonic airliner program. It is one of two H.P. 115 aircraft built for this purpose. *The Aeroplane*, Aug. 24, 1961, pp. 196-197.

Aug. 17 An all-USAF team launches an all-solid-fuel Blue Scout Jr. R&D rocket to collect data in support of military space and weapons development programs. The payload is to aid the development of methods for detecting nuclear explosions from space. The Blue Scout rocket is the military version of the Scout launch vehicle for orbiting small payloads. *Aviation Week*, Sept. 25, 1961, p. 72.

Aug. 23 Ranger 1 is launched and completes 110 Earth orbits before it reenters the atmosphere and burns up. Its mission, considered only partly successful, was to test spacecraft systems and strategies for future lunar missions of other Ranger craft. *Flight*, Sept. 7, 1961, p. 407, and Sept. 21, 1961, p. 469.

Aug. 24 Famed aviatrix Jacqueline Cochran claims a new women's world jet speed record of 842.6 mph for a 15-km straightaway course, at Edwards AFB, Calif., in a Northrop T-38 trainer. *Aviation Week*, Sept. 4, 1961, p. 36.

Aug. 26 The USS Iwo Jima is commissioned at Bremerton, near Seattle. It is the Navy's first amphibious

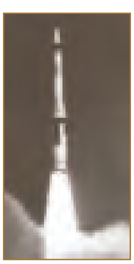


Past

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

assault ship that is also equipped to operate a helicopter squadron, with Marine combat troops. *United States Naval Aviation 1910-1980*, p. 243.

Aug. 28 A Navy-McDonnell F4H Phantom II piloted by Lt. Hunt Hardisty, with radar interceptor officer Lt. Earl DeEsch aboard, sets a new low-altitude world speed record of 902.76 mph at Holloman AFB, N.M., flying over a 3-km course in which the plane is just 100 m from the ground. *Aviation Week*, Sept. 4, 1961, p. 36; *United States Naval Aviation 1910-1980*, p. 243.



Aug. 30 The first attempt to launch a solid-fuel Minuteman ICBM from a silo fails when the second stage ignites prematurely, just as the missile clears the silo. The Range Safety Officer has to destroy it, causing "the biggest explosion ever seen at Cape Canaveral." *Aviation Week*, Sept. 18, 1961, p. 63; *Flight*, Sept. 7, 1961, p. 406.

75 Years Ago, August 1936

Aug. 1 Louis Bleriot, one of the world's great aviation pioneers, dies near Paris of a heart ailment. Bleriot is best known for being the first man to fly in a heavier-than-air machine across the English Channel, in 1909. Also a highly successful aircraft designer and manufacturer, he had begun to experiment with aircraft as early as 1906-1907. He preferred the monoplane configuration, making the channel flight in his Type XI. At the start of WW I, he acquired Deperdussin, the aircraft company that turned out the Spad, one of the best known fighters of the war. Bleriot's factory produced 10,000 aircraft for the armed forces of France and other allies. He also produced a wide variety of experimental and novel designs, from high-speed single-engine airplanes to large, four-engine flying boats. *The Aeroplane*, Aug. 5, 1936, p. 174, and Aug. 12, 1936, p. 211.

Aug. 5 Soviet aviators fly from Los Angeles to Moscow to investigate the possibility of conducting a regular airline service over the 10,000-mi. route. The pilots, Sigmund Levanevsky and Victor Levchenko, use a float-equipped Vultee. Their course lies northward along the west coast of North America to Alaska, then across the Bering Sea to Siberia, and then to Moscow. For the Siberian leg, the floats are replaced with land gear. *Aero Digest*, Sept. 1936, p. 74.

Aug. 8 Margo Tanner sets two new women's seaplane records at Langley Field, Va., when she pilots her Aeronca-powered seaplane over a 100-km course in 55 min 55 sec at an average speed of 66.68 mph. *Aero Digest*, Sept. 1936, p. 74.

Aug. 17 Georges Detre of France establishes a new world's airplane altitude record when he flies his Potez 50 to 48,600 ft above Villacoublay Airport, France. The plane is the same one used by Maryse Hilsz the previous June when she broke the French record by flying to just over 47,000 ft. *The Aeroplane*, Sept. 2, 1936, p. 292.

Aug. 30 Maryse Hilsz wins the Coupe Helene Boucher in the Women's Annual Air Race from Paris to Cannes, flying her Caudron C.680 at a speed of 228 mph. The distance covered is about 430 mi. Six competitors are in the race. *The Aeroplane*, Sept. 2, 1936, p. 311.

And During August 1936

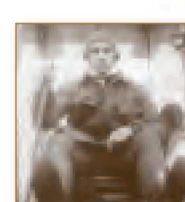
—Junkers introduces its latest transport airplane, the Ju 86. Two 750-hp radial motors power the aircraft, which can also be fitted with two Junkers Jumo 205 diesels. The Ju 86 has a top speed of 226 mph with a range of 665 mi. *The Aeroplane*, Aug. 26, 1936, pp. 268-269.

100 Years Ago, August 1911

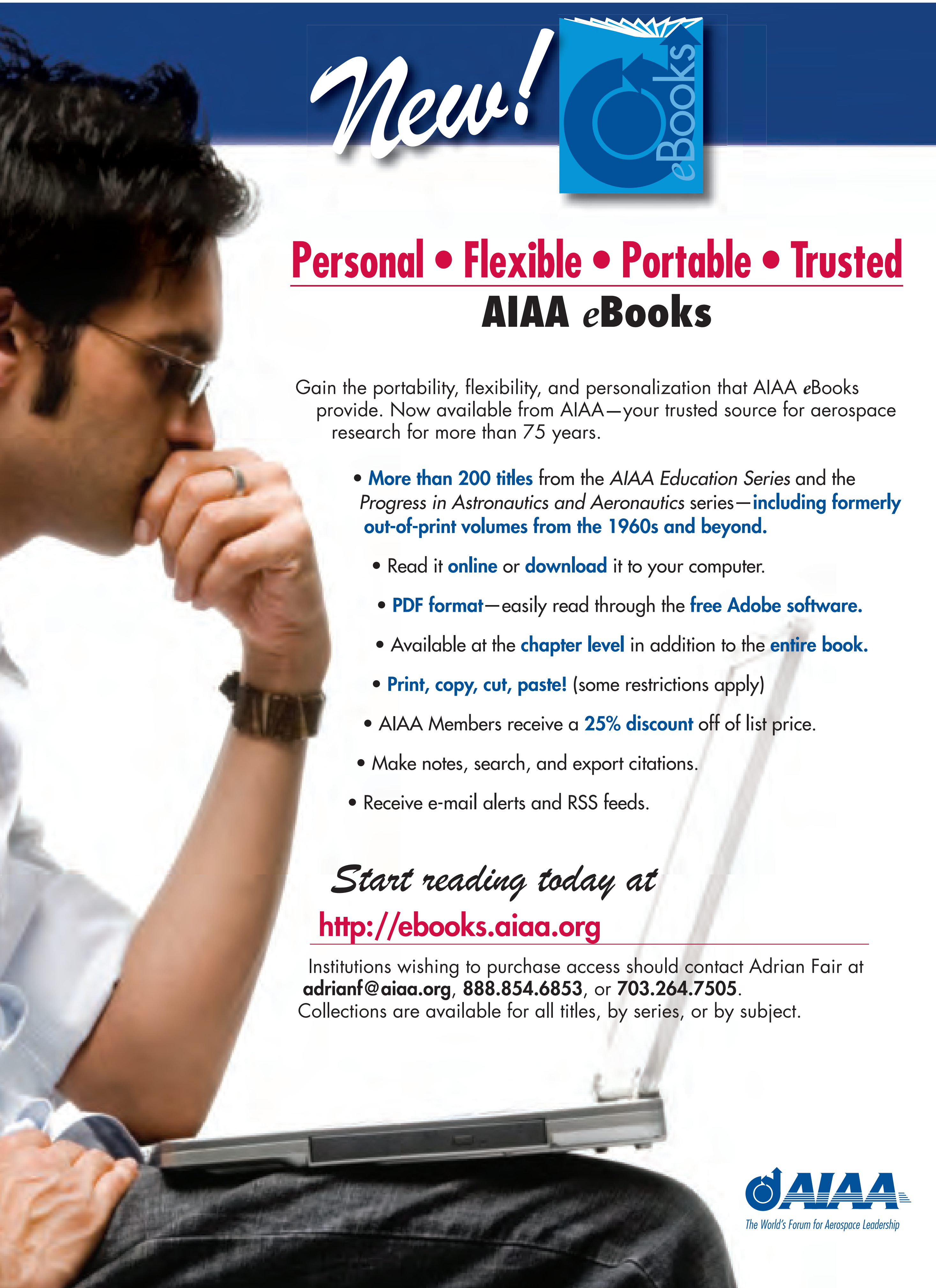
Aug. 2 Harriet Quimby becomes the first American woman to receive her pilot's license, No. 37, from the Fédération Aéronautque Internationale. A. van Hoorebeeck, *La Conquete de L'Air*, p. 91.

Aug. 14-25 The first long-distance cross-country flight in the U.S. occurs when H.N. Atwood flies his Wright Baby aircraft from St. Louis to New York City, covering 1,454 mi. in 28 hr 9 min of flight time over the course of 11 days. A. van Hoorebeeck, *La Conquete de L'Air*, p. 91.

And During August 1911



—Claude Graham White establishes an air mail service between London and Windsor, England, to carry 130,000 postcards in celebration of the coronation of King George V. A. van Hoorebeeck, *La Conquete de L'Air*, p. 91.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