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April 2010

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20 HUBBLE at

Reflections on the universe... and ourselves

A PUBLICATION OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

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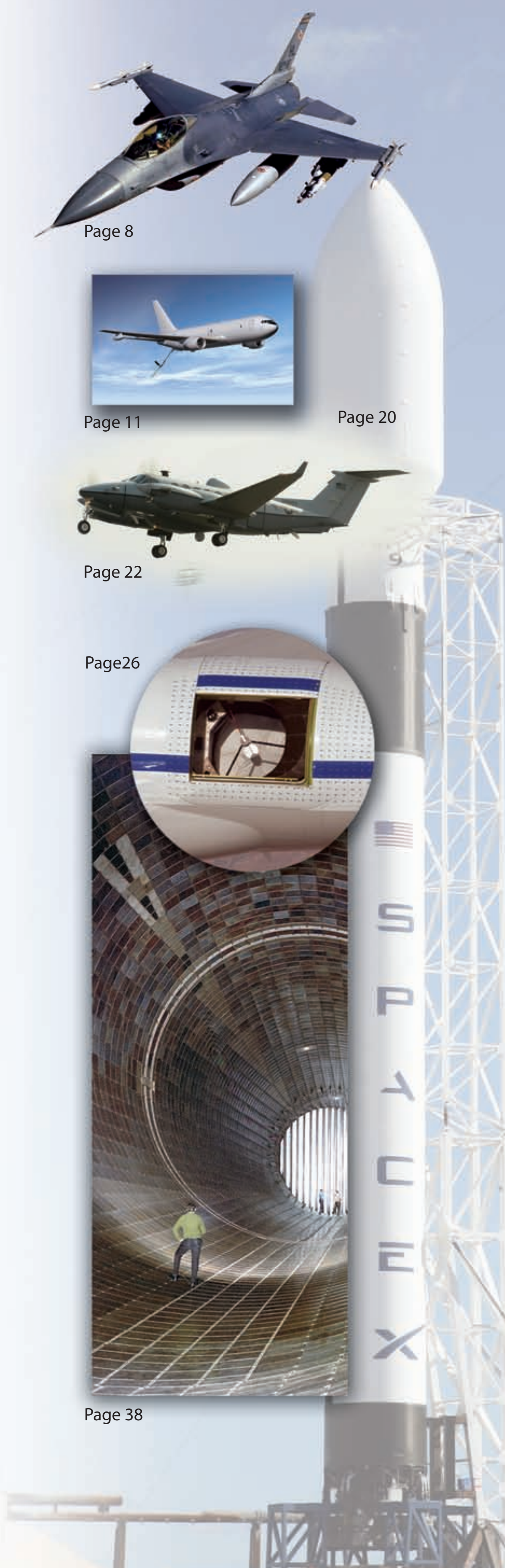

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Editorial

Working toward compromise

When we were young, nothing thrilled us as much as shiny new toys. The newest bicycle in the store window made our trusty old one seem shabby and boring. Never mind that sometimes, when we got it home, we found that it was too difficult to pedal, or we would fall down all the time, or that our parents couldn't really afford it. It was new and we wanted it.

The space shuttle is getting old, and after having served us well for so long, many believe it is just about ready for a well-deserved retirement. Constellation, on the other hand, was big, and shiny, and new…but our government really doesn't seem to be able to afford it, and, even if it someday lives up to its billing, like most other government programs, it would probably take far longer and cost far more than predicted to get there.

The Obama administration has ordered the cancellation of the entire Constellation program, turning instead to private industry to lead us back into space. As these companies work toward development of rockets and crew carriers, the government would purchase rides to the space station on Russian Soyuz launch vehicles.

Many legislators oppose this approach, as it represents lost jobs, a waste of the billions of dollars already spent on Constellation, and a massive flow of new dollars out of the country. They argue that work should continue on Constellation, to protect jobs and maintain U.S. access to space. However, the Augustine Commission has already established that this program will cost far more—and take far longer to complete—than first anticipated.

But in the search for a replacement system for the space shuttle, did we overlook maybe not the newest, but certainly one of the most reliable options? The evolved expendable launch vehicles built for the Air Force, Lockheed Martin's Atlas V and Boeing's Delta IV, have outstanding safety records. Is there not some possibility of taking some of the funding that had been allocated to Constellation's Ares I rocket and using it to human-rate these launch vehicles?

Rather than shutting down the Orion crew exploration vehicle, could work not continue, while reconfiguring it to be accommodated by one of the EELVs? Could work also continue on the launch abort system, to make sure that we add another layer of safety for its precious cargo?

And while these developments proceed, could we not ask the venerable shuttles to take just a few more trips into space before finding homes in museums and space parks? Restarting assembly of the external tanks would also restart some lost jobs.

In the interim, private industry can continue to build, test, fly—crash—and fly again, until they get it right.

It might not save all the jobs that would be lost by termination of Constellation, but it should save many. And we might still have to hitch a ride now and again from Russia, but not every time.

As we get a little older, we start to realize that shiny and new really isn't what matters. Solid and dependable trumps it every time.

Elaine Camhi
Editor-in-Chief

Europe tackles runway capacity issue

One of the toughest challenges of the Single European Sky ATM Research (SESAR) program is the doubling or trebling of airspace capacity by 2025 over 2005. In the three dimensions of European airspace this is tough, but feasible. In the two dimensions of the runways at Europe's major airport hubs, the goal of trebling capacity looks virtually impossible; for environmental reasons it will simply not be practical to build new runways to cope with future demand.

But if this issue is not addressed, then the entire $30-billion SESAR program is threatened—without enough runway capacity, all SESAR will do is move increasing amounts of air traffic more swiftly between the bottlenecks on the ground.

So Europe's air traffic management (ATM) experts are contemplating some radical technologies and procedures to ensure that airports do not become the bottlenecks to future growth.

Surprising differences

There are some startling differences between the current runway throughput rates of Europe's largest airports. It would be tempting, looking at these figures, to say the simple answer to the runway congestion problem is to analyze how London/Heathrow traffic is managed and then replicate this elsewhere. Heathrow's ability to manage 89 aircraft movements an hour off two runways is even more remarkable considering the high percentage of larger (and therefore slower and more widely spaced) planes using the airport. The number of aircraft movements at Heathrow is closely comparable to those at Detroit Metropolitan Wayne County Airport, but Detroit has six runways, and the aircraft that use it are much smaller, on average, than those at Heathrow.

But every airport is different; the environmental and curfew constraints and the airport runway and taxiway layout make accurate comparisons nearly impossible. Heathrow's runway performance levels have been realized through a mixture of applying new technology, refining procedures and, increasingly, collaborative decision-making (CDM) tools designed to involve all stakeholders in maximizing runway efficiencies.

"We had the target at Heathrow of achieving an average of less than 50 seconds' occupancy time across a wide range of aircraft," says Peter Tomlinson, airport technical expert at the U.K.'s NATS (National Air Traffic Services), which oversees the ATM system at the airport. "One of the ways we looked to reach this target was to identify who was the 'best-in-class' among the aircraft operators using a particular aircraft type and then try to replicate that airline's procedures across the board. It is surprising how different the procedures are for the same aircraft—when the checklists are completed, for example—and this can have a major difference on runway and taxiway occupancy times."

Using the best-practice model has been a core element of Eurocontrol's airport airside capacity enhancement (ACE) program, which has helped increase capacity at Lisbon and Prague airports by factors of 20% and 40% respectively, according to Eric Miart, program manager of the airport operations program at Eurocontrol. ACE relies on taking accurate measurements of the performance of the airport operation, assessing capacity and introducing best practice techniques to controllers, pilots and airport operators.

Improving traffic flow and safety

The tools for increasing runway capacity levels have been in place for some time. Apart from building rapid exit taxiways and other taxiways running parallel to the main runway, some new technologies coming into operation offer substantial improvements on legacy systems.

For example, A-SMGCS (advanced surface movement guidance and control systems)—which provide routing, guidance and surveillance to aircraft under all weather conditions—have been in operation since the early years of the decade. Precision Runway Monitoring-Alternative (PRM-A) is an accurate multilateration surveillance system that gives the precise aircraft position information needed to simultaneously separate planes on approach into closely spaced parallel runways. And light detection and ranging (LiDAR) systems measure the Doppler shift of light scattered from atmospheric particles to identify wake vortex occurrences and separate aircraft on approach based on actual, rather than theoretical, wake vortex occurrences.

But if a 300% increase in airport ca-

Airport	Runways	Aircraft movements	Reporting period	Average daily movements per runway
Paris Charles de Gaulle	4	518,018	January–December2009	354.8
London Heathrow	2	462,835	October 2008-September 2009	634.0
Frankfurt	3	463,111	January-December 2009	422.9
Madrid	4	435,179	January-December 2009	298.0
Amsterdam/Schiphol	5	391,000	January-December 2009	214.2

pacity is to be achieved without trebling the number of runways and taxiways, an entirely new way of managing airport operations will be needed. Already under way in Europe is research on developing a network-enabled information system that will link new ground-based and airborne technologies along with best-in-class procedures for radically enhancing airport capacity levels. Ultimately the goal will be to automate the entire runway/taxiway operation, ensuring that both are being used to their optimal capacity, whatever the weather, and without degrading the required safety levels.

"Whatever the improvements, safety has to be improved, and especially the prevention of runway incursions," says Eric Miart. "Risk increases as a square of the increase in traffic; if traffic doubles or triples, then risk increases by a factor of four or nine respectively."

Network enhancement

In Europe the catalyst to the development of a common information network encompassing pilots, controllers and airport operations managers is the European Airport CDM (www.euro-cdm.org) program promoted by Eurocontrol, Airports Council International Europe and the International Air Transport Association. The largest weakness in the current European ATM capacity management system is a lack of coordination between airports and ATM network managers.

The Central Flow Management Unit, based in Eurocontrol's Brussels headquarters, operates a continental flow management system by matching aircraft operator flight plans with the available capacity of airspace sectors and airport runways. It forecasts where potential sectors may become overloaded and calculates alternative operations—such as delaying takeoff times or rerouting aircraft in flight—to keep supply and demand in balance.

One of the major current weaknesses in the system is a lack of accurate information on actual airport operations—the time the aircraft pushes back from the terminal, its progress through the airport taxiway system and the time when it rolls onto the runway for takeoff. The key piece of information here is the Target Start Up Approval Time (TSAT), which lets ATC, airport and airline colleagues know exactly when the aircraft is ready to move from the terminal. By feeding this information into a central planning tool it will be possible to calculate accurately whether the aircraft will meet the takeoff slot-time it has been given—and, if not, how traffic can best be managed to accommodate changes to slot times.

NATS has been testing a version of what it calls a TSAT-generator. "Once we know when the aircraft will be ready to move, we can project the taxiing time, look at how this would work in an unconstrained demand situation, then feed in the various variables," according to Tomlinson. "We can calculate the optimum sequence and then work out exactly what time the aircraft needs to leave the gate. We think this will give us an extra two departures an hour while reducing the amount of time the aircraft waits at the gate by 50% and taxi times by 6 minutes."

It seems like a modest improvement, but the development of a CDM information network linking the cockpit, the control tower and the airport will provide the essential framework to a new runway and operations management system. The network needs to evolve from a planning tool to an operational system; but once this is done, increasing levels of automation can be introduced.

For example, A-SMGCS systems are now used mainly to improve surveillance of aircraft and ground vehicles at airports in bad weather. However, ultimately (defined as "level four" operations) they can evolve to provide automatic conflict resolution and automatic planning and guidance for pilots and controllers. The FAA, Eurocontrol and ICAO are working on developing standards and procedures for these levels of operation.

Airborne additions

New airborne technologies will need to be added to the information network. For example, the FAA is funding research into how electronic flight bags can be evolved to show airport moving map displays and own-ship positions, so pilots can see the exact location of their aircraft on the airfield. But in the future, the networks will have to be developed

Aircraft queue for takeoff at Heathrow.

to incorporate new automated airborne systems.

For example, the Airbus A380 features an automated "brake-to-vacate" facility that combines satellite positioning with the on-board airport database and flight-control management system. The pilot selects a runway exit point and the system manages the braking process to ensure the aircraft reaches the chosen exit point at the optimal speed, having factored in runway and weather conditions. According to Airbus, the system minimizes runway occupancy time and allows up to 15% more departures to be scheduled.

The European Commission is also helping to fund a research program called "Green-wake," where an airborne LiDAR alerts pilots to wake vortex and wind shear occurrences on final approach. This is part of the wider WakeNet3 (www.wakenet3-europe.eu) commission-funded research program (2008-11) that examines how crosswinds, wind shear and wake vortex conditions can be measured, reported and acted upon promptly.

Looking ahead

Other, more esoteric planning and operational tools are waiting in the wings. "NATS is working with the McLaren Formula One racing team, using race team prediction software and putting this into an airport environment," according to Tomlinson. "It allows us to predict the future of airport operations with a high degree of accuracy over half-hour, 1-hr and 2-hr time slots. We can then color-code the areas of the airport where we see potential capacity problems arising."

At the moment, at least, the airport and runway capacity problem has abated because of the recent downturn in the air travel market. But growth will return, probably later this year, and with it the pressure on Europe's hub runways will reemerge.

If the future anticipated traffic levels are to be met then without the appearance of five new runways at Europe's major hubs, the development of network-enabled airport CDM operations is more than just a helpful aid to improving capacity. It is an empirical necessity.

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Events Calendar

APRIL 12-15
Fifty-first AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference; 18th AIAA/ASME/AHS Adaptive Structures Conference; 12th AIAA Nondeterministic Approaches Conference; 11th AIAA Gossamer Systems Forum; Sixth AIAA Multidisciplinary Design Optimization Specialist Conference, Orlando, Fla.
Contact: 703.264.7500

APRIL 12-15
Twenty-sixth National Space Symposium, Colorado Springs, Colo.
Contact: 719.660.6380

APRIL 20-22
AIAA Infotech@Aerospace 2010, Atlanta, Ga.
Contact: 703.264.7500

APRIL 25-30
SpaceOps 2010 Conference: Delivering on the Dream (hosted by NASA Marshall and organized by AIAA), Huntsville, Ala.
Contact: 703.264.7500

MAY 4-6
ASTRO 2010—15th CASI Astronautics Conference, Toronto, Ontario, Canada.
Contact: G. Languedoc, 613.591.8787; www.casi.ca

MAY 11-12
Inside Aerospace—An International Forum for Aviation and Space Leaders, Arlington, Va.
Contact: 703/264-7500

MAY 11-13
Integrated Communications, Navigation and Surveillance Conference, Herndon, Va.
Contact: James Dieudonne, 703/983-6578, jdieudon@mitre.org

MAY 13-15
Fifth Argentine Congress on Space Technology, Mar del Plata, Argentina.
Contact: Pablo de Leon, 701/777-2369; Deleon@aate.org

MAY 31-JUNE 2
Seventeenth St. Petersburg International Conference on Integrated Navigation Systems, St. Petersburg, Russia.
Contact: Prof. V. Peshekhonov, www.elektropribor.spb.ru

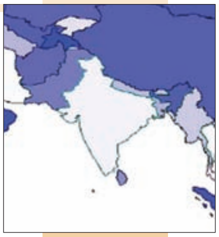
JUNE 1-4
Fourth International Conference on Research in Air Transportation, Budapest, Hungary.
Contact: Andres Zellweger, dres.z@comcast.net

JUNE 7-9
Sixteenth AIAA/CEAS Aeroacoustics Conference, Stockholm, Sweden.
Contact: Hans Bodén, hansbod@kth.se

JUNE 8-10
Third International Symposium on System and Control in Aeronautics and Astronautics, Harbin, People's Republic of China.
Contact: Zhenshen Qu, ocicq@126.com

JUNE 14-18
ASME TurboExpo 2010, Glasgow, Scotland, U.K.
Contact: www.turboexpo.org

India joins the race



There is no way the aerospace and defense manufacturers of India (or any other nation) can hope to leap into direct competition with industry titans such as Boeing or EADS. Even joining the second tier with companies such as Brazil's Embraer and Canada's Bombardier is difficult enough, with China's AVIC (Aviation Industries of China) and Japan's Mitsubishi now just reaching that level after many years of effort and frustration.

Nevertheless, India's developments in spaceflight—including its January announcement of plans for a manned mission in 2016—are the harbinger of renewed efforts to match its giant neighbor China's surge into the international arena in aerospace technology. The question now is whether it can step up to the plate in attracting foreign investment, partners, and new technology to propel it into the top ranks.

The X-factor

In theory, there seems no good reason why India should not have been able to parallel China's steps up the technology ladder over the years. Both took on license production of military and civil aircraft types at various times, and both have—at least in principle—huge domestic markets to develop that could underpin the production of passenger aircraft locally.

In practice, their separate paths of economic development and their reliance on Western or former Soviet allies for access to training and technology have led to very different mindsets, and hence to very different approaches to acquiring and applying expertise.

It is not merely a matter of technical or scientific knowledge and ability; both approaches embody these factors. Nor is it a matter of industrial capacity; again, both China and India are perfectly capable of churning out different kinds of high-tech "widgets" or other gadgets.

But being able to produce reliably, even monotonously, complex items that themselves involve the integration of complex components and systems, and then to sell and support those products in the world marketplace, needs something else—call it the X-factor if you will. It is something that has been learned over many years by the U.S. and Europe, and later by Canada and Brazil.

Japan with its regional jet project will have to show that it has learned it, having tried with other aviation projects that, no matter how technically excellent they were, failed to impress markets beyond its shores. Russia, too, is now seeking to win the world's confidence—its military products are well known for their capabilities, but its civil airliners have not won admiration beyond a very limited group of customers, and so Russian aerospace makers are also seeking to upgrade their products' reputations.

Avenues to progress

This leaves China and India at the back of the queue, still partnering or seeking to partner with foreign manufacturers, but trying to gain work shares that involve more than just being "screwdriver" operations, simply assembling aircraft or components from kits or supplied drawings. In this regard, China is further ahead than India; both have assembled foreign-designed military aircraft (MiGs and Sukhoi designs in both countries, British Aerospace Hawks and Sepecat Jaguars in India). Both have assembled foreign-designed airliners in the past—various Antonov fixed-wing models and MD80 twinjets (though a very limited number of the latter) in China, and small British HS748 turboprop airliners in India. Both have also put together various Russian and Western helicopters in series production.

But China took the lead in the 1980s with manufacturing major components for U.S. and European aircraft makers. It is now reaping the reward by partnering with Europe's Airbus to produce A320 airliners on a new production line set up in Harbin. It is also renewing attempts, first made in the 1970s, at developing its own regional and larger jet airliners, this time buying modern foreign systems as it deems necessary and learning to integrate them into its own state-of-the-art overall design.

Both nations have made progress toward high-grade production via manufacturing automobiles, partnering with foreign makers. While India is now the world's fourth-largest exporter of cars after the U.S., Japan and South Korea, China has gone further and faster down this road in terms of new technology. India now needs something similar as a way of driving its technology base forward and broadening it from its acknowledged information technology and software-based excellence, building on its strengths: a pool of skilled engineering talent, and low costs.

A new approach

New Delhi's latest approach to attracting foreign interest into its aerospace and defense industries is to encourage its own private companies to take part. Until 2001, aerospace and defense were the preserve of public sector units controlled by the government, the largest of which was the government-controlled Hindustan Aeronautics Ltd. (HAL)—the 600-lb gorilla in the room, with the finance, the expertise and the industrial "magnetism" to attract the best talent.

Since then, private investment has been allowed, combined with a defense offset policy introduced in 2006 and followed up by significant liberalization in 2008.

The result should be a win-win situation for all concerned—the government is happy to give tax breaks to attract foreign investors with new technology and expand the country's high-tech manufacturing base, while foreign companies are happy to be able to seek alternatives to HAL, thus enlarging their pool of partnership options.

The government has also been encouraging the establishment of aerospace parks and special economic zones with tax advantages (so far seven have been formally proposed), all in India's southern or midcountry sectors. This approach should come as no great surprise, given that India's high-tech industries were originally clustered around Bangalore, where the old airport is owned by HAL.

There is no shortage of potential takers, although HAL is going to continue to be a big winner. The current contest to pick India's next major fighter aircraft illustrates the point: The so-called medium multirole combat aircraft contest features six types from four continents for a projected buy of 126 units, of which only 18 will be built overseas, with the remaining 108 manufactured under license by HAL.

In contention are the Lockheed Martin F-16 and Boeing F/A-18 from the U.S., Saab's Gripen from Sweden, Russia's MiG-35, France's Dassault Rafale and European consortium Eurofighter's Typhoon. A decision is expected later this year.

The government had also tasked HAL with designing and building more than 180 light utility helicopters for its military forces. But this project has now morphed into somewhat smaller and more complex chunks, with Europe's Eurocopter saying it is bidding to supply (whether complete or license-built in India was not stated) about 90 aircraft, with U.S. maker Sikorsky also a contender for this deal. Meanwhile, Anglo-Italian helicopter maker AgustaWestland is seeking a joint venture with India's giant conglomerate Tata Group to produce light helicopters for the Indian military as well as for export. Tata has been seeking permission to build an aerospace manufacturing plant near Hyderabad in southern India's Andhra Pradesh state.

Other linkages include a defense electronics joint venture between EADS and Mumbai engineering giant Larsen & Toubro, as well as between L&T and Boeing and L&T with Raytheon. In terms of aircraft production, major Indian motorcycle maker Hero Motors is seeking to build light aircraft in a special aerospace section in central Madhya Pradesh. Also, Indian car maker Mahindra & Mahindra has had several agreements with foreign high-tech companies, including Britain's BAE Systems, but it has a partnership with India's state aerospace research company, National Aerospace Laboratories, to produce a light aircraft with 2-18 seats. NAL is to develop and certify the aircraft for domestic use, while Mahindra Aerospace (a subsidiary of Mahindra & Mahindra) is to seek certification abroad and take charge of serial production.

Surprising gains

While to many people in India all of this probably seems—and indeed is—very much state of the art, to most observers outside the country it seems pretty small beer. Its significance is not so much what has been achieved so far, but that it is happening at all. For example, HAL has been discussing plans to build a 70-90-seat regional jet for several years, but so far nothing has resulted. India's government bureaucracy has a well-earned rep-

Dassault Rafale

Eurofighter Typhoon

Mikoyan MiG-35

Saab Gripen

Lockheed Martin F-16

Boeing F/A-18

These aircraft are in contention to become India's next major fighter, with most units to be built by HAL.

utation for stifling initiative, so the recent and current wave of liberalization is surprising for the gains it has made to date.

Even government-controlled entities have benefitted, with HAL, for instance, being among a relative handful of such companies to be granted so-called Navaratna status, allowing it considerable commercial freedom in such matters as setting up joint ventures with private companies. As HAL officials note, HAL has actually been responsible to a considerable extent for building up high-tech expertise in the private sector by subcontracting work that it did not have sufficient capacity to complete on its own.

Constraints and barriers

Last year, accounting and corporate research giant PricewaterhouseCoopers issued a study on Indian defense and aerospace industry and investment opportunities; it pointed out that the limit of 26% on foreign ownership might restrict investors' enthusiasm for joint ventures, though it added that this limit might give Indian companies more leverage in negotiations. In practice, Indian companies have echoed the opinion that the 26% limit needs to be overtaken with something more like 49%, based on the premise that technology transfers need to be well rewarded if they are to be real and not just disguised attempts at exploiting cheap labor in India.

Tata is probably the only Indian company other than HAL that could make serious inroads into manufacturing aircraft, not just because of its size but because of its background in aviation—the national carrier, Air India, was originally a division of the Tata Group. But going via the civil rather than military route is made more difficult by taxation; a foreign sale to the Ministry of Defense is exempt from tax, while spare parts for airliners are subject to import duty. This is currently a barrier to India promoting itself as a major center for maintenance, repair and overhaul—another avenue that can lead to significant technology transfers and training.

The PricewaterhouseCoopers study also looks at whether India can emulate China's sprint toward aerospace eminence, but comes to no real conclusion,

BAE Hawks for the Indian air force are built at HAL production line in Bangalore. Photo by Ajai Shukla.

except to say: "The fragmented nature of the Indian aerospace sector has been a hindrance in India achieving self-reliance in its aerospace capabilities." It points out that China has made a concerted effort to acquire technology from outside via joint ventures as well as developing its own resources, and has deliberately focused on building capabilities of all kinds.

"China also centralized its aerospace activities under one ministry at the government level; the majority of orders from its government drove economies of scale and encouraged exports," the study says. But in India, "With so many authorities as stakeholders in the development of this sector, there is no single national aeronautical policy or plan that has emerged to focus on industry's growth and self-reliance."

India's recent liberalizations of defense and aerospace investment are therefore a hugely welcome breath of fresh air. But win-win or not, it is going to need time to generate an Indian equivalent of Embraer or Bombardier. The learning process takes literally years.

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Season for endings?

The Obama administration says it is killing the Constellation human spaceflight effort. The program was meant to provide a next-generation replacement for the familiar shuttle, which is being retired this year. Now the administration wants to partner with the private sector to develop what NASA Administrator Charles Bolden calls "quicker, cheaper, homegrown capacity to put astronauts into orbit."

Major shift for NASA

President Barack Obama has not made a public statement about his space policy even though the shift from Constellation to commercialization is the biggest change for NASA since the agency was created 52 years ago. Bolden, however, has made repeated trips to Capitol Hill to defend the policy.

The administration's FY11 budget proposal calls for the space agency to outsource rocket development for human spaceflight to commercial companies. This shift ends any immediate prospect of travel to the Moon or Mars and terminates the Ares I booster and the Orion crew exploration vehicle.

It is unclear whether the new policy can survive the scrutiny by Capitol Hill space proponents like Sen. Bill Nelson (D-Fla.) and Sen. Barbara Mikulski (D-Md.). In hearings at the end of February, senators and outside experts including NASA Advisory Council member Miles O'Brien criticized NASA for no longer having a destination. Bolden said the space agency still hopes to go to Mars but acknowledged that the current plan does not take U.S. astronauts to any specific place. Sen. David Vitter (R-La.) said the outsourcing plan is a "waste of money" without a goal. One congressional staffer said NASA has a "nebulous" sense of direction.

Bolden told Congress that his agency is making preparations to dismantle the Constellation program, even though some lawmakers say he needs their permission to do so. Among those legislators are Rep. Pete Olson (R-Texas), 19 other Republicans and four Democrats, who wrote to Bolden citing a provision included in a 2010 omnibus spending bill that bars NASA from terminating any part of the space shuttle replacement effort without formal congressional approval. Bolden sent a letter in response to this claim that NASA is breaking the law, saying that he and the White House will fight any Capitol Hill opposition to the administration's proposed budget.

Some point out that the aerospace industry has not yet tested or flown a private sector, crewed vehicle that can assure sustained flights in LEO and service the ISS, which is the essential short-term goal for U.S. human spaceflight.

One bidder for a private sector role in space is Elon Musk's company, SpaceX, which wants to launch astronauts on its Falcon 9 rocket. "SpaceX is out to prove that a commercial approach will work," says Jeffrey Johnson, an analyst on space issues at Binghamton University in New York. But although the first Falcon 9 was being prepared for a test launch at press time, critics were asking whether any private company can complete a crewed vehicle that meets reliability, safety and cost specifications by 2013, the date promised by SpaceX. Said one spaceflight veteran, "If this gambit fails, we have no Plan B and no access to the International Space Station except by renting space on Russian Soyuz vehicles."

Support for the White House plan came from an unexpected quarter: Former Speaker of the House Newt Gingrich and former Science and Technology Committee Chairman Robert Walker opined in *The Washington Post* that the administration's plan "deserves strong approval from Republicans" because "it does what is obvious to anyone who cares about man's future in space and what presidential commissions have been recommending for nearly a decade."

Even though NASA will receive more money in FY11 than in FY10, the agency will cut some jobs and assess the "role and size" of its astronaut corps—suggesting that some of the most recently named astronauts may never get to fly in space. One Washington observer estimated that termination of Constellation's Ares I booster and Orion crew capsule will "put 20,000 engineers out on the streets." The end of shuttle flights will cost about 7,000 jobs in the region around the Kennedy Spaceflight Center.

Just four shuttle missions remain on NASA's agenda following the February 21 landing of Endeavour and its six astronauts, commanded by Marine Corps Col. George D. Zamka, finishing the STS-130 mission that effectively completed construction of the ISS.

The mission boded well for relations between NASA and its European partners. STS-130 delivered the European-designed Tranquility life-support module along with a seven-window cupola intended for use by robot arm operators. One astronaut compared it to completing the final room of a house under construction. The space station is now 98% complete, with a pressurized volume of 28,947 ft^3, nearly the same as the interior of a Boeing 747 widebody jetliner.

NASA Administrator Charles Bolden

STS-130 delivered the seven-window cupola to the space station, providing astronauts with a whole new perspective.

KC-X tanker program

On March 8 Northrop Grumman announced that it would not offer a bid in the Air Force's KC-X competition to build a new air refueling tanker. The move appears to open the way for rival Boeing to win a $35 billion contract for 179 tankers based on the company's 767-200 widebody jetliner. The KC-X tanker would begin replacing the current fleet of about 450 Eisenhower-era KC-135R Stratotankers.

Northrop had been teamed with Airbus parent EADS to offer a version of the Airbus A330-200 to be manufactured in a new assembly plant in Birmingham, Alabama. Boeing will assemble its tankers in Everett, Washington, and fit them out in Wichita, Kansas. Northrop also announced that it would not protest any award to Boeing, while EADS said it would not offer a tanker independently of its U.S. prime contractor.

Many analysts believe that either aircraft could do the job but that Boeing's would offer a lower price while Northrop Grumman's would have greater range and load-carrying capacity. Northrop chief executive officer Wes Bush said the rules in the current tanker competition—the service's third since 2001—favored the smaller Boeing entry.

Deputy Defense Secretary William Lynn said Pentagon officials "are disappointed" by Northrop's withdrawal. Typical of supporters of the Northrop bid, Sen. Richard Shelby (R-Ala.) told reporters: "The Air Force had a chance to deliver the most capable tanker possible to our warfighters and blew it." Typical of those favoring the Boeing entry, Rep. Norm Dicks (D-Wash.) said he had been assured by Defense Secretary Robert Gates that the Pentagon would proceed with the planned tanker acquisition, even after being left with just one aircraft as a candidate.

The Boeing KC-767 would be assembled in Washington.

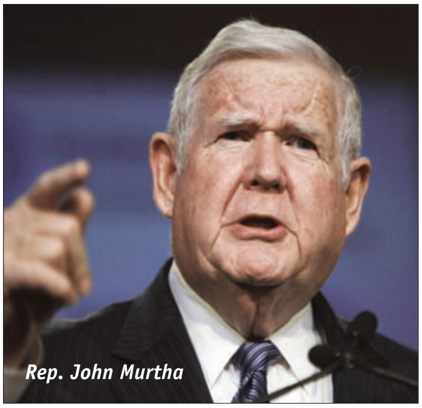
On March 4 Dicks was named chairman of the House appropriations subcommittee that writes the Pentagon's budget, replacing Rep. John Murtha (D-Pa.), who died unexpectedly after surgery on February 8. Murtha's career was marked by power and controversy, and he established himself as a strong friend of the defense and aerospace industries. In 1974 Murtha became the first Vietnam veteran in the House of Representatives. He drew praise and criticism for using Capitol Hill's earmarks process to bring federal dollars to his Pennsylvania district. Supporters marveled over his attention to detail on aerospace and military concerns. *The Wall Street Journal* dubbed the congressman a "defense stalwart." Murtha had been receptive to the idea, now defunct, of a 'split" tanker purchase for the Air Force, with Boeing and Northrop both providing aircraft.

Murtha was "exasperated" that the government was taking so long to give troops the new refueling airplane they need. In a telephone interview with this author two years ago, Murtha said, "Our airmen need a new tanker on the ramp, ready to fly, and they need it now."

Dicks is another defense expert and, like Murtha, is renowned for earmarks. He is an unabashed champion of Boeing, the largest manufacturer in his state. Kyung M. Song of the *Seattle Times* pegged Dicks as "A much more expansive personality than Murtha was, the type who instinctively holds elevator doors ajar for late dashers." Dicks is expected to maintain close watch on the KC-X competition as the Air Force contemplates its next step.

F-35 JSF delay

Pentagon officials announced in February that they are implementing a delay of about one year in the F-35 Lightning II Joint Strike Fighter (JSF) program,



Rep. John Murtha

Rep. Norm Dicks

which has experienced cost increases and technical difficulties.

Much is at stake. Assembly of the Air Force F-22 Raptor and Navy F-18E/F Super Hornet will end in 2012, leaving the JSF as the only U.S. fighter in production. At the height of the Cold War in 1956, 26 production lines in the U.S. were turning out 10 types of fighters.

Of 168 test flights planned for JSF in calendar year 2009, just 16 were completed. A Pentagon report says F-35 unit costs have increased 54% since the contract was awarded in 2001, while Lockheed officials say the figure is 38%. Gen. William Fraser, head of the USAF Air Combat Command, said in February that initial operating capability, or IOC—the milestone that marks an airplane's entry into service—will "slip significantly" from its one-time goal of 2013.

Intended for the Air Force, Marine Corps and Navy and a dozen overseas users, JSF is the most ambitious aircraft program in history when measured in dollars, with likely sales of about 4,500 aircraft totaling more than $700 billion.

Deputy Defense Secretary Lynn says JSF's development schedule will slip "12-13 months" beyond what officials expected when they restructured the program in February. Air Force chief of staff Gen. Norton Schwartz signaled his impatience by warning that the program may breach the Nunn-McCurdy Act, which requires the DOD to report to Congress any cost increase of 15% or more and also requires a congressional review of alternatives. Schwartz also faulted his colleagues in the Pentagon, shortly after the secretary relieved the Marine two-star general in charge of the fighter program.

"It would be disingenuous of me to say when we underperform, it's exclusively industry's problem," Schwartz said at a press conference. "Our inability to manage requirements [is] reflected, our ability to manage funding is reflected."

The Marine Corps is slated to receive its first F-35B models in 2012; the Air Force is expected to receive the F-35A in 2013 and the Navy the F-35C in 2013. But technical glitches grounded the first Marine F-35B to reach the test facility at Patuxent River, Md. for several weeks, and the F-35C has not yet made its maiden flight.

Gen. Norton Schwartz

In the February restructuring, Gates relieved Marine Maj. Gen. David Heinz, the JSF program manager. Many in Washington saw this as a show of determination by Gates, not a reflection on Heinz, who did not cause JSF's problems. Gates said he would raise the program manager's job from two- to three-star rank. To replace Heinz, Gates was expected to name Vice Adm. David J. Venlet, a naval flight officer with an aerial victory to his credit: On August 19, 1981, Venlet was back-seater on one of two Navy F-14 Tomcats that shot down two Libyan Sukhoi Su-22 "Fitters" over the Gulf of Sidra.

Gates withheld $614 million in performance award fees from prime contractor Lockheed Martin. "A number of key goals and benchmarks were not met," Gates told reporters, adding, "the taxpayer should not have to bear the entire burden of getting the JSF program back on track." In a statement, Lockheed Martin said it has been working with military officials "on a plan to get the program back on track" and is "committed to stabilizing F-35 cost [and] affordability and to fielding the aircraft on time." A source told the author of this column that Lockheed hopes to recoup some of the withheld funds by meeting revised incentive goals.

Vice Adm. David J. Venlet

The F-35 is facing delays and cost overruns.

Leaders in the Air Force and Navy, warning of a "fighter gap," want to resume production of "legacy" fighters like the F-16 Fighting Falcon, order larger numbers of F-22s, or increase the Navy's F-18A/F purchase. None of these steps is seen as likely, given Gates' efforts to make JSF succeed.

New TSA chief nominated

President Obama has selected retired Army Major Gen. Robert A. Harding to lead the Transportation Security Administration. Before retiring from the military, Harding was deputy to the Army's chief of intelligence and earlier served as director for operations in the Defense Intelligence Agency. He retired from the Army in 2001, after 33 years of service.

In 2003, he founded Harding Security Associates, a defense and intelligence contracting firm he sold in 2009. The appointment follows the withdrawal of the previous nominee, Erroll Southers, who faced a confirmation battle.

Robert F. Dorr
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Dietmar Schrick

"In my opinion, there is still a long way to go until we will have reached a fully transparent and open market, as we see it in Europe."

Germany's aerospace companies, like those of North America and Europe, are operating in an increasingly competitive global climate, with new firms emerging in Asia and the Middle East competing for the first time for complex manufacturing work. Are these new companies a threat or an opportunity? And what is the right response to increasing global competition?

The situation is indeed ambiguous to some extent. On the one hand, existing industrial joint ventures or cooperation in the fields of research, codevelopment and manufacturing are part of our necessary efforts to increase European industry's independence of Eurozone-related cost structures and globally streamline our supply chain. On the other hand, some of the new companies, especially in China, are competing with our local and regional industries in several fields. So it's both a threat and an opportunity.

The right response to this challenging situation is to secure synergies wherever feasible and to protect knowledge and core competencies as far as possible. For our supplier industry and our engineering companies, there will be no way around developing a global footprint to remain competitive in the long run. Aircraft and engine manufacturers have to focus on their core competencies—design, materials, ecoefficiency and systems integration. In these fields we have the longest window of opportunity to remain at the leading edge.

Most European aerospace companies have avoided cutbacks and consolidation in the wake of the airline recession. What has been the impact of the recession on German aerospace manufacturers, and how have they coped? Especially for small and medium-sized enterprises [SMEs], is the relationship changing between niche suppliers and the major manufacturers?

Compared to other branches of industry we are still lucky. Overall, we have managed through the last, difficult year without major bruises. Large order backlogs at all original equipment manufacturers [OEMs] and a very flexible production planning process—combined with our abilities to counter the global stagnation in orders by moderately reducing the independent workforce—enabled us to finish 2009 with rather good, or at least acceptable, results. Without a doubt 2010 will get more difficult for our national aerospace industry, as we expect some process-critical SMEs to collapse due to a lack of free capital and good credit ratings.

As to your second question: The general procurement policies of all major OEMs have decisively changed. In all recent programs—regardless of whether they are commercial or military—engineering and aerostructure specialists and suppliers are facing bigger challenges. OEMs are streamlining their supply chain, which is more and more globally set up. They are reducing depth of value-creation, focusing on core competencies they have defined for themselves. OEMs are channeling their supply through a much-reduced number of partly system-capable tier-one suppliers they directly deal with. The complete chain below that level has to reshape itself under the guidance of these tier-one suppliers. To fulfill their needs, the national supplier industry has to consolidate.

This process is under way at different speeds in different European countries. Nevertheless, there are quite a number of niche suppliers with excellent market shares, being firmly positioned in this rapidly changing environment in Germany.

Is the market becoming more or less open? In other words, how easy it for German companies to win business in the U.S. compared to a few years ago?

European aerospace industry can be very successful in the United States. Let's just take Eurocopter as an excellent example. The company has been leading the U.S. market in the most important helicopter segments for several years now. The company's products have a proven track record and successfully serve in many areas of the commercial and para-public sectors.

Procurement agencies and customers look for the best value-for-money products. So Eurocopter could succeed—via EADS North America—in winning a U.S. army tender for new light utility helicopters with the military version of its twin-engine bestseller the EC145, in a contract covering initially almost 200 aircraft. The USAF is also considering introducing the UH-72A. The helicopter is built in EADS' U.S. facilities and is equipped and serviced with U.S. partner companies—the industrial program being a good example of seamless Euro-American cooperation.

In the commercial aviation sector Airbus has an excellent market position, too, as U.S. operators have long realized decisive product advantages of Airbus aircraft: ecoefficiency, consistent cockpit architectures for flexible personnel planning, efficient training as well as cost-efficient fleet management.

But the defense-related business may be very difficult for European vendors. The latest example is the U.S. tanker tender, which will now go into a third round, with EADS and its U.S. partner Northrop Grumman possibly not participating. In this case we see a clear political impact on the procurement process. On the customer side, this tender is driven by a desperate need to renew an old fleet of aircraft by the best possible solution in the market, which

Interview by Philip Butterworth-Hayes

we consider the modern Airbus to be.

In my opinion, there is still a long way to go until we will have reached a fully transparent and open market, as we see it in Europe. But future competitive threats coming from emerging aerospace nations such as China, India and others will force the U.S. and Europe to a more intense partnering to protect Western technology and industrial competitiveness. On this point, the U.S. Aerospace Industries Association, the Aerospace and Defense Industries Association of Europe and the German Aerospace Industries Association (BDLI) fully agree.

How are R&D budgets holding up? Does industry continue to have access to sufficient capital to fund research programs such as SESAR, Clean Sky and so on?

Basically there is money available. Indeed, not all available funding has been used. This is because the economic crisis has deeply affected the cash and capital situation of many smaller companies. As all major European research tenders are based on a 50% cash investment by the company that wants European Union funding, many companies simply cannot afford to make use of these EU funds. In the long run, available budgets will surely not be sufficient. In general, these days there are funding opportunities both from European and national sources.

Nevertheless, in the short term the financial situation of the industry—in conjunction with many challenging programs such as the A350XWB and A400M—is leading to a shortage of matching research capital, both human and financial. Midterm and in the long run, these capacities will be free again for further future projects, but it is likely that the continuous availability of research support and the expediency of funding will not be self-evident any more in the future.

SESAR and Clean Sky are programs that support the larger companies very well. Small and medium-sized companies, who want to engage in active research through the EU framework, depend on other programs called "collaborative research." As this work has to take place before the major programs such as Clean Sky with regard to their technology cycle, they will have to be kept up.

Is the strength of the euro a problem for you, or are aerospace transactions between European partner aerospace companies now taking place in euros? What can be done about the competitiveness of Europe's aerospace sector if the euro remains high against the U.S. dollar?

The currently varying euro/dollar ratio is a clear problem for our industry. Companies like Airbus, for example, may lose billions in marginal rises of the euro/U.S. dollar ratio. There is a clear trend for OEMs—even in the framework of military programs—to pay suppliers in U.S. dollars. European aircraft companies like Airbus and Eurocopter already have a large share of their value creation generated in the dollar zone.

To give you an example: Today, the Airbus A350XWB cost base is nearly 70% in U.S. dollars. Major U.S. suppliers involved in the A350XWB program—whether they produce for us in the U.S. or not, and excluding engine work—include Spirit, Honeywell, Rockwell Collins, Moog, Parker, B/E Aerospace, Goodrich and Atkins. We have contracted with the above-listed suppliers work packages that represent in

Dietmar Schrick is the managing director of the German Aerospace Industries Association, BDLI (Bundesverband der Deutschen Luft- und Raumfahrtindustrie eV). He earned a degree in engineering from the University of Applied Sciences in Düsseldorf in 1973 and then undertook postgraduate studies at the Niederrhein University of Applied Sciences. In 1975 he joined Messerschmitt-Bölkow-Blohm (MBB) as an engineer and in 1984 was appointed head of the MBB marketing department for helicopters and aircraft.

In 1987 Schrick was appointed consultant to the MBB corporate strategic planning business unit and head of marketing and foreign relations. He became head of corporate strategic planning and foreign relations in the military airplanes division and in 1999 director of the Manching plant, where front-line fighters for the German air force are assembled. In 2003 he was appointed a member of the executive board of EADS Military Air Systems, responsible for product support, and a director of Dornier Flugzeugwerft. He became managing director of BDLI in January 2007.

value around 45% of the total purchase price of the aircraft.

Hedging is another mechanism to reduce currency-related financial risks.

Has the ILA Berlin Air Show been impacted by the recession? How important is it that this show continue to develop, especially given the centrifugal forces of Paris and Farnborough?

All the shows that we evaluated or participated in last year have suffered from the general economic setbacks, at least in size. Nevertheless we are very optimistic that we will be able to achieve 2008's success for the ILA show. To ensure optimal value for the money, we have further optimized the setup of the ILA Berlin Air Show. We will have nine new sections at the show. They include commercial air transport, spaceflight, defense and security, equipment, engines and materials, alongside the international suppliers center [ISC], general aviation incorporating the HeliCenter, the career center and an extensive conference program. The Path of Innovation will be presenting selected innovation projects that focus on the environment.

The ISC will offer an International Buyers' Day [June 9]—a new feature in 2010—which will make it possible for ISC exhibitors to exclusively engage in direct business-to-business talks with buyers from leading international OEMs and first-tier suppliers. The career center will provide a superb platform for small and medium-sized companies. Here, booths, lecture slots in the conference rooms and a spacious, informal lounge area are available for companies to get in touch with their future employees. A variety of additional measures are intended to boost potential employees' fascination with aerospace.

Are you finding it difficult to recruit new people to the industry? After all, aerospace no longer has quite the same reputation for innovation it once had, and media/IT jobs now pay just as well. How should we all try to change the image of aerospace within society to attract new people and allay some of the public's worry about the environmental consequences of unrestricted aviation growth?

Although currently there are large numbers of people on the job market, due to the latest economic crisis, we are facing great difficulties in recruiting industry-specific skilled personnel, especially engineers. This turns out to be a central challenge for our industry to ensure our competitive strength in the decades to come. I am convinced that aerospace itself has not lost its fascination. In the 1990s our industry went through some difficult times: job cuts, political debates on new military programs and old national enterprises vanishing and being replaced by multinational companies. Continuity and long-term visions were not well communicated.

At the same time, other industries came up with fascinating, very innovative technology—biotech, new energy technologies, automobile innovations, just to name a few. Today, we are competing with many attractive job packages. We must communicate the unique fascination of designing and engineering the world's most complex products at an early stage in the education process. Apart from that, we have to stress more in our communications that the working environment in multicultural, multinational and globally located team structures is a unique chance for personal skill development and cultural experience.

For these reasons we established—among other activities—Germany's biggest aerospace job platform, the ILA CareerCenter, two years ago. We see the environmental aspects of research, product design and production activities as being important drivers for attracting young people to a career in our industry.

Are manufacturing members coming under increasing pressure to reduce their carbon footprint? If so, are these national, European or global pressures, and what impact are they having on investment and profitability?

"Carbon footprint" is a key phrase in political discussions on air transport and future environmental politics. In our industry, it is on top of our agenda. In air transport, environmental-friendliness and a low carbon footprint also mean economic efficiency in operations. This coherence has been a decisive driver in our sales figures in recent years. An economic crisis like the one in 2009 even boosted "green" production and operation of transport systems. Ecoefficiency becomes a competitive advantage, leading to a general trend in developing green technologies. I am absolutely sure that those companies that do not realize this will be out of business in the midterm.

Less known to the broad public, and even to parts of the industry, another challenge has arisen from new environmental legislation in the EU. Of course, we fully support these new laws and regulations, as their primary goal is to protect people and nature from substances of very high concern. Since product life cycles, certification processes and safety regulations are extremely long in our industry, a 1:1 implementation of these new regulations brings along an enormous and disproportionate burden. At the same time, there is no provable contribution to the protection of the environment and health.

This is an issue; the European aerospace industry should closely cooperate with its counterparts in other regions of the world to jointly encourage reasonable legislative frameworks.

How important is it that we improve the links between industry and academic institutions so we can get more theoretical research more quickly and efficiently into the market? What role can BDLI play in this?

A future, and demand-oriented, vocational education and training policy in the aerospace sector is a key factor in making our industry fit for the future. The aerospace industry, unlike any other sector, requires a growing number of qualified technicians and engineers to be able to carry out current and future multinational and complex programs. At present, almost 2,000 qualified technicians and engineers are needed in Germany and must be recruited.

The German aerospace industry has been carrying out comprehensive recruitment measures at trade shows for many years now. In addition, many BDLI member companies are actively involved in national initiatives, or have company project days to attract potential new recruits—whether they be elementary school students or university graduates—to the varied vocational field of aerospace engineering. There are also many activities in creating and interlinking exchange platforms with the educational sector.

Special events like the Germany-wide Girls' Day or Engineers' Day are designed to create awareness and interest at an early stage of young girls' and boys' education.

At the student level, universities and student-led initiatives such as BONDING and EUROAVIA enable students to perform active networking within the aerospace industry's environment. Close cooperation between science, applied research and industry allows educational institutions and industry to jointly ensure that new recruits can be sensitized at an early date and receive need-driven, time-optimized training. Both the universities and industrial enterprises involved will benefit from the synergies created in terms of job relevance and development competence. Sponsored institutes for specific aeronautic sciences are adding to this effect.

The BDLI strategically supports these efforts through its own ILA CareerCenter initiative, which serves as an international contact platform for OEMs, equipment and material suppliers and all those career starters, university graduates and other specialists seeking jobs or working in the aerospace industry.

How much of Germany's aerospace output relies on government contracts? Will the government, through the military or through other state concerns, have a bigger or smaller size of the market in the next five years?

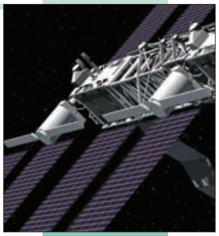
Approximately 25-30% of the turnover generated in our industry last year derived from government and defense-related business. This area has remained stable and showed a moderate growth rate during last year's economic crisis. As an industry this balance between commercial and government business helps us to cope with the latest market cycles better than some other industries, which were strongly affected lately.

How important is regional government support to aerospace industry throughout Germany? Are there new aerospace clusters developing?

Most of our companies and sites in Germany profit from a generally positive environment and public perception. Politics has long realized the importance of the aerospace industry as a general technology driver. There are some clusters developing, and we welcome this general development of regional competence centers, as this ensures a solid technology basis for our industry, especially for our SMEs.

BDLI takes an active coordinating role in this setup, through its regional forum, a platform for regional associations. BDLI thus assures that budgets for research are assigned efficiently and supports an effective development and bundling of competencies.

A boost for commercial human spaceflight



The Vision for Space Exploration (VSE), first announced to the public by President George W. Bush on January 14, 2004, officially ended on February 1, 2010, with the cancellation of its cornerstone program, Constellation.

The VSE, which envisioned returning astronauts to the Moon and eventually using the lunar surface as a launch site for manned missions to Mars, was intended as a way to rebuild slumping morale at NASA and provide a road map for the future after the 2003 loss of the shuttle Columbia. Another goal of the strategy was to reenergize the public's interest in human spaceflight and recapture the sense of excitement and national pride felt during the Apollo era of the late 1960s and early 1970s.

Six years and $9 billion later, the Obama administration has decided to terminate Constellation by canceling work on its core elements—the Orion crew exploration vehicle and Ares I rocket. Orion/Ares I would have been the follow-on system to the space shuttle fleet, scheduled for retirement by the end of this year. It would also have served as the basis for development of a more powerful system designed to transport astronauts and supplies to the Moon by 2020.

The decision to terminate Constellation will essentially leave NASA without its own manned space transportation system for the first time in half a century. Some within government and industry are interpreting this as the beginning of a marked decline in America's space leadership and the start of a trend that will see countries such as China and India catch and even surpass the U.S. in the area of human spaceflight. We see the exact opposite.

The root cause

The reality is that the VSE has never been adequately funded, and was never going to succeed without a massive infusion of funding for NASA, a move that was not going to happen anytime in the near future given the immense demands on the federal budget (including two wars), the growing U.S. budget deficits, mounting debt and the continuing stagnation of the economy. So the choice was between funding an increasingly expensive R&D program with insufficient budgets, in hopes of eventually producing an Orion/Ares I system, or deciding to radically change the strategy for the way NASA conducts human spaceflight.

In a report submitted to Congress in October, a U.S. human spaceflight policy review panel headed by Norman Augustine noted, "The U.S. human spaceflight program appears to be on an unsustainable trajectory. It is perpetuating the perilous practice of pursuing goals that do not match allocated resources." We think that this observation goes to the heart of why the current administration felt it had to end Orion/Ares I and change course.

The Augustine panel concluded that the budget for Orion/Ares I would have to be increased by at least $3 billion a year to keep the program relatively on track. The Obama administration was only willing to grow NASA's overall budget from $18.7 billion in FY10 to $19 billion in FY11, which means the agency was simply not going to be given anywhere close to the amount of money needed to keep Orion/Ares I alive.

In addition, the panel's recommendation that the administration allocate $11 billion more for manned space exploration than it had previously budgeted for FY11 through FY15 reflects a commonsense realization that there will be program delays that add to costs.

The point is that the U.S. has finally arrived at a crossroads where there is a vast disconnect between the country's human spaceflight goals, as broadly outlined by the VSE and Constellation, and the financial investment the U.S. government is willing and able to make. It is a crossroads that could easily have been foreseen by the Bush administration and the industry in 2004, but at that time there was an inherent unwillingness to discuss the question of what the vision would end up costing U.S. taxpayers.

As part of an effort to collect feedback on the VSE from industry and academia, the Bush administration established a nine-member space policy advisory panel of scientists and business leaders. The President's Commission on Moon, Mars and Beyond, chaired by former astronaut Pete Aldridge, held a series of public hearings in 2004 to help formulate a blueprint for the vision.

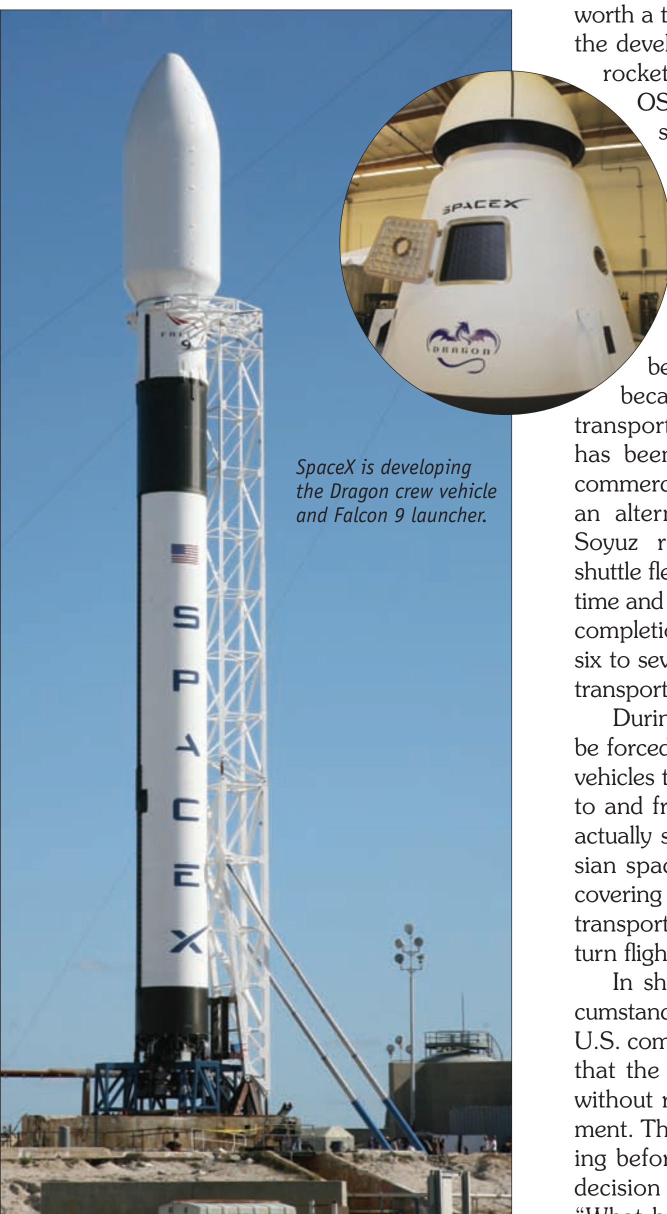
Ultimately, the commission published an extremely superficial report, more a collection of vague ideas and possibilities in support of the vision than a detailed plan for how that vision would be implemented and funded and how it would benefit the U.S. It was an exercise in rubber stamping the VSE rather than determining whether or not the strategy was realistically possible and why it was worthwhile to undertake.

From the start of the VSE, our sense was that no one in the Bush administration wanted to talk about its potential cost, because estimates that ranged in the hundreds of billions of dollars would be politically unpalatable and would derail the program before it ever got off the ground. But everyone knew that to make even the first phase of the VSE happen, NASA's budget, which at that time was still less than $16 billion, would have to grow at a pace significantly higher than the annual rates of inflation over the course of at least a decade.

The silver lining

It was determined that the details of how to come up with the funding needed for the VSE would be left up to future administrations. It was also decided that a detailed rationale for why the effort was so important to the U.S. would eventually become self-evident. After the loss of the shuttle Columbia, morale at NASA was low. The VSE was designed more as a morale booster, and to give the agency a new sense of purpose and direction. It succeeded—and in the process, the strategy stimulated the U.S. civil space industry and funded some billions of dollars of R&D work. However, as a vision for attaining a specific goal, it was a dead-end strategy.

The good news about the VSE and Constellation is that they highlighted a reality fast becoming apparent under the tenure of NASA Administrator Michael Griffin, from April 2005 through January 2009: that the U.S. civil space program as it has always existed had to be overhauled. There was growing talk about NASA becoming less the dominant player and gradually allowing commercial industry to lead.



SpaceX is developing the Dragon crew vehicle and Falcon 9 launcher.

In 2008, NASA awarded contracts to Orbital Sciences (OSC) and Space Exploration Technologies (SpaceX) to provide cargo launch services to and from ISS through 2016. This was a major step toward the agency growing more dependent on the commercial spaceflight industry and thus becoming more of a facilitator of the industry's growth rather than a competitor. The contracts, worth a total of $3.5 billion, have fueled the development of SpaceX's Falcon 9 rocket and Dragon capsule and OSC's Taurus II and Cygnus capsule. They not only have provided development funding for the systems but also have sent a clear signal to industry that there is now a new and potentially lucrative market for ISS cargo transport services.

This new market has been made possible precisely because in seeking a cargo transport service provider NASA has been forced to look to the commercial spaceflight industry as an alternative to Russia and its Soyuz rocket/capsule. With the shuttle fleet nearing the end of its lifetime and Orion/Ares I many years from completion, NASA was facing a gap of six to seven years without its own space transportation vehicle.

During that time, the agency would be forced to lease space aboard Russian vehicles to ferry its astronauts and cargo to and from ISS. In May 2009, NASA actually signed a contract with the Russian space agency worth $306 million covering two Soyuz missions in 2012 to transport astronauts to ISS and two return flights in 2013.

In short, NASA was forced by circumstances beyond its control to turn to U.S. commercial industry to meet a need that the agency could no longer meet without relying on the Russian government. The question that had been lingering before the Obama administration's decision to end Constellation was, "What happens to the emerging commercial space transportation services industry when Orion/Ares I is completed and NASA becomes the dominant player again?" That question has now been rendered irrelevant.

A second Moon race

A major concern of some who oppose the cancellation decision is that the U.S. is ceding its world leadership position in the area of human spaceflight and space exploration. Without its space shuttle, NASA next year will be completely reliant on the Russians for gaining access to ISS—a facility that has cost the U.S. government more than $100 billion to build and assemble over the past quarter-

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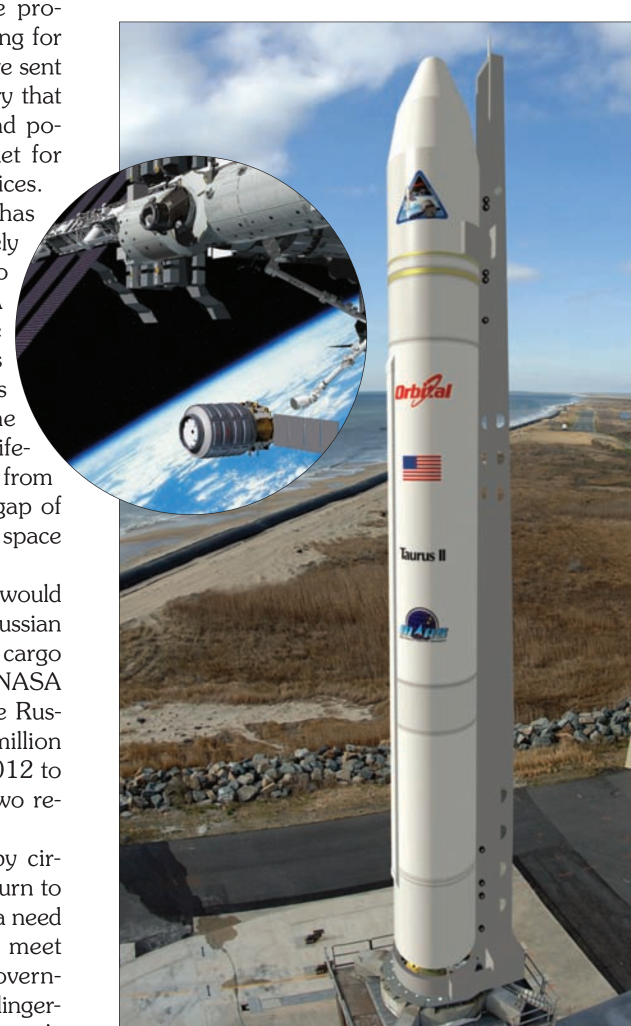


Orbital Sciences has the Taurus II rocket and is working on its Cygnus crew vehicle.

Geography drives ISR technology

An MC-12W takes off from Bagram Airfield, Afghanistan, on the first mission of the newly activated 4th Expeditionary Reconnaissance Squadron, December 29, 2009. (USAF photo by Tech. Sgt. Jeremy K. Cross.)

PROBABLY THE BIGGEST BUZZWORD IN DEfense electronics today is ISR (intelligence, surveillance and reconnaissance). At the end of 2009, senior commanders from the U.S., European, Northern, Southern and Special Operations commands all listed increased air and space ISR assets as their organizations' top needs, cited as an "unquenchable ISR thirst."

A USAF source claimed, "There's an insatiable demand for ground moving target indicator [data] right now." The Air Force has been considering establishing an independent ISR command, which would not only rationalize cross-discipline planning, but also promote a number of intelligence officers to senior levels, where they would have more influence in war planning. And, of course, Secretary of Defense Robert Gates continues to be a staunch supporter of improved ISR.

Clearly ISR is the media and military's darling of the moment, but in this case it is likely to have some staying power. ISR growth is everywhere; it is the common thread to nearly all electronics markets, air, ground and naval. Even if ISR programs are not the biggest in terms of total funding (it is hard to beat Joint Strike Fighter or even F-22), they are often the fastest growing, and by far comprise the bulk of new program starts.

Two distinct *new* ISR flavors of the past year will become an important part of the market in years to come—a return to manned ISR, and a return to the wide-field-of-view surveillance that was central to the Cold War period and is now coming back after a decade of "soda straw" sensors developed for UAVs.

Big future for small planes?

In January 2009, the Air Force publicly confirmed that it had launched Project Liberty, an urgent effort to deploy 37 manned ISR aircraft to Iraq and Afghanistan—beginning in April 2009—to aid high-value targeting and other tactical intelligence missions. The $950-million program began in April 2008 with the service asking used aircraft dealers to sell them as many good Hawker Beechcraft King Air 350 twin-turboprops as were available. They even bought private-owner craft, to allow immediate fitting with ISR sensors and systems.

The resulting MC-12W Project Liberty craft are equipped with off-the-shelf sensors to facilitate accurate weapon targeting and identification of improvised explosive devices (IEDs). "We always need to know about the environment, especially in the counterinsurgency fight," says Brig. Gen. Blair Hansen, director of the Air Force's ISR capabilities.

By July 2009, delays had slowed the program, blamed on the unexpected complexity of converting used aircraft into a common military configuration. But L-3 Communications had converted all seven used King Air 350s ordered by the Air Force as part of Project Liberty Phase 1. In September 2009, the service was considering contracting with Northrop Grumman and Boeing to add full-motion video and SIGINT payloads to the 37 planned MC-12W aircraft, indicating that this project might be followed quickly by continuing upgrades.

But how much staying power will these makeshift ISR aircraft have? Many in the services have already criticized the shift of funding away from longer endurance UAVs. Are these aircraft a stopgap measure, or a return to the reconnaissance lessons learned throughout the 20th century, when more than one man in the cockpit was considered vital for *good*, rather than just plentiful, intelligence? We should keep in mind that even midsized manned aircraft have a payload capacity equal to Global Hawk (one argument for keeping U-2s in service), and in-the-air operator consoles mitigate the problem of processing (or wasting) voluminous UAV sensor data on the ground: Greater endurance can mean more *useless* data.

Teal Group does see the U.S. returning to a more solid manned ISR capability—sort of a post-Cold-War return to fighter tactical reconnaissance, but at a time when total air superiority makes putting sensors on business jets more practical than putting them on RF-4 Phantoms. We see the next few years establishing a number of moderate new programs of record for manned ISR—for synthetic aperture radar (SAR), electro-optical/infrared (EO/IR) and SIGINT sensors. But not huge programs: Even the Army is considering descoping its gold-plated Aerial Common Sensor program to something more like Project Liberty, a quicker way to get new sensors in the air on platforms with payloads bigger than Predator/Warrior UAVs.

International demand

In a related development, L-3 Communications and Hawker Beechcraft are now offering the same aircraft used for Project Liberty and several other U.S. ISR programs—the King Air 350ER—for international sales with a standard or customized ISR payload: $8 million for the 8-hr endurance aircraft, plus $5 million-$10 million for a basic EO/IR turret setup with satellite communications and two operator stations.

The recent surge of new manned ISR aircraft has Hawker and L-3 predicting a market for 225 aircraft, worth $3.8 billion, over the next decade. The 350 has a payload of 2,000-2,800 lb, compared to a Global Hawk Block 30/40 (the biggest UAV) with 3,000 lb. Teal Group believes a much smaller market may exist, but there should be a number of minor sales. Over 6,000 King Airs have been built already, mainly in civil service, currently operating in 94 countries.

In 2009, Lockheed Martin was also offering to lease various custom or reconfigured manned ISR aircraft, from Gulfstream G550s and Bombardier Q400s (with a 20,000-lb payload) down to King Airs. Lockheed used an acquired Gulfstream III business jet, which it had developed as an "airborne multiintelligence laboratory," to show its wares on a "road show" through Europe on the way to the Dubai Air Show in November 2009. Initial sensor offerings included FLIR systems, EO/IR and SIGINT sensors and Lockheed's own Phoenix Eye.

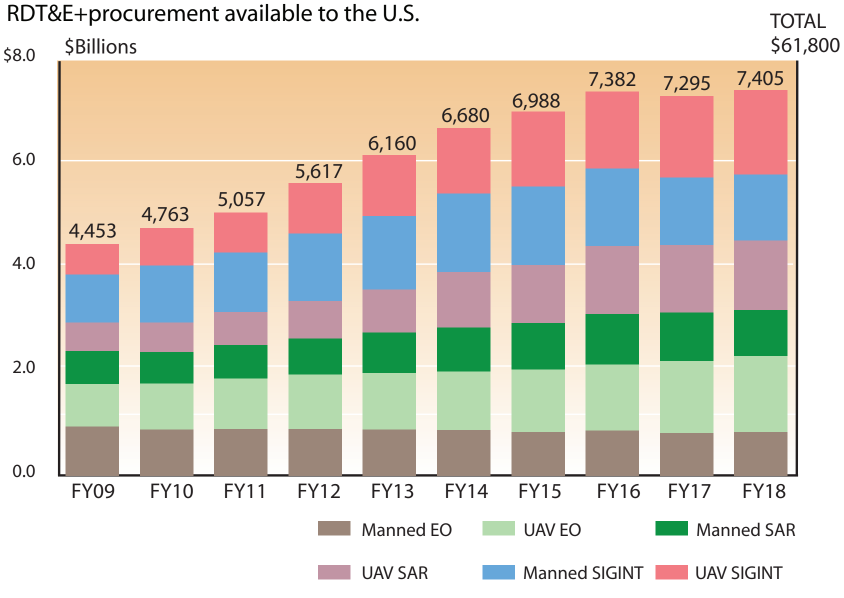
These offerings may see limited international acquisitions, on the order of a couple of platforms for a few countries each, but the U.S. is still the only nation that can afford to buy 37 (plus more for the Army and USMC) new multimillion-dollar ISR aircraft, almost on a whim. We do not see this as a broad-based return to manned ISR outside the U.S., when most countries are just beginning to get their first few (long-awaited) endurance UAVs. Most of the hundreds of dedicated European tactical reconnaissance fighters from the Cold War will stay dead.

Sensors go wide

In terms of sensors, because of their small payload and lack of on-board crew (who can scan wide areas for points of interest with sensors called "eyes"), the rampant UAV growth of last decade resulted in a drastic shift from the ISR sensors of the last century. UAV EO/IR sensors are almost universally narrow field-of-view (FOV) telephoto systems,

AIRBORNE ISR MARKET FORECAST

RDT&E+procurement available to the U.S.



The Shorts 360 Constant Hawk carries a a persistent surveillance WFOV airborne ISR system for the Army. (Photo copyright Ian Howat.)

which can zoom in on vehicles, roads, buildings and people, but do a relatively poor job of scanning countryside and large areas. The sensors must be cued (often today by a laser designator for weapon targeting) to find their target.

Since the first gulf war, in 1990-1991, the U.S. military has always been the dominant military power in theater, and has been primarily concerned with relatively known targets, especially in population centers such as cities. There has not been the Cold War need to spot threatening military forces moving anywhere across a broad landscape, or diverse forces that might be hiding behind national borders. In Iraq, most important military targets have been either in cities or in places where there are threats to localized groups of U.S. or allied troops. Thus, wide field-of-view (WFOV) surveillance has had less importance. But in the past few years, with new missions, several new WFOV ISR programs have begun.

The Army's Constant Hawk is a persistent surveillance WFOV airborne ISR system for conducting counter-IED surveillance and forensic force protection missions in Iraq and Afghanistan, with development reportedly begun in 2006. Constant Hawk mounts high-resolution EO cameras on Shorts 360 and King Air 350 aircraft, loitering over areas of interest for 5-6 hr collecting and storing imagery data. These data are processed on the ground, with resulting intelligence pushed out to commanders within hours of the mission's completion.

Several near-term upgrades are being planned for Constant Hawk, including the addition of a real-time data link, improved processing tools, better EO sensors, and an infrared sensor to allow for day and night operations (today's Constant Hawk is pretty crude—day only and not real-time). The new sensor system will be BAE Systems' airborne wide area persistent surveillance system.

The Marine Corps' wide field-of-view persistent surveillance (WFVPS) program (also called Angel Fire) also offers persistent ISR, IED mitigation, and actionable intelligence in urban and other operations (disaster relief, security). It delivers broad-area, near-real-time georegistered imagery down to the tactical level. Development reportedly began in 2007.

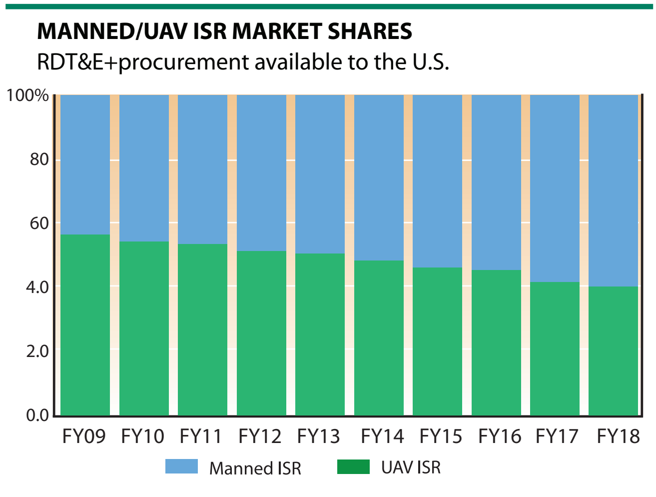
The airborne payload consists of an imager sensor (currently daytime-only EO, believed to be Goodrich ISR's CA-247 camera), on-board processors and

The Gorgon Stare is being carried by the Reaper.

an air-to-ground communication link. The ground distribution network consists of the ground receive station, servers, storage and viewer client stations. The Angel Fire system is hosted on manned platforms, currently the Hawker Beechcraft King Air A-90; pilots fly the plane while the sensors can be controlled from the ground through autonomous software. The USMC ultimately plans to shift the WFVPS mission to a UAV.

The Air Force's wide area airborne surveillance (WAAS) program, now somewhat bizarrely renamed Gorgon Stare (and also sometimes called the wide area persistent surveillance sensor), will develop a multiple aperture EO/IR pod for the Reaper or another UAV (it is too large for the Predator). It will provide a similar wide-angle view as the new Angel Fire and Constant Hawk manned ISR aircraft, both in great demand in combat areas. Advantages of this program will be the IR sensor, as well as a real-time data link, downloading images through the Rover system. The aim is to field 10 systems, beginning in 2010.

Another WAAS version is to be specifically optimized for operation in urban



areas, where the "urban canyon" effect makes tracking personnel on the ground difficult. An airship is being considered, to provide even more persistent surveillance and steeper view angles from high above a city, but this would be even more vulnerable to ground fire and missiles than UAVs are.

International programs also exist, though these are more difficult to locate. In April 2009, photos showed one of four new King Air 350 aircraft procured by the U.K. under a classified program named Shadow R.1 by the RAF.

A broad future for WFOV?

All of the new WFOV EO sensor aircraft in or entering service today are urgent procurements, mostly developed to combat IEDs in Iraq and Afghanistan. Most of these aircraft, based on the manned King Air, have moderate endurance and very little survivability in contested airspace. They can fly above man-portable surface-to-air missiles, but other than that are essentially defenseless commercial aircraft. Thus future applications will be limited.

The WAAS/Gorgon Stare will be carried by the Reaper, providing greater endurance and, if not greater survivability, at least less concern about losses. It has been suggested that an aerostat would provide even better performance with even greater endurance, but these applications would be mostly limited to fixed sites, not aiding mobile forces.

Since all these programs are recent developments, there is very little basis for reliable forecasts. Immediate procurements will all be over fairly soon, and what will come after is uncertain. What we can say is that since UAVs began to take over from manned fighter tactical reconnaissance and other ISR aircraft with WFOV sensors such as the U-2 Dragonlady, WFOV reconnaissance has been largely ignored. Nearly all UAV EO/IR sensors today provide narrow FOV soda-straw views that are great for watching the highways of Iraq, but do not work as well trying to locate soldiers hiding across hundreds of miles of Afghan mountains; in this regard, at least, our military is realizing that not every opponent will be urban, and WFOVs are again sometimes necessary.

On the other hand, the Army has also been actively considering needs for future conflicts: Demographic and migration trends point to an increasing emphasis on urban and littoral locations, with almost three-fourths of the world's population living in those areas, which will require yet again different equipment and training—and even more new ISR systems.

But when the U.S. services acquire an ability, they generally want to do it better, and so far this century the defense budget has not declined. Today's rudimentary WFOV EO sensors (most are not even night-vision capable) clearly present great opportunities for future development. Our speculative forecast assumes that each service (except, perhaps, the USMC) will soon begin a formal program of record for WFOV ISR. We will have to wait to see exactly what these future development programs are, and exactly what will become of today's essentially prototype systems, but our forecast funding continues today's programs with at least similar funding levels through the decade.

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(Continued from page 21)

century. Russia will unquestionably be the premier country in this arena, followed by China, which is now spending $2 billion annually on its human spaceflight program.

China has already launched taikonauts to LEO aboard its Long March CZ-2F/Shenzhou system. It is also aiming to launch space stations to LEO by 2015 and a manned mission to the Moon sometime between 2020 and 2022.

India could soon have a national human spaceflight capability as well. Following the successful Chandrayaan-1 unmanned lunar orbiter mission in November 2008, India is now conducting a serious effort to send a manned mission to the Moon by 2015. Earlier this year, the Indian government announced that it plans to spend $2.7 billion on this program, with the ultimate goal of landing an Indian astronaut on the lunar surface by 2020.

It is an extremely ambitious undertaking, particularly since India has never had a human-rated space vehicle. Nonetheless, it is becoming apparent that the second race to the Moon will be between China and India.

The Russian government has expressed an interest in sending a manned mission to the Moon by 2025, but its focus seems to be less on winning the second lunar race than on eventually building a permanent lunar base. The Russian space agency has speculated that it could begin assembling a manned station on the Moon as early as 2027.

There is no doubt that this next race to the Moon will receive considerable international publicity and help advance the human spaceflight capabilities of India and China. The technological stature of both countries will be enhanced during the coming decade, and when each country successfully completes a manned lunar landing. So is the U.S. making a mistake by giving up on the VSE?

China has already launched taikonauts to LEO and may be aiming for the Moon next.

The answer depends on whether or not you assume that repeating the Apollo program's achievements of four decades ago is a worthwhile goal. Obviously, it is worthwhile for countries that have never come close to attaining what NASA did by the end of the 1960s. It is different for the U.S. The VSE never satisfactorily answered the question, "Why are we going to the Moon again?" And it definitely did not address the question, "How does it justify the necessary financial investment?"

Getting out of the way

The cancellation of the VSE is a pragmatic decision by the Obama administration. There is just not enough money in the U.S. budget to pay for a space transportation and exploration initiative in which the tangible benefits to the nation are not clear. It is important to note, though, that the decision is pragmatic not only because of what it eliminates, but also because of what it will allow to occur as a result.

Without its own human spaceflight capability, NASA will now no longer be both the main customer for and the main provider of human spaceflight services in the U.S., as it has always been before. The agency will quickly become noncompetitive as a provider of such services and thus will gradually become less dominant as a customer.

By looking to the still-nascent U.S. commercial spaceflight industry to compete with the Russians for ISS cargo transportation services, NASA will help fund efforts by companies like SpaceX and OSC to develop human-rated space vehicles that will eventually be able to transport astronauts. These vehicles can, in turn, be adapted and offered to spur the development of new commercial markets such as space tourism. This will stimulate private capital investment in these types of space transportation programs, and before you know it you will have a growing and vibrant commercial human spaceflight industry.

The United Launch Alliance may offer a human-rated Atlas V (left) or Delta IV for future astronaut launches.

NASA's evolution from being the dominant player in human spaceflight to being a facilitator for the expansion of this commercial industry will take time, and it will not happen without the usual setbacks and delays that occur with any new industry. Neither will it occur without considerable pain to some of the agency's traditional contractors, who stood to secure lucrative long-term business by building hardware and creating software for the follow-on to the shuttle.

The good news is that you can already begin to envision the potential benefits that this sudden paradigm shift could bring to the U.S. NASA announced in February a total of $50 million in contracts for work on "space taxis" to several aerospace companies, including Paragon Space Development, Blue Origin, Sierra Nevada, and United Launch Alliance. There also are other companies besides these—SpaceX and OSC are working on cargo and human transportation space vehicles. All they need is a consistent series of incentives and R&D investments from NASA, in much the same way that the U.S. government provided the railroad and aircraft industries in their early years.

While China and India are busy racing to the Moon to plant their respective national flags, the U.S. will be fueling the growth of a commercial industry, one that may well lead to innovations that spark the creation of countless other industries—in much the same way that the invention of the Internet permanently changed the technological landscape.

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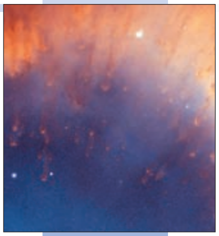

SOFIA's smooth ride shakes up astronomy

MOST ASTRONOMERS WOULD NOT DREAM of opening their observatory's doors in 100-mph winds. Yet NASA's new SOFIA telescope recently flew in an airplane at 250 mph with doors wide open. On December 18, the Stratospheric Observatory for Infrared Astronomy flew in a modified Boeing 747SP at 15,000 ft for 1 hour and 19 minutes. For two minutes of that time, the door by the telescope was wide open.

SOFIA passed with flying colors. "Everything went well. No adjustments or corrections were needed. Nothing shook loose or got damaged."

The 98-in. German-built infrared telescope weighs 20 tons and is ultimately destined to fly above 40,000 ft and study a range of astronomical objects over its expected 20-year lifetime. Those objects include other galaxies and the center of our own Milky Way; the interstellar medium, especially the building blocks of life it contains; the formation of stars and planets; and comets and asteroids in our solar system.

A close-up shows the telescope in flight.

"This was the first time the door was fully opened in flight," says Bob Meyer, SOFIA program manager at Dryden. "We wanted to find out whether opening the door affected flying and handling the aircraft, caused acoustic resonance in the cavity or made anything come loose in the cavity because of wind.

"When you blow air over a soda pop bottle and hear a hum, that's acoustic resonance. If that happened in the plane, it could vibrate the structure of the plane and the telescope and cause problems," he explains.

"SOFIA is set to achieve some spectacular science," says project scientist Pamela Marcum. "For instance, this telescope will help us figure out how planets form and how our own solar system came to be."

Above the veil

As a mobile observatory, SOFIA can fly anywhere, anytime. It can move into position to capture especially interesting astronomical events such as stellar occultations (when celestial objects cross in front of background stars), while ground-based telescopes fastened to a "wrong" geographic location on Earth's surface miss the show. SOFIA will fly above the veil of water vapor that surrounds Earth to take a wide-eyed look at the cosmos.

This veil of vapor acts like an invisible brick wall to the infrared energy from cosmic objects that SOFIA wants to see. SOFIA solves this problem by viewing the heavens from "above the veil"—something ground-based scopes cannot do. Like space-based telescopes, SOFIA will collect infrared energy before it reaches Earth.

Seeing the birth of planets

Although our galaxy teems with planetary systems, astronomers do not know exactly how they form. That is because ordinary telescopes cannot see through the giant, dense clouds of gas and dust that spawn planets. Using infrared wavelengths, SOFIA can pierce the haze and watch the birthing process—showing scientists how molecules come together to construct worlds.

"SOFIA will be able to locate the 'planetary snowline,' where water vapor turns to ice in the disk of dust and gas around young stars," says Marcum. "That's important, because we think that is where gas giants are born. The most massive planetary cores are fashioned [around the snowline] because conditions are best for rock and ice to build up." (Sticky ice particles help form planets.)

"Once a large enough core forms, its gravity becomes strong enough to hold on to gas so more hydrogen and helium molecules can 'stick.' Then these large cores can grow into gas giants like Jupiter and Saturn. Otherwise, they remain as smaller rock-ice planets.

"SOFIA will also be able to pinpoint where basic building blocks like oxygen, methane and carbon dioxide are located within the protoplanetary disk," Marcum says. Knowing where various substances are located in the disk will cast light on how they come together, from the "ground" up, to form planets.

Time to spare

One of the telescope's key strengths is its ability to complement other infrared observatories. With a 20-year lifetime, it can do follow-up studies on objects that shorter lived infrared scopes do not have time to home in on. If, for example, an orbiting observatory such as WISE spots something deserving of more attention, SOFIA can move in for a long, slow look while WISE continues gazing at the rest of the sky.

"WISE is designed to scan the entire sky at infrared wavelengths, gathering survey data for multitudes of objects rather than studying targeted objects in great depth," says Marcum. "But SOFIA has time to spare for deeper studies."

SOFIA can also do follow-up science to reap the full benefits of discoveries from Herschel's deep spatial surveys, and later, the James Webb Space Telescope's near- to mid-infrared investigations. Herschel is the European Space Agency's space observatory (formerly called Far Infrared and Submillimeter Telescope, or FIRST).

"Once Herschel runs out of its three-year supply of coolant, SOFIA will be the only observatory routinely providing coverage within the far-infrared to submillimeter wavelength range. This part of the spectrum is largely unexplored territory," Marcum says.

"And although SOFIA covers the same part of the spectrum James Webb covers, SOFIA is optimized for wavelengths just beyond JWST to complement its observations. SOFIA will do a bang-up job observing between the JWST and Herschel wavelength gap."

Unlike these space-based scopes, SOFIA can "head back to the barn" periodically for instruments to be repaired, adjusted or even swapped out for new and improved science devices—keeping pace with cutting-edge science from a "mere" airplane.

It will do so while looking through the open door of its aircraft. As in the test, the telescope, with its primary, secondary and tertiary mirrors, will sit in a cavity in the rear of the plane. The telescope's controls, computers, spectrometers and other instruments will ride in the pressurized cabin. The scientists, also in the cabin, can look through a physical window in the cabin wall to view the actual image the telescope takes. The image is transmitted through a conduit called a Nasmyth tube attached to the window on one end and to the telescope on the other.

NASA's SOFIA 747SP aircraft begins its December 18, 2009, test flight.

Test runs

More testing is planned for this spring before SOFIA can begin science operations in the fall. "We will test at all the speeds the plane can fly and all the altitudes planned for the mission," Meyer says. "We will also test different pointing elevations of the telescope itself.

"Our first light test, where we actually look at an image and characterize the telescope, is set for April. In that test we will unlock and uncage the telescope so it will move as though it is really observing. The wind will be buffeting and shaking SOFIA, so that will be the first true test of its ability to obtain stable images," he explains.

Keeping a telescope still enough to point accurately and stay "on point" in a moving airplane with the door open requires good engineering.

"The telescope rests on big shock mounts that isolate the mechanical vibrations of the plane from it. And on the back edge of the cavity there is a ramp that catches the airflow entering the cavity and redirects it back over the ramp and out of the cavity."

SOFIA will also have weights attached to it that can be sized and tuned to dampen any shaking. And the drive system can move the scope back and forth to compensate for lower frequency vibrations or movement of the aircraft. The secondary mirror can even be oscillated to take out the shaking of the image itself.

"SOFIA is really a marvelous piece of engineering," Meyer concludes. The recent flight test "represents a huge success and significant milestone for all the people who have worked hard for a decade on this mission."

Future plans

Operations costs and observing time will be shared by the U.S. (80%) and Germany (20%). SOFIA will offer international science teams approximately 1,000 cloud-free high-altitude science observing hours a year during its two-decade design lifetime. More than 50 science proposals will be selected each year through a rigorous peer review process.

Although the primary impact of SOFIA will be its science return, it is expected to yield other benefits as well. Discoveries will follow the development of new technology—technology that can be demonstrated readily on SOFIA.

Young scientists-in-training, educators and journalists will also fly on SOFIA, making it a valuable training platform and public ambassador.

Nine first-generation science instruments are under development by institutions in the U.S. and Germany, including imaging cameras and spectrographs. SOFIA will observe at wavelengths from 0.3 µm to 1.6 mm. With its first-generation instruments, it will be capable of high-resolution (greater than 10^4) spectroscopy at wavelengths between 5 and 600 µm. SOFIA's diffraction-limited imaging longward of 25 µm will produce the sharpest images of any current or planned IR telescope operating in the 30-60-µm region.

Key benefits

The SOFIA Observatory concept embodies a number of key advantages that make it a unique tool for astronomy in the coming decades.

One is that SOFIA comes home after every flight. Its scientific instruments can be exchanged regularly for repairs, to accommodate changing science requirements and incorporate new technologies. These instruments do not need to be space qualified.

Another plus is that SOFIA can study transient events and operate on short notice from air bases worldwide to respond to new scientific opportunities.

In addition, SOFIA's diverse range of instrumentation will facilitate a coordinated effort to analyze specific targets and science questions. Its 20-year design lifetime will enable long-term studies and follow-up of work initiated by SOFIA itself and by other observatories, as well as future facilities.

Moreover, because of its accessibility and ability to carry passengers, SOFIA will include an education and public outreach program designed to exploit the unique attributes of airborne astronomy. With its large suite of science instruments and broad wavelength coverage, it will be capable of undertaking a huge breadth of different investigations.

Focus areas

SOFIA has unique capabilities in three investigative areas: massive stars, protoplanetary disks and astrochemistry processes.

The process of massive star formation remains largely unknown despite recent progress in the observation and theory of low-mass star formation. SOFIA will collect comprehensive data on hundreds of massive stars. These data will help astronomers understand how massive stars form in different environments by distinguishing physical, chemical and dynamical differences between high- and low-mass star formation regions.

SOFIA measurements of the broad spectral energy distribution of nascent massive stars, which are dark in the near- and sometimes mid-infrared, will help scientists develop models of collapsing cores. SOFIA's high spatial resolution over a broad spectral range (25-300 µm) that encompasses the luminous output of massive stars will reveal structural details not seen by previous missions.

To understand the origin of the solar system, scientists must investigate the protoplanetary environment in which planets form: the circumstellar disks around young stars. Over the last two decades, the study of circumstellar disks has focused on the shape of their spectral energy distributions and direct millimeter interferometric imaging. SOFIA data will be used to refine accretion and cooling models of these disks, and to study the kinematics, composition and evolution of disks around low-mass young stellar objects.

The study of exoplanetary systems and the astrochemistry involved in their formation is one of the fastest growing topics in astronomy, with far-reaching implications for understanding our place in the universe. Intimately related to this topic is the study of the chemical composition of the gaseous and solid-state material out of which new planets form and how it is modified in the dense protostellar and protoplanetary environments. With the ability to track the formation of complex hydrocarbons, SOFIA—in concert with the Atacama Large Millimeter/submillimeter Array, Herschel, and the JWST—has an important role in tracing our chemical origins.

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SOFIA is a joint effort between NASA and the German space agency, Deutsches Zentrum fur Luft- und Raumfahrt, in Bonn, Germany. The program is managed by NASA Dryden. The aircraft is based at the Dryden Aircraft Operations Facility, Palmdale, California. NASA Ames manages the science and mission operations in cooperation with the Universities Space Research Association in Columbia, Maryland, and the Deutsches SOFIA Institute in Stuttgart, Germany.

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REFLECTIONS ON THE UNIVERSE

HUBBLE AT 20

Since its launch in 1990, the remarkable Hubble Space Telescope has become an icon of astronomical exploration—seeing more, seeing farther, seeing deeper. But arriving at that lofty position and attaining such capability has not come easily.

Hubble's scrutiny of the surrounding universe far surpasses that of ground-based telescopes. The orbiting observatory has won the cosmic staring contest hands down, showcasing its ability to help resolve the age of the universe, identify quasars and scope out the existence of dark energy.

As one of NASA's most successful and long-lasting science missions Hubble is also, quite literally, a tangible symbol of human dexterity, staying power and resolve. On-orbit service calls by a succession of shuttle crews to change out instruments and replace life-limiting items have ensured Hubble's endurance as a 21st-century machine of breakthroughs and breathtaking discoveries.

Its successor, the James Webb Space Telescope now in development, has a planned launch in 2014. As a large infrared telescope with a 6.5-m primary mirror, it will be the premier observatory of the next decade—building upon the Hubble's lasting legacy.

Liberation from Earth's atmosphere

The idea of parking a telescope in space has been credited to an early founder of rocketry, German scientist Hermann Oberth, who wrote of the possibility in the 1920s. Some 20 years later U.S. astrophysicist Lyman Spitzer Jr. authored a seminal report for Project RAND, titled *The Astronomical Advantages of an Extraterrestrial Observatory.* In that September 1946 paper, the scientist suggested that a space-based telescope—liberated from the blurring of Earth's atmosphere and its distortion of light streaming in from stars—could "uncover new phenomena not yet imagined," and perhaps "modify profoundly our basic concepts of space and time."

Spitzer shouldered decades of work to make the space telescope a reality. In 1965, the Princeton University astronomer headed a National Academy of Sciences committee to define the scientific objectives for a proposed large space telescope. The idea did not find universal support among astronomers, who

by Leonard David
Contributing writer

...AND OURSELVES

FROM THE PEAKS OF EXCITEMENT DURING ITS 1990 LAUNCH TO DESPAIR AFTER DISCOVERY OF WHAT SEEMED A FATAL FLAW, THE HUBBLE SPACE TELESCOPE HAS EMERGED TRIUMPHANT, CONTINUING TO PROVIDE DAZZLING IMAGES AND HISTORIC BREAKTHROUGHS IN OUR UNDERSTANDING OF THE UNIVERSE.

On the first servicing mission, STS-61 astronaut Story Musgrave, anchored to the end of the remote manipulator arm, prepares to be elevated to the top of the towering HST to install protective covers on magnetometers. Astronaut Jeffrey Hoffman assisted Musgrave with the final servicing tasks.

feared that its high price tag would lessen support for ground-based efforts.

Undaunted, Spitzer began an aggressive campaign to persuade both the scientific community and Congress of the great value of placing a large telescope into space. His diligent advocacy helped spur NASA to approve the Large Space Telescope project in 1969.

In the mid-1970s, NASA and ESA took up the idea and outlined a 3-m space telescope—a facility that was "descoped," in both size and the number of instruments, because of budget considerations. Funding began to flow for the project in 1978; a few years later the telescope was named after U.S. astronomer Edwin Powell Hubble. It was Hubble who confirmed an "expanding" universe and was first to understand the true nature of galaxies. Indeed, it is Hubble's Law that provides the foundation for the Big Bang theory of the beginning of the universe.

Work began on the Hubble Space Telescope (HST), an observatory carrying a 2.4-m mirror and interchangeable instruments to perform its visible, infrared and ultraviolet light astronomical duties. It would be placed in orbit by NASA's space shuttle, which was still unfinished, and either be returned to Earth for repairs and replacement instruments, or be serviced in space.

The HST began to take physical shape as contractors, universities and NASA centers plunged into the effort. Marshall would handle design, development and construction of the telescope and its support systems. Goddard would see to the design, development and construction of the science instruments, and would also perform ground control.

Perkin-Elmer was given the task of fabricating the HST assembly, including the mirrors and fine guidance sensors required to point and direct the telescope. Lockheed Missiles—now Lockheed Martin—was contracted to build the structure and supporting systems, and to assemble and test the telescope.

By 1979, astronauts were fully immersed in training on a telescope mock-up, conducting underwater tank work to simulate the working conditions induced by microgravity.

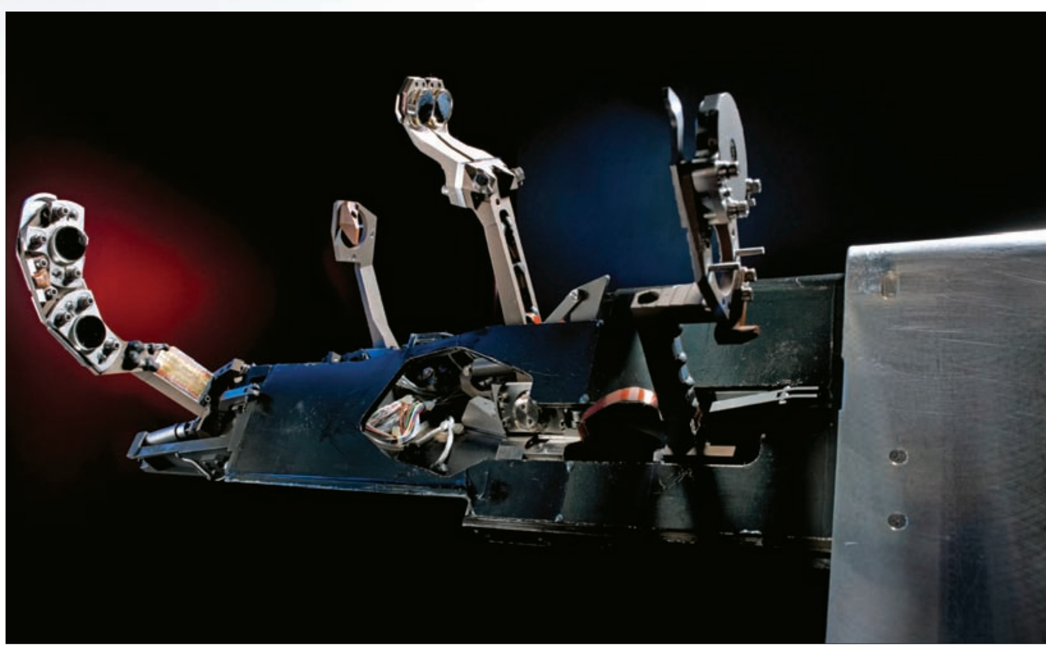
Hubble's shuttle sendoff had been slated for October 1986, but the tragic Challenger accident earlier that year had led to a two-year stoppage of shuttle missions. On April 24, 1990, on its STS-31 mission, space shuttle Discovery roared skyward, later to deploy HST into a circular orbit 600 km above the Earth, inclined at 28.5 deg to the equator.

Some 70 years had passed since an orbiting observatory had first been proposed. But as Hubble's aperture door swung open to soak in its first views, the telescope's history-making potential became more a focal point of disappointment.

Baltimore…we have a problem!

Shortly after the HST began functioning in orbit, James Crocker, then head of the programs office at the Space Telescope Science Institute in Baltimore, Md., heard the words "spherical aberration" used in connection with Hubble. He was told by a colleague: "There's a fundamental flaw with the mirror. It can't be fixed. You can't focus it out."

The blurry imagery was the result of Hubble's primary mirror having been precisely ground to the wrong shape. Later investigation found that a main null corrector—a device used to verify the exact shape of the mirror—had been incorrectly assembled. During polishing, Perkin-Elmer specialists had scrutinized the large mirror's surface with two other null correctors, both of which correctly found



Soon after its launch, scientists realized that the HST's large primary mirror was flawed. Shuttle crews installed this corrective optics package, called COSTAR, in 1993. The hardware was later returned to Earth and is now on display at the National Air and Space Museum. Photo by Eric Long, courtesy of the Smithsonian Institution.

that, indeed, the mirror suffered from spherical aberration. However, those test results were considered less accurate than the primary device, which was reporting that the mirror was perfectly configured.

The mirror's slightly wrong shape caused the light that bounced off the center to focus in a different place than the light bouncing off the edge. The tiny flaw—about 1/50th the thickness of a sheet of paper—was enough to distort the view.

Edward Weiler, NASA's associate administrator for the Science Mission Directorate, recalls that Hubble's spherical aberration "was like death by a thousand duck bites." In his role at the time, Weiler was the HST chief scientist, serving as prime scientific spokesperson for the program from 1979 until 1998. Given the telescope's eyesight woes, he says, "It was hopeless at that point. To describe it as a roller-coaster ride is an underestimate."

Then-director Charles Pellerin of NASA's Astrophysics Division writes in his book, *How NASA Builds Teams,* that after 15 years and $1.7 billion spent, Hubble became a national disaster, permeating popular culture and seen as a technological dud analogous to the Hindenburg on fire or the Titanic sinking.

A leadership failure had caused the flaw, a review board later reported. The board, notes Pellerin, found that NASA's hostile management of its Perkin-Elmer contractor caused the company to become wary of reporting technical problems if they could rationalize them. Managerial failings and quality control shortcomings on both sides, coupled with schedule slips and cost overruns, had conspired to produce the imperfect mirror.

The fix is in

For James Crocker, now vice president and general manager of Sensing and Exploration Systems at Lockheed Martin Space Systems, a slice of good news was that the tool used, the null corrector, was found in bonded storage at Perkin-Elmer. He tells *Aerospace America*: "While we didn't have Hubble's eyes…we had the tool that was used to make the Hubble wrong. We had the prescription. We knew what the error was. And if I can measure your eyes, I can make glasses for you."

Financially backed by Pellerin's Astrophysics Division, a crack team of specialists from NASA, ESA, industry and academia were brought together to brainstorm a fix for Hubble—an expert team that included Crocker. "No idea was too stupid…but some were pretty wacky," he recalls.

Bruce McCandless, a crewmember on STS-31, was also a member of that brainstorming group. "There were weird ideas," he says, a number of which ground control officials would never support, for safety reasons.

"Could an astronaut be sent down inside the telescope to spray something on the mirror to change its curvature? There was thought about thickening the outer edges of the mirror, then resilver it in place. There was no lack of imagination," says McCandless, now a Colorado-based aerospace consultant.

A first-order nonstarter was bringing Hubble back to Earth. "There was a belief, which I subscribed to as well, that if we ever brought it down, the likelihood of getting it relaunched was fairly remote," McCandless says. "So the decision was to do everything possible to fix it in place and in the meantime

HOUSE CALLS TO HUBBLE

Following its deployment in 1990, the HST has been shuttle serviced on five separate occasions.

The repairs that have been done on Hubble "are really leading edge for human spaceflight," says Mark LaPole, the Hubble mission program manager for Ball Aerospace in Boulder, Colo. "When you talk to the astronaut crew that gets assigned to Hubble, the energy that comes out of their pores is just phenomenal," he says.

Ball Aerospace has been involved in building Hubble instruments since June 1978, having built seven so far. Following the May 2009 servicing mission, all the instruments aboard the observatory are Ball-built. Probably more than 50% of the company has touched Hubble, LaPole adds.

"There's not much left to replace, because everything has been replaced," he says. "Every piece of electronics… batteries, solar arrays. Everything is new…and it could be new again."

Servicing Mission 1, December 1993

•Installation of two new devices, the wide field and planetary camera 2 and the corrective optics space telescope axial replacement, both designed to compensate for the primary mirror's incorrect shape.
•New solar arrays attached to reduce "jitter" caused by excessive flexing of the solar panels during the telescope's transit from cold darkness into warm daylight.
•New gyroscopes that help point and track the telescope, along with fuse plugs and electronic units.

Servicing Mission 2, February 1997

•Installation of the near-infrared camera and multiobject spectrometer and the space telescope imaging spectrograph.
•A refurbished fine guidance sensor, a solid state recorder and a renovated, spare reaction wheel assembly.

Servicing Mission 3A, December 1999

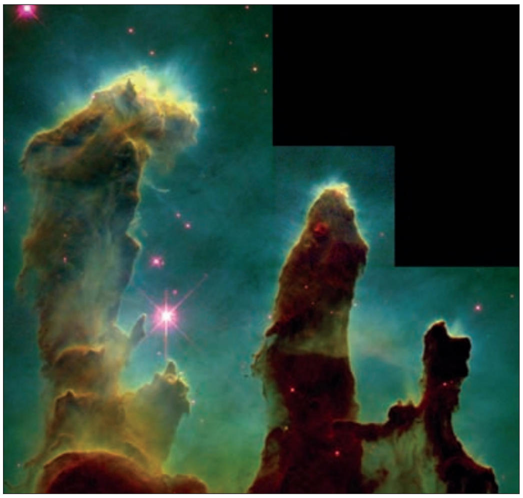
•Replacement of six gyroscopes, one fine guidance sensor and a transmitter.
•Installation of an advanced central computer, a digital data recorder, an electronics enhancement kit, battery improvement kits and new outer layers of thermal protection.

Servicing Mission 3B, March 2002

•A new science instrument called the advanced camera for surveys.
•A solar array panel swap-out with smaller, more powerful units and replacement of an outdated power control unit.
•Installation of a new cooling system for the near-infrared camera and multiobject spectrometer.
•Replacement of one of the four reaction wheel assemblies.

Servicing Mission 4, May 2009

•Considered Hubble's most challenging servicing mission, featuring installation of a new wide field camera 3 and the cosmic origins spectrograph, as well as extraction of COSTAR.
•Installation of the spare science instrument command and data handling unit.
•On-site repairs of nonworking advanced camera for surveys and the space telescope imaging spectrograph. Requirement for spacewalkers to access the interior of the instruments, switch out components and reroute power.



These eerie, dark pillar-like structures are columns of cool interstellar hydrogen gas and dust that are also incubators for new stars. They are part of the Eagle Nebula, a nearby star-forming region 7,000 light-years away in the constellation Serpens. The picture was taken on April 1, 1995, with the WF/PC 2.

get as much data as we could with the unit as it existed."

Still, even with the best image enhancement software available, Hubble's myopic condition—as well as its embarrassing techno-turkey status in the public eye—was intolerable. Furthermore, beyond the needed optical fix, the telescope was also experiencing solar array twang, among other teething issues.

Crocker is noted for conceiving the idea of the corrective optics space telescope axial replacement (COSTAR) and leading the Ball Aerospace team that developed it. This was a eureka solution, he relates, one that came to him while he was taking a shower, as he stared at a sliding shower head.

COSTAR was a series of small mirrors used to intercept the light reflecting off Hubble's mirror, correct for the flaw, and bounce the light to the telescope's array of science instruments. The device could be installed in place of one of the telescope's other instruments; Hubble's high-speed photometer was sacrificed.

Astronauts could also replace the wide field and planetary camera with a new version (WF/PC 2) that contained small mirrors to correct for the aberration. This was the first of Hubble's instruments to have built-in corrective optics.

Bolstered by nearly a year of training, the crew of Endeavour headed for Hubble on December 2, 1993. Following five days of spacewalks and repairs, the telescope received its first makeover, revitalized and reshaped into the powerful observatory that had been originally promised.

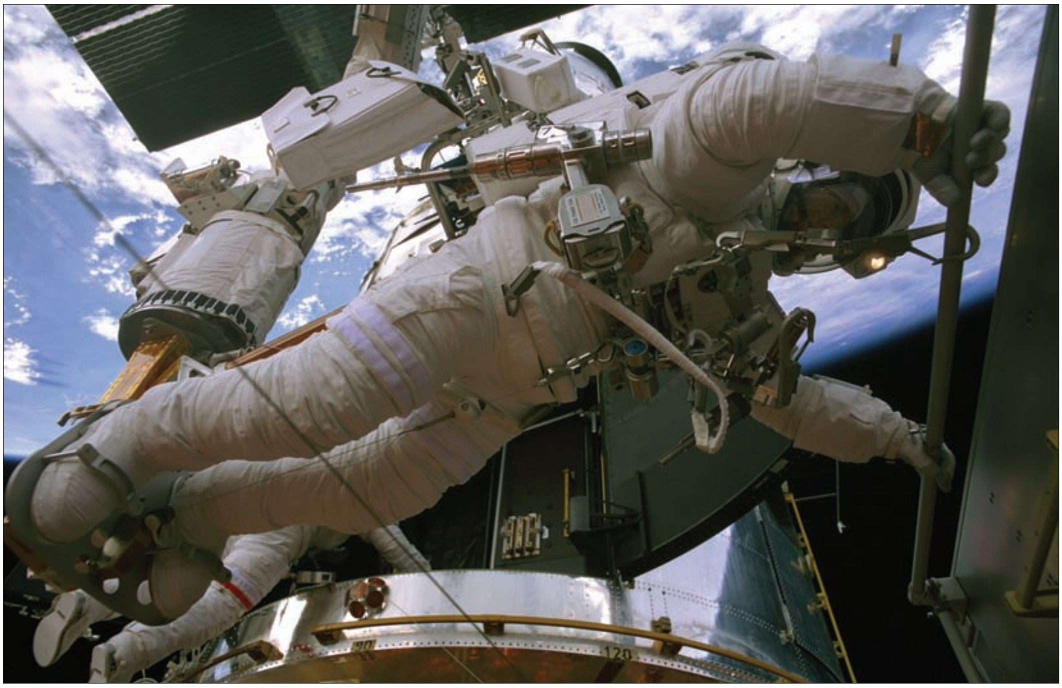
Beyond the grandeur of the universe revealed by the rejuvenated telescope, Crocker concludes, Hubble's story is a classic American saga of snatching victory from the jaws of defeat, "with brave astronauts launching into space to save the day—damn the torpedoes, full speed ahead—and overcoming adversity."

On seeing the first image from the transformed Hubble on the night of December 18, 1993, Weiler recollects: "All I can describe is vindication. That was the emotion. We had been dumped on; we had been ridiculed for three years. That was the true birth of Hubble. That's the anniversary that counts."

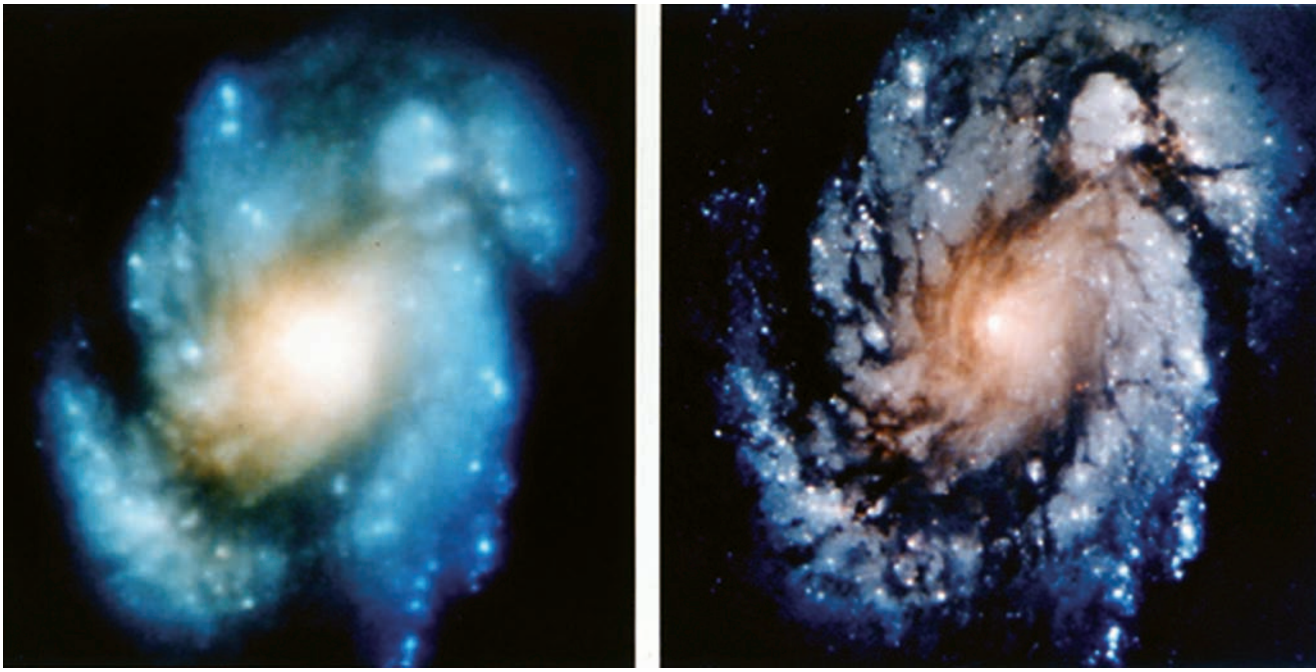
Hubble's vision was successfully repaired. In the first test of the telescope's advertised capability to be serviced and repaired in orbit, it passed in a full spectrum of flying colors.

The human factor

Since its 1990 launch into Earth orbit, five shuttle servicing missions have flown to Hubble. There has been a steady progression from



Captured by the IMAX 3D cargo bay camera, Astronaut Andrew Feustel transfers the COSTAR unit from the telescope to its temporary stowage position in the Atlantis cargo bay.



Side-by-side images of the core of the galaxy M100 show the dramatic improvement in the HST's view of the universe after the first servicing mission. The new image, taken withWF/PC-2, demonstrates that the camera's corrective optics compensate fully for the optical aberration in the primary mirror. Credit: NASA/STScI.

routine work to a reboosting of the facility to extend its useful lifetime.

The disastrous loss of the shuttle Columbia and its crew on February 1, 2003, nixed a scheduled HST visit that following year, sparking heated debate over the safety risk to humans, even spurring a major look into robotic servicing of the observatory.

That intense debate eventually subsided and led to the spectacular May 2009 "final" servicing mission to enhance Hubble's health and augment its observational skills at least into 2014 and perhaps beyond. During that last human stopover, Hubble was outfitted with a soft capture and rendezvous system to enable the telescope's safe disposal by either a future crew or robotic system.

Originally blueprinted for a 15-year service life, the telescope's performance continues, without question, to be truly stellar. But Hubble also represents a bridge-building between two communities: space science and human spaceflight.

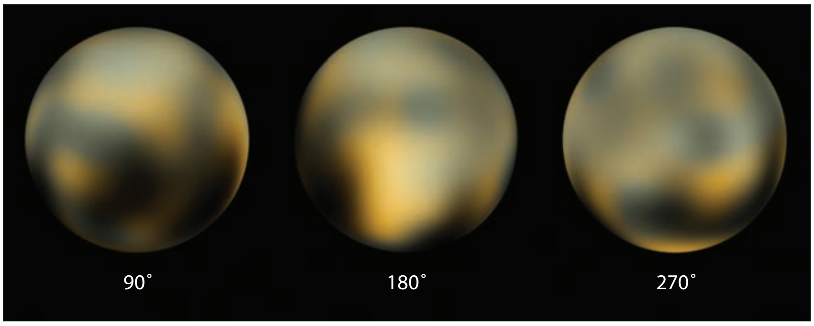
"Hubble is the shining star in the merger of science and the human space program. Hubble was designed from day one to be serviced…with astronauts in mind," Weiler tells *Aerospace America.* Indeed, if it were not for the human space program, he continues, "it would already have made one hell of a light show reentering."

John Grunsfeld, newly appointed deputy director of the Space Telescope Science Institute, has often been called the chief HST repairman—an unabashed "Hubble hugger." As a NASA astronaut he participated in three flights to service the telescope: STS-103 in December 1999, STS-109 in March 2002, and most recently, STS-125 in May 2009. He also served on two other shuttle flights.

There have been many twists and turns that make Hubble an incredible story, far beyond what an engineer could ever devise, Grunsfeld suggests. "It would take the likes of an Ernest Hemingway to really create a story with this much intrigue, politics…probably love stories buried in there somewhere. Certainly we have love for the telescope. It's a story about humans struggling and striving to do great things. And the best part of it…we don't know how it ends."

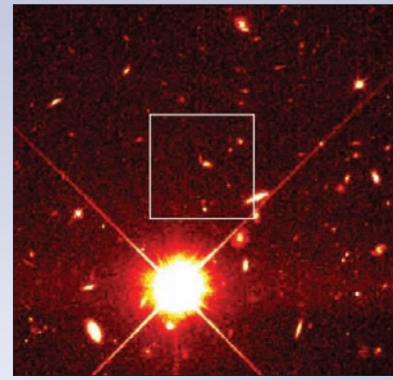
If Hubble had not been serviced by astronauts, Grunsfeld wonders, would it have remained in the public eye as much as it has?

The most detailed and dramatic images ever taken of the distant dwarf planet Pluto, released in February 2010, show an icy, mottled, dark molasses-colored world undergoing seasonal surface color and brightness changes. Credit: NASA, ESA, and M. Buie/SRI.



REFLECT ON THIS! HUBBLE'S MAJOR SCIENTIFIC FINDINGS

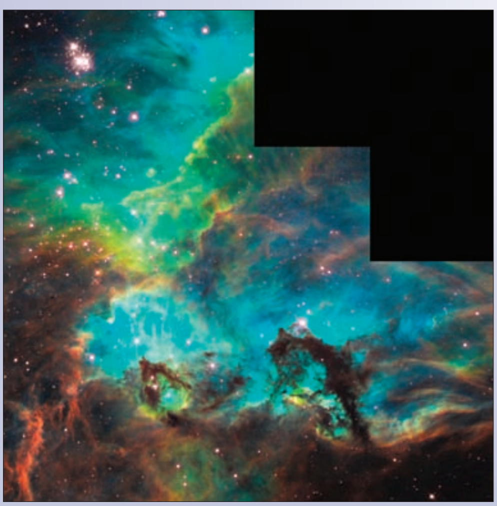
Over the last two decades, the Hubble Space Telescope has been an astronomical anchor for scientific study of the surrounding universe. The observatory's workhorse findings have had a major impact in every area of astronomy, with thousands of technical publications reporting on the facility's sharp-shooting productivity. Herewith, a "Top 10" summary of some of Hubble's major scientific results:



The accelerating universe and dark energy. *Hubble's ability to detect faint supernovae contributed to the discovery that the expansion rate of the universe is accelerating, indicating the existence of mysterious "dark energy" in space.* ➤

◄ ***The distance scale and age of the universe.*** *Observations of Cepheid variable stars in nearby galaxies were used to establish the expansion rate of the universe to better than 10% accuracy.*

The evolution of galaxies. *The Hubble Deep Field provided a deep view into the distant past of the universe, allowing scientists to reconstruct how galaxies evolve and grow by swallowing other galaxies.* ➤



◄ ***The birth of stars and planets.*** *Peering into nearby regions of star birth in the Milky Way galaxy, Hubble has revealed flattened disks of gas and dust that are the likely birthplaces of new planets.*

Stellar death. *When Sun-like stars end their lives, they eject spectacular nebulae. Hubble has revealed the enigmatic details of this process.* ➤

On the other hand, it has provided a flood of images that time and time again elicit expressions of awe and fascination.

"It has been a long-term love affair, if you will, with the public. The visibility of the images, the Eagle Nebula, the Hubble Deep Field…they show the public that the universe is much more interesting than ever imagined, not just a bunch of stars and points of light."

Spirit of discovery

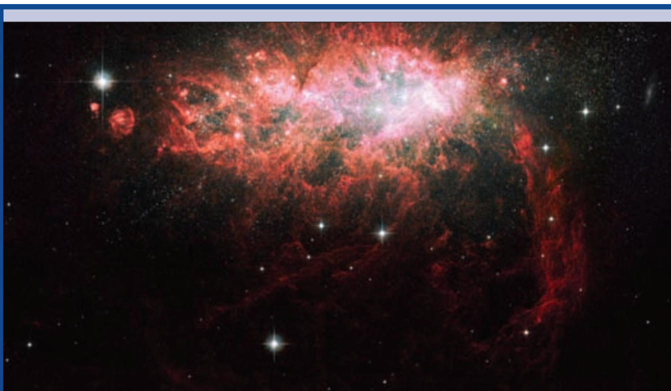
The public hungers for human space exploration. Moreover, people want to see an effective use of the nation's investment in such activity, says Frank Cepollina, the manager of NASA's Hubble Space Telescope Development Project at Goddard.

"The fact that we put these great scientific machines up…that's significant for a few days," Cepollina says. "It's even more significant when you see humans for a few weeks working on those machines in space…and then they see the result of that work."

Cepollina is widely regarded as the "father" of repairing and upgrading satellites, designing the tools and technologies that enable astronauts to perform intricate tasks difficult to do even on the ground. He has been responsible for carrying out the on-orbit servicing that has maintained Hubble in peak condition, leading the charge on hardware that has allowed the observatory to stay on the cutting edge of technology throughout its long life.

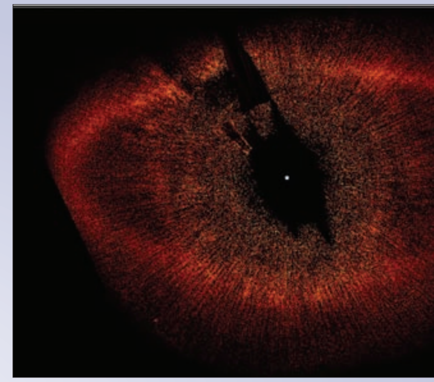
Scientists making use of Hubble are direct beneficiaries of the near-term application of a new Moore's Law in orbit, an evolution of capability, says Cepollina. (Moore's Law refers to the observation—in computer parlance—that the number of transistors that can be placed on a computer chip roughly doubles every two years.)

"The new equipment has much better sig-



Stellar populations in nearby galaxies. *Deep images by Hubble that resolve individual stars in other galaxies have revealed the history of star formation.*

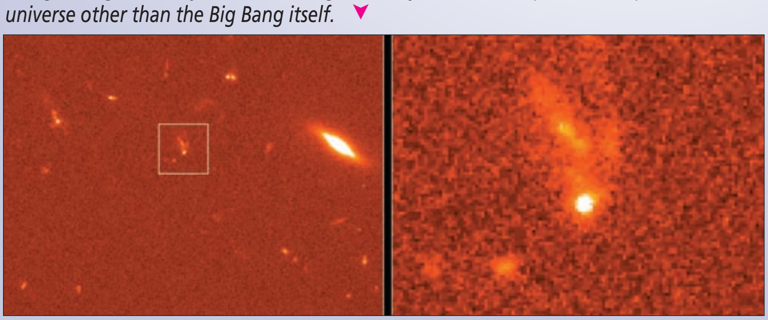
Planets around other stars. *Hubble made detailed measurements of a Jupiter-sized planet orbiting a nearby star, including the first detection of the atmosphere of an extrasolar planet.*



The impact of comet Shoemaker-Levy 9 on Jupiter. *The explosive collision of the comet with Jupiter in 1994 was observed by Hubble, providing Earthlings with a cautionary tale of the danger posed by cometary impacts.*

Black holes in galaxies. *Hubble observations have shown that monster black holes, with masses millions to billions of times the mass of our Sun, inhabit the centers of most galaxies.*

Gamma-ray bursts. *Hubble has played a key role in determining the distances and energies of gamma-ray bursts, showing that they are the most powerful explosions in the universe other than the Big Bang itself.*



With special thanks to the Space Telescope Science Institute.

nal-to-noise ratios, far fewer disturbances. There are these immediately observable improvements. They are getting much better imagery. It is not a new telescope, but it has brand-new scientific instruments," Cepollina says. "And that's what satellite servicing does in the big picture…progressively change out the scientific instrumentation so that you can continuously improve your return."

Over the years there has also been a progressive evolution of astronaut capability in orbit. Much, but not all, of that, Cepollina says, is due to more intelligent tools that can take on the brunt of a spacewalker's workload. "Let the batteries and self-powered devices do the work for them. Use their intelligence more keenly than in the past, where we relied on their brute force, skill and endurance."

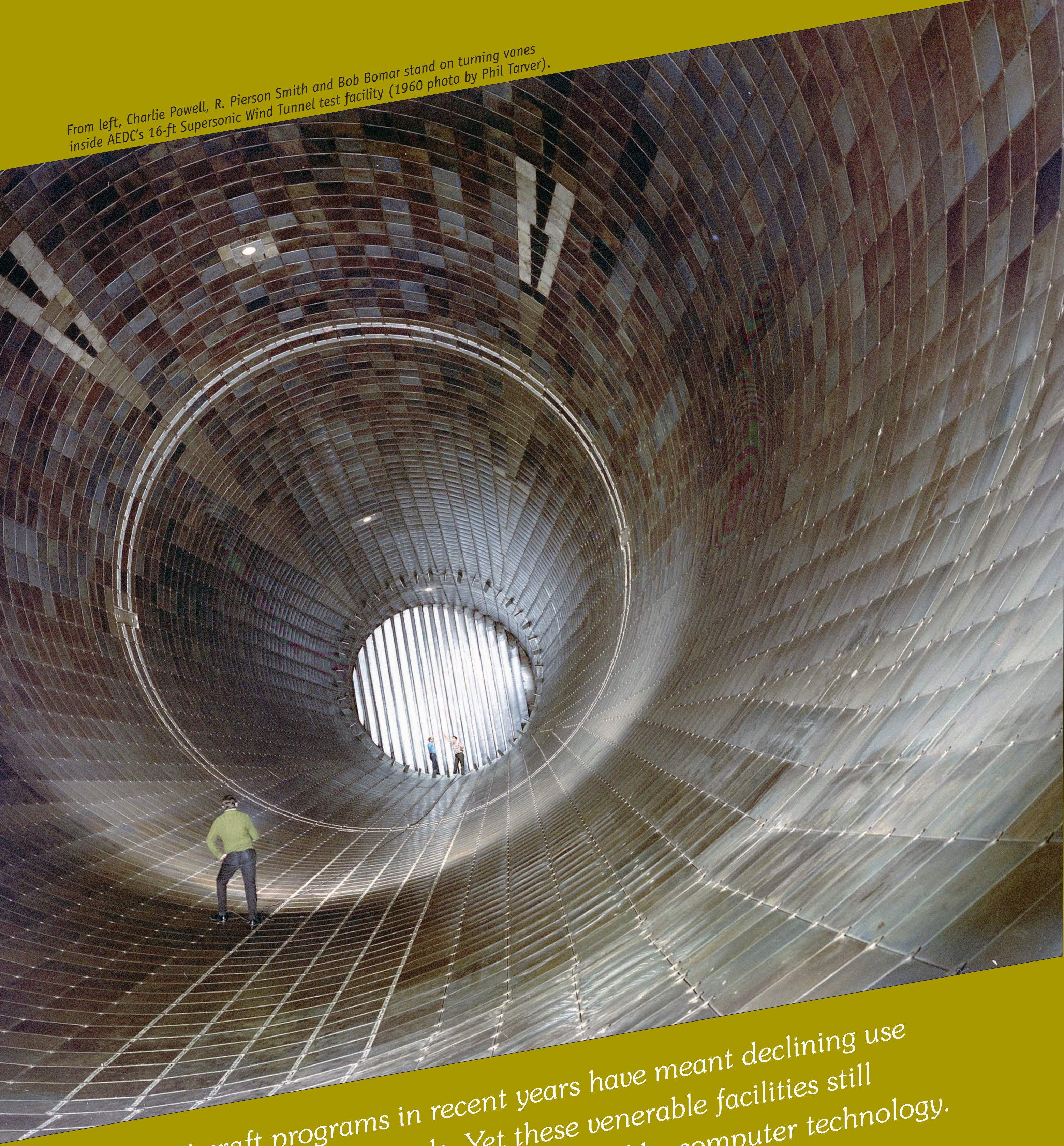
What Hubble represents, he believes, is the human spirit of fostering discovery using the least costly approach possible, given the human and hardware assets already financed by U.S. taxpayers.

In saluting Hubble and what it has taught, Cepollina advises that scientific discovery becomes a direct function of our ability to provide Moore's Law every four or five years to orbit. When you do that, he adds, the products are tremendous leaps in information flow and discovery potential.

Barring a life-ending Hubble event, have we seen the last servicing mission to the esteemed orbiting facility?

Cepollina is quick to respond. "No, because I think the value of a machine like Hubble—as long as it demonstrates that it can keep making scientific advancements—we have not seen the end of it. Hubble represents a spirit of discovery. And as long as discoveries keep coming, we should do everything in our power to keep it upgraded and innovated with new technology."

From left, Charlie Powell, R. Pierson Smith and Bob Bomar stand on turning vanes inside AEDC's 16-ft Supersonic Wind Tunnel test facility (1960 photo by Phil Tarver).



Fewer aircraft programs in recent years have meant declining use of the nation's wind tunnels. Yet these venerable facilities still offer vital insights that cannot be matched by computer technology.

by **Edward Goldstein**
Contributing writer

Wind tunnels

DON'T COUNT THEM OUT

Aviation pioneer Richard Whitcomb, who died last October at the age of 88, was definitely an old-school engineer. Described by Smithsonian Institution aviation historian Tom Crouch as "the most important aerodynamic contributor in the second half of the century of flight," Whitcomb studied at Worcester Polytechnic Institute. During his engineering career at the National Advisory Committee for Aeronautics' Langley Memorial Aeronautical Laboratory (after 1958, NASA Langley Research Center), wind tunnels were critical to proving his three revolutionary aircraft design innovations: the Whitcomb area rule concept, the supercritical wing and winglets.

In describing how his area rule concept evolved from a flash of inspiration into a tangible innovation, Whitcomb recalled, "We built airplane models with Coke-bottle-shaped fuselages, and lo and behold the drag of the wing just disappeared. The [transonic] wind tunnel showed it worked perfectly."

THE VALUE OF TIME

One cannot overestimate the value of the wind tunnel time Whitcomb had for testing his ideas. "He was basically given license to take a wind tunnel and use it as his personal tool to investigate aerodynamics," notes Edward M. Kraft, chief technologist at Arnold Engineering Development Center (AEDC). "We don't really do that any more. We use wind tunnels now as production tools for getting data. That's a shift in mentality over two or three decades. Wind tunnels are looked at as being relatively expensive, so you try to get in, get a lot of data and get out. Whitcomb had the luxury of being able to stay in a wind tunnel for months and years. If you read any of his bios, he would literally go in and file wing shapes by hand trimming them down for minor improvements in drag and really came up with some breakthrough phenomena."

Ironically, a month before Whitcomb's death, another piece of Langley's proud heritage, its Full-Scale 30x60-Ft Wind Tunnel—which tested everything from biplanes to X-planes—was put out to pasture after 78 years of operation. This was not an aberration; the U.S. is faced with an aging and in some cases declining wind tunnel infrastructure, a result of the apparent drag on agency budgets—fewer vehicle programs mean decreasing tunnel use. NASA, for example, has reduced its wind tunnel facilities by roughly one-third; as budget constraints continue, the agency may see additional mothballing or outright decommissioning of these classic structures.

"The environment has changed," says Mike George, director of the Aeronautics Test Program at NASA Ames. "What we need in the future is going to be different from what we've had in the past…and probably a little different from what we have today. If you go back to about 1990, about the time the Berlin Wall fell, a big change came in the aerospace industry; you can see that by the downsizing in the number of companies, the number of new starts and the number of programs. Today we have fewer programs [to test], and the role of computational physics [CFD] has also played a part in changing the role of the wind tunnel in the aircraft design and aircraft R&D environment."

A 5% scale model of the Orion launch abort vehicle was installed in Langley's Unitary Plan Wind Tunnel for supersonic jet effects testing. The model was painted with pressure-sensitive paint and illuminated to produce surface static pressure maps in the locations of the attitude control motor nozzles and the aft-body interaction regions.

ASSESSING CAPABILITIES

Philip S. Antón, lead author of the 2004 RAND National Defense Research Institute report *Wind Tunnel and Propulsion Test Facilities: An Assessment of NASA's Capabilities to Serve National Needs*, says he hears a lot of concern from people who say, "These facilities are 40-50 years old, and we're not certain how long they will last. The question is: Will we need to make serious investments in new capabilities, or work to maintain and improve those we have now? I don't think there's a definitive answer for that."

Currently, NASA centers with remaining wind tunnel facilities include Langley, Glenn and the adjacent Plum Brook Station in Sandusky, and Ames. The Defense Dept. maintains AEDC wind tunnels at three locations—at Arnold AFB, White Oak Federal Research Center in Maryland (which AEDC took over from the Navy during base closures), and AEDC Moffett Field in Mountain View, California (where it took over operations of a NASA facility). DOD also maintains wind tunnels at the Air Force Research Laboratory in Dayton, Ohio, and at the Naval Surface Warfare Center in Bethesda, Maryland.

A number of major aerospace corporations, including Boeing and Lockheed, maintain their own wind tunnel facilities, as do several universities. Boeing's development of the 787 Dreamliner benefited from 15,000 hr of wind tunnel testing at its Transonic Wind Tunnel facility in Seattle, the state-of-the-art QinetiQ 5-m low-speed tunnel in Farnborough, England, NASA Ames and the University of Washington's low-speed tunnel in Seattle.

MANAGING RESOURCES

In 2007, NASA and DOD entered into a formal agreement, the National Partnership for Aeronautical Testing, to help manage federal government wind tunnel resources. "The partnership looks at how we decide what facilities go forward, how we decide where to invest—not from a NASA point of view or a DOD point of view, but really from a joint NASA and DOD point of view," says George.

From a larger national policy standpoint, the Aeronautics Science and Technology Subcommittee of the National Science and Technology Council is looking at wind tunnel needs as it updates the National Plan for Aeronautics, Research, Development, Testing and Evaluation and Related Infrastructure. As part of this report, the subcommittee will address national R&D needs as related to the National Aeronautics R&D Policy in wind tunnel capabilities and will assess where we stand today relative to those needs. The report will be presented to the White House Office of Science and Technology by midyear.

Two years ago, supported by the work of its Ground Test Technical Committee, the AIAA developed a white paper expressing its alarm "at the continuing deterioration of our wind tunnel test infrastructure in the United States." The paper observed, "DOD, NASA and private industry currently use wind tunnels as required on a project-by-project basis. Fluctuations in government budgets and industrial consolidations have led to cyclical use of these facilities. The resulting business model for wind tunnels does not compare favorably with other uses of the real estate involved. As a result, many wind tunnels have closed and some capabilities have been permanently lost."

LOST CAPABILITIES

The white paper concluded that this decline "decreases our national ability to develop and field complex aeronautics systems, consequently forcing the use of non-U.S. international facilities that may not be available when needed, may not provide adequate capabilities, and may not afford protection from unauthorized access to technologies under test."

As an example of losing a key capability, the white paper pointed to the shutdown in 2008 of the North American Trisonic Wind Tunnel in El Segundo. This tunnel—which supported development of the XB-70 supersonic bomber, X-15, Saturn booster, Apollo spacecraft, space shuttle and B1-bomber—was closed by its last owner, the University of California at Los Angeles, for environmental reasons. Its loss "will force compromises in model scaling and test capacity supporting missiles systems development," noted the white paper.

While the Air Force has not downsized its wind tunnel capacity as much as NASA, Kraft observes, "I think we've probably reached a

The Trisonic Wind Tunnel was the testing ground for a broad array of aerospace vehicles. Copyright 2009 Damon J. Duran.

Frank Quinto, facility manager for the 14x22-ft Subsonic Tunnel at NASA Langley, inspects the fan blade area of the tunnel. Photo courtesy NASA/Sean Smith.

steady state on capacity unless the federal budget keeps pushing on budgets….People will argue, 'Wait a minute, wind tunnels aren't full all the time.' But they don't understand the essence of capacity. When I want to do an F-35 [wind tunnel testing campaign], I need three or four wind tunnels simultaneously. If I were to start taking other wind tunnels off line, and let's say a next-generation long-range bomber were put on the table for a new development, and I only had one wind tunnel, it would take six or seven years to develop the database for that, not three."

Antón adds that it is also a matter of what types of capabilities a facility offers. No single wind tunnel can economically or technically offer all that is needed, so different facilities were built that together cover the envelope of operational parameters and specialized tests.

LINK FROM A PIONEERING ERA

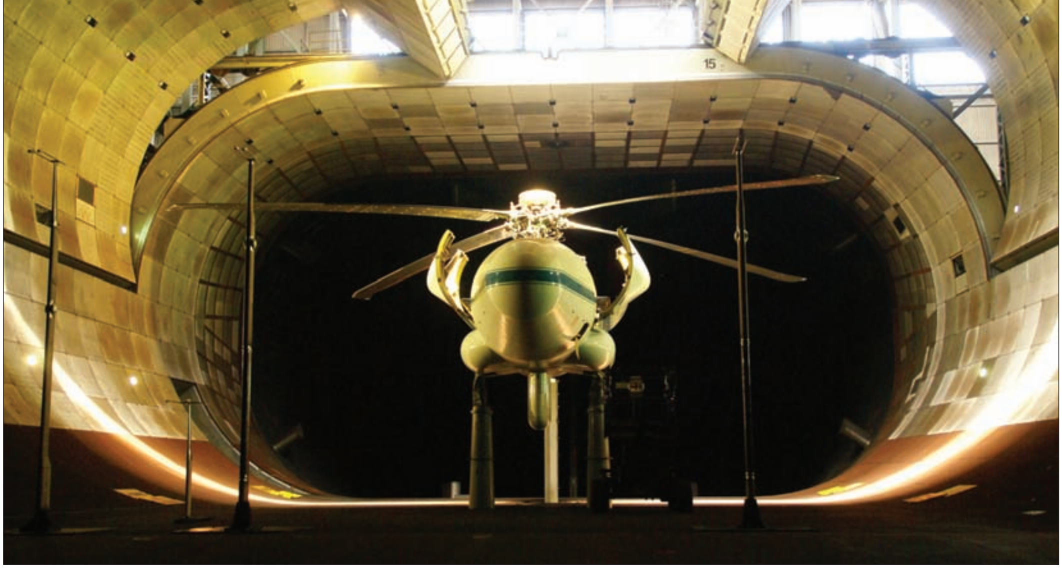
Although there are concerns about the cost of operating less than fully scheduled wind tunnel facilities, many experts ironically point out that it is a drop in the bucket compared to the cost of major new aviation or space development programs. Wind tunnel advocates argue with passion for the practicality of this technological link to aviation's pioneering days.

Monica Walker, test director at the Naval Surface Warfare Center's Carderock Division, gives a nautical example for why wind tunnel testing is still vital: "Right now, if you test an aircraft carrier [to see how it reacts to forces such as the airflow over its deck], you can build a model with detail down to a few thousandths of an inch and test on an 8-ft-long model, and you'll have quite a bit of detail on that aircraft carrier. To have a comparable amount of detail in a CFD model, it has so many grid points that [computer] storage and processing are really limiting factors. I think CFD is going to advance farther and faster as things continue to grow….But if you are looking right now for the effect of a tiny little detail on a giant problem, that becomes a challenge for some of the CFD tools."

In addition, wind tunnels are required to validate CFD models, so in many cases one simply cannot simulate everything based on current knowledge of the physics involved.

The 8x10-Ft Subsonic Wind Tunnel that Walker and her colleague Kevin Kimmel show visitors at Carderock is an example of a fine, gracefully aging wine. The tunnel still operates with its original 1940s-era propeller blades (it is much easier to spot cracks in these than in a composite material propeller, notes Walker). Its six-component Toledo force in moment system, which measures a model's lift, drag

An X-48C is mounted in the recently dismantled Full-Scale 30x60-ft Wind Tunnel. USAF photo by Staff Sgt. Barry Loo.



The UH-60 rotor is mounted on the Large Rotor Test Apparatus during testing of the individual blade control system at AEDC's National Full-Scale Aerodynamics Complex's 40x80-ft wind tunnel. Photo by Philip Lorenz III.

and side forces as well as rolling, pitching and yawing moment, is of similar vintage. But the tunnel works like a charm, testing everything from aircraft carriers, submarines, unmanned aerial vehicles, Navy buoys and parachutes to bobsleds for the U.S. Olympic team.

While it would be nice to have the newest wind tunnel technology, says Walker, what is really "make or break" is the "knowledge of the people that use them, and what they use them for."

Mike Worthy, senior staff engineer of the Aerodynamics Group at Lockheed Martin's Missiles and Fire Control group in Dallas, puts it this way: "Wind tunnels are still used in the development of just about every flight vehicle we have; we don't fly a vehicle unless we test it in a tunnel. They're very important. We might use analysis techniques for preliminary work, but when it comes down to getting the vehicle ready for flight, verifying it, modeling it, we're going to rely on the wind tunnel to generate the critical data we need."

Adds colleague Tim Fennel, senior manager for wind tunnel laboratories, "In what we do with today's aircraft, with improvements in flight control systems, we're pushing the aircraft to fly closer and closer to the edge of their envelope. So you end up having to do a lot more testing out there at the edges, to gather the data and characterize how the airframe flies out there.

"CFD is really good for helping us with the preliminary design and narrowing down [options], but you still need the wind tunnel to gather the data in those areas where you have a lot of turbulent flow and you have complex shapes," says Fennel.

Moreover, "if you wait until flight testing of a full-scale vehicle to ensure you are not missing something, the cost of redesigning major components late in a development program are much higher than if you find problems earlier," says Antón. "Also, testing is valuable for helping to ensure that programs meet performance target guarantees, which can have significant cost penalties if missed."

PROSPECTS FOR THE FUTURE

Turning to the future, Ed Mickle, manager of aerodynamics test facility planning at AEDC, Arnold AFB, says, "We are really going to have to look at how we are going to use test facilities in the future. I think this is where you will see more merging of large-scale computations with testing. Not in spite of, or in replacement of, but the two will meld more to each other."

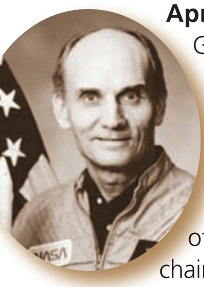
Mickle adds that there might be a process change in the duration of time a customer will need a wind tunnel. "We sometimes bring a model into a wind tunnel during early development and it will have multiple test entries, each entry requiring several weeks or more, over a period of months up to several years [for large systems], to refine and define a concept," he notes. "I think with the advances in the design of experiments and with advanced computations you'll look for getting in [a tunnel] for a reduced time per test, but also a reduction in the number of test entries per flight vehicle program, and potentially only for a few hours for getting answers to specific design questions supporting concept development and early trade studies.

"Now, you could retrofit the tunnels we have, or we as a nation could say, 'Let's put together the facility we need in the future.' A new facility could also bring in energy efficiencies and bring in better access for diagnostic tools so that you could optimize the aerodynamic design process."

The bottom line when we consider the future of wind tunnels, says Kraft, is that while "you can do fundamental designs with known physics on computers, they can't give you the kind of insights that Dick Whitcomb gained. You have to do that experimentally."

Out of the

25 Years Ago, April 1985



April 12-19 Sen. E.J. "Jake" Garn (R.-Utah) serves as a mission specialist on the STS-51D mission of the space shuttle Discovery and earns the distinction of being the first member of Congress in space. Garn, chair of the Senate subcommittee overseeing the NASA budget, undertakes research on space sickness during the flight. He is wired to record electrical signals from his brain and heart. He does exercises to induce nausea, while other instruments measure his bone growth or shrinkage in weightlessness. NASA, Press Release 85-9; *New York Times*, Jan. 18, 1985, p. A13, and April 13, 1985, p. A1.

50 Years Ago, April 1960

April 1 A Thor-Able rocket launches TIROS 1, the world's first weather satellite, which provides the first global cloud-cover photos from its nearly circular orbit of 429-467 mi. The primary mission of the 270-lb spacecraft is to test experimental TV techniques toward the development of a worldwide weather satellite system. During the 78 days of its operational life, TIROS 1 transmits 22,952 photos from its two TV cameras. E. Emme, ed., *Astronautics and Aeronautics 1915-60*, pp. 121, 146; *FAA Historical Chronology*, p. 66.

April 1 The fourth inflatable 100-ft-diam Shotput is launched to an altitude of 235 mi. and successfully inflates. E. Emme, ed., *Astronautics and Aeronautics 1915-60*, p. 121.

April 2 The USSR's Luna, or Lunik 1, space probe completes its first solar orbit. E. Emme, ed., *Astronautics and Aeronautics 1915-60*, p. 121.

April 4 Project Ozma begins at the National Radio Astronomy Observatory at Green Bank, W.Va., to detect possible signal patterns from outer space, which would be different from "natural" noises from space. This is a pioneering SETI (Search for Extraterrestrial Intelligence) experiment started by Cornell University astronomer Frank Drake. The object is to search for signs of life in distant solar systems through interstellar radio waves; however, no such signals are found. E. Emme, ed., *Astronautics and Aeronautics 1915-60*, p. 121.

April 6 The Soviet Union's Sputnik 3 satellite, launched on May 15, 1958, reenters Earth's atmosphere and burns up. Its 7,000-lb weight includes about 2,935 lb of instrumentation for experiments in gathering data on atmospheric pressures, ions, micrometeorites and Earth's electrostatic and magnetic fields. *Flight*, April 22, 1960, p. 555; *The Aeroplane*, Feb. 12, 1960, p. 204.

April 13 The rocket-booster ramjet-powered Bomarc B surface-to-air missile is successfully tested for the first time at Eglin AFB, Fla. *The 1961 Aerospace Year Book*, p. 444.

April 13 Britain's minister of defense announces the cancellation of the Blue Streak long-range ballistic missile. This was the U.K.'s biggest weapons system and could also have been used as a launch vehicle for spacecraft. *Flight*, April 22, 1960, p. 552.

April 13 The Navy's Transit 1-B satellite is successfully orbited by a Thor-Able-Star booster rocket from Cape Canaveral, Fla. The 265-lb Transit carries a military navigation payload experiment. This flight also demonstrates the first engine start in space and the use of satellites as navigational aids. E. Emme, ed., *Astronautics and Aeronautics 1915-60*, pp. 121, 147.

April 14 The first underwater launch of the all-solid-fuel Polaris 1,500-mi. fleet ballistic submarine-launched missile takes place from a specially made underwater tube off San Clemente Island, Calif. E. Emme, ed., *Astronautics and Aeronautics 1915-60*, p. 121.

April 15 The Discoverer XI reconnaissance satellite is launched from Vandenberg AFB, Calif., by a Thor-Agena. Code-named Corona, the satellite is used for photographic surveillance of the USSR, China and other areas. E. Emme, ed., *Astronautics and Aeronautics 1915-60*, pp. 121, 147.

April 18 A test vehicle for the all-solid-fuel Scout launch vehicle undergoes its first firing with live first and third stages from NASA's Wallops Island, Va., facility. However, the rocket breaks up following the first-stage burnout. E. Emme, ed., *Astronautics and Aeronautics 1915-60*, p. 121.

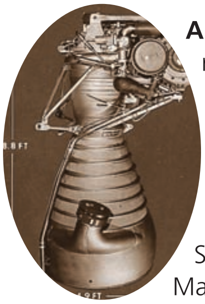
April 28 The first full-scale 250-mi.-range Nike-Zeus antiballistic missile is launched at the White Sands Proving Grounds, N.M. The missile's first stage is a 450,000-lb-thrust motor,

Past

An Aerospace Chronology
by Frank H. Winter, Ret.
and Robert van der Linden
National Air and Space Museum

the most powerful solid-fuel motor to date. D. Baker, *Spaceflight and Rocketry: A Chronology*, p. 102.

April 29 Skylark, Britain's two-stage solid-fuel sounding rocket, is launched from the Woomera rocket range in Australia and reaches a record altitude of 136 mi. The previous height attained by this rocket was 100 mi. *Flight*, May 13, 1960, p. 649.



April 29 All eight H-1 rocket engines for the Saturn launch vehicle are fired simultaneously for the first time, for a combined thrust of 1.3 million lb, at the Marshall Space Flight Center. *Flight*, May 6, 1960, p. 618.

75 Years Ago, April 1935

April 1 Vera Fedorova, a 24-year-old Soviet parachute jumper, claims a new world's record for jumping, without oxygen, from an airplane at 21,160 ft. *The Aeroplane*, April 10, 1935, p. 404.

April 3 Lewin B. Barringer glides 156.6 mi. from Ellenville, N.Y., to a point 10 mi. north of Harrisburg, Pa. In the air almost 7 hr, Barringer uses the Bowlus-du Pont Albatross II sail-plane in which Richard du Pont established the U.S. gliding record of 158 mi. *Aero Digest*, May 1935, p. 60.

April 8 Jean Batten, the only woman to have flown solo from Australia to England, attempts to beat her record Australia-to-England flight of 14 days 23 hr 25 min, but does not succeed. She pilots her veteran Gipsy Moth G-AARB from Sydney, but when she is 250 mi. from land over the Timor Sea the engine stops at 6,000 ft and restarts only after a 4,000-ft glide. Her progress is further delayed by a thunder-storm and headwinds that reduce her groundspeed to 60 mph. At Marseilles, later in the flight, there is engine trouble. This is remedied, but during takeoff a tire bursts. *Flight*, May 2, 1935, p. 471.

April 11 The de Havilland DH.88 Comet used by Cathcart Jones and Kenneth Waller in their record round-trip flight between England and Australia sets a new record for the 220-mi. flight between London and Paris. Capt. Hugh Buckingham flies the plane over this route in 53 min. This surpasses the record held by American Frank Hawks by 14 min. The plane, one of two purchased by the French government, maintains an average speed of 240 mph. *Aero Digest*, May 1935.

April 28 England's Imperial Airways begins trial flights on the London-to-Brindisi, Italy, route in preparation for regular passenger and airmail service. The machines used are the Avro 652 Ava and Avalon. *The Aeroplane*, May 15, 1935, p. 574.

And During April 1935

—The Soviet government issues an edict making military and technical aviation training compulsory for the almost 5 million young people (ages 16-24) belonging to the junior organization of the Communist Party and young working people not affiliated with the organization. The training includes at least one parachute jump from one of the towers especially erected for the purpose, at least 30 hr of aircraft engine studies, training in marksmanship and, in some cases, aircraft and glider piloting. *Aero Digest*, May 1935, p. 16.

100 Years Ago, April 1910

April 6 Alberto Santos Dumont flies a distance of 2,000 m from St. Cyr in his tiny Demoiselle XX. A. van Hoorebeeck, *La Conquete de L'Air*, p. 76.

Lecturer
Aerospace Engineering

The Aerospace Engineering Program at Arizona State University seeks an outstanding candidate for the position of Lecturer, starting August 9, 2010. Job responsibilities include teaching undergraduate courses in several areas of Aerospace Engineering, such as aircraft and spacecraft design, aircraft and spacecraft dynamics and control, air-breathing and rocket propulsion and aerospace structures, as well as other undergraduate or graduate courses in aerospace engineering. Other responsibilities include holding office hours, supervising undergraduate design and research projects, and participating in course and program assessment. An earned doctorate in Aerospace Engineering or a closely related field and previous college/university teaching experience are required. At least one year of universitylevel teaching experience in one or more of the above areas, including course development, administration, instruction and evaluation, is highly desired. Candidates with industrial experience in aircraft and/or spacecraft design or with academic experience in teaching aircraft and/or spacecraft design will be given particular consideration. Application materials are due by 5:00 p.m. on April 15, 2010. Interested individuals must send a cover letter, detailed résumé, written Statement of Teaching Experience, Interests and Philosophy, and contact information for three professional references to:

Dr. Valana Wells, Chair, Lecturer Search Committee
School of Mechanical, Aerospace, Chemical and Materials Engineering
Arizona State University
P.O. Box 876106, Tempe, AZ 85287-6106
Valana@asu.edu

This position is non-tenure-track. It is anticipated that the contract will be renewed annually subject to satisfactory performance. A background check is required for employment. AA/EOE

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NAVAL RESEARCH LABORATORY

RESEARCH PHYSICIST. The Laboratory for Computational Physics and Fluid Dynamics at the Naval Research Laboratory in Washington, DC is looking for a Research Physicist to initiate and conduct theoretical and numerical investigations of the dynamics of complex reactive-flow systems that occur over a wide range of flow regimes. These include highly compressible flows with shock waves and shock-flame interactions, flows in the presence of magnetic fields, as well as in highly dynamic and non-equilibrium states. The applicant must have a demonstrated knowledge of various aspects of physical modeling of multi-scale multi-physics reactive and non-reactive flows in order to initiate and conduct theoretical and numerical investigations. This is an NP-1310-III position with a salary range of $61,890 to $115,961 (this range includes DC locality). Salary is based on qualifications, experience and market consideration. This position requires a degree in physics or related degree that included at least 24 semester hours in physics. For applicants without status, apply to Vacancy Announcement Number NE0-1310-03NRL0079-DE. For applicants with status, apply to Vacancy Announcement Number NE0-1310-03-K9448774-IN. Please visit https://chart.donhr.navy.mil to search for the appropriate Vacancy Announcement and learn how to apply. The announcements will be open from 4/1/10 through 4/30/10.

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The department of aerospace engineering and geodesy of the Universität Stuttgart invites applications for the position of

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The professorship includes the position of director of the institute of aircraft design.

Applicants will be conducting both research and teaching in the field of aircraft design. The teaching should focus on the practical application of theoretical basics. Some years of experience in the construction and manufacturing of aerial vehicles would be advantageous. Research on composite materials is a key aspect of work in the department of aerospace engineering and geodesy and in the university as a whole. Applicants are expected to make outstanding contributions especially in the research and optimization of aircraft components and structures. In addition new and cheaper means of fabrication are to be researched.

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Applicants should have a sufficient academic reputation, theoretical background and experience in aircraft design and aircraft components. In addition teaching experience is required. Furthermore didactic skills, experience in the acquisition of research grants as well as leadership and soft skills will be required. Interdisciplinary cooperation will be part of the job of the Professor.

The requirements for employment listed in § 47 Baden-Württemberg university law apply; in case of first-time appointment as professor employment can be limited to three years.

Please send your applications to:
Vorsitzender der Berufungskommission, Prof. Dr.-Ing. Stephan Staudacher, Dekanat der Fakultät Luft- und Raumfahrttechnik und Geodäsie der Universität Stuttgart, Pfaffenwaldring 27, 70569 Stuttgart, Germany

Applications have to be received before **May 28th, 2010** to be considered.

The University of Stuttgart wishes to increase the proportion of female academic staff and, for this reason, especially welcomes applications from women. Severely challenged persons will be given preference in case of equal qualification.

GENERAL ENGINEER
U.S. ARMY RESEARCH OFFICE
RESEARCH TRIANGLE PARK, N.C.

Applications are being solicited for a General Engineer, DB-0801-03 (equivalent to the GS-12/13 grade levels), $70,906-$109,611 per annum; or General Engineer, DB-0801-04 (equivalent to GS 14/15 grade levels), $99,638-$152,364 per annum. Salary within the ranges above includes a locality adjustment and depends upon individual qualifications and salary history. The position is located at the U.S. Army Research Office in Research Triangle Park, North Carolina. The incumbent serves as Program Manager for Army extramural basic research program in Actuation, Dynamics and Mechanisms (ADaM). Work involves the creation, management, and leadership of a high risk, opportunity-driven, basic-research program with potential for major impact on Army and DoD capabilities, as well as promotion and coordination of relationships between Army and national and international scientific, educational, and research institutions to affect the transition of this research into current and future Army systems. Serves as the principal Army advocate and representative for basic research activities and needs. Expertise is required in the areas of complex interacting systems, structural dynamics, mechanisms and novel actuation systems. Duties include: Analyzing and evaluating research proposals. Communicating with grantees and contractors and evaluating performance. Reviewing and analyzing research reports, and ensuring their effective distribution. Stimulating technology transfer to both Army and civilian users. Disseminating program policies and research results. Maintaining intimate awareness of recent developments and coordinating with representatives (intra- and inter-discipline) from DoD and other agencies to evaluate research initiatives. Developing and presenting briefings and research summaries that highlight projects, objectives, progress, accomplishments and emerging opportunity areas. Conducts workshops, conferences and symposia related to research initiatives within ADaM to identify emerging opportunities. In order to maintain scientific acumen, the incumbent may perform research at a local university for up to one day per week. Travel up to 20% of the time may be required. Outstanding verbal and written skills are required. Applicants must show successful completion of a full 4-year course of study in an accredited college or university leading to a bachelor's or higher degree in professional engineering, or a combination of education and experience equal to a GS-12/13 level position in the Federal government for DB-03 or GS-14/15 for DB-04. An advanced degree at the PhD level preferred. Experience must have been in or related to the work of the position and have equipped the applicant with the knowledge, skills, and abilities to successfully perform the duties of the position.

Applicants must be U.S. citizens, be able to obtain a secret clearance, and comply with provisions of the Ethics in Government Act. Interested individuals must apply electronically following instructions at www.usajobs.opm.gov or at www.cpol.army.mil. Vacancy Announcement numbers are NEAC10077440/NEAC10077440D for the DB-03 and NEAC10078053/NEAC10078053D for the DB-04.

Opening date for this position is March 8, 2010 and closing date will be April 30, 2010. If you have questions, please contact Mrs. Paula Valdez, 301-394-2109, e-mail: paula.geny.valdez@us.army.mil or Wanda Wilson, Administrative Officer, Army Research Office at (919) 549-4296, e-mail: wanda.wilson@us.army.mil.