April 2011

AEROSPACE AMERICA

New helicopter designs take off

A conversation with Scott Pace

NanoSail-D2 breaks free

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4 AEROSPACE AMERICA APRIL 2011

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April 2011

DEPARTMENTS

FEATURES

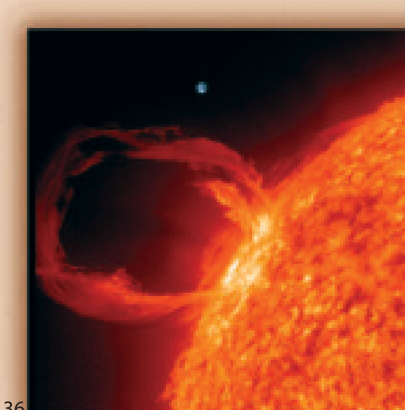
BULLETIN

Page 4

Page 8

Page 18

Page 22



Page 36

COVER
The Eurocopter X3 is just one of many innovative new helicopter designs emerging on the market. To find out about these new vehicles, turn to the story beginning on page 26.

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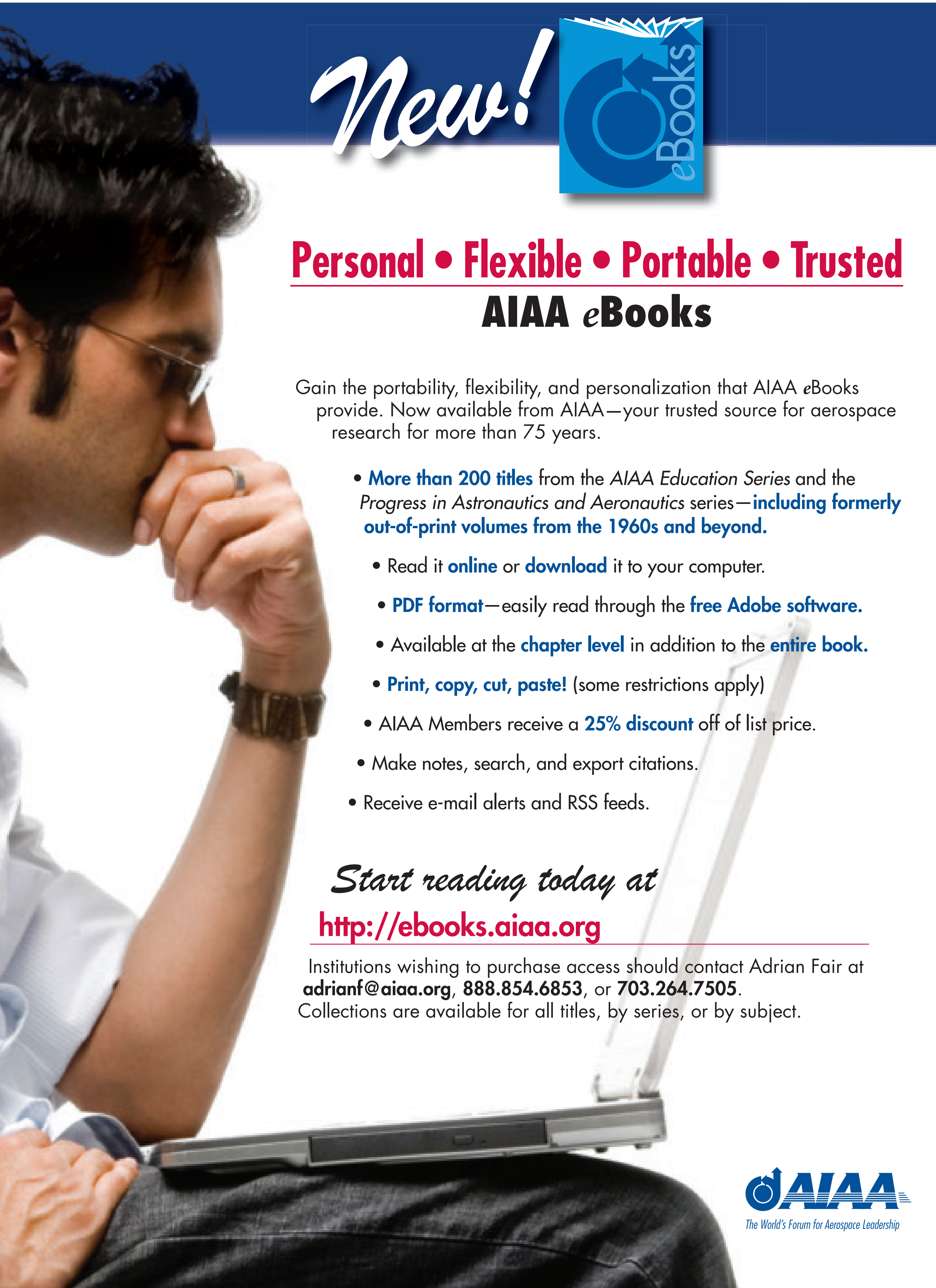

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Commentary

Cyberscience and 21st-century education

Technology changes at an exponential rate, yet engineering courses and curricula may take years or even decades to change. If you compare course requirements and Ph.D. examinations from 20 years ago with today's, you'd find little difference, in part due to the inability of humans to keep up with technological changes. We must modernize engineering education in order to keep up with these rapid changes. We owe it to our students to prepare them for the future.

The 'old aerospace engineering' (aerodynamics, structures, propulsion, dynamics, and control) was adequate for aircraft designed, built, and flown without computers or software. But since about 1970, cyberscience, for lack of a better word, has become increasingly important in aerospace systems. Cyberscience is broadly defined here to comprise computing, software, networking, numerical algorithms, electronics, computational intelligence, digital avionics, human-machine interactions, and the like. For current aircraft, the cost of the onboard computers and software is roughly 50% of the total cost, not including the cost of computers and software used to design and build the systems.

Faculty often argue that it is not possible to add more material to the curriculum. This is true if you do not remove any of the older material, much of which is taught primarily for historical reasons. Similar problems probably exist within almost all academic disciplines, including computer science, and are not limited to undergraduate education. How can this material remain unchanged while technology changes exponentially?

We need to stop preparing students to solve yesterday's problems.

Hiring practices also reflect a disconnect. In 2009 the Lockheed Martin employment Web page showed 1,914 openings in the areas of systems, software, EE, and IT; they had 21 in aerospace engineering. Likewise, Boeing in 2009 showed 190 openings in systems, software, EE, and IT, and just four openings for aerospace engineers.

We cannot keep teaching the same material we taught 50, 20, or even five years ago. There is not time in four years to teach students all the accumulated material over the history of aerospace engineering. They need courses in software engineering, systems engineering, electronics, computing, autonomous systems, navigation, and so much more.

The other change needed is in faculty hiring and learning. Aerospace engineering departments need to hire cyberscience faculty, not just experts in old aerospace engineering. Faculty also must continuously learn new technology. This would improve and expand the research, as well as help enormously in educating the students. Many aerospace faculty incredibly and wrongly equate software engineering with programming, and fail to keep up with modern languages.

For much of the history of aerospace engineering the focus has been on physics-based teaching and research, and justifiably so, but those areas are now fairly mature. It is time to focus on the system as a whole and recognize the importance of cyberscience to designing, building, and flying aerospace systems. A paradigm shift is required in university education. It is not enough to tweak the curriculum. It is time to completely redefine what it means to be an aerospace engineer.

Lyle N. Long
Distinguished Professor, Pennsylvania State University

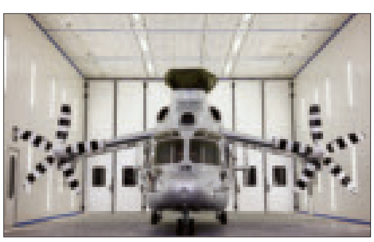
Tilt-rotors: A target for Europe's researchers

The second stage of Eurocopter's X3 high-speed hybrid helicopter demonstrator flight test program began in March and is due to last three months. The aim is to increase the sustained cruise speed of the heavily modified Dauphin to 220 kt. The aircraft already attained 180 kt in the first phase of the flight test program, which began in September 2010.

A new, faster generation

The X3 is part of a new generation of rotorcraft, including the Sikorsky X2, featuring much greater speeds than current types. (See "New helicopter designs take off," page 26.) The X3 is based on a conventional Eurocopter Dauphin airframe that has been heavily altered with the addition of two propellers installed on short-span fixed wings, and a five-blade main rotor system, all powered by two turboshaft engines.

Like a tilt-rotor, the hybrid configuration seeks to marry the speed of a turboprop-powered aircraft and the full hover flight capabilities of a helicopter. The X3 demonstrator flight tests have been used to validate new antitorque function and yaw controls and to investigate the optimization of controlled thrust through the propellers, rotor inclination effects, and rotor and propeller controls. As the performance envelope is extended during the second series of flight trials, stress and vibration levels will be evaluated and different flight configurations explored.



The Eurocopter X3 demonstrator flight test program is in its second stage.

According to Eurocopter chief executive Lutz Bertling, speaking at the company's annual results meeting in Paris in February, X3 technologies could become available on the market around 2017, as an optional variant to a conventionally configured type. Although the X3 ('cost-effective high-speed' program as defined by the company) is unlikely to match the cruise performance provided by a production variant of an X2-configured helicopter, it will offer higher speeds at a relatively modest increase in cost, just 25% more than conventional configurations, according to Eurocopter.

BA609 and beyond

Meanwhile, Italy's Agusta is working as a partner with Bell on the BA609 civil tilt-rotor, with the flight tests of two prototypes currently taking place at Bell's headquarters in Texas. But progress toward certification of the type is slow, with the aircraft now in its 13th year of development and little news of operational timelines from either company.

When asked in February about possible certification dates, Bell said the companies were "committed to certifying and delivering the world's first commercial tilt-rotor. As we have done before, we are evaluating the best way to ensure BA609's success."

The BA609 is not the only civil tilt-rotor in which European companies have an interest. Since the 1980s European researchers have been working on the complexities of tilt-rotor power management, piloting laws, and the interaction between airframe and engines, initially as part of the European Commission (EC)-funded EUROFAR research program and, more recently, through the enhanced rotorcraft innovative achievement, or ERICA, project.

A key component of recent ERICA work has been wind tunnel tests by the National Aerospace Laboratory in Amsterdam and the German Aerospace Center (DLR) in Braunschweig on one-fifth-scale models of the finished design. These are part of a research initiative that, in theory, will culminate at the end of the decade in the construction of a 10-tonne prototype capable of carrying 22 passengers at speeds of up to 350 kt.

But meeting performance and production deadlines for tilt-rotor designs has been notoriously difficult in the past, and few in Europe's aerospace industry are counting on an advanced European version of a V-22 taking to the skies by 2020. Although the EC helped fund considerable research into tilt-rotors within the fifth (1998-2002) and sixth framework (2002-06) programs, the most recent EC-coordinated seventh framework program (2007-14) has emphasized environmental research over high-speed tilt-rotor concepts.

Environmental factors

The environmental benefits of its X3 demonstrator program are hard to define at this early stage. "The constraints caused by the using of existing aircraft subassemblies have prevented any specific efforts to reduce the aircraft weight, aerodynamic drag, or noise levels," says a Eurocopter source.

Yet although tilt-rotor technologies are far more complex than the high-speed hybrid design being worked on by Eurocopter, the lure of tilt-rotors is still strong in Europe. A recent EC analysis of significant air transport technology requirements in the continent has underlined the importance of this technology "as a breakthrough concept for Europe," one that promises "to be a solution in increasing airport capacities without major infrastructural changes." With this market in mind, the emphasis is on developing much larger aircraft than those

The Bell-Agusta BA609 is in its 13th year of development.

currently being flown and tested, while ensuring that the environmental challenges can be overcome.

Alongside the EU coordinated research programs, studies on tilt-rotor research have been under way at a national level, with, for example, the French government funding tilt-rotor blade developments. AgustaWestland, the Anglo/Italian consortium, is also studying advanced tilt-rotor concepts outside Agusta's work on the BA609, and with European partners.

Some of the spinoff results of the earlier EC-backed research are finding their way into the market.

"The X3 benefits from the lessons we've learned after more than 20 years of research in the field, such as the tilt-rotor technology that we studied as part of the EUROFAR project," explains Jean-Michel Billig, executive vice president of R&D at Eurocopter, writing in the company's January *Rotor*. "The problem with this technology was the extreme technical complexity, not to mention major concerns about its cost-effectiveness. We also examined other concepts for the aircraft's architecture but finally abandoned them as they proved to be too complex as well. The key points we focused on when designing the X3 were to maintain the multifunction capabilities of the aircraft. It can perform hover flight, autorotation, and a wide range of missions."

Ambitious goals

For the moment, coordinated EC-backed research is focusing on developing more cost-effective and less polluting helicopters. The Green Rotorcraft Integrated Technology Demonstrator Program, part of the EC's Clean Sky research initiative, is focusing on reducing CO_2 emissions by 26-40% over 2000 levels, and NO_x emissions by 53-65% for each flight, while halving the noise impact, reducing the footprint area by 50%, and lowering the effective perceived noise by 10 dB.

The program, led by AgustaWestland and Eurocopter, also has some aggressive timescale goals. The preliminary design for new active and passive rotor blades is to be achieved by early 2012, concepts and technologies for drag reduction frozen by early 2012, and the preliminary design review of a new diesel engine for a light helicopter to be completed by 2012.

Tilt-rotor designs remain an integral part of this research—a further Clean Sky objective is to research the optimization of flight procedures for tilt-rotor configurations, studying procedures that will enable the minimization of the tilt-rotor noise footprint during approach and departure.

The €160-million Green Rotorcraft research program team includes Poland's PZL Swidnik and the French, German, and Italian research centers ONERA, DLR, and CIRA.

Progress and challenges

Advanced European tilt-rotor research is continuing within the framework of the NICE-TRIP program, which builds on previous ERICA research. In particular, the DLR is evaluating some ERICA theoretical research concepts within its wind tunnel network. Among other work "there will be two wind tunnel tests with a powered full-span model where DLR is responsible for the model control and data acquisition," said a DLR researcher in February.

Producing a second-generation European tilt-rotor will be a highly complex affair, and not just because of the technologies involved. It is unlikely that a single European company could develop such an aircraft on its own in the current financial climate. Eurocopter has already suggested it will have to limit the amount of new 'green' technology on its next-genera-

NICETRIP is conducting wind tunnel tests where the model is put through various rotor configurations: upward (above) for takeoff; tilting forward in transition to normal flight (middle); then fully forward. Image: DLR.

tion X4 civil helicopter, a Dauphin replacement, unless it receives clear funding support from the French government. But in 2005 there was a complaint on alleged unfair support by the Italian government to Agusta for research into new helicopter technologies with both civil and military applications. As a result, the EC and the Italian government had to jointly evaluate how future government support to such a project could be given within the rules on state aid for R&D.

It is clear that there is a market for commercial tilt-rotors in Europe, given the increasing airport congestion now emerging as an immediate effect of the return to airline growth within the continent. What is less clear is whether the preliminary work done so far on tilt-rotor research in Europe has given industry enough confidence in the maturity of key technology areas to risk the major investment needed.

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Europe's decades of tilt-rotor research

The initial research work within the ERICA program, totaling more than €35 million—funded in part by the EC and in part by industry—is now complete. The aircraft concept differs from the V-22 and BA609 in that it will have smaller rotors (7.4 m), the outer wing sections will tilt independently of the nacelles, and there will be a continuous structural connection between the rotors.

The research findings are now being incorporated into Clean Sky and NICE-TRIP (novel innovative competitive effective tilt-rotor integrated project) research. NICE-TRIP is a pan-European program aimed at integrating critical technologies developed in previous projects, designing and manufacturing full-scale tilt-rotor parts, defining a new generation of actuators (for nacelle, wing, rotor), developing a powered full-span mock-up (one-fifth size), developing new types of testing rigs to accommodate the novel features, producing the very demanding tilt-rotor environment, and analyzing the integration of tilt-rotors in air traffic management/control.

The ERICA program is building on the following programs of tilt-rotor research, coordinated by the EC:

- *RHILP (rotorcraft handling, interactions, and loads prediction) to study specific aspects of tilt-rotor aeromechanics.*
- *TILTAERO (tilt-rotor interactional aerodynamics) to research how rotor blades can be made as short and efficient as possible but still allow the aircraft to take off and land vertically.*
- *ADYN (advanced European tilt-rotor dynamics and noise) to conduct wind tunnel research into acoustics and performance dynamics.*
- *ACT-TILT (active control technology for tilt-rotors) to study the flight control system—fly-by-wire and fly-by-light—and to define new control laws.*
- *DART (development of an advanced rotor for tilt-rotor design) to manufacture and test a full-scale rotor hub.*
- *TRYSID (tilt-rotor integrated drive system development) to develop and manufacture a new drive system, including researching issues around nacelle integration.*

Correspondence

In **A new boom in supersonics** (February, page 30) and the cover picture information, it is stated that the condensation cloud around the aircraft is due to exceeding the speed of sound. This is not true, and there are many pictures of all types of aircraft displaying this effect, particularly from the Navy.

Events Calendar

APRIL 4-7
Fifty-second AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference; 19th AIAA/ASME/AHS Adaptive Structures Conference; 13th AIAA Nondeterministic Approaches Conferences; 12th AIAA Gossamer Systems Forum; Seventh AIAA Multidisciplinary Design Optimization Specialist Conference; including AIAA Dynamics Specialists Conference. Denver, Colo.
Contact: 703/264-7500

APRIL 11-14
Seventeenth AIAA International Space Planes and Hypersonic Systems and Technologies Conference, San Francisco, Calif.
Contact: 703/264-7500

APRIL 13-15
First CEAS Specialist Conference on Guidance, Navigation, and Control, Munich, Germany.
Contact: DGLR, +49 228 30 80 5-0; gnc@dglr.de

MAY 2-5
Reinventing Space 2011, Los Angeles, Calif.
Contact: James R. Wertz, jwertz@smad.com

MAY 9-12
IAA Planetary Defense Conference, Bucharest, Romania.
Contact: William Ailor, 310/336-1135, william.h.ailor@aero.org

MAY 10-12
IEEE/AESS/AIAA Integrated Communications, Navigation and Surveillance Conference, Washington, D.C.
Contact: Col. John C. Gonda III, jgonda@mitre.org, www.i-cns.org

MAY 18-20
Sixth Argentine Congress on Space Technology, San Luis, Argentina.
Contact: Pablo de Leon, 701/777-2369 (U.S); www.aate.org

MAY 23-26
Twenty-first AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar, Dublin, Ireland.
Contact: 703/264-7500

The cloud occurs when the relative humidity is high and the aircraft speed is sufficient to cause it but not necessarily supersonic. The effect is due to the flow around the aircraft generally being in compression up to the point of maximum cross-sectional area and as it passes that point it suddenly is in expansion and the condensation occurs. The effect has nothing to do with the speed of sound.

As an aircraft approaches the speed of sound a bow shock forms at the nose and some other localized normal shocks occur around the aircraft. These shocks can only be seen in the wind tunnel using a Schlieren process; they can never be seen by the naked eye when the aircraft is in flight. These photos are commonly mislabeled by photographers who do not know the science.

Ralph M. Barnes

I would like to correct two mistakes in the otherwise excellent article on supersonics. First, the X-1 flight in October 1947 was not the first flight to exceed the speed of sound, but it was the first to do so in level flight. Previously, several aircraft had exceeded the speed of sound in dives.

Second, the photos on pages 31 (F/A-18) and 35 (F-22) do not show supersonic flight but rather high subsonic flight. Similar pictures can be found in *Patterns in the Sky,* NASA SP-514. To quote from the text, for level flight of an F-14 at Mach 0.9, "The free-stream flow accelerates to supersonic speeds above and below the wing; this causes the flow to condense in an almost straight line in the expansion waves in the front portion of the condensation pattern. The aft end of the pattern is created by a shock wave through which the flow is decelerated to subsonic speeds aft of the airplane."

The aerodynamicists in your readership will be familiar with the Transonic Area Rule, first enunciated by Whitcomb, which describes how, at transonic speeds, the flow around a slender vehicle reacts predominantly to the changes in cross-sectional area. Hence, we can see precisely the same flow pattern in shadowgraphs of projectiles at high subsonic speeds in Van Dyke's "An Album of Fluid Motion."

Michael J. Hemsch

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Correction: The upper photo on page 8 of the February issue is not an ARJ21, it is just an RJ. The pdf of the article on the *Aerospace America* Website and the digital version of the story have been corrected.

The virtue of patience

Achieving gains in high technology isn't usually a simple story

WITH THE SCALE OF MEDIA HYPE SURrounding developing aerospace industries in China and India, one might be forgiven for wondering whether a bias toward the liberal arts in education in recent years is coming home to roost.

That may not be entirely fair, but not so many years ago there would have been questions asked in response to manufacturers' or national institutions' claims relating to technology. Instead, nowadays the apparent expectation that virtually overnight either or both countries—particularly China—will be delivering knockout blows to the West's high-tech industries seems to have become commonplace.

But it isn't true in either country, both of which need time to develop their economies and their industries further—to absorb technologies they have bought, borrowed, or otherwise adopted from other places.

Polar opposites

Within Asia there are two models from which lessons may be learned: Japan and Vietnam. Japan is a hugely successful economy with an excellent high-tech industrial base. It has its problems (what economy doesn't?), and in raw scale it has recently been overtaken by China's economy, which is now second in the world behind the U.S. No matter; taking a very simplistic view of Japan's technological history by ignoring its prowess before and during WW II, Japan rebuilt its economy and manufacturing base after the war with huge amounts of mostly U.S. help to be able to feed its people and manufacture for the world.

Just as China has done in more recent years, Japan went through a long period of pulling itself up the technology ladder. It learned by copying, analyzing what it was making, improving those products bit by bit, then coming up with its own designs and processes that became management 'how to' lore for the rest of the world. But it did not happen overnight, and no one in those days expected that it would.

Japan, then, can be viewed as a positive model of achievement, one worthy of emulation when nascent economic and technological powerhouses seek to set their developmental styles. Even allowing for economic vicissitudes in recent times, Japan sits firmly on the 'plus' side of the developmental ledger.

Vietnam is the opposite. Its war with the U.S. left it with nowhere to go except up, yet it found ways to stagnate. It has been a country with massive potential for economic development for years, yet little changed until comparatively recent times. Analysts galore have been telling investors for years that Vietnam is 'hot,' that it is the upcoming opportunity and the like. But somehow the country has never quite leapt over the edge to actually become a hot market.

The 748 Series 1 and 2 were license-produced in India by Hindustan Aeronautics in the 1960s.

India and China: the middle ground

In technology terms, India and China lie somewhere between the two extremes, although heavily on the positive side. Both have active space programs, although China seems to be further ahead, having put men into orbit and returned them home safely. Both have nuclear arms. The two countries have active military R&D programs, originally developed with help from the former Soviet Union.

Both have civil aviation development plans that include building their own transport aircraft of various sizes, with China further along that particular road. Each has done coproduction or license production of twin-turboprop aircraft—India with the British Avro (later Hawker Siddeley) 748 airliner and military transport and China with the Soviet Antonov, An-12 (Y8 in China) military transport and An-24 (Y7) military and civilian transport.

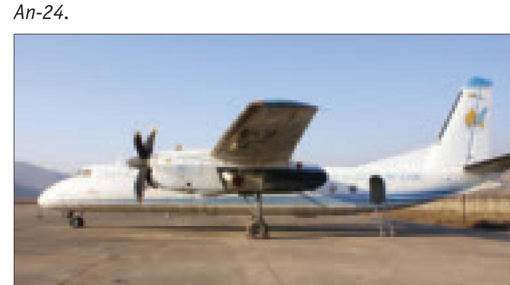
Both countries lean heavily on foreign companies for acquisition of technology, and have embarked on partnerships with them intending to go beyond domestic sales and into the international arena.

Buy or build, or boast

From here their paths seem to diverge. India freely admits it needs foreign partnerships because it cannot go it alone with any real chance of success—it would take far too much time and too much money in effect to replicate research already done by Western companies. But China, while actually working with foreign partners, seems to want all the credit for itself for whatever technical advances it can show, whether or not its claims stand up to even the lightest scrutiny.

The two countries suffer in organizational terms from the handicaps of being huge states with immense bureaucracies, plagued by poverty while trying to lift people to at least a rea-

China's turboprop Y7 is based on the Antonov An-24.



sonable standard of housing, availability of food, and productive work.

In this regard, India presents a somewhat misleading and confused picture. As a giant, multiparty state, its government is secular, yet it and the nation's politics are heavily influenced by religions. It is a huge democracy in which the private sector is diversified and spread out both geographically and throughout its various industries, including aerospace and defense. The government approves, or not, deals with foreign partners, but the initiative for such deals largely rests with the private sector.

Such publicity as there is about aerospace and defense tends to be related to individual companies, with the exception of space, which is very much within the government's purview. But there seems to be little in the way of an Indian national psyche that needs to be massaged or glory that needs to be reflected onto local corporate or individual egos.

Further, India demonstrates at senior government levels a totally realistic attitude concerning the level of technology a foreign partner is willing to hand over: surely not the most recent, and probably two generations behind what is current in the partner's latest offerings at home.

Self-reliance is the answer, but it takes time and money. Indian Defense Minister A.K. Antony, opening the Aero India show in February, pointed out that technology development usually comes ahead of product development, but because some foreign technology was restricted, India had to handle both stages simultaneously in projects such as its Tejas light combat aircraft.

The minister's chief scientific advisor and head of the country's Defense Research and Development Organization, V.K. Saraswat, added that he believed collaboration was the best approach because developing pieces of technology locally was too time consuming and expensive. Adding local content is the icing on the cake.

In short, buy the technology elsewhere and adapt it to fit local needs by adding applications, as Japan has done for years with imported U.S. military aircraft built under license at home, while developing and maintaining the core of its own expertise in major design-and-build projects with limited production runs of its own aircraft.

The Tejas has many indigenous Indian features.

Japan also offers lessons for India and China in this regard. Japan has been through what seems to be the traditional cycle for indigenous aircraft development—the small trainer, a medium-size twin-prop transport (the YS-11), and fighter aircraft. The YS-11 was rated as a technically successful aircraft that came late to the market so it never sold overseas in the numbers that had been sought. Japan's latest experiment is the Mitsubishi Regional Jet, a twin-engined 70-90-seat airliner due to enter service in 2014. So far it has gained 125 orders, mostly involving operators in the U.S.

The MRJ's size puts it firmly into competition with other relative newcomers to the commuter jet market: Bombardier's C-Series (yet to fly), Brazilian Embraer's series of small jets (in service), Russia's Sukhoi Superjet family (already flying and recently certified), and China's ARJ 21 (already flying, due to enter service late this year). The market seems somewhat crowded. India, too, is talking about building a regional transport. All of these models compete with the smallest of the Boeing 737 and Airbus family.

Japan's YS-11 was never a big seller overseas.

China is trying to jump into the next size up as well, with the C919 at about the same size as the Airbus A320. This is often claimed as China's home-grown 'jumbo jet,' although it is in fact of medium size and—as was the ARJ 21—is being designed with foreign help and will contain many foreign-made components and systems.

Then there is the J20 'stealth fighter' that first flew late in 2010 with much pseudosecrecy giving way to a public relations blitz pushing China's technological abilities. There is also an alleged 'carrier killer' missile with a range of about 900-1,000 miles and 'pinpoint accuracy.' Finally, there are high-speed trains that will put Japan's Shinkansen and Europe's railways to shame, or so the publicity would have us believe.

Quota over quality

China has some probably painful experience to endure before its claims are likely to ring true. While there are

The J20 quickly became one of China's worst kept 'secrets.'

indeed areas of excellence in many of China's aircraft factories, these are like oases scattered across a vast desert. Quality control is a massive problem, and it is endemic, largely as a result of a manufacturing ethos that until recently emphasized meeting production quotas instead of stressing quality. 'Zero defects' may be a concept worthy of discussion, but it is far from being implemented as a policy, let alone as a standard working practice.

None of this should be seen as belittling the efforts China's scientists and engineers are putting into upgrading existing products and creating new ones. The difficulties should be seen as obstacles to progress that must be overcome on the road to success.

It is unfortunate that the concept of 'face' seems to militate against honest appraisals of projects or arguing against unrealistic deadlines—this latter problem leads to short-cutting, shaving safety margins, or ignoring safety altogether in a rush to complete a job. This has already been widely reported concerning high-speed trains: In the haste to finish projects, a large amount of substandard rail-bed material has been installed, probably halving the life of the tracks concerned. Which tracks and how long before they become unsafe has not been stated.

The problem of quality control in China is nothing new; Hong Kong businessmen buying from factories in the southern mainland have long been used to putting in their own inspectors and checks to ensure the goods they are paying for are made according to specification. Foreign manufacturers of aircraft engine parts in China have at various times been shaken by the casual attitude to the precision necessary to produce work of an acceptable standard.

The problems may be declining in number, but progress is slow, and impatience with intricate processes is no help. That Chinese companies rip off foreign technology is a given. It is actually a good thing in some ways: first because it inculcates a particular style of technology into local thinking, so there is a level of comfort with that type of technology; second, because a large part of successfully reproducing such technology necessarily involves having the patience to do it properly.

As many foreign companies are only too well aware, a major part of creating and sustaining a market is a process of educating customers—making them part of the system instead of merely purchasers and users. That tends to lead to satisfied customers, and satisfied customers usually come back for more. But, unlike in the media, it doesn't happen overnight.

Michael Westlake
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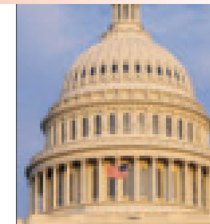
China's C-919, aimed as competition for the Airbus A320, contains many foreign parts.



The budget—a continuing saga

In Washington, debate continues over when, whether, how, and how much to fund the operations of government for the current fiscal year and into the future. When we went to press, federal agencies were still without an FY11 budget, and government had just enacted a continuing resolution (CR) to keep operations running for a mere two weeks, until March 18.

This short-term measure amounts to "kicking the can down the road," says budget analyst Charles Konigsberg. Budget-cutting Republicans in charge of the House of Representatives were saying they would continue their piecemeal assault on spending with short-term CRs; the Democrats in control of the Senate and White House were urging a longer term compromise that would keep government at work until September 30, the end of the current fiscal year.

What was billed in the press as a debate over spending cuts—aimed at addressing the nation's $14-trillion national debt and $1.1-trillion annual deficit—was actually something less. Leaders on both sides of the aisle are focused solely on nonmilitary discretionary spending, which makes up less than 12% of annual government expenditures.

Despite the intensity of the debate, with its ever-looming threat that government could shut down if no legislation is passed at all, no one in Washington is proposing cuts to the major programs that drive up deficits: Social Security, Medicare, Medicaid, and defense. No leader in either party has suggested addressing the deficit by raising taxes. And while the debate continues, the Obama administration's proposed budget for FY12, which begins October 1, is largely out of the limelight.

The debate is less than it appears for other reasons: Even without a government, most of the functions of government would continue until a CR or a budget was passed. Any losses incurred during a shutdown would be made up later.

For those in aerospace, the debate had little immediate impact. NASA was likely to take some hits under any circumstances but continues to function amid separate discussions on the future of human spaceflight. The Pentagon continues to pursue most of its major programs and has announced its choice for a new Air Force refueling tanker. And every short- or long-term bill being mooted on Capitol Hill includes funding for the FAA's NextGen project to bring airway navigation into the digital age.

NASA FY12 budget request

Although NASA still does not have a formal appropriations bill for FY11, government and industry are right on schedule scrutinizing the administration's $18.7-billion FY12 budget request for the agency, released on February 14. On both sides of the aisle, lawmakers who have an interest in space policy, such as Sen. Bill Nelson (D-Fla.) and Rep. John Culberson (R-Texas), say the FY12 amount is too low. A commentary by William Harwood on the CBS News web site says, "Until Congress weighs in with actual funding, it's not clear when a viable United States manned spacecraft will emerge to service the station or when eventual deep space missions might occur." Others insist that confusion over spaceflight goals, more than budgetary issues, is hindering NASA.

The agency has traditionally been responsible for designing, developing, and deploying human spaceflight vehicles, but many in Washington now believe public-sector dominance in spaceflight is coming to an end. The $18.7-billion amount is less than the administration promised as recently as last year, although still more than cost-cutting advocates on Capitol Hill want.

"This budget requires us to live within our means so we can invest in our future," says NASA administrator Charles Bolden. "It maintains our commitment to human spaceflight and provides for strong programs to continue the outstanding science, aeronautics research, and education needed to win the future." Bolden's critics say he needs to be more

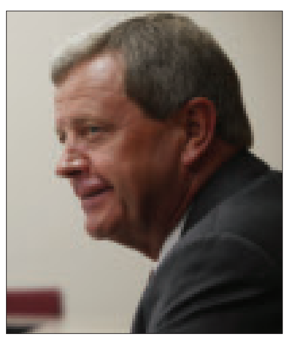
Bill Gerstenmaier

NASA Administrator Charles Bolden testified during a House Committee on Science, Space, and Technology budget hearing, Wednesday, March 2, 2011. Photo Credit: NASA/Bill Ingalls.

proactive in defining and shaping the nation's spaceflight policy.

The FY12 budget proposal—"an austere blueprint," according to the newspaper *Florida Today*—calls for programs such as a nonprofit organization to handle research conducted at the ISS. The proposal includes funding for commercial spaceflight but not, as many had expected, an increase.

The FY12 budget request, wrote Mark K. Matthews in the *Orlando Sentinel*, has the White House picking a fight with Congress that many thought had been resolved. Wrote Matthews: "Last year, the White House and Congress feuded for months about how NASA should replace the space shuttle before compromising on a plan that would spend limited money on commercial spacecraft while pushing NASA to build the new rocket and Apollo-like crew capsule. Congress prodded NASA to use the main engines and solid rocket boosters developed for the shuttle 30 years ago."



Rep. Tom Latham

Closer to home for many who work for or support the agency, the budget request reduces a plan for modernization of the Kennedy Space Center. The proposed Atlantis shuttle mission to resupply the ISS is not included in the request because the flight is slated for this year (probably July), but it is not clear whether NASA can afford to make the flight with existing funds. Bill Gerstenmaier, associate administrator for the Space Operations Directorate, says the agency is "pressing on" with work toward the flight (the last ever by the shuttles), which officials say is essential to the long-term health of the space station.

FAA FY12 budget request

Also on February 14, the administration released its $18.66-billion FY12 budget request for the FAA. Almost equal to NASA's budget, it reduces federal grants to the nation's medium and large airports but gives a green light to the long-delayed NextGen airway navigation system.

By setting aside $1.24 billion for NextGen, the budget request recognizes that the U.S. is lagging behind the rest of the world in introducing a modern navigation system and must catch up. The total compares with $868 million for NextGen in FY10, the most recent year in which an FAA appropriations bill was enacted.

Boeing's bid in the tanker competition was said to come in at about 10% less than the EADS proposal.

Tom Latham (R-Iowa), the House appropriations subcommittee chairman, says NextGen is a "top priority" and will not be affected by reductions in other FAA programs.

Tanker, at last

The Air Force says its first Boeing KC-46A air refueling tanker will be operational in 2017. If the new plane arrives right on schedule—something that happens rarely in major defense programs—more than 20 years will have elapsed since planners in the Pentagon first began studying a next-generation tanker.

On February 24, Pentagon leaders announced that Boeing's tanker, derived from its 767-200 airliner, had been selected over the proposed Airbus A330-200 tanker from EADS.

The Boeing term for its aircraft is 767 NewGen. The EADS name for its plane is KC-45. The competition was called KC-X, and KC-46A is the military designation for the winning Boeing design. The winning planemaker will eventually reap $35 billion for 179 new aircraft to replace about 490 Eisenhower-era KC-135 Stratotankers. The initial contract in the administration's FY12 budget request will be $3.5 billion for the first 18 airframes.

Boeing will build the planes in Everett, Washington, and outfit them in Wichita, Kansas. EADS had wanted to build a new plant in Mobile, Alabama, and hoped a tanker contract would be a foot in Alabama's door, so to speak, to enable it to assemble civilian air freighters in Mobile as well.

The award to Boeing is expected to evolve into the biggest defense con-

Undersecretary of Defense for Acquisition, Technology and Logistics Ashton B. Carter speaks with the press about the KC-X contract announcement during a briefng with Air Force Chief of Staff Gen. Norton A. Schwartz, Secretary of the Air Force Michael B. Donley, and Deputy Defense Secretary William J. Lynn III. DOD photo by Cherie Cullen.

tract so far in the 21st century. The decision comes after more than a decade of troubled efforts.

The KC-135 Stratotankerhas been in continuous service with the Air Force since 1957.

In the nation's capital, reaction to the announcement showed how eager lawmakers are to bring high-paying aerospace jobs to their states. To Sen. Patty Murray (D-Wash.), the choice was "great news." Sen. Richard Shelby (R-Ala.), who had lobbied hard for the Mobile plant, called the decision "Chi-cago politics"—noting that President Obama is from that city, and Boeing is headquartered there—and said the Air Force had picked an "inferior plane."

Seemingly in support of Shelby's assertion, Rich Michalski, general vice president of the International Association of Machinists and Aerospace Workers, said his union, which supported Obama in 2008, took its case directly to the White House. Michalski told reporters that Obama should be credited for responding to the union's message.

Air Force Secretary Michael Donley said the contract selection was the result of a "thorough and transparent selection process" and "represents a long-overdue start to a much-needed program." The Air Force says the competition was managed without reference to politics.

The losing candidate from Airbus was bigger, more robust, and based on a newer design. The winning plane from Boeing is based on an older design and smaller—closer in size to the KC-135 it will replace. Donley says the selection "took into account mission effectiveness in wartime and life-cycle costs as embodied in fuel efficiency and military construction costs."

Sen. Patty Murray

Many lawmakers and analysts believe that either aircraft could have done the job. One critic suggests that Washington could have been spared a decade of turmoil if Air Force acquisitions officers had picked up a couple of aviation magazines and read about the Boeing and Airbus rivals. Donley says that both tanker designs earned a passing grade for all 372 mandatory KC-X pass/fail requirements.

Though the losing bid was filed by EADS' North America subsidy, EADS is a European company that some have accused of receiving unfair government subsidy. Transatlantic implications were obvious in German Chancellor Angela Merkel's statement that she "deplored" the decision. The WTO (World Trade Organization) told the European Union that European countries had provided $20 billion in launch and other government aid to EADS, but also charged that Boeing received billions in illegal subsidies from the U.S. government. However, shortly afterthe announcement EADS said it would not appeal the decision.

Some point out that, as the price of fuel continues to rise each day, the smaller Boeing aircraft, with its lower fuel usage, becomes more and more appealing.

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Scott Pace

You've had a lead role in space programming, budgeting, and strategy at the White House and NASA. What do you think of the Obama administration's move to kill NASA's Constellation program and its impact on the future of human space exploration?

Let's begin with the broader issue, which is how to sustain a human spaceflight program across multiple administrations. We don't change our astrophysics program every time we have an election. We don't debate whether we will have a Navy or not. The amount of available resources changes, and we may emphasize one area or another, but as a fundamental matter, we maintain a sustainable and predictable environment. That is not the case now with space, especially human spaceflight.

So you take issue with the Obama space policy?

I think the administration deserves credit for continuing the policy of human space exploration beyond low Earth orbit. They could have said, we're going to return to the Clinton administration policy where the only human spaceflight effort is the international space station. They didn't do that; they left in the idea of exploration beyond low Earth orbit, so that is an asset. But programmatically, I think they made a number of errors.

What were those errors?

They weren't just matters of communication; they were matters of timing and execution. It was perfectly possible to imagine an increased emphasis on using more commercial-like contracts, on human-rating commercial crew vehicles, and on new technology, which NASA desperately needs to do more work in. But the whole approach could have been done in a way that would have been much less politically and economically disruptive, and in a way that would have led to less uncertainty both domestically and internationally.

Elaborate on that point.

The amount of uncertainty that the administration's strategy has generated from both a domestic and international standpoint has been, I think, very harmful to the United States. It is not a matter of being pro-commercial or not, or pro-technology or not. It is a matter of how we manage one of the most critical challenges that we have in space today, which is the transition off the space shuttle, protecting the space station and ensuring its success, and creating a stable foundation for international and commercial cooperation in human spaceflight beyond low Earth orbit.

There was a plan in the form of Constellation that did all that, but the new administration wanted to change it, to reallocate the available resources, and that was wrong, in my view.

Some would argue that the previous administration's program had its faults.

Yes, the counter argument would be that the previous administration's portfolio was too concentrated on the government option and did not do enough in technology and commercial programs. I can understand why someone would say that. But if you are going to transition that portfolio to a new one, you should transition it more gradually and in a way that allows for both the international community and the business community to adapt.

"Right now the number one human spaceflight objective of the U.S. should be protecting and utilizing the space station."

Instead, what was done in the 2011 budget was a very sharp break that created political, economic, and international ripples that we're going to be dealing with for some time to come. It's one thing to choose a new direction with a new program, but another to do so in a way that breaks the system.

The administration argued that its strategy for space was pegged to the findings and recommendations of the Augustine committee.

I don't find that terribly convincing, because the Augustine committee was very clear that additional resources would be necessary to implement those recommendations. If you look at historical NASA budgets, you see that the current administration is spending at roughly the same level as the last one. If you take the 2005 Bush administration budget and assume an increase in inflation-adjusted terms of 2.4% a year and run that out, and look at where the budget is now, you find that those budgets are about the same in constant dollars.

That is seldom noted. There seems to be a widespread notion that spending on space has increased rather substantially.

The reason for that is that people don't recall what the baseline was. What happened with the Bush administration space budget was that NASA did not get all the money in 2005 that had been projected for exploration in 2005. There were a number of rescissions and deficit-reduction actions, along with additional costs of the [shuttle] return-to-flight decision that NASA was told to absorb. As a result, the overall amounts of money in the NASA budgets from 2005 through 2009 were somewhat lower, and that

Interview by James W. Canan

is what caused the schedule slip of a year to two years in the Ares I/Orion program at the heart of Constellation.

The FY10 budget was depressed by a $3-billion asterisk in the exploration line, pending the outcome of the Augustine committee and lowering expected inflation from 2.4% to 1.36%. The FY11 NASA budget, which contained the Obama administration's new proposals, represented a return to the previous top line, but with a different internal portfolio.

What do you see as the major differences between the Bush and Obama space portfolios?

The Bush administration budget had a mixed portfolio of a large government program—Constellation—and some emphasis on commercial programs, primarily commercial cargo transportation. It had relatively little money for technology, only the technology that was necessary for the Constellation program and lunar return.

The Obama administration redid that portfolio by having a much smaller governmental development effort, and by placing larger bets on commercial cargo and crew programs, on developing new technology, and on non-exploration, non-human spaceflight efforts. The money to pay for science and technology programs and for commercial crew and cargo activities was taken from the Constellation program, from the governmental part of NASA's space exploration portfolio.

Tell us more about why you think the redoing was wrong.

I didn't think it was a wise approach, because I believe there should be a government option, a public option, in the program until we know that some of the private sector activities can, in fact, take over the job. What people don't often recall is that Ares I/Orion was designed for going to the Moon. In addition, the U.S. would have a way of getting to the space station with Ares I/Orion if commercial crew and cargo systems were slow in coming.

Commercial cargo capabilities to the station were to be developed first and demonstrated, and then attention could turn to commercial crew. The Ares I created the foundation for the heavy-lift Ares V that could be used to support a lunar base and future human missions to Mars.

Where does the space station fit in the context of space priorities? Just how important is it?

Right now the number one human spaceflight objective of the U.S. should be protecting and utilizing the space station. In that regard, the funding for the STS 135 flight [to the ISS] is absolutely critical to build margin for the station's sustainment. In 2008 or 2009, if asked if I would support that mission, I would have said no, that it was too expensive and that other options, such as continuing the Ares1/Orion program would be more beneficial in the long term. And I was hopeful that some of the commercial cargo programs would make faster progress. Well, none of those things has come

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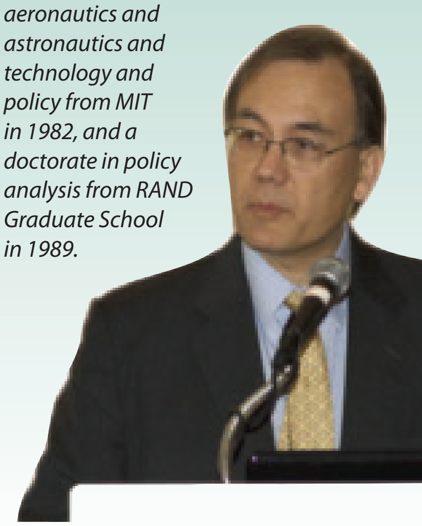
From 2005 to 2008, Pace served as associate administrator for program analysis and evaluation at NASA, responsible for providing objective studies and analyses in support of policy, program, and budget decisions by the NASA administrator. Previously he served as chief technologist for space communications in NASA's Office of Space Operations, where he was responsible for issues related to space-based information systems. He had also served as deputy chief of staff to NASA Administrator Sean O'Keefe.

He participated in negotiations that resulted in the 2004 GPS-Galileo Agreement between the U.S. and the EC.

Prior to his service at NASA, Pace was the assistant director for space and aeronautics in the Office of Science and Technology Policy (OSTP). He was responsible for space and aviation-related issues and coordination of civil and commercial space issues through the Space Policy Coordinating Committee of the National Security Council.

From 1993 to 2000, Pace worked for RAND's Science and Technology Policy Institute, a federally funded research and development center for OSTP. He also was a member of the DOD Senior Review Group on Commercial Remote Sensing and the National Research Council's Committee on Earth Sciences. Previously, he served as deputy director and acting director of the Office of Space Commerce in the Office of the Deputy Secretary of Commerce.

He received a bachelor of science degree in physics from Harvey Mudd College in 1980, masters degrees in aeronautics and astronautics and technology and policy from MIT in 1982, and a doctorate in policy analysis from RAND Graduate School in 1989.



to pass. So as I look at it today, I think the space station program, although expensive, absolutely needs that [shuttle] mission.

What about the argument that the shuttle is too risky to keep flying?

After the Columbia Accident Investigation Board report, it was decided that returning the shuttle to flight and completing the ISS in order to keep our commitment to international partners was of such national importance that it was worth risking lives. The decision to return the shuttle to flight and commit to the completion of the space station was a very, very thoughtful one.

At the same time, it was also very clear that the shuttle program needed to end, that we needed to transition to a much safer vehicle—not just to one with higher reliability but also with crew escape options.

So your conclusion is that continuing to fly the shuttle is worth the risk?

Again, we have to ask ourselves, is the mission really that important, important enough to have the crew take a risk. I think it is. If we are serious about our commitment to our international partners and to the station, it is something we should do.

Does this mean that you advocate extending the shuttle program pretty far into the future?

I would prefer not to, but since our mission objective is sustainment of the international space station, the USA [United Space Alliance] proposal to continue flying the shuttle two flights a year through 2017 is well worth a look. Again, if you had asked me a few years ago, I would have said no, because I thought we were going to make progress in other areas and I didn't want to take the risk. But with the transition plan that we had with Constellation now gone, and taking into consideration the capabilities and risks that we have today, I think it's worth doing an analysis of the proposal, and I would not exclude it. But I'm not committed to extending the shuttle. I want us to transition toward a higher reliability and safer vehicle.

In the end, who do you think will build such a vehicle?

I don't care if it comes from a commercial source or a government source. I believe a mixed strategy of commercial and government systems makes more sense than sole reliance on commercial. As I see it, the immediate objective for human spaceflight is the protection of the space station. The station is the most immediate toehold that we have in space, and it is central to human space exploration beyond that. If we let it fail, we will not live up to our international partnership commitment, and we will lose a valuable testbed for space exploration technology.

Why is the station so vital to the future of human space exploration?

If that program were to be damaged or to fail, I don't know that there would be the political or economic will necessary to restart a human space exploration program. I'm not saying that we wouldn't be able technically to build a replacement; I'm saying that in terms of budget, political will, and the industrial base, I don't know that it would be possible.

And presumably the current emphasis on fiscal austerity also works against robust spending on space, along with everything else?

Correct. So we have to protect our investments in our options for space, and the best way to do that is through diversification—not placing our bets on any single approach but on a variety of approaches, public and private.

Why do you doubt the political will for human space exploration?

If you look solely inside the Beltway, you find a relatively small cadre of dedicated, sharp, committed people on both sides of the aisle who are supportive of human spaceflight, human space exploration, not just for what's in their congressional districts, for example, but also because they think it is good for the country. The broader public supports it but doesn't know very much about it.

On the other hand, I think space is so entrenched in people's idea of what the United States is and what it stands for, that turning away from space would be quite a shock.

So where do you come out in all that?

I think there is interest and support for space development in the country, but there is not really recognition of the kinds of risks our space program is facing right now. That's why I keep coming back to my argument for a balanced portfolio and having diversification and backup options.

Back to the launch vehicle issue. What's at stake there?

If we think that exploration beyond low Earth orbit is important, we are going to need a heavy lift vehicle, a space exploration vehicle, for lunar outposts and eventually for Mars. How do we build it? Well, if we can't build it all at once, we can make a down payment on it. We didn't build the Saturn V heavy-lift vehicle for Apollo immediately; we first built the Saturn 1B, which led to Saturn V.

So what can we build now that gets us toward this heavy-lift vehicle we know we'll need in the long term? The Constellation program's answer to that was Ares I, because in building that system we would make most of the down payment necessary to building the heavy-lift Ares V with relatively modest additional cost. Saturn 1B was the Ares I equivalent of its time.

Well, Ares I seems out of the picture, so what now?

The ATK/Astrium proposal is an interesting option that I hope gets a closer look. But the key is to define an architecture today that gets us toward that heavy-lift vehicle tomorrow. There isn't really a clear answer to that. I am glad the administration is proposing exploration beyond low Earth orbit, but I wish it would be willing to fund a more balanced program with a more logical alignment of priorities.

I give the administration credit for its emphasis on funding commercial cargo transportation. There have been delays, and it hasn't happened as quickly as people had hoped. But I am confident that they will get there, that it will happen.

How do you size up NASA nowadays? What do you see ahead for your former agency?

I think NASA is facing a broad range of problems across the board,

"If that program [ISS] were to be damaged or to fail, I don't know that there would be the political or economic will necessary to restart a human space exploration program."

not just in human spaceflight but also in its science programs, its astrophysics line. The James Webb telescope overruns are troublesome. We thought we had established a stable technical baseline and had absorbed the bulk of the cost increases, but there have been additional increases and their magnitude comes as a surprise to me. As an analyst, I would like to know more deeply why that occurred. And there have been cost increases and technical challenges in the Mars Science Laboratory program.

What do those problems portend for the future?

Those are both flagship-level NASA programs, so the implications of the cost increases will have profound impacts on the whole NASA science scene for many years to come, because other programs will have to be cut or delayed, too. So that is a problem for the NASA science community, but it is something that can be solved within the NASA budget, in the science community lines.

NASA will make the choices that it needs to make. It has faced these kinds of problems before, and no one questions that there will be an astrophysics line or that there will be a planetary exploration line.

You mentioned NASA's human spaceflight problem. Tell us about that.

The problem with human spaceflight is one of uncertainty, and that is not solely in NASA's hands. It is really up to the country as to what we want NASA to do. The programmatic uncertainties facing NASA are created externally. NASA has always tried—and is trying—to do what the White House and Congress have asked it to do. This means that both ends of Pennsylvania Avenue have to be in sync for there to be a stable space policy environment. It is not the fault of NASA that it is pulled in different directions and with an inadequate budget.

What do you see ahead for commercial space?

Each successive generation of commercial entrepreneurial space programs has been better funded, better managed, smarter technically, and has made better progress. But at the same time, in every generation, with maybe one or two exceptions, all the companies have died. That is the nature of the business; entrepreneurial ventures fail. This generation of companies—SpaceX, Bigelow, Virgin Galactic, and a number of others—is the strongest and the best that we've seen to date. They have made progress, but if history is a guide, most will die.

Government policies must encourage and support the companies—provide them with a stable regulatory environment, advantageous contracting arrangements, and everything else that gives them the best chance of success. But this does not mean that you build a national space policy on the assumption that they are going to succeed. In spaceflight, we should always hope for the best but plan for the worst.

New environments drive UAV radar growth

DEFENSE SPENDING FOR UAV SYNthetic aperture radar (SAR) development has already increased drastically in the past few years. Several new SAR programs, including radar for the next generation of the ubiquitous Predator UAV—the Air Force Reaper and Army-Grey Eagle/Sky Warrior—will soon add capabilities to today's EO (electrooptic) and IR sensors.

These new ISR tools will be especially important in the different environments of today's conflicts. Instead of the urban setting of Iraq, where narrow field-of-view EO/IR cameras have focused on monitoring and protecting our own forces, the broad, mountainous countryside of Afghanistan requires a different kind of surveillance. The SAR's all-weather GMTI (ground moving target indication) ability and 3D topographic location/detection/identification features will allow better processing of enemies who may not always be civilians (although UAV SARs are also being tested by the U.S. Customs and Border Patrol and private contractors, for sealing the U.S./Mexican border).

Airborne SARs process radar returns as if they were collected by an antenna up to several hundred meters long. This 'synthetic' antenna aperture is created by the movement of the aircraft itself and allows a parallax view of the ground similar to a stereoscopic optical image. It not only provides 3D images in spot mode, but can autonomously detect objects (people, vehicles, and so on) that have displaced even slightly during the long radar scan. Unlike optical sensors, SARs' radio waves are not blocked by clouds or smoke.

Production of the next generation of SARs is just beginning, greatly expanding on today's legacy Raytheon 'HISAR' radars aboard the handful of RQ-4 Global Hawks in service. But it will be production of Northrop Grumman's MP-RTIP (multiplatform radar technology insertion program) that will result in Teal Group's forecast 15.9% compound annual growth rate (CAGR) from FY11 to FY16.

In the out-years, SAR miniaturization will increasingly expand service to smaller tactical and mini-UAVs (and combat UCAVs), contributing to a still substantial overall 9.8% CAGR from FY11 to FY20, even after MP-RTIP production trails off near the end of the decade. UAV SAR funding will increase from $550 million in FY11 to $1.3 billion in FY20.

Manned/UAV transition

Preproduction versions of the Boeing 707-based JSTARS (joint surveillance target attack radar system) served with great success in the 1990-1991 Persian Gulf War over Iraq, and at least seven production aircraft served in Operation Iraqi Freedom in 2003. JSTARS continues to be the world's 800-lb SAR gorilla, in both capability and funding, having been joined only recently by newer systems like Britain's manned ASTOR (airborne stand-off radar) and the Navy's manned AN/APS-149(V) littoral surveillance radar system.

Although large manned SARs will always provide a capability not available elsewhere—in-the-air command and control—smaller SARs will increasingly be mounted on UAVs. Without a command and control function, and with SARs providing all-weather all-the-time surveillance, a persistent sensor will function just as well on an unmanned platform—better, in fact, considering the longer endurance of most unmanned systems.

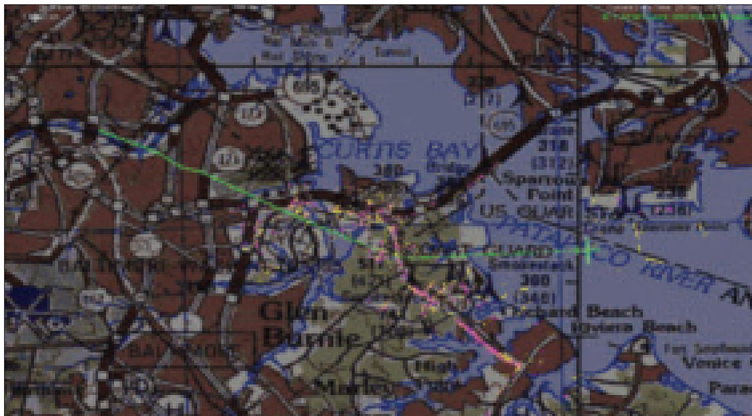
The gorilla in question

Manned JSTARS aircraft disappeared from the news a few years ago, in part to encourage funding for the Air Force MP-RTIP, which began development in 1998. MP-RTIP is a joint Northrop-Raytheon program for a very-high-resolution SAR using a modular, scalable active electronically scanned array antenna. It is currently planned only for the Global Hawk, and even NATO has decided to morph its originally manned AGS (alliance ground surveillance) program into an off-the-shelf Global Hawk MP-RTIP buy, but the developers hope for future use on both smaller and larger platforms.

In December 2010, Northrop delivered the first production MP-RTIP to Edwards AFB for integration on the USAF's first Block 40 Global Hawk. The first flight on the UAV was scheduled for early this year.

There have, however, been threats to MP-RTIP. With the much-delayed billion-dollar procurement phase still to come, in April 2010 the Air Force launched a 'quick-

The Starlite SAR/GMTI radar is a major Northrop Grumman SAR development.



look study,' asking industry whether a more affordable SAR with GMTI could be available in 24-36 months. In June 2010, Air Force senior acquisition executive David Van Buren said, "We are not happy with the cost of the [Global Hawk] air vehicle and the sensors; I'm not happy with the pace of the program…both the government side and the contractor side need to do better in the future." Van Buren also specifically criticized Northrop's MP-RTIP radar.

Though there is not yet an immediate threat, it is possible we may be talking about the 'MP-RTIP technology demonstrator' in a few years, rather than an ongoing production program. For now, Teal Group will tentatively forecast the planned schedule for full production for the USAF, NATO (AGS), and a few more radars for undetermined customers.

Other new SARs

In 2010, testing continued for the Navy's broad area maritime surveillance (BAMS) Global Hawk sensor suite, including Northrop Grumman's maritime-optimized, inverse synthetic aperture radar (ISAR), the multifunction active sensor (MFAS).

For maritime UAVs, especially endurance types, the radar is the primary sensor, not the electrooptical payload. Maritime missions involve longer slant ranges, with detecting and identifying ships the primary goal, rather than picking small targets out of ground clutter for medium-range reconnaissance and targeting. A long-range SAR, which can pierce clouds and moisture,

General Atomics is scheduled to deliver two-plus Warrior UAVs a month through the end of 2012.

The Global Hawk (USAF or NATO AGS) features MP-RTIP.

is much more effective than an EO/IR payload, which will be secondary on endurance maritime UAVs.

The belly-mounted MFAS operates in the same 8-12.5-GHz band as the MP-RTIP. Its antenna rotates mechanically through 360 deg, unlike the fixed MP-RTIP antenna, and MFAS will provide more commonality with Northrop's AN/APG-81 radar on the F-35.

In 2010, the Navy commissioned an independent MFAS assessment from MIT Lincoln Laboratory—perhaps concerned about MP-RTIP's long delays—and it compared well with Northrop Grumman's modeling. The Navy has been using a leased Gulfstream G-II aircraft for early MFAS flight testing.

In September 2010, Northrop began work on the first BAMS air vehicle at its Moss Point, Mississippi, facility. About 40 Navy BAMS air vehicles are eventually planned.

Northrop's other major new UAV SAR program is the AN/ZPY-1 Starlite SAR/GMTI radar. In early 2011, Starlite weighed 65 lb, occupied 1.2 ft^3, and required less than 750 W of power. Starlite is now entering production for the Army's Grey Eagle UAV, derived from General Atomics' smaller Predator A. The Air Force's larger Reaper/Predator B mounts General Atomics' 83-lb Ku-band AN/APY-8 Lynx SAR/GMTI radar, in series production now.

In February 2010, Northrop Grumman delivered the first two production Starlite SARs to the Army, following 18 months of qualification tests by the service. In April 2010, Northrop announced it was in discussions with the Army to install Starlite on the PTDS (persistent threat detection system) tethered aerostat, because although a number of radars were ready for installation, General Atomics was not yet ready for Grey Eagle integration. This claim could involve a bit of bluster, however, as Global Hawk producer Northrop has attempted to make Predator A/B builder (and bitter rival) General Atomics seem 'not up to the task' at other times.

In July 2010, General Atomics received $195.5 million in funding from the Army toward an estimated $399-million contract for low-rate initial production of Sky Warrior (now Grey Eagle), for 34 vehicles. The company is scheduled to deliver over two aircraft a month through the end of 2012.

In November 2010, the Army awarded a contract option to Northrop Grumman for 40 more Starlite radars

An A160 Hummingbird UAV crashed during testing of the FORESTER sensor in September 2010.

for Grey Eagle, with deliveries through March 2012.

Another good opportunity for SAR development today, and potentially major production tomorrow, is the Navy's new UCLASS (unmanned carrier-launched surveillance and strike) air vehicle. In March 2010, the Navy released a request for information for a next-generation follow-on to the UCAS-D (unmanned combat air system demonstrator). A request for proposals is expected by June. Perhaps notable from an operational as well as a sensor perspective is the new inclusion of 'surveillance' in the previously all 'combat' UCAV.

Last August, Rear Adm. Ted Kraft, Navy director of ISR, discussed sensor needs. "In the maritime environment, it's got to be so much more than EO/IR cameras," he said. At a minimum, UCLASS will need to have radar and an automatic identification system, to cue a narrow-field-of-view EO/IR sensor over vast expanses of empty ocean. A SIGINT package would also be useful, according to Kraft.

New technologies

Several other new UAV radar programs continue in development. Some may become moderate procurements, providing special abilities or technologies. Most of them follow the recent Army tradition of having cool names.

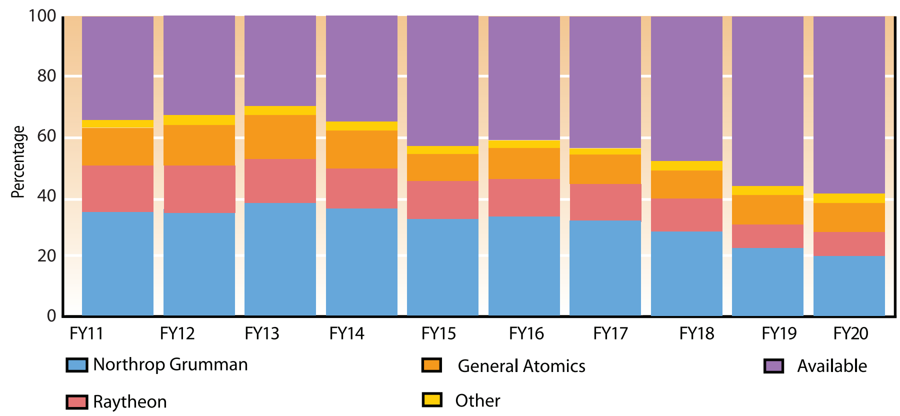
The Army's VADER (vehicle and dismount exploitation radar) was initially in development as the first SAR able to detect and track individuals on the ground (other radars now also claim this ability), specifically individuals leaving vehicles, such as terrorists planting roadside bombs under the cover of weather that denies EO/IR detection. The Northrop Grumman VADER is built into a Hellfire-missile-sized pod, designed to be carried by the Army's Grey Eagle UAV. In February 2010, the Army planned to send one of two VADER prototypes to Afghanistan aboard a manned DHC-6 Twin Otter aircraft, for an operational deployment.

In February 2010, a modified Customs and Border Patrol (CBP) Predator B (designated 'Guardian') entered operational test and evaluation with Raytheon's belly-mounted SeaVue SAR/ISAR and an over-water-optimized Raytheon MTS-B EO/IR sensor. Guardian is planned for maritime drug-traffic monitoring, specifically of small, fast-moving boats. CBP has a strategic plan for up to 18 Predator-type UAVs, with six planned for maritime missions.

In September 2010, an Army Boeing A160 Hummingbird UAV crashed during testing of Syracuse Research's FORESTER (foliage-penetrating reconnaissance, surveillance, tracking, and engagement radar) sensor. FORESTER is a UHF real-time GMTI SAR radar. The Army hopes to improve its ability to detect and track targets hiding under tree cover.

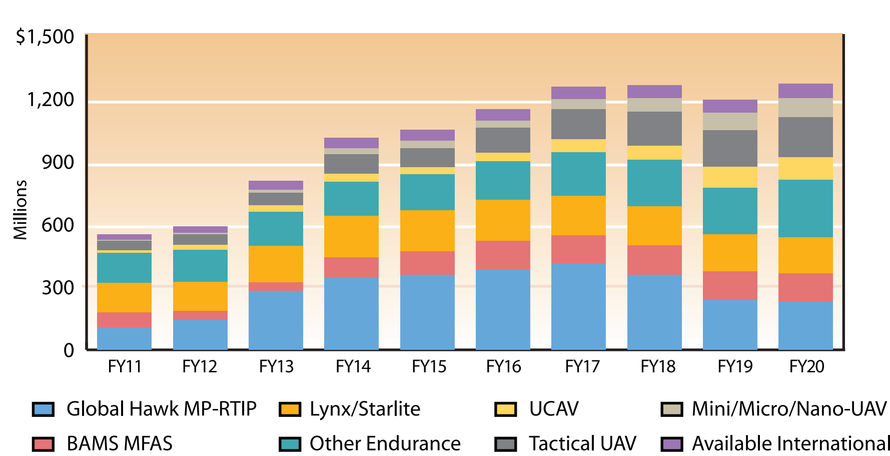
In late 2010, Lockheed Martin's TRACER (tactical reconnaissance and counter-concealment enabled radar) was flown for the first time on a NASA Predator B. TRACER is an Army low-frequency SAR that also provides improved foliage penetration. TRACER could potentially be procured for Grey Eagle; it is currently flying in an unpressurized wing pod.

UAV SAR Market Share
RDT&E+Procurement



Syracuse Research should have trace percentages in FY11–FY14.

UAV SAR FUNDING FORECAST
RDT&E+Procurement (FY11 $ Millions)



Market shares: Northrop in front

In terms of market access, UAV SARs appeared to be offering great opportunities, with several small developers earning big contracts—General Atomics with its Lynx and Lynx II, Telephonics with the RDR 1700, and Syracuse Research with the Army Future Combat System A160 FORESTER SAR. This seemed incredible a few years ago and, in fact, it was.

The Army has now dropped the Lynx II from its Grey Eagle (for Northrop's Starlite) as well as its FCS Fire Scout, and Telephonics lost a good program when the Coast Guard dropped the overdue Eagle Eye UAV from Deepwater. And don't expect Syracuse Research to get a production contract for FORESTER, especially as—surprise, surprise—Lockheed Martin also seems to be developing an Army foliage penetration radar, TRACER.

These losses largely came with little justification, and we have to assume it has often been a question of lobbying and influence. As in most other UAV electronics markets, the opportunities will now be mostly for subcontractors.

The SeaVue SAR/ISAR and an over-water-optimized MTS-B EO/IR sensor were mounted in the belly of a Guardian UAV for the CBP.

On the other hand, nearly 50% of forecast market funding is still uncontracted and available for most of our forecast period. Obviously, Northrop Grumman and Raytheon will earn some of this, but small technology companies could suddenly find themselves at least a moderate player (before being bought out or passed over), especially for tactical or micro/nano-UAVs. And General Atomics is still holding on to a sizable chunk of funding for its Air Force Reaper Lynx, at least for the moment. For established radar firms, good opportunities may exist through acquisition or internal development.

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NanoSail-D2 breaks free

NASA ENGINEERS ARE PONDERING THE mystery of how the 10-m^2 plastic sail they launched into orbit in November somehow freed itself from its carrier spacecraft after refusing to deploy for five weeks. They are enjoying the new lease on life given to NanoSail-2D, which is now orbiting at an altitude of about 400 mi.

For several more months, they expect the kite-shaped sail to bring attention to the innovative concept of packing plastic sails into small units and attaching them to future satellites. The sails can then spring into action at the end of a mission to deorbit dying spacecraft through atmospheric friction. In other applications, they could catch photons the way sailboats catch the wind, providing an inexhaustible source of propulsion for satellites, or enabling them to circle over polar regions in non-Keplerian orbits.

While reveling in their good fortune, NanoSail-D2 team members say they are devising theories about how the sail became stuck. Although no one may ever know the answer with full confidence, the theories could help those planning to use the same deployment technique in the future. NanoSail-D2 was deployed using an eight-year-old design called a poly-picosat orbital deployer, or P-POD, which is counted as one of the great successes of the small satellite industry.

What's going on?

The mystery began when NanoSat-D was launched in a small NASA spacecraft called FASTSAT (Fast, Affordable Science and Technology Satellite) as one of six experiments on the spacecraft. On December 6, 2010, controllers opened a small door on FASTSAT to release the sail, which was supposed to spring into space and then unfurl. Instead, nothing happened.

"We spent the better part of the next month going through and trying to figure out what was going on," says electromechanical engineer Dean Alhorn, the NanoSail-D principal investigator at NASA Marshall. Because the sail was just one experiment aboard the craft, the FASTSAT managers had no choice but to shift their focus elsewhere. "It went from being first to last" in priority, Alhorn says.

The situation was frustrating for NanoSail-D engineers from Marshall and Ames. In just four months, they had figured out how to squeeze the sail, deployment booms, eight lithium ion batteries, and an antenna into the precise rectangular shape required for deployment from a P-POD. They had even posted a video on YouTube showing how the 10x10x30-cm package could transform itself into a kite-shaped spacecraft in just 5 sec. But their first attempt to test the approach had ended in disaster in 2008 when a SpaceX Falcon 1 rocket failed to reach orbit. Engineers had converted spare hardware into NanoSail-D2, but there were no spares left.

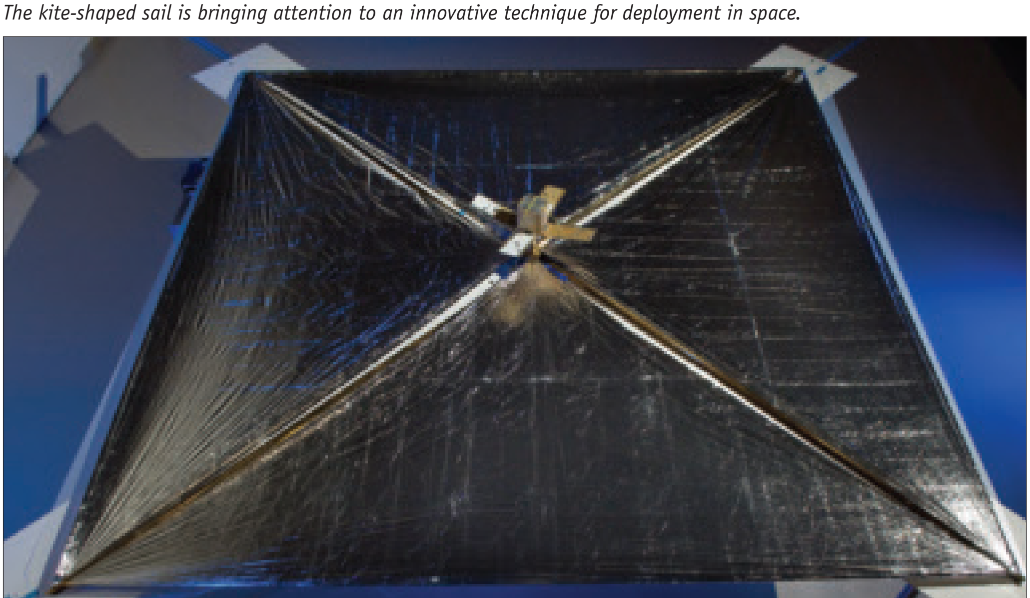
As for the P-POD approach, it appeared as if this mission could be a black mark in the series of missions that have been launched from Russian and U.S. rockets since 2003.

Then, on January 17, 2010, the outlook changed completely. Controllers in Huntsville, Alabama, detected a 3.5-deg rotation in FASTSAT, a torque that could come only from NanoSail-D2 ejecting from the spacecraft. There was no one to call immediately—it was a holiday, Alhorn notes. But on January 19, he was called to the mission operations center in Huntsville for the most pleasant surprise of his career.

"I'm looking on the white board and I see '3.5 degrees per second.' I said, 'Is this real?'" recalls Alhorn. Space surveillance tracking and, later, imagery, confirmed that NanoSail-D2 was indeed flying separately from FASTSAT.

Seventy-two hours after it

The kite-shaped sail is bringing attention to an innovative technique for deployment in space.



sprang free, the rectangular package transformed itself into the kite-shaped sail exactly as planned, beginning a 70-120-day mission.

Solving the mystery

NASA engineers are doing their best to untangle the mystery of the delayed ejection. "We probably will never know 100% why it got stuck," says Alhorn, "unless we go up there and get a 'CSI' satellite to take a look."

But coming up with plausible theories is not just an academic exercise. Engineers planning future P-POD missions might need to adjust their plans to avoid getting jammed the same way.

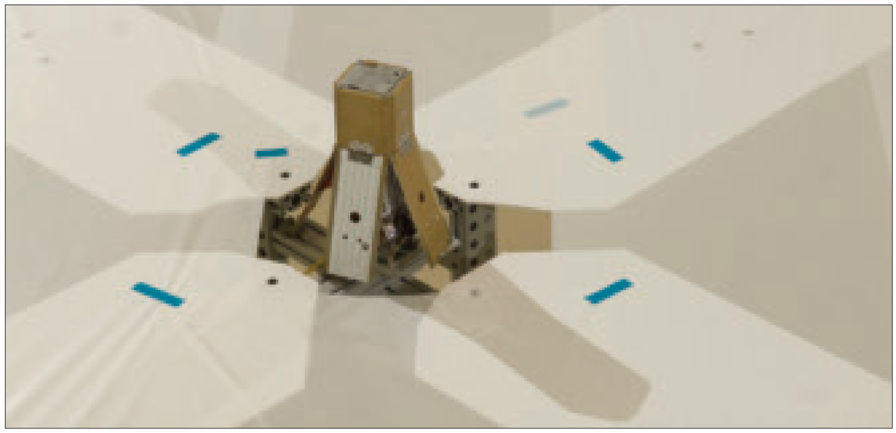
"When we heard we didn't come out, the team out at Ames Research Center cobbled together some old hardware that we had sent out there; some doors and a bus," Alhorn says. "They went through several iterations of trying to eject it in different configurations, and they sent us that data." That, coupled with on-orbit data "and what I know about operations of P-PODS," he recalls, "has led me to a theory that I think is true."

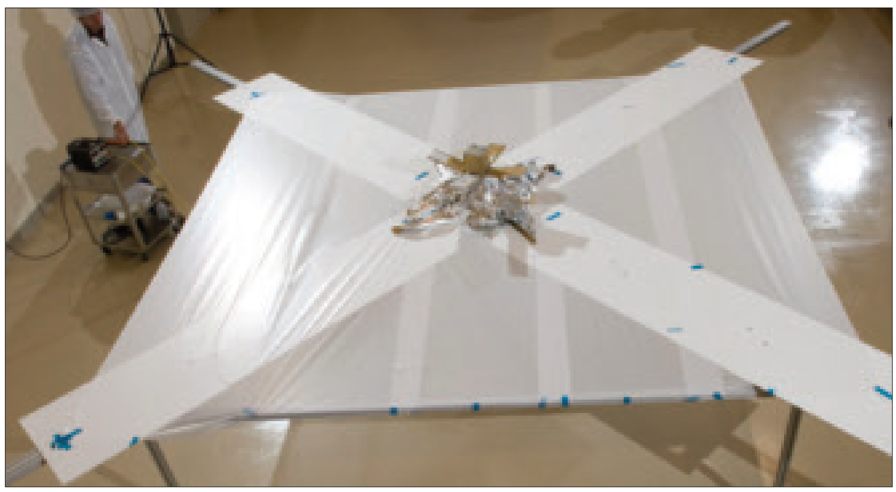
He says he will not discuss that theory until he presents a paper at the annual Small Satellite Conference, scheduled for August 8-11 in Logan, Utah.

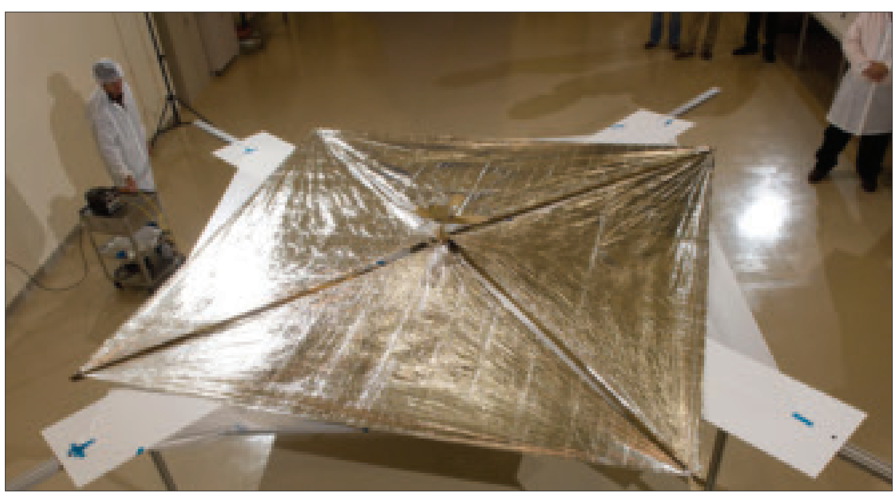
"It's such a simple system that if I were to say anything, you'd [think], 'oh, that's it,'" he says. "Suffice it to say that I have an idea of why it stuck and I'm in the process of verifying the analysis."

Other engineers involved with the project and with P-POD technology, however, were willing to offer some of their thoughts.

"Obviously, there was some friction somewhere in the system that prevented deployment," says aerospace engineer Jordi Puig-Suari, regarded as the grandfather of the P-POD mechanism. He is a professor at California Polytechnic State University (the poly in P-POD), San Luis Obispo. He suspects the attitude maneuver shifted the NanoSail package, or perhaps the canister, just enough to free it from FASTSAT.







(From the top) Three days into flight, the spacecraft would open four hinged doors, allowing the square sail to deploy.

The sail, made of extremely lightweight gossamer fabric, begins to unfurl, supported by rigid track booms provided by the Air Force Research Laboratory. The sail material is less than 1/16th the thickness of a human hair and is coated with an extremely thin layer of aluminum to enhance its ability to reflect solar energy. For this test engineers used rubber bands to secure the doors in the open position.

Fully deployed, the sail area measures 107 ft^2. It comprises four triangular membranes supported by thin metal tape booms. Full deployment takes just 5 sec. Image credit: NASA/MSFC/D. Higginbotham.

Friction is the enemy

But what caused the friction that kept the satellite in place? Puig-Suari remains somewhat confounded. "Everything is designed for the satellite to come out, which [the others] always have done," he says.

Friction was the enemy from the start. From 1999 through 2000, he and colleagues devised a concept for installing Teflon-coated aluminum rails inside storage containers and installing tabs on payloads to ride on those rails when the payload is ejected. They settled on a standard geometry and shared it with fellow small satellite enthusiasts, who have used the approach to launch up to three separate cubesats at a time. The strategy was a way to conduct several relatively low-cost experiments with one rocket launch.

A variety of cubesat experiments have flown, including NASA's 5-kg GeneSat in 2006. GeneSat carried a payload of bacteria and sensors to look for genetic variations caused by 0 *g*. GeneSat's bus, containing power and communications systems, became the foundation for NanoSail-D's bus design.

With the P-POD approach, engineers also have the option of ejecting single satellites filling the same volume. Small-sat engineers call these '3u' (three unit) satellites, and that is what NanoSail-D2 is.

When a payload is loaded into a P-POD, an off-the-shelf stainless steel spring is compressed, and the spring-loaded trap door is closed over it. Thin wires hold the door closed, but when a command is sent to put an electric charge through the wires, they dissolve and the door springs open. Without the pressure from the door, the stainless steel spring decompresses, ejecting the payload.

"It's basically a jack-in-the-box," Puig-Suari says.

It took Puig-Suari a while to convince NASA that a P-POD door would not fly open prematurely, damaging or destroying a rocket's multimillion-dollar primary payload. He says builders of multibillion-dollar geosynchronous communications satellites use the same technology to keep solar arrays in place until they are ready to deploy.

Christopher Beasley, NASA Ames engineer, integrates NanoSail-D onto the ride share adapter, a piece of hardware that sits inside the shroud of the SpaceX Falcon 1 launch vehicle. Credit: NASA/ARC, Orlando Diaz.

To keep the cubesats from getting stuck once the door opens, engineers must be careful to minimize friction between the canister and the payload. "The corners of the satellites have to be clean so the satellite can slide properly," Puig-Suari explains. Other, smaller, springs keep the payload properly positioned.

As with any technical mystery, engineers began by looking for ways that the NanoSail mission was different from other P-POD missions. One difference was that the NanoSail-D2 payload was mechanically complex, though designed not to shift within the aluminum panels that housed it before it was transformed. Compared to other instruments and what they do, says Puig-Suari, "it's a very complex, sophisticated spacecraft."

There was an even bigger difference. As Puig-Suari points out, in all P-POD flights to date the canisters were attached to the upper stages of their carrier rockets. This was the first time a P-POD was installed inside a satellite. In this case, a hole was cut into the lower deck of FASTSAT to accommodate the canister.

Puig-Suari mentions this disparity, but is still pondering whether it mattered: "There is no reason to think that should make a difference," he says.

Thermal challenge

NASA Ames engineer Bruce Yost, who helped coordinate the first NanoSail-D attempt, has an idea about why a P-POD vehicle might have reacted differently when launched from a free-flying satellite.

"Typically, as soon as the vehicle reaches orbit, it's deployed" from the P-POD, he says. "You want to get away from the rocket before it goes inert."

A P-POD ejection usually happens within 1.5 hr of reaching orbit, Puig-Suari notes. However, once FASTSAT separated from its Minotaur 4 rocket, no one expected controllers to deploy NanoSail-2D immediately. FASTSAT's attitude control and other systems had to be turned on and checked out. The spacecraft had to be oriented correctly to eject the sail into a safe zone, so that it would not slow down and fly back into FASTSAT.

"NanoSail-D was in the box for days," Puig-Suari says. The satellite was launched November 22 from Kodiak Island, Alaska. The door was opened on December 6.

There was plenty of time for 'thermal soak,' adds Yost. With parts of FASTSAT exposed to sunlight and others exposed to the cold of space, perhaps the thermal changes "were enough to change the geometry of the P-POD—or the spacecraft, for that matter," he says. That could have caused just enough friction to keep NanoSail-D2 from springing out until the attitude maneuver.

It is just a theory, but Yost has some concrete advice for anyone planning a similar mission. Before launch, "You could simply do a thermal test," he says. "You could cold soak the spacecraft" in a thermal chamber "for hours or days—however long it takes for the cold to have its effect—and then test" the deployment.

For the time being, he says, Ames plans to continue attaching its P-PODS to rockets.

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"A helicopter is an assembly of 40,000 loose pieces, flying more or less in formation."

New helicopter designs

Although the helicopter is a concept that dates back more than a thousand years, a practical rotorcraft did not become a reality until WW II. After more than a half-century, today's versions look remarkably unchanged. Technology developments, although slow, have finally begun to produce significant advances that may overcome some of the many instabilities inherent in helicopter design.

by J.R. Wilson
Contributing writer

While Leonardo da Vinci typically is credited with the first helicopter design, he actually was bested a millennium earlier by a Chinese toymaker. There is no evidence anyone tried to turn the fourth-century Chinese "flying car" from toy to reality, however—just as da Vinci's 15th-century design for a full-size "helical air screw" apparently never flew.

The closest thing to a modern helicopter, historians believe, was designed by aviation pioneer George Cayley. His 1843 "convertiplane" or "aerial carriage" was the culmination of a lifetime of attempts to design a flying machine capable of carrying an adult human and "landing at any place where there is space to receive [it], and of ascending again from that point." Such a craft "should likewise be capable of remaining stationary, or nearly so, in the air, when required."

Cayley was much more successful with his glider designs—a true rotorcraft would not become a reality for another century, when the Focke-Wulf Fw 61 became the world's first operational helicopter in 1936. Designed by professor Henrich Focke and engineer Gerd Achgelis, it demonstrated the viability of a rotor-wing aircraft as the necessary technologies—turbine engines and autogyros—came into being. Only two vehicles were built, and the resulting company, Focke-Wulf Flugzeugbau, went on to produce many of Nazi Germany's fixed-wing aircraft and, after the war, a series of experimental rockets and jet planes.

Practical reality

It was a Ukrainian-born engineer who would design the first helicopter to go into

ANONYMOUS (usually attributed to an unnamed veteran helicopter pilot)

take off

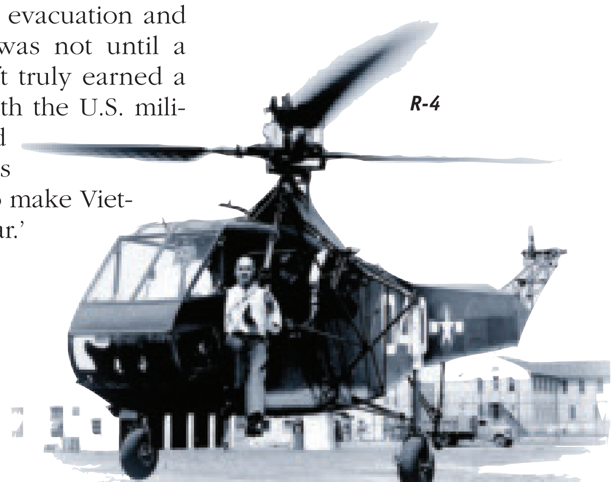
The Sikorsky X2 technology demonstrator team was the recipient of the 2010 Robert J. Collier Trophy.

mass production. Igor Sikorsky, who had immigrated to the U.S. in 1919, founded Sikorsky Aircraft in 1923, initially building flying boats for Pan American Airways. In 1939, as WW II was getting under way in Europe, Sikorsky flew the first true American helicopter, the Vought-Sikorsky VS-300, using the rotor configuration that would become the trademark of helicopters for the next 70 years.

In 1942, a modified version, the Sikorsky R-4, became the world's first mass-produced helicopter. Used somewhat experimentally by the U.S. military during WW II, the R-4 also became the first helicopter to land on a ship, and the first to execute a rescue mission, evacuating four crewmembers of a bomber that had crashed in Japanese-held Burma in 1944.

The Korean War saw helicopters come into heavy use as medical evacuation and transport aircraft. But it was not until a decade later that rotorcraft truly earned a permanent combat role with the U.S. military, as new gunship and troop transport designs joined the medevac fleet to make Vietnam the first 'helicopter war.'

VS-300



R-4

MD 520N

Tweaking the bumblebee

Each decade since the 1930s has seen some advance in helicopter design, capability, and mission. However, the basic look has changed little since 1861, when French engineer Gustave de Ponton d'Amecourt gave the vehicle its name, combining two Greek terms—'heliko' (twisted; spiral) and 'pteron' (wing)—to form 'hélicoptère.' And despite thousands of major and minor advances and design tweaks, despite its ubiquitous use by groups ranging from tiny police forces to global military superpowers, the modern helicopter remains the mechanical version of a bumblebee: It does not seem reasonable that it should fly at all.

"We're not going to present this to Congress; I believe they're going to come to us."

Sikorsky Aircraft President JEFF PINO on the October 2010 debut of the superquiet, speed-record-setting X2.


S-97

In fact, some have noted a similarity between a bee's wing function and 'reverse-pitch semirotary helicopter blades.'

Although the bumblebee occupies a successful niche in the insect world, engineers continually work to improve the helicopter—in some cases to meet new demands from battlefield commanders, in others to reduce its thunderous noise levels, which annoy civilians and alert enemies as it approaches.

Design modifications also are intended to address some of the limitations and hazards that have plagued helicopter operations from the beginning. Those include not only noise, but also low speed, which increases vulnerability and reduces mission capability, and vibration, which not only can shake parts loose but also can be harmful to crews, resulting in everything from pain and numbness to loss of tactile discrimination and dexterity. The list of flight hazards is even longer.

Recent advances

Numerous new designs were introduced in the closing decades of the 20th century to address those issues. One such was the no-tail rotor (NOTAR), developed by Hughes Helicopters in the 1970s and produced on the MD 520N, MD 600N, and MD Explorer after Hughes was acquired by McDonnell Douglas Helicopter Systems (now Boeing). As with many new designs, the NOTAR addressed multiple issues, including wire and tree strikes as well as noise.

More recent efforts have sought to further reduce noise and heat signature and to incorporate stealth designs and technologies borrowed from fighter aircraft, thus reducing helicopter vulnerabilities to enemy antiaircraft rockets and other ground defenses. Others have increased helicopter speed and range, which would significantly enhance mission capability.

In October 2010, for example, Sikorsky committed to production of two prototype light tactical helicopters based on its X2 technology demonstrator. That vehicle set an unofficial speed record of 287 mph (250 kt) in September, shattering the 216-kt record set in the mid-1980s by a Westland Lynx for 3,500-kg-class rotorcraft. The average speed of modern helicopters is about 130-140 kt.

The X2 also incorporates an integrated fly-by-wire system that enables full rotor speed control throughout the flight envelope, high lift-to-drag rigid blades, low-drag hub fairings, active vibration control, twin coaxial counterrotating main rotors (in place of one main rotor and a tail rotor), and a pusher propeller.

"Having proved the X2 technology design to ourselves, we have full confidence we can now mature the technology for the U.S. Army's light armed reconnaissance helicopter size," explains Sikorsky's president, Jeffrey Pino, who had earlier declared the speed record a "new horizon" for the aerospace industry.

"Self-funding the design of a brand new light tactical helicopter—the Sikorsky S-97—and manufacturing two prototypes we have designated as the Raider X2 helicopter will help military aviation evaluate the viability of a fast and maneuverable next-generation rotorcraft for a variety of combat missions."

In addition, the company plans to use its recently unveiled X2 technology light tactical helicopter simulator to demonstrate and further advance the military applications evolving from the X2 program.

"With the simulator, we can fly a light tactical helicopter variant of the X2 technology demonstrator through various mission scenarios and demonstrate the advantages of speed, high agility, low acoustic signature, and low vibrations," says Sikorsky mission systems integration vice president Teresa Carleton.

"It will be a tremendous mobile tool that we can bring to potential customers to give them a 'hands-on' sense of the flight and mission advantages we are bringing to the aviation landscape," she adds.

International activities

Advancements in helicopter design are proceeding globally, as demonstrated by the November 19, 2010, maiden flight of AugustaWestland's third and final AW159 test helicopter in the U.K., to be known as the Lynx Wildcat when it enters U.K. military service. Delivery of the first of 62 copies of the new 6-ton multirole helicopter is set for the end of this year.

It is scheduled to become fully operational with the British Army in 2014 for reconnaissance, command and control, troop and cargo transport, and force protection. Beginning in 2015, a Royal Navy variant will provide antisurface warfare capabilities, force protection, and support of amphibious operations.

While the AW159 might be called state-of-the-art in current-generation rotorcraft, Europe also is pushing the envelope on the next generation with Eurocopter's X3 hybrid helicraft. Although entirely company funded, the X3—also referred to as a 'hoverplane'—made its maiden flight under strict secrecy on September 6 at a French army base near Marseille.

With both the Sikorsky X2 and Eurocopter X3 using a NOTAR design and other elements highlighting speed, the X3's designers see it as a challenger not only to the X2 on speed (220 kt), but also to the Bell Boeing V22 Osprey tilt-rotor aircraft used by the U.S. Marine Corps. The key, according to Eurocopter chief executive Lutz Bertling, is to implement such advancements without making it too costly for current tight defense budgets.

AW159

X3

"All big helicopter manufacturers are looking for more distance and more speed," he told reporters at the X3's unveiling. "It only makes sense to increase speed if in the end what you gain is not overcompensated by increased cost."

Even so, Eurocopter acknowledged that a helicopter incorporating X3-type wings, giving it a 50% boost in speed, probably would cost 20-25% more than a standard rotorcraft.

In September 2010 Eurocopter also unveiled the latest design for its proposed future heavy transport helicopter (HTH), intended to meet the requirements of the European Defense Agency (EDA) for a new rotorcraft capable of lifting 13 tons of equipment and supplies. As might be expected from a new cooperative agreement with Boeing, the HTH, though larger, bears a strong resemblance to the CH-47 Chinook.

With a 33-ton maximum takeoff weight (compared to the CH-47D/F's 25 tons), the HTH features a tandem four-bladed main rotor with a 64-ft span and carries up to 56 troops in addition to its three-member crew. It has a top speed of 167 kt and a cruise speed of 148 kt at 23,000-ft altitude. With a maximum 13-ton payload, it has a projected range of 162 n.mi. or 540 n.mi. carrying 8 tons; aerial refueling could stretch its range up to 2,700 n.mi.

"What is quite logical is that two global players are sitting together and sharing their strengths and knowledge," notes Hans Weber, Eurocopter's HTH program vice president. "We have a logical structure of workshare driven by competencies and not by politics. What you see is the outcome so far. The predesign is very mature and meets the requirements set by the NATO staff targets."

The agreement calls for each company to perform 50% of the work on any future contracts.

Russia, which has fallen behind the U.S. and the EU in new helicopter designs since the collapse of the Soviet Union, and China, which is still building its aviation industry, announced plans in July to jointly develop and produce a new heavy-lift helicopter, possibly based on the massive Russian Mi-26 Halo, which has nearly twice the capacity of the proposed HTH.

"This machine will be oriented toward the Chinese market, and the project will be commercial," says Russian deputy industry and trade minister Denis Manturov.

Not all new designs involve complete aircraft. In April 2010, for example, Eurocopter announced its new Blue Edge rotor blade, a radical departure from standard blade design, along with a 'Blue Pulse' system using three flap modules in the trailing edge of each rotor blade. The flaps are ac-

tuated at 15-40 times per second by piezoelectric motors. Together they minimize the blade-vortex interaction of the main rotor—the source of the familiar pulsating sound of helicopters flying overhead. In tests on an EC155, the company said, they were able to reduce the helicopter's noise level by 3-4 dB.

A160 Hummingbird

Unmanned designs

Another new development in the helicopter arena is unmanned rotorcraft. Two primary candidates are currently being tested by the U.S. military.

The K-MAX unmanned helicopter is a joint effort of Lockheed Martin and Kaman Aerospace to convert a manned helicopter for unmanned operations, primarily delivering water and other cargo to forward units on the battlefield. The aircraft, which has flown some 400 hr in autonomous mode since 2007, can deliver 6,000 lb of cargo at sea level and more than 4,000 lb at 15,000-ft density altitude—the operational average in Afghanistan.

In three years of tests with the Army and Marines, the K-MAX has performed both low- and high-altitude parachute drops, multiple flights—day and night—in a single exercise, and has been rerouted to a new destination while in autonomous flight.

Its primary competition is the Boeing A160T Hummingbird, a significantly smaller aircraft—a factor Boeing touts as making it more agile and able to operate in tighter spaces. While the 2,500-lb cargo target set by the Marine Corps is at the Hummingbird's limit, Boeing claims the A160T's other attributes add significantly to its overall mission capability. Those include a unique technology that improves efficiency by enabling rotor speed adjustment at different altitudes, gross weights, and cruise speeds. This feature also allows the craft to hover at 20,000 ft and to cruise at more than 140 kt. In 2008, the Hummingbird set a world endurance record in its class with an 18.7-hr unrefueled flight.

Both were awarded contracts in March 2010 from the Marine Corps Warfighting Lab to demonstrate they could deliver more than 2,500 lb of cargo at ranges up to 75

"I have discovered that a screw-shaped device such as this, if it is well made from starched linen, will rise in the air if turned quickly."

LEONARDO da VINCI

Flight hazards of rotorcraft

•Settling with power or a vortex ring state, in which the rotor's downwash interferes with its aerodynamics and ability to control descent.

•Retreating blade stall, which limits the aircraft's forward speed.

•Ground resonance, in which a helicopter touching down or sitting on the ground with the rotors spinning can experience a quick buildup of violent oscillations.

•Low-g condition, where a helicopter is in free-fall or goes into an excessively rapid autorotation.

•Dynamic rollover, in which the helicopter pivots around a skid or wheel and falls on its side.

•Power-train failures.

•Tail rotor failures.

•Brownout in dusty conditions.

•Whiteout in snowy conditions.

•Low rotor RPM (also called rotor droop), in which the engine cannot drive the blades at sufficient speed to maintain flight.

•Rotor overspeed, where overstressed rotor hub pitch bearings can cause the blade to separate from the aircraft.

•Wire and tree strikes during low-altitude flight or takeoffs and landings in remote locations.

•Controlled flight into terrain—a failure of pilot situational awareness that results in the aircraft being flown into the ground.

Disc Rotor

n.mi. in less than 6 hr. Both aircraft met that challenge in subsequent exercises.

"This capability will save lives by getting troops and trucks off roads where they are highly vulnerable to improvised explosive device attacks," explains Vic Sweberg, director of Boeing Unmanned Airborne Systems.

Radical departure

Perhaps the greatest departure from standard helicopter design at the moment is the high-speed combat search-and-rescue concept that Boeing is developing as part of DARPA's DiscRotor program.

While little has been revealed about the aircraft to date, it combines the speed and capacity of a fixed-wing airplane with the vertical functionality of a rotorcraft—but without traditional helicopter blades, which have always limited such hybrids. At the same time, it does not rely on tilt-rotors, as does the V-22, or vector thrust engines, as in the AV-8B Harrier or F-35B.

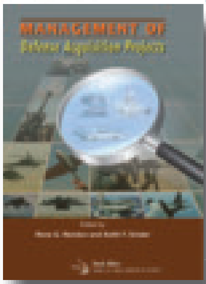
Instead, the DiscRotor uses blades that act as a helicopter rotor in vertical flight, but retract into a top-mounted disc and become a third wing in forward flight. NASA and others have looked at the concept in the past but have never pursued it to production, citing a variety of problems. Now Boeing believes its new technology can overcome those challenges, though it says doing so will be "feasible, but not easy."

✈✈✈

In all likelihood, the vast majority of helicopters coming off the design table and into service in the next several decades would be easily recognizable to a WW II helicopter pilot—and probably to da Vinci, Cayley, and d'Amecourt as well. At the same time, new technologies and advances in materials and engineering will be adding significant variations to the mix—from hovercraft to VSTOL jets to DiscRotors, and perhaps even more unusual designs.

And whether such a vehicle ever becomes a practical part of the family or not, the 21st century almost certainly will see someone finally build and fly the Helical Air Screw first envisioned by da Vinci.

New and Best-Selling Books from AIAA



"An excellent way to get a solid grounding in the complex and challenging acquisition process."
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Management of Defense Acquisition Projects
Rene G. Rendon and Keith F. Snider
Naval Postgraduate School
2008, 292 pages, Hardback, ISBN: 978-1-56347-950-2
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AIAA Member Price: $49.95

A History of Two CIA Projects. *Based on interviews, memoirs, and oral histories of the scientists and engineers involved, as well as recently declassified CIA documents, and photographs, reports, and technical drawings from Lockheed and Convair, this is a technical history of the evolution of the Lockheed A-12 Blackbird.*

From RAINBOW to GUSTO: Stealth and the Design of the Lockheed Blackbird
Paul A. Suhler
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While the focus of this book is on ground combat system vulnerability, many of the principles, methodologies, and tools discussed are also applicable to the air and sea system communities.

Fundamentals of Ground Combat System Ballistic Vulnerability/Lethality
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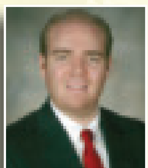

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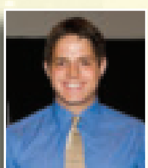

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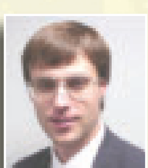

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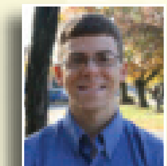

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University of Colorado
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Texas A&M University
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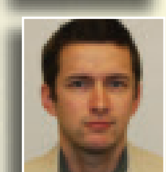
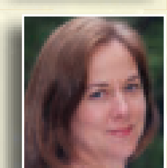


Adam Trebs
Purdue University
West Lafayette, Indiana



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Mary Kay Carson
Cincinnati, Ohio

Dryden Lectureship in Research

Chung "Ed" Law
Robert H. Goddard Professor
Department of Mechanical and Aerospace Engineering
Princeton University
Princeton, New Jersey

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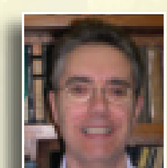
David Finkleman
Senior Scientist
Center for Space Standards and Innovation
Analytical Graphics, Inc.
Colorado Springs, Colorado

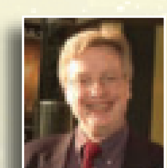
F. E. Newbold/VSTOL Award

James A. Franklin
Aeronautical Engineer (Retired)
NASA Ames Research Center
Moffett Field, California



Faculty Advisor Award

Robert G. Melton
Professor of Aerospace Engineering
The Pennsylvania State University
University Park, Pennsylvania



History Manuscript Award

Roger D. Launius
Senior Curator, Division of Space History
Smithsonian Air and Space Museum
Washington, D.C.

Dennis R. Jenkins
Aerospace Historian
Cape Canaveral, Florida

11-0321

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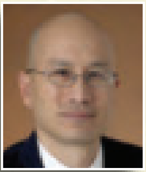
Honoring and awarding such achievement is an important AIAA tradition. Every quarter, award recipients are showcased through our Honors and Awards Program, so that all members have the opportunity to recognize their peers.

October 2010 and March 2011 include:



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Pasadena, California

Lawrence Sperry Award
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Edward C. Wells Professor in the School of Engineering, Emeritus
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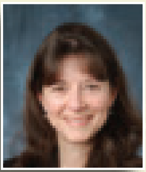
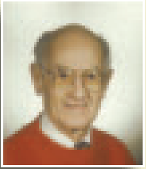
James J. Spilker Jr.
Professor (Consulting)
Electrical Engineering and Aeronautics and Astronautics Departments
Stanford University
Stanford, California



Penina Axelrad
Professor, Aerospace Engineering Sciences
University of Colorado
Boulder, Colorado

Per K. Enge
Professor in Aeronautics and Astronautics
Stanford University
Stanford, California



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Cornell Aeronautical Laboratory (Retired)
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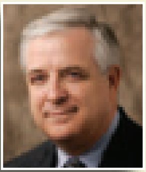

Wright Brothers Lectureship in Aeronautics
Michael Francis
Chief, Advanced Programs and Senior Fellow
United Technologies Research Center
East Hartford, Connecticut

The World's Forum for Aerospace Leadership

Thank You Nominators!
AIAA appreciate your time and efforts in preparing the nomination package!

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George Lesieutre
Rao Mannepalli
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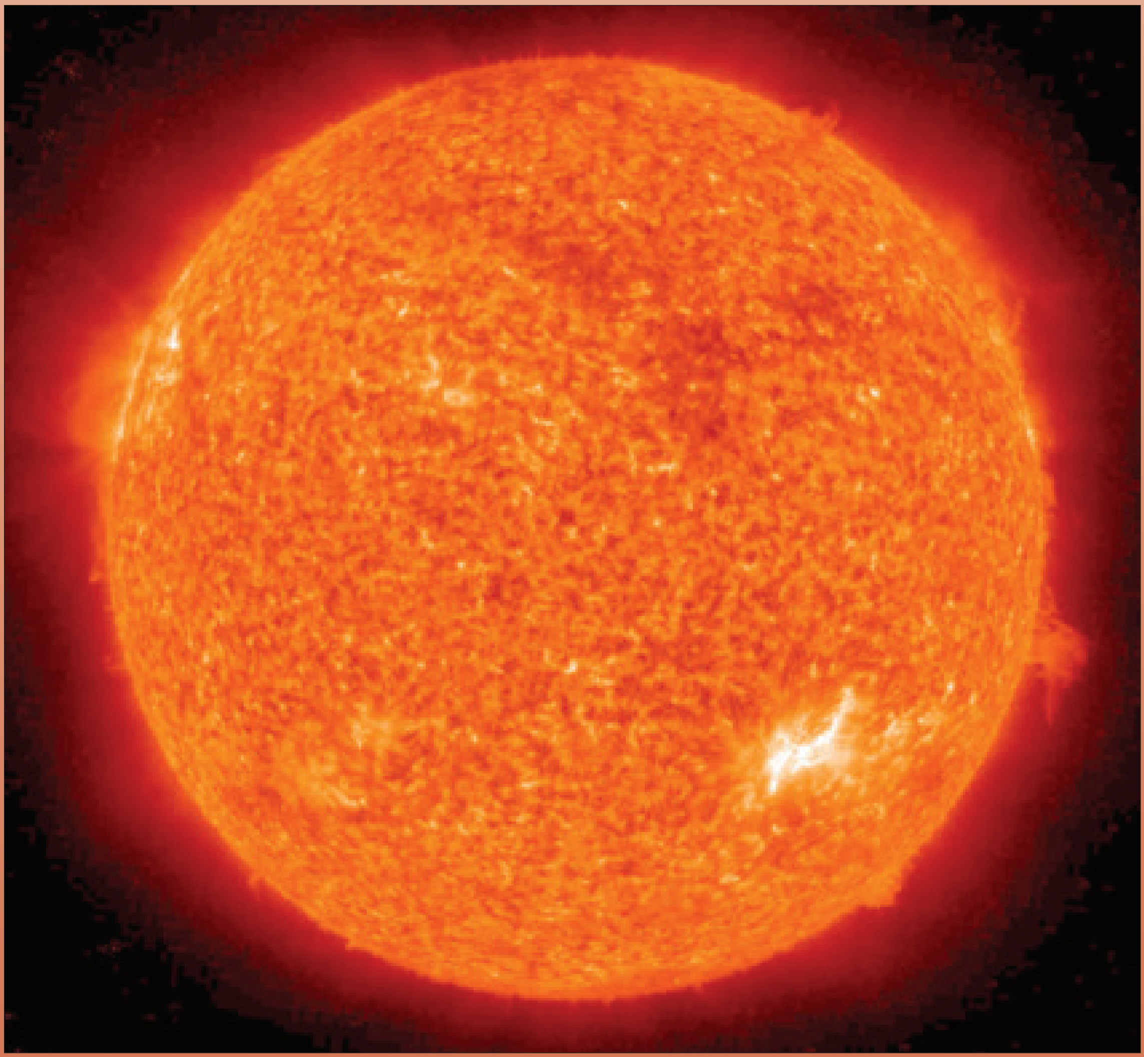


New views of the seething Sun

by Craig Covault
Contributing writer

Advances in imaging and other technologies are making waves in the solar physics community, causing a fundamental shift in the way scientists approach studies of our nearest star. New spacecraft are beginning to reveal the Sun's mysterious workings, 'seeing' for the first time the unimaginably vast scale on which its explosive blasts and other dynamic events occur.

Newly discovered events on the Sun, occurring hundreds of thousands of miles apart, are interacting to create gargantuan surface features spanning an entire solar hemisphere. These phenomena are forcing a major revision in the theories of 20th-century researchers, who did not have rapid enough imaging or sufficient spacecraft resolution to perceive that the Sun can generate interaction on such a gigantic scale.

New solar imaging satellites have now changed all that, showing for the first time that events on the Sun as far apart as the Earth and the Moon are interacting to create new features.

So big

The 870,000-mi.-diam. Sun routinely drives magnetic fields that within seconds can accelerate 200 billion lb of multimillion-degree plasma to velocities of 1 million mph. Researchers had always believed these occurred on a regional scale, not over a whole hemisphere or more.

But on August 1, 2010, three NASA and APL (Applied Physics Laboratory) spacecraft—the high-resolution Solar Dynamics Observatory (SDO) and the twin STEREO (Solar Terrestrial Relations Observatory) satellites—watched an entire hemisphere of the Sun erupt.

The eruption occurred mostly on the side facing Earth, posing a real risk to other orbiting satellites and to large electrical facilities on the ground. Facility operators and satellite controllers were ready with procedures to limit damage, but once the large coronal mass arrived at the planet it proved less dense than anticipated and therefore less of a threat.

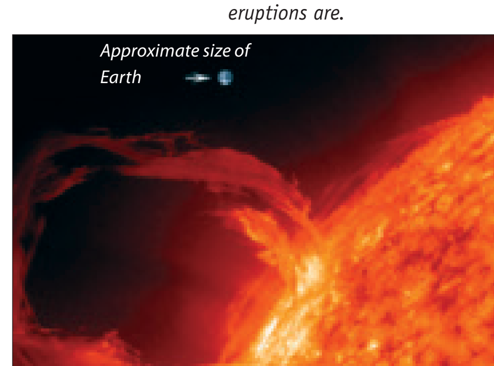
The wide-ranging eruption was documented by measurements of magnetic field lines dancing across half the Sun. Filaments of magnetism also were observed as they snapped and exploded, pushing huge shock waves across the stellar surface and blasting billion-ton clouds of hot gas into space. Astronomers knew they had witnessed something big—so big that it shattered old ideas about solar activity.

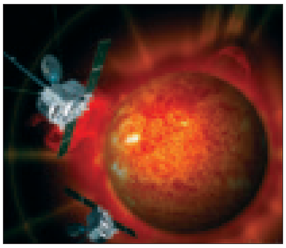
Watching the fireworks

The Sun is coming out of solar minimum, the period when solar events dwindle, quieting the star. But as the mid-2011-2014 solar maximum draws closer, solar fireworks are going to intensify. Watching them will be powerful instruments on the STEREO space-

(Opposite) A flare bursts from the Sun in this detailed image taken on August 1, 2010, by the STEREO Ahead telescope.

The Earth is superimposed on a solar eruptive prominence as seen in extreme UV light (March 30, 2010) to give a sense of how large these eruptions are.





As the two STEREO spacecraft orbit the Sun, one is far ahead of Earth and the other far behind. This enables them to cover virtually the entire solar disk simultaneously.

craft, which can capture 3D images, and SDO, a marvel of high-resolution simultaneous multiwavelength imaging in extreme ultraviolet.

SDO is one of the largest solar observing spacecraft ever placed in orbit. The satellite's solar panels are 21.3 ft wide; its total mass during its February 2010 launch on an Atlas V was 6,800 lb.

The SDO telescopes can take images every 0.75 sec. The resulting data are having the same transformative effect on solar physics that the invention of high-speed photography had on many sciences in the 19th century, says a NASA Goddard SDO engineer. And SDO does not stop at the stellar surface. A sensor on the observatory can actually look inside the Sun at the solar dynamo itself—the source of solar activity.

Imagine watching an IMAX movie that never stops. The enormous screen in effect stars a star. The new trio of spacecraft have the primary mission of helping to improve space weather forecasting—a growing scientific field affecting military and civil spacecraft operations and hundreds of other Earth-based operations that involve electrical and magnetic energy. But the Sun is also a star, and watching it much more closely yields tremendous data about what is happening on the surface of every distant pinpoint of light in the night sky going back millions and billions of light-years.

Voluminous yield

The volume of images and data that SDO can feed onto the IMAX screen is equivalent to downloading half a million I-Tunes each day. By some estimates, SDO will transmit 50 times more science data than any mission in NASA history.

Its images all have 10 times greater resolution than high-definition television. And because such fast imaging cadences have never before been attempted by an orbiting observatory, the potential for discovery is great. The data rate is equally great.

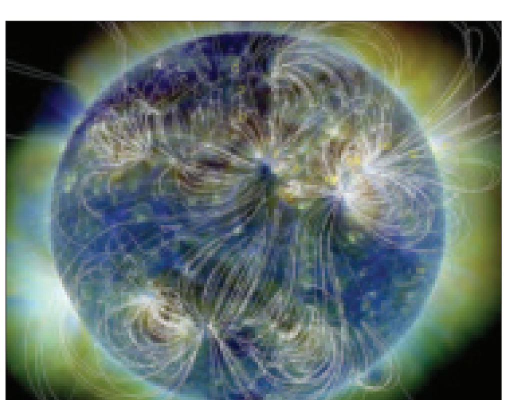
To handle the load, NASA has built two 60-ft SDO antennas near Las Cruces, New Mexico. SDO's geosynchronous orbit will keep the observatory in constant view of the antennas around the clock for the duration of the observatory's 5-10-year lifespan.

Spectacular images have been acquired by SDO's three instruments:

• The Extreme Ultraviolet Variability Experiment will measure changes in the Sun's ultraviolet output. Extreme UV (EUV) radiation from the Sun has a direct and powerful effect on Earth's upper atmosphere, heating it, puffing it up, and breaking apart atoms and molecules.

• The Helioseismic and Magnetic Imager will map solar surface magnetic fields and peer beneath the Sun's opaque surface using a technique called helioseismology. A key goal of this experiment is to decipher the physics of the Sun's magnetic dynamo, which in pictures resembles the circular splash of a rock thrown into a pond.

• The Atmospheric Imaging Assembly, or AIA, is a battery of four telescopes designed to photograph the Sun's surface and atmosphere in 10 different wavelengths, or colors, selected to reveal key aspects of solar activity. Each telescope supports two separately coated halves of both the primary and secondary mirrors. The mirrors, in combination with front and back filters, and in one telescope a mechanical selector, provide access to 10 distinct wavelength intervals. These range from a broadband visible channel and two UV channels to seven channels in the extreme ultraviolet.



After the August 2010 eruption, a second major eruption showing magnetic field lines dancing across the Sun's front side was measured using graphics. Filaments of magnetism snapped and exploded, shock waves raced across the stellar surface, as billion-ton clouds of hot gas billowed into space.

Seeing in STEREO

During the solar cataclysm, researchers were watching with the seven SDO EUV channels taking images every 12 sec.

Although SDO is extremely high resolution, the orbits of the twin STEREO spacecraft provide spacing between the Earth and Sun to give coverage of nearly two solar hemispheres simultaneously. This offered the first ever opportunity to see back around the solar disk to discern the size of the event—and the scale of what was happening astonished everyone watching.

When the twin satellites were launched in 2006, one spacecraft was maneuvered well forward of Earth and the other parked well behind to watch much larger areas of the Sun simultaneously. The two spacecraft weigh 1,364 lb each and were launched one atop the other on an Atlas V. The mission's total cost is about $550 million, while SDO cost about $850 million.

STEREO's specialty is to image coronal mass ejections (CMEs) blown off the Sun by big solar flares—explosions within the surface plasma. A CME is a giant blast of solar material with a mass of billions of tons.

There are 16 instruments per STEREO spacecraft. Both satellites, by imaging CMEs in 3D, have the same objectives: to understand the causes and mechanisms of CME initiation and characterize their propagation; and to discover the mechanisms and sites of energetic particle acceleration in the low corona and the interplanetary medium. They also aim to improve determination of the structure of the ambient solar wind.

CMEs, storms, and magnetic mayhem

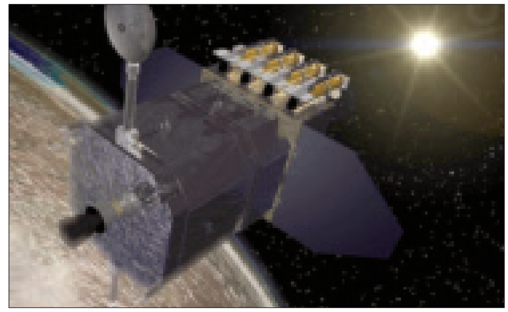
CMEs are the most energetic of solar explosions, ejecting up to 200 billion lb of multimillion-degree plasma into interplanetary space, at departure velocities of up to 1,000 mi./sec. They often look like bubbles and, when seen close to the Sun, can appear bigger than the Sun itself, though their density is extremely low.

In contrast to the steady-state solar wind, CMEs originate in regions where the magnetic field is closed. They result from the catastrophic disruption of large-scale magnetic structures such as coronal streamers. CMEs can occur at any time during the solar cycle, but they increase in daily frequency from about 0.5 during the solar minimum to about 2.5 daily during the solar maximum, which the Sun is entering.

Fast CMEs—those that outpace the ambient solar wind—give rise to large geomagnetic storms when they encounter Earth's magnetosphere. These storms can disrupt power grids, damage satellite systems, and threaten astronauts. They can result from the passage of the CME itself or the shock created by the fast CME's interaction with the slower moving solar wind.

"The August 1st event really opened our eyes," says Karel Schrijver of Lockheed Martin's Solar and Astrophysics Lab in Palo Alto, California. "We see that solar storms can be global events, playing out on scales we scarcely imagined before."

For the past several months, Schrijver has been working with fellow solar physicist Alan Title to understand what happened during what they call 'the Great Eruption,' an event likely to appear in science textbooks for decades.



Equipped with the most powerful civilian data system ever flown, the $850-million SDO is studying the solar atmosphere on small scales of space and time and in numerous wavelengths simultaneously. It is the highest resolution solar spacecraft ever launched.

"To predict eruptions we can no longer focus on the magnetic fields of isolated active regions; we have to know the surface magnetic field of practically the entire Sun," Title told the fall 2010 meeting of the American Geophysical Union (AGU).

August 1—the Great Eruption

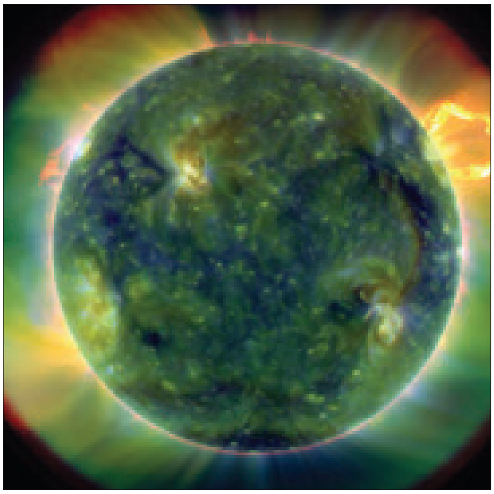
Tony Phillips, another solar researcher for NASA, described the importance of the observations and the sequence of events. The new data show that "explosions on the Sun are not localized or isolated events; instead, solar activity is interconnected by magnetism over breathtaking distances. Solar flares, tsunamis, coronal mass ejections—they can go off all at once, hundreds of thousands of miles apart, in a dizzyingly complex concert of mayhem," said Phillips in his NASA blog.

This revelation increases the workload for space weather forecasters, but it also improves the potential accuracy of their predictions.

"The whole-Sun approach could lead to breakthroughs in predicting solar activity," says Rodney Viereck of NOAA's Space Weather Prediction Center in Boulder, Colorado. "This in turn would provide improved forecasts to our customers, such as electric power grid operators and commercial airlines, who could take action to protect their systems and ensure the safety of passengers and crew."

In a paper they prepared for the *Journal of Geophysical Research* (JGR), Schrijver and Title broke down the Great Eruption into more than a dozen significant shock waves, flares, filament eruptions, and CMEs spanning 180 deg of solar longitude and 28 hr of time. It seemed to be a cacophony of disorder—until they plotted the events on a map of the Sun's magnetic field.

The events involved a lot of what solar physicists call a 'separatrix,' a magnetic fault zone where small changes in surrounding plasma currents can set off big electromagnetic storms.



In this full-disk, multiwavelength EUV image of the Sun taken by SDO on March 30, 2010, false colors trace different gas temperatures. Reds are relatively cool at about 107,540 F; blues and greens are hotter, greater than 1,799,540 F.

Title describes the 'Eureka!' moment: "We discovered that all the events of substantial coronal activity were connected by a wide-ranging system of separatrices, separators, and quasiseparatrix layers."

Phillips says that researchers have long suspected this kind of magnetic connection was possible. "The notion of 'sympathetic' flares goes back at least three quarters of a century," according to what Schrij-ver and Title wrote in their JGR paper. Sometimes observers would see flares going off one after another, like popcorn, but it was impossible to prove a link between them. Arguments in favor of cause and effect were statistical, and frequently full of uncertainty.

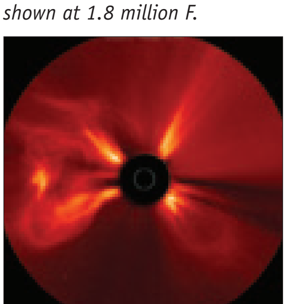
Says Lika Guhathakurta, NASA's Living with a Star program scientist, "For this kind of work, SDO and STEREO are game-changers. Together, the three spacecraft monitor 97% of the Sun, which allows researchers to see connections that they could only guess at in the past."

To wit, barely two-thirds of the August event was visible from Earth, yet all of it could be seen by the SDO-STEREO team. Moreover, SDO's measurements of the magnetic field revealed direct connections between the various components of the Great Eruption—no statistics required.

Much remains to be done. "We're still sorting out cause and effect," says Schrijver. "Was the event one big chain reaction, in which one eruption triggered another—bang, bang, bang—in sequence? Or did everything go off together as a consequence of some greater change in the Sun's global magnetic field?"

Further analysis may yet reveal the underlying trigger; for now, team members are still wrapping their minds around the global character of solar activity. "Not all eruptions are going to be global," notes Guhathakurta. "But the global character of solar activity can no longer be ignored."

The occulting disk on SDO blocks the bright solar surface to observe fine detail in a CME. These result from explosions caused by magnetic stress in the Sun's atmosphere, which is shown at 1.8 million F.



Another mystery

SDO is also helping to solve the great mystery of why the Sun's outer atmosphere, the corona, is a million degrees hotter than the surface, the photosphere.

"Among the many constantly moving, appearing, disappearing, and generally explosive events in the Sun's atmosphere, there exist giant plumes of gas—as wide as a state and as long as Earth—that zoom up from the Sun's surface at 150,000 mph. Known as spicules, these are among several phenomena known to transfer energy and heat throughout the Sun's magnetic atmosphere, or corona," says Karen C. Fox, who often writes on solar physics at NASA Goddard.

Thanks to SDO and the Japanese satellite Hinode, these spicules have recently been imaged and measured better than ever before. The imagery shows that they contain hotter gas than previously observed and thus may play a key role in helping to heat the Sun's corona to a staggering million degrees or more—a number made more surprising because the Sun's surface itself is only about 10,000 F.

"The traditional view is that all heating happens higher up in the corona," says solar physicist Dean Pesnell, SDO's project scientist at Goddard. "The suggestion is that cool gas is ejected from the Sun's surface in spicules and gets heated on its way to the corona. This doesn't mean the old view has been completely overturned, but this is a strong suggestion that part of the spicule material gets heated to very high temperatures and provides some coronal heating," Pesnell says.

Spicules were first named in the 1940s, but were hard to study in detail until recently, says Bart De Pontieu of Lockheed Martin's Solar and Astrophysics Laboratory in Palo Alto, California.

In visible light, spicules are seen to send large masses of so-called plasma—the electromagnetic gas that surrounds the Sun—up through the lower solar atmosphere or photosphere. The amount of material sent up is stunning, some 100 times as much as streams away from the Sun in the solar wind toward the edges of the solar system. But nobody knew if the spicules contained hot gas.

"Heating of spicules to the necessary hot temperatures had never been observed, so their role in coronal heating had been dismissed as unlikely," says De Pontieu.

Now, De Pontieu's team—which included researchers at Lockheed Martin, the High Altitude Observatory of the National Center for Atmospheric Research (NCAR) in Colorado, and the University of Oslo—was able to combine images from SDO and Hinode to produce a more complete picture of the gas inside these gigantic fountains.

Tracking the movement and temperature of spicules relies on successfully identifying the same phenomenon in all of the images. One complication is that different instruments 'see' gas at different temperatures. Pictures from Hinode in the visible light range, for example, show only cool gas, while those that record UV light show gas that is up to several million degrees.

To show that the previously known cool gas in a spicule lies side by side with some very hot gas requires showing that the hot and cold gas in separate images are located in the same space. Each spacecraft offered specific advantages to help confirm that one was seeing the same event in multiple images.

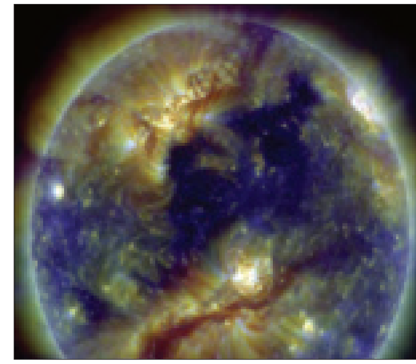
In 2009, scientists used observations from Hinode and telescopes on Earth to identify, for the first time, a spicule when looking at it head-on. (Imagine how difficult it is to determine, from over 90 million mi. away, that you are looking at a fountain when you have only a top-down view instead of a side view.) The top-down view of a spicule ensures an image with less extraneous solar material between the camera and the fountain, thus increasing confidence that any hotter gases observed are indeed part of the spicule itself.

The second aid to tracking a single spicule is SDO's ability to capture an image of the Sun every 12 sec. "You can track things from one image to the next and know you're looking at the same thing in a different spot," says Pesnell. "If you had an image only every 12 min, you couldn't be sure that what you're looking at is the same event, since you didn't watch its whole history."

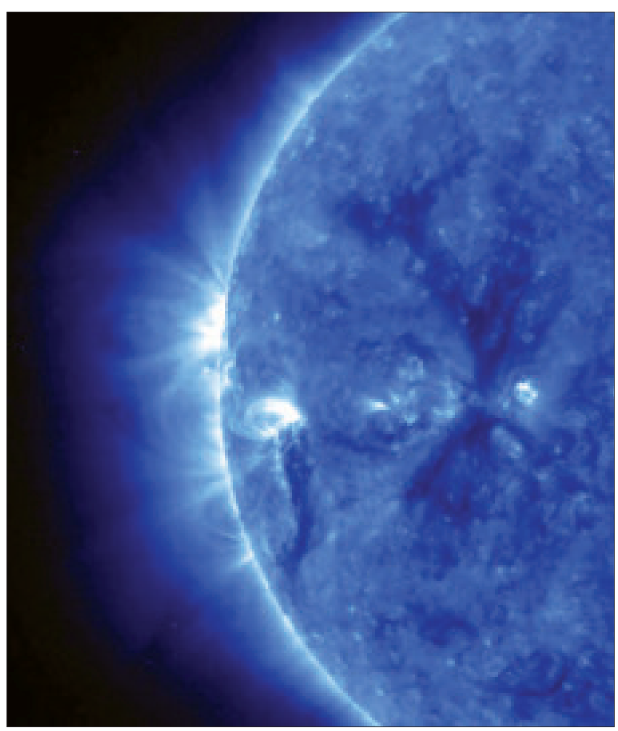
Bringing these tools together, scientists could compare simultaneous images in SDO and Hinode to create a much more complete image of spicules.

They found that much of the gas is heated to 100,000 F, while a small fraction of it is heated to millions of degrees. Time-lapsed images show that this hot material spews high up into the corona, with much of it falling back down toward the surface of the Sun. However, the small fraction of the gas that is heated to millions of degrees does not immediately return to the surface. "Given the large number of spicules on the Sun, and the amount of material in them, if even some of that superhot plasma stays aloft it would make a fair contribution to coronal heating," says Scott McIntosh from NCAR, who is part of the research team.

Of course, De Pontieu cautions that the team's results do not yet solve the coronal heating mystery. But, he says, they do challenge theorists to incorporate the possibility that some coronal heating occurs at lower heights in the solar atmosphere. De Pontieu's next step is to help figure out how great a role spicules play by studying how they form, how they move so quickly, how they get heated to such high temperatures in a short time, and how much mass stays up in the corona.



On August 1, 2010, the entire Earth-facing side of the Sun erupted in tumult. There was a powerful solar flare (white area upper left), a solar tsunami (center left), and multiple filaments of magnetism lifting off the stellar surface at lower left, large-scale shaking of the solar corona, radio bursts, a coronal mass ejection and more. Hemisphere wide violence was also imaged at far right. This multi-wavelength EUV snapshot from SDO depicts different colors for different temperatures from 1-2 million F.



Loops of highly charged particles shoot out from the Sun, as seen in extreme ultraviolet wavelengths by the STEREO spacecraft. Blue color is used to indicate temperatures in the corona of about 1,800,000 F.

Fox notes that astrophysicist Jonathan Certain, the U.S. project scientist for Hinode at NASA Marshall, says incorporating such new information helps address an important question that reaches far beyond the Sun. "This breakthrough in our understanding of the mechanisms which transfer energy from the solar photosphere to the corona addresses one of the most compelling questions in stellar astrophysics: 'How is the atmosphere of a star heated?' This is a truly fantastic discovery," says Certain.

Out of the

25 Years Ago, April 1986

April 23 Airship Industries opens scheduled sightseeing flights over the city of London with its Skyship 500 airship. *Popular Mechanics*, July 1986, pp 75-77.

50 Years Ago, April 1961

April 4 Capital Airlines merges with United Air Lines. *The 1962 Aerospace Year Book*, p. 470.

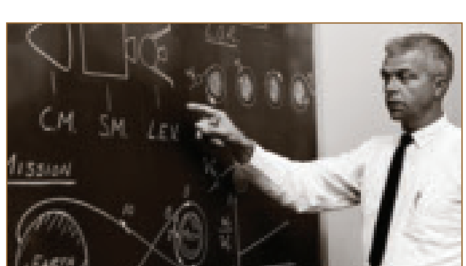
April 5 France's Dassault Mirage IIIE long-range intruder aircraft makes its first flight. Powered by a 14,110-lb-thrust SNECMA Atar 9C turbojet engine, the plane is 2 ft 6 in. longer than its predecessor. Eventually, some 532 of the Mirage IIIEs are to be built for 13 air forces of the world. D. Baker, *Flight and Flying*, p. 375.

April 10 Production of prototypes of the B-70 Valkyrie six-engined deep penetration Mach 3+ bomber is to be limited to just three aircraft, two XB-70s and one YB-70, as strictly high-speed aerodynamic test vehicles. D. Baker, *Flight and Flying*, p. 375.

April 12 Yuri Gagarin becomes the first man in space, launched in the Soviet Union's Project Mercury-like Vostok I space capsule from the Tyuratam launch site. Gagarin remains in orbit for 108 min before a braking engine is deployed and the capsule and pilot reenter Earth's atmosphere, parachuting safely into the USSR. Gagarin's 10,425-lb capsule attains a speed of 17,000 mph with a perigee of 110 mi. and apogee of 188 mi. He does not have manual control of the spacecraft during the flight. D. Baker, *Spaceflight and Rocketry*, p. 116; *Aircraft & Missiles*, May 1961, p. 15; *The Apollo Spacecraft: A Chronology, Vol. I*, p. 81.

April 14 Rocketdyne's F-1 rocket engine is fired up to 1,640,000 lb in its first 'long' run of 13 sec, at Edwards AFB, Calif. *The 1962 Aerospace Year Book*, p. 471; *Aircraft & Missiles*, June 1961, p. 11.

April 19 John Houbolt of NASA Langley releases his own study of a U.S. space initiative, titled *Manned Lunar Landing via Rendezvous.* It outlines such a mission and suggests two Saturn C-2 launch vehicles, one to send up a command vehicle and lunar lander into Earth orbit, and the second to send the docked vehicles to lunar orbit. The plan is not carried out, but Houbolt does succeed with his proposed lunar orbit rendezvous. This flight path, which involves a single Saturn V launch vehicle, is endorsed by Wernher von Braun in June 1961 and approved for the Apollo program early in 1962. D. Baker, *Spaceflight and Rocketry*, p. 116.



April 21 The X-15, flown by Capt. Robert M. White, becomes the first plane to fly faster than 3,000 mph

when it reaches Mach 4.62, or 3,074 mph, at a maximum altitude of 105,000 ft in the 15th flight of the aircraft. D. Baker, *Flight and Flying*, p. 375; D. Jenkins, *X-15: Extending the Frontiers of Flight*, p. 617.

April 24 The huge Soviet Tu-114 turboprop-powered long-range airliner, designed by the Tupolev design bureau, begins Aeroflot service on its Moscow-Khabarovsk route. The largest and fastest passenger plane at the time, it remains one of the fastest turboprop passenger carriers of any era. Able to seat up to 224 passengers (but 170 as the standard), the plane is 177 ft 4 in. long with a wing span of 167 ft 7.7 in. and a maximum speed of 541 mph. It becomes very successful, carrying more than 6 million passengers before being replaced by the jet-powered IL-62. F. Mason and M. Windrow, *Know Aviation*, p. 61; Tu-114 file, NASM Library.

April 27 The Juno II launch vehicle makes its last flight, launching the 95-lb Explorer XI satellite. As its first stage the Juno II uses a modified Jupiter missile, with clusters of scaled-down solid-fuel Sergeant motors as the second and third stages. This arrangement is similar to that of the Jupiter-C (also called Juno I), which launched the

Past

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

first Explorer series. One of the original U.S. launchers, it was first used in 1959 for Pioneer III and IV space probes as well as Explorer satellites VII and VIII. Explorer XI, a unique gamma-ray telescope developed by MIT and designed to detect gamma rays in space, became the first spacecraft to do so. D. Baker, *Spaceflight and Rocketry*, p. 118.

April 28 An experimental version of the Soviet MiG-21 sets a world altitude record of 113,898 ft, flown by Soviet air force Col. Georgy Massolov.

The plane is powered by a 13,228-lb-thrust TDR Mk.R-37F turbojet with a GRD Mk.U2 rocket motor for supplementary power. D. Baker, *Flight and Flying*, p. 375.

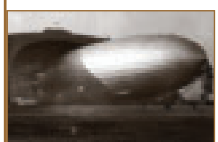
And During April 1961

—Construction starts on the first hardened Minuteman ICBM base at Malmstrom AFB, Mont., and is to include 150 underground launch silos for the solid-fuel missile. *Aircraft & Missiles*, April 1961, p. 12.

75 Years Ago, April 1936

April 4 The 18th anniversary of the Woman's Royal Air Force is honored by a banquet at London's Criterion Restaurant. Guests include Air Marshal Sir John Steel. The affair is attended by 120 women who served with the unit during WW I. *The Aeroplane*, April 8, 1936, pp. 437-438.

April 4 A new method of studying the substratosphere is successfully demonstrated over Moscow. Gliders are towed by conventional aircraft and soar to higher altitudes while attached. Carrying barographs, wind gauges, and other instruments, the closed-cabin gliders rise about 5,000 ft above the towing planes to an altitude of about 4 mi. *Aero Digest*, May 1936, p. 66.



April 6 The dirigible Hindenburg leaves Rio de Janeiro to return from its first long transatlantic journey. It heads for home in Friedrichshafen, Germany, carrying 36 passengers, a crew of 40, and 5 tons of freight. *The Aeroplane*, April 22, 1936. p. 489.

April 14 A Sikorsky S-43 amphibian piloted by Capt. Boris Sergievsky breaks two altitude records. Carrying passenger Igor Sikorsky, mechanic Michael Pravikoff, and a 500-kg payload, it climbs to 27,950 ft over Stratford, Conn. *Aero Digest*, May 1936, p. 66.

April 17 The coveted Harmon Trophy, established in 1926 by balloonist and aviator Clifford B. Harmon for outstanding achievements in the art and/or science of aeronautics, is won by Capt. Edwin C. Musick for his pioneering work as a pilot with Pan American Airways' transpacific Martin M-130 China Clipper flights. Amelia Earhart of the U.S. and Jean Batten of the U.K. share the world award for women. *Aero Digest*, May 1936, p. 66.

April 30 Millionaire movie producer Howard Hughes breaks the transcontinental U.S. speed record, flying 1,096 mi. in a Northrop Gamma from Miami to New York in 4 hr 21 min 32 sec at an average speed of 250 mph. *The Aeroplane*, June 3, 1936, p. 681, *Aircraft Year Book*, 1937, p. 411.

And During April 1936

—The Italian air force has flown 20,000 hr of combat and support missions so far, following Italy's invasion of Ethiopia in October 1935. The Italians have dropped 2,000 tons of explosives and fired 300,000 bullets. *Flight*, April 2, 1936, p. 347.

Pierre Prier

100 Years Ago, April 1911

April 12 Pierre Prier is the first to fly nonstop from London to Paris, making the 250-mi., 4-hr flight in a Bleriot. The feat leads to many other long-distance flights, many of them at air meets. C. Gibbs-Smith, *Aviation*, p. 159.

April 13 F. Rodman Law is the first to parachute from a seaplane, a Burgess hydroaeroplane, piloted by P.W. Page at Marblehead, Mass. He falls in the water and is rescued by a motor boat before 35,000 spectators. *Flight*, May 11, 1912, p. 42.

The Daniel Guggenheim School of Aerospace Engineering at Georgia Institute of Technology invites applications for faculty positions in the following areas.

• The first is a non tenure-track appointment at the rank of Professor of the Practice in Flight Vehicle Design. A PhD is not required, but the selected candidate will have a national/global reputation for excellence, and a rich and extensive background in fields and disciplines related to aerospace engineering. Responsibilities for this position include teaching courses at the undergraduate and graduate levels and serving as liaison with the professional world in identifying teaching and research opportunities. This search is headed by Prof. Dimitri Mavris (dimitri.mavris@ae.gatech.edu)

• The second is a tenure track appointment, preferably at the assistant or associate professor level, with an experimental aerodynamics background applicable to studies of next generation transportation configurations. This search is headed by Prof. Lakshmi Sankar (lsankar@ea.gatech.edu)

• The third is a tenure track appointment in the area of combustion, propulsion, and energetics. The selected candidate will have experimental and/or computational expertise in combustion and its application in propulsion, power generation and energetic. This search is headed by Prof. Ben Zinn (ben.zinn@ea.gatech.edu)

More details on these openings may be found at www.ae.gatech.edu/careers . Responsibilities for the tenure-track positions include teaching courses at the undergraduate and graduate levels, supervising graduate students, developing externally funded research projects and interacting with faculty in collaborative areas.

A cover letter indicating the position of interest, a CV, and names and contact information for 6 references should be sent to Ms. Susan Jackson, Administrative Manager, School of Aerospace Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0150, or by email to the Search Committee Chairs listed above, with copy to susan.jackson@ae.gatech.edu . Evaluation of applications will commence immediately. Georgia Tech is a unit of the University System of Georgia, an Equal Opportunity Affirmative Action employer fully committed to achieving a diverse workforce.

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This Fellowship program will offer the special salary to the Fellows of 790,000 Japanese Yen before tax/month (equivalent to an annual salary of $100,000 US dollars at a typical exchange rate of 94.80JPY / dollar). The program will provide them with the financial support for expenses for travel and equipment up to a maximum of 2,500,000 Japanese Yen / year.

The closing date: April 30, 2011

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Institute of Space and Astronautical Science
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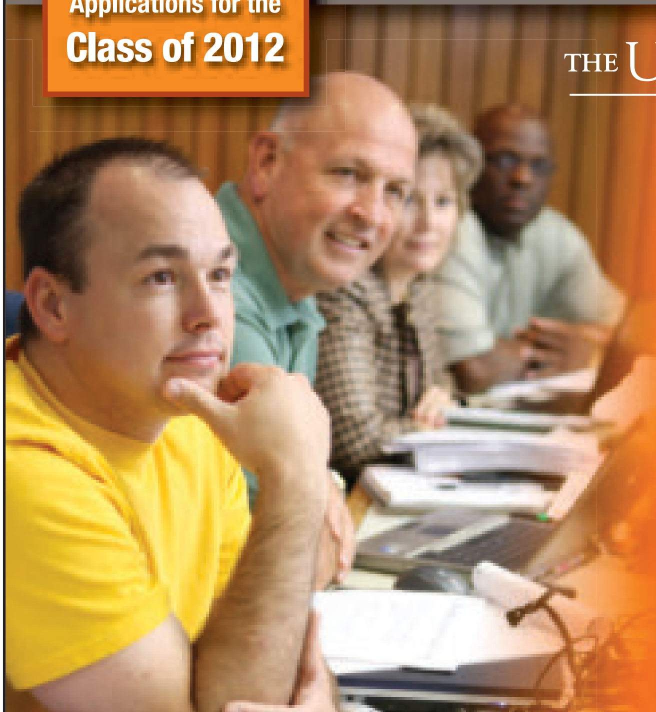

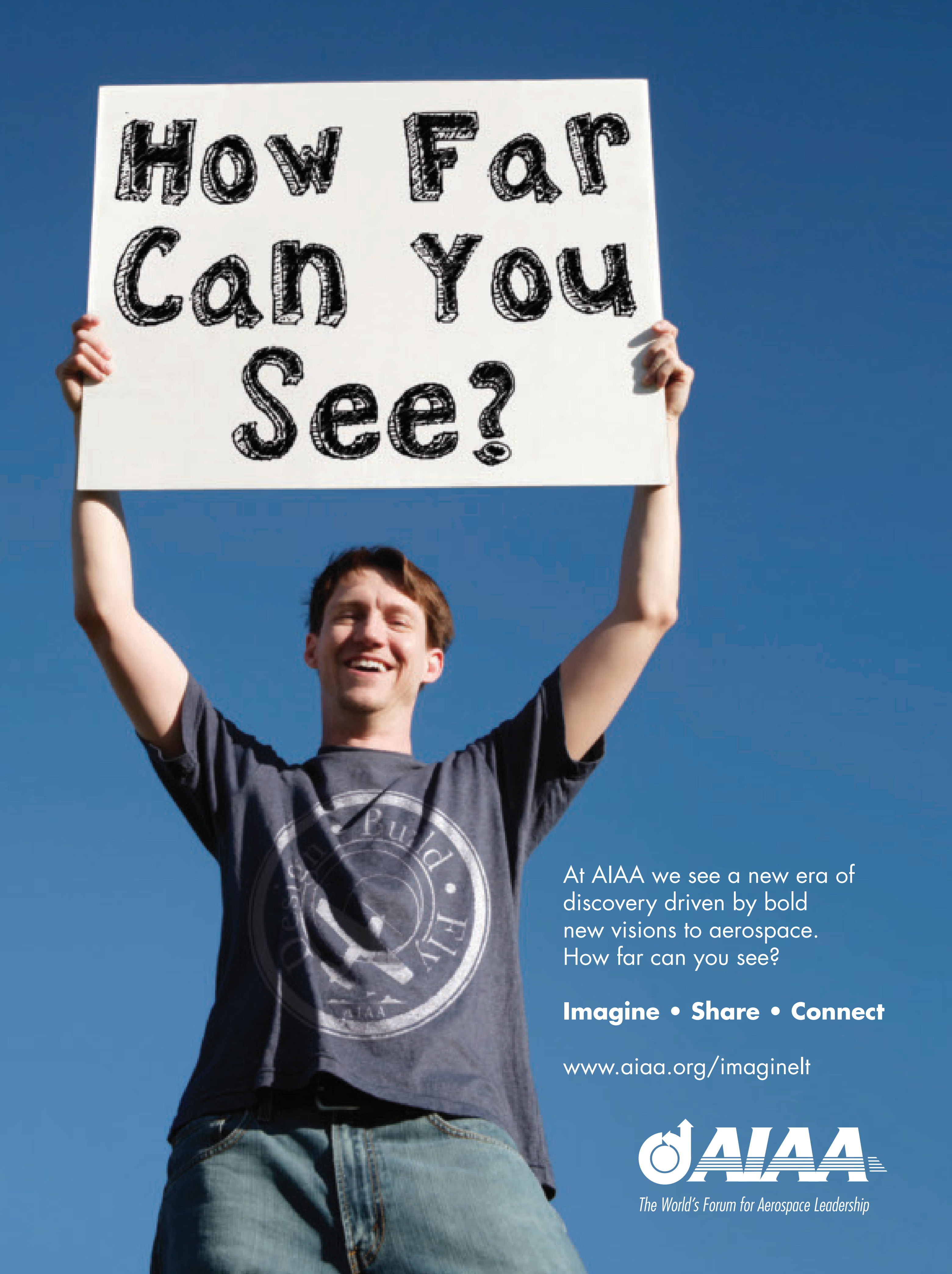
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