May 2010

AEROSPACE AMERICA

NextGen

A SLOW TRANSFORMATION

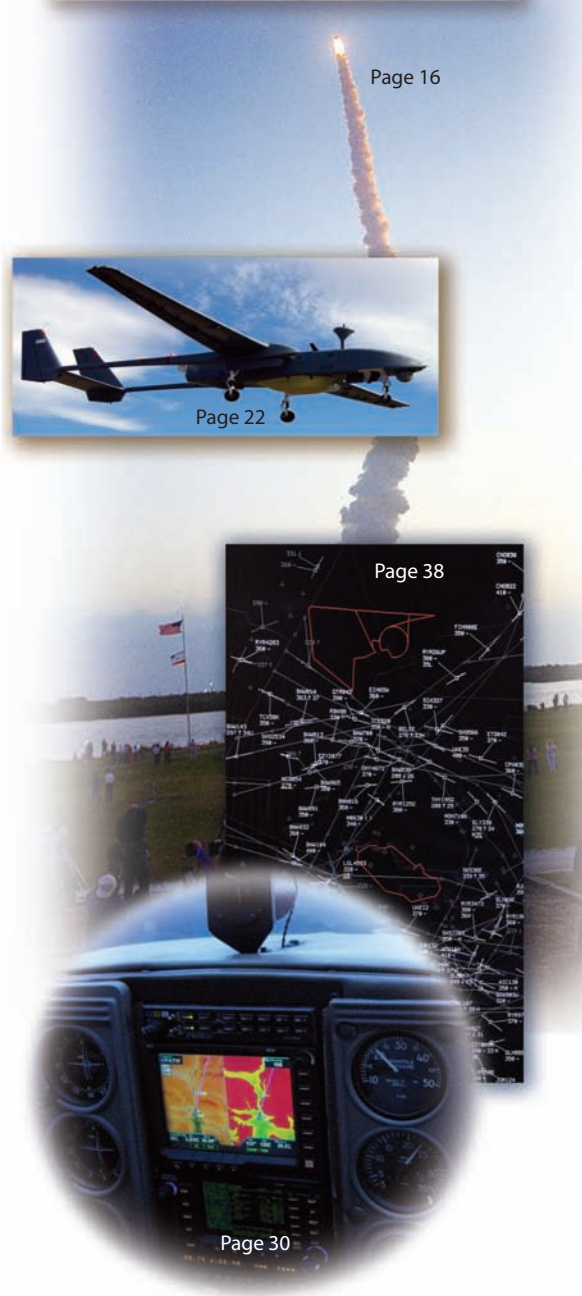
SESAR faces nontechnical hurdles

A conversation with Richard Brookes

A PUBLICATION OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

AEROSPACE AMERICA

May 2010



DEPARTMENTS

FEATURES

BULLETIN

COVER
New technologies and programs for the next generation of air transportation systems both in the U.S. and Europe are making progress, to greater and lesser degrees. To find out how they are faring, turn to pages 30-43.

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Elaine J. Camhi
Editor-in-Chief
Patricia Jefferson
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Greg Wilson
Production Editor
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Fitzgerald Art & Design
Art Direction and Design

Craig Byl, *Manufacturing and Distribution*
Mark Lewis, *President*
Robert S. Dickman, *Publisher*

Send materials to Craig Byl, AIAA, 1801 Alexander Bell Drive, Suite 500, Reston, VA 20191-4344. Changes of address should be sent to Customer Service at the same address, by e-mail at custserv@aiaa.org, or by fax at 703/264-7606.
Send Letters to the Editor to Elaine Camhi at the same address or elainec@aiaa.org

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Editorial

As the tanker turns

In late 2001, the USAF proposes leasing 100 air-refueling tankers from Boeing to replace its aging fleet of KC-135 Stratotankers, which had begun service in 1957. The replacements are to be based on the Boeing 767 and are to come in at a cost of about $20 billion or so on a sole-source contract.

This proposal, however, is met with a hailstorm of criticism, led by Sen. John McCain, who believes the company is being given a sweetheart deal, and that there are alternative plans that should be examined before any contracts are let. This eventually leads to investigations, a CFO dismissal, a CEO forced into retirement and, by November 2003, a jail term.

By early 2004, the leasing deal is effectively scrapped.

After the dust settles, the Air Force introduces the KC-X replacement program, and on January 30, 2007, the Dept. of Defense posts a request for proposals.

Boeing again proposes a 767 derivative, and a joint venture between Northrop Grumman and EADS offers the Multi-Role Tanker Transport, based on the Airbus A330-200 and called the KC-45. Both competitors file before the deadline; both promise that manufacture of the aircraft would take place in the U.S.

In February 2008, the Pentagon announces that the contract, now worth $35 billion to $40 billion, will be awarded to the Northrop Grumman/EADS joint venture.

But it doesn't end there.

Boeing immediately files a protest, which is upheld by the Government Accountability Office. In July 2008, Secretary of Defense Robert Gates calls for an "expedited recompetition" and issues a new RFP. Boeing then asks for more time, which it eventually receives, as the RFP is cancelled, leaving the issue to be handled by the next administration.

Those Stratotankers are now seven years older.

Among the ideas floated in Congress is a split award, offering contracts to both companies, making some states, and their representatives—and the maintenance and overhaul folks—happy. Gates turns this suggestion down.

In September 2009, the Pentagon formally releases a new RFP. Boeing offers two proposals, one again based on its 767 and another based on the 777. Northrop Grumman threatens to withdraw, believing the new RFP offers advantages to Boeing and its smaller offering, and follows through on that threat in March 2010. EADS announces that it will not compete on its own.

However, no one, except Boeing, is happy about awarding an uncompeted contract. EADS then decides that it may look for a new partner, or perhaps compete on its own. But the company requests additional time to decide, and to prepare a new response to the RFP.

Rumors pop up and are quickly debunked. The Russians are going to bid. No they're not. EADS is going to protest. No it's not.

In the end, the decision may come down to a choice between two fine aircraft, either of which could fill the Air Force's needs. But political pressures, both domestic and international, may make a difficult call even harder, overshadowing an evaluation of the merits of the proposals.

And the Stratotankers keep getting older. Tune in tomorrow.

Elaine Camhi
Editor-in-Chief

Euro Hawk sparks UAS integration plans

By the end of 2010 the German defense ministry is due to take delivery of its first Euro Hawk unmanned air system. In January 2007 the ministry awarded a $559-million contract to Euro Hawk GmbH, a 50-50 joint venture between Northrop Grumman and EADS, for the development, test and support of the Euro Hawk unmanned SIGINT (signals intelligence) surveillance and reconnaissance system. It will replace Germany's aging fleet of Breguet Atlantic aircraft, in service since 1972.


Eurohawk

After the first demonstrator vehicle, four further Euro Hawk platforms, with an operational capability, are scheduled for delivery between 2015 and 2016.

For Europe's aviation safety regulators and air traffic management (ATM) officials, the arrival of Euro Hawk within Europe is a timely reminder that there is a great deal of work still to be done to develop regulations on the three areas that will allow UAS platforms to share airspace safely with civil aircraft: vehicle airworthiness, remote command and control systems, and ATM—especially sense-and-avoid technologies.

But Euro Hawk is in many ways an atypical UAS. It operates above 50,000 ft—higher than the main traffic lanes—and is large enough to accommodate many of the sense-and-avoid systems found on airliners. The platform is U.S. based, a derivative of the Northrop Grumman Block 20 Global Hawk, but the on-board systems are European. The SIGINT mission system that detects electronic intelligence radar and communications intelligence emitters is under development by EADS Defence & Security, as are the ground stations that will receive and analyze the data from Euro Hawk.

2012 target for regulations

The various European regulatory bodies are working toward development of certification regulations for the key technologies by 2012 to integrate all shapes and sizes of UAS platforms within Europe's airspace, with their implementation from 2015.

EUROCAE, the European Organization for Civil Aviation Equipment, has been undertaking much of the work within Europe to develop the necessary standards for operating UAS vehicles in civil airspace and proposing regulations to the European Aviation Safety Agency, which will be ultimately responsible for

EUROCAE Working Group 73: Developing UAS draft standards and requirements

EUROCAE's Working Group 73 has been formed to develop a requirements framework that will enable UAS platforms to operate within the current system without segregation from other airspace users. It held its first meeting in the Eurocontrol Brussels headquarters in April 2006. It works through four subgroups: UAS operations—sense and avoid; airworthiness and continued airworthiness; command and control, communications and spectrum security; and light UAS (under 150 kg) and operations with visual management and separation.

EUROCAE's work program has six main elements:

- *Drawing up an "operational concept" to highlight airworthiness certification and operational approval items that need to be addressed—completed January 2007.*
- *Drawing up a plan of programs and timescales—ongoing.*
- *Developing a concept for UAS airworthiness certification and operational approval in the context of nonsegregated airspace. The object is to develop a report of recommendations—and a requirements framework for civil UAS—that could be adopted as a basis for regulatory policy by national administrations. The scope covers general regulatory issues, security, radio spectrum requirements, operational approval, airworthiness certification and maintenance. A specific volume focuses on UAS, typically less than 150 kg mass, limited to visual line-of-sight operations—final version of the document to appear in 2010.*
- *Developing a document to define the requirements for command, control and communication systems including autonomous operation—document to appear in the second quarter of 2010.*
- *Developing a document to define the requirements for UAS associated with separation assurance and collision avoidance—document to appear in the fourth quarter of 2012.*
- *Developing a document to identify those aspects of UAS normal and abnormal operations that would require special ATM consideration—ongoing.*

The MIDCAS consortium

The MIDCAS consortium comprises 13 aerospace industries from five countries, with Sweden's Saab leading the project. Flight tests will be carried out at the CEV flight testing center in Istres, France. Thales and Sagem will research the "sense" technologies. Thales will coordinate work on cooperative sensors—such as radar, transponders and TCAS—with Sagem coordinating work on noncooperative sensors (infrared imagers, video, radar). Full consortium members are:

Saab
Alenia Aeronautica S.p.A.
Diehl BGT Defence GmbH & Co. KG
Deutsches Zentrum für Luft- und Raumfahrt e. V. in der Helmholtz-Gemeinschaft
EADS Deutschland GmbH
ESG Elektroniksystem- und Logistik-GmbH
Galileo Avionica S.p.A.
INDRA SISTEMAS S.A.
Italian Aerospace Research Center CIRA S.c.p.A.
Sagem (Safran Group)
Selex Communications S.p.A.
SELEX Sistemi Integrati S.p.A.
THALES Systèmes Aéroportés S.A.

certifying and regulating these operations. This year, two important documents are due to be published outlining draft regulations on airworthiness and command, control and communications.

Working group 73 of EUROCAE, an organization of European companies, is drawing up the regulatory proposals in consultation with the International Civil Aviation Organization, the U.S. Federal Aviation Administration, Eurocontrol and RTCA, among many others. Work on accelerating the regulatory and operational frameworks to allow UAS platforms to fly within European airspace has taken place in the past 12 months.

Eurocontrol published the first ATM specifications in December 2007 to set out how UAVs should fly in European airspace. The organization's UAV Operational Air Traffic Task Force concluded that if UAS platforms are to operate in nonsegregated airspace—that is, in the same airspace occupied by airliners and general aviation aircraft operators—UAS platforms would have to meet the same requirements as manned aircraft to interact with air traffic controllers and carry out sense-and-avoid maneuvers to maintain separation. This means developing new sense-and-avoid technologies and new procedures for certifying airworthiness, security operations and operator training.

The European Defence Agency (EDA) has set a target date of 2015 for UAS platforms to become integrated within the current civil airspace structure on a "file and fly" basis. The EDA produced its study on sense-and-avoid technologies for long-endurance unmanned air vehicles in 2007 (http://www.edaeuropa.eu/genericitem.aspx?area=31&id=305), covering the mapping of applicable regulations, definition of requirements and definition of potential technical solutions. It also covered testing of the proposed technical solutions through sim-ulations and assessment of how implementing the solutions will affect the future use of long-endurance UAVs, ATM procedures and safety considerations.

A forum on aviation cooperation was held in October in Montreal.

Integration approaches

In May 2007 EDA was given the job of addressing this challenge on the basis of a stepped approach toward integration. According to Carlo Magrassi, EDA deputy chief executive (strategy), speaking in Montreal at a forum on civil/military cooperation in October 2009, "A major strategic technology development….is the so-called MIDCAS project [Midair Collision Avoidance System]. The objective of this €50-million technology demonstrator is to support the development of the critical sense-and-avoid technology and hereby, complementary with other activities, enable the operation of UAVs in nonsegregated airspace."

MIDCAS team members met for the first time on February 16 at Eurocontrol headquarters in Brussels, with around 70 representatives from various European aviation authorities, air traffic control (ATC) organizations, aviation industries and research organizations. The work on developing standards and systems for sense-and-avoid equipment—with standardization work taking place under EUROCAE—will culminate in flight trials with the new equipment on board an Italian Alenia Sky-Y UAS by the end of 2012.

A need for improved ATC datalinks was also highlighted by the European Commission (EC)-funded Innovative Operational UAV Integration (INOUI), a 24-month, €4.3-million research study completed in October 2009 and led by German air navigation service provider DFS Deutschflugsicherung, which investigated how current data-link technologies could be developed to fulfill the ATC role, perhaps through mandating satellite communications, given the requirement for UAV platforms to operate beyond line of sight. The report also highlighted the potential for low-cost general aviation collision avoidance technologies, such as those developed by Flarm Technology (http://www.flarm.com).

Another emerging technology that could provide the basis for sense-and-avoid systems on board smaller UAVs is automatic dependent surveillance broadcast (ADS-B) services that would require a simple transponder with a backup data-link transmission system. Such a technology has been investigated recently under the NASA Aeronautics Research Mission Directorate *Integration of Advanced Concepts and Vehicles into the Next Generation Air Transportation System (NextGen)* study.

In planning for integration of UAS platforms into European airspace, Eurocontrol is implementing a two-phase strategy: a near-term objective of enabling UAS integration into the ATM system based on current technologies and

Air4All and ASTRAEA

There have been two other significant European programs to develop strategies to integrate UAS platforms into civil airspace.

*The EDA commissioned the **Air4All** consortium to develop a detailed action plan to demonstrate how UAVs are to be able to fly in civil airspace by 2015. The plan was released in 2008 and included a roadmap for an implementation plan with technological, regulatory and cost estimates. Participants included Alenia Aeronautica (Italy), BAE Systems (U.K., Sweden), Dassault Aviation (France), Diehl BGT Defence (Germany), EADS CASA (Spain), EADS Defense & Security Germany, Selex Galileo (Italy), QinetiQ (U.K.), Rheinmetall Defense Electronics (Germany), SAAB AB (Sweden), Sagem Defense Systems (France) and Thales Aerospace (France, U.K.).*

*Meanwhile the U.K. has been developing its own UAS integration strategy in the form of the **ASTRAEA** program, a £32-million aerospace program involving a consortium of companies including BAE Systems, EADS, Cobham, QinetiQ, Rolls-Royce and Thales, working with autonomous systems specialist Agent Oriented Software. The ASTRAEA program focused on assessing the viability of enabling autonomous aircraft to operate within U.K. airspace and in October 2008 carried out a number of simulated flights with an autonomous UAS, at the ParcAberporth range in the U.K.*

procedures and a long-term strategy of enabling UAVs to fly alongside manned aircraft within the Single European Sky concept of operations, due to be fully implemented from 2020.

INOUI also highlighted a requirement for "dynamic replanning"—when a UAS flight plan would need to be altered because of a potential conflict. It suggested that technologies developed within the EC-funded SOFIA (Safe Automatic Flight Back and Landing of Aircraft) project (http://www.sofia.isdefe.es), which investigated the technologies and procedures to return an aircraft automatically to a safe landing following a hostile action, could be reconfigured for such a role.

"Two further important UAS work strands under the EDA umbrella are worth mentioning, both initiated from the Air4All Roadmap development," according to Magrassi. "The first [is] the so-called SIGAT activity, with the aim to support the preparation of the World Radio Conference in 2012 and subsequently in 2015. EDA participating member states, in August 2008, tasked the Air4All Frequency Group to work toward the identification of appropriate spectrum requirements to consolidate a common European position regarding regulatory and operational UAS requirements for the upcoming World Radio Conference.

"Another activity being coordinated with the European Space Agency is the common approach regarding command and control of UAS and satellite services, as well as the air traffic control data link."

Satellite study contracts

In February 2010 EDA and ESA signed contracts, worth €400,000 each, with two consortia to progress the work on command and control alongside ATC data-link services. EDA has contracted EADS Astrium Services/EADS Defence & Security—Military Air Systems (France) to investigate the command and control segment. ESA signed a second contract with INDRA Espacio of Spain to investigate the ATC link segment.

The studies will examine how UAS platforms can be integrated into nonsegregated airspace using satellite communications and satellite navigation for command and control, sense and avoid, and ATC. They will also research the added value of satellite communications for high-data-rate payload links; the viability of such a solution for future services based on UAS supported by space systems; the investments that will be necessary in the future; the next steps needed in technical and regulatory terms for establishing such a service; and the road map for civilian, security and military services.

Tackling smaller UAVs

But many in the industry believe the key challenge will be to introduce new sense-and-avoid technologies, procedures and regulations for UAVs that are not large enough to accommodate current traffic collision avoidance systems.

"Programs such as MIDCAS are aimed predominantly at the larger UAS vehicles entering the market," said Peter van Blyenburgh, president of UAS trade association UVS International, "but there is very little work to develop appropriate technologies for the smaller systems, those under 150 kg."

Much of the work to develop regulations of these smaller systems has been led by the Joint Authorities for Rulemaking on UAS group of national European civil aviation authorities. Led by the Netherlands, JARUS is working on developing a single set of airworthiness and operational airspace requirements for consideration by the relevant regulatory authorities. But with these small systems about to enter the market in growing numbers, there is increasing awareness within Europe of the need to focus regulatory attention at this level of UAS.

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For Europe, the key focus now is to pull together all the work undertaken by national and international agencies and deliver a cohesive regulatory structure that meets the short-term aerospace safety requirements of national states while being able to harness the longer-term technological promises of data-fusion, miniaturization and increasing autonomy.

As ever in Europe, the issues of developing joint approaches across national and international institutions are proving as much of a challenge as developing the appropriate technologies.

Philip Butterworth-Hayes
Brighton, U.K.
phayes@mistral.co.uk

Correspondence

In **Environmental regulations fly high and wide** (March, page 4), Mr. Butterworth-Hayes states that the Carbon Reduction Commitment (CRC), a regulatory scheme put in place by the U.K., will attempt to reduce emissions by 60% over 2008 levels by 2050. The emission reductions demanded for aircraft by the CRC is unclear, but the International Air Transport Association is stated as proposing 50% reductions for aircraft by 2050.

Missing from the article are important numbers. Given that the rate of increase in CO_2 levels, as reported from the Mauna Loa, Hawaii, observatory and other sources was about 1.9 ppm per year, and given that aircraft contribute about 2% of this CO_2, reducing CO_2 contributions by aircraft by 50% would reduce global CO_2 emissions by about 0.019 ppm per year. From 2050 to 2100, this would mean a reduction of only 0.95 ppm in atmospheric CO_2 concentrations, or 0.2% of the 2008 concentration of 385 ppm. Note that the percentage of CO_2 in the atmosphere is only 0.038%.

Given this minuscule difference in the percentage of CO_2 in the atmosphere caused by this reduction, how much cooler will it be in 2100 if the reduction is made than if it isn't? Also, how much revenue will be lost by the airlines, the aircraft production industry (AIAA's membership), and tourism in-

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dustry if the cuts are made (through increased taxes and thereby ticket costs)?

Joe Sheeley
Tullahoma, Tenn.

Reply by author: The huge current cost of research into new fuels, more efficient engines and air traffic management procedures will make it possible for the aerospace industry to reach IATA's target of a net reduction in carbon emissions of 50% in 2050 compared to 2005, despite trebling the number of aircraft in operation over the same period. The question is, is this investment worth it?

The industry can only respond with a technological solution to what is a political question. The results may seem, in context, minuscule. But with regulators in Europe and elsewhere contemplating caps on air traffic growth on the basis of the industry's carbon footprint, if you can demonstrate that technology will decouple growth and environmental impact there will be no justifiable reason to cap growth in the first place.

I have just read **Why asteroids beckon** (March page 12), and, sad to say, found Tom Jones' arguments wanting. He has attempted to intermingle manned exploration of NEOs with the need to prepare to deflect one of these should it endanger Earth, two very different objectives. The former is elective, the latter, not.

But overriding this is the question: whither human spaceflight. We are at a very uncomfortable crossroads. The "vision" program was begun by President Bush, who then chose to tacitly continue it without further verbal support, only to have it terminated by President Obama. NASA geared itself around the Constellation program, spending billions of dollars on it, only to have it dumped in the waste can.

As I have felt before, I thought returning to the Moon was a lousy goal, a "been there, done that" effort that would not attract public support. NASA appears to have counted on the continuation of the program without doing much to sell the public on it. The coup de grace to the program was the poker play by the Augustine Commission, essentially daring the president to put up or kill it. He chose the latter, probably quite startling the members of the commission. Augustine gave himself absolutely no wiggle room, such as suggesting that Constellation could continue with the current funding if one assumed that the space station's life would be extended. That has now been done, but the Constellation program is now, unless resurrected, dead.

And, if Tom Jones thought that returning to the Moon was a public yawn, manned visitations to NEOs would be a total sleepwalk. Exactly how do you build excitement? The only goal that would attract public support is a manned Mars mission and, right now, a hell of a lot of PR would be needed even for that.

If in the NASA budget there will now be money for advanced propulsion system development, success in this area could resurrect the human spaceflight program. In the interim, I am afraid that the technical expertise will be disbanded and lost. I sincerely doubt that manned exploration of Mars can be handled by commercial spaceflight development.

May I suggest that this issue be the subject of much debate within AIAA and its sister organizations, one in which we consider the various options we might take to get us back to manned spaceflight and the exploration of Mars? I believe that we are now like Moses wandering in the wilderness, and that it will be years of soul searching until we recover the will to move on—somewhat akin to the period following the end of the manned Moon expeditions. I am dismayed by the matter-of-factness in both the editorial, **Space, safety—and risk** (March, page 3), and in Tom's article; we have been gored and are simply too acquiescent to speak out. **Richard Eiger**

Events Calendar

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 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

Feeling the pinch and fighting back

"THE PRESIDENT MADE A MISTAKE," SAID Sen. Bill Nelson (D-Fla.) at a public space forum in Cocoa, Fla., on March 19.

Nelson, Congress's most visible advocate for human spaceflight, was referring to President Barack Obama's decision to delete the Constellation human spaceflight program from the administration's FY11 NASA budget request. Nelson spoke of the "perception" that Obama "killed the space program," but he also called Obama "a vigorous supporter of the manned space program."

In objecting to Constellation's absence from the funding proposal, Nelson has plenty of company on Capitol Hill and in industry. Twenty-seven members of Congress (two-thirds of them from Alabama and Texas) initially wrote to NASA Administrator Charles Bolden saying, "The termination of the Constellation programs is a proposal by the president, but it is Congress that will accept or reject that proposal. In the meantime, FY10 funds for the Constellation programs are to be spent as if the program will continue." Among signatories to the letter is Rep. Ron Paul (R-Texas), who is usually a voice for smaller government and a foe of federal spending. Since that initial letter was written, other lawmakers have joined in.

With the nation's capital and especially Congress focused on the economy, health care and immigration, it is unclear how much of their own personal clout lawmakers are willing to expend to try to reverse the proposal. However, the administration is listening, and there are preliminary signs that the White House and NASA are taking another look.

Rep. Ron Paul

Sen. Bill Nelson

The Constellation project, one goal of which is to return astronauts to the Moon by 2020, grew out of the far-sighted 2004 "vision" of a replacement for the space shuttle to deliver astronauts to LEO and eventually take them farther into space. But the public seems to have little interest. While Constellation remains in the current (FY10) budget, the idea of restoring it to FY11 funding appears to enjoy limited support outside Alabama, Florida, Maryland and Texas, states where key NASA facilities are situated.

If left unchanged, the administration's new policy will be especially difficult at Florida's Kennedy Space Center, which will have no manned space activity to support, and at Alabama's George C. Marshall Space Flight Center, which has developed rockets from the Apollo-era Saturn to the present-day Ares.

Under the administration's plan, NASA will scuttle the shuttle successor Orion and the lunar lander Altair. The agency will also abandon both Ares I, the launch vehicle for Orion, and Ares V, the heavy-lift launch vehicle designed to send Orion and Altair to the Moon. The revelation that the administration is abandoning government-funded human space exploration was handled poorly. In a telecast to NASA field centers soon after the February 1 release of the budget proposal, NASA's Bolden apologized for the abruptness with which the policy shift was announced.

Ironically, at a time when federal deficits and the national debt are issues, a decision to drop Constellation will not result in NASA returning any funds to the treasury. The FY11 budget plan is actually slightly larger than FY10 spending, with funds going to private rocket and space companies, atmospheric physics research and climate science, as well as robotic exploration of the solar system.

When we went to press, the president had called for a "space summit" on April 15, at which, among others, officials in Florida—heavily impacted by the coming retirement of the shuttle and the cancellation of its replacement, Constellation—were scheduled to attend. *Florida Today* reported that rally organizers were seeking to assemble 5,000 spaceflight supporters to tell the president, as Brevard County Commissioner Robin Fisher put it, "This current [NASA] budget, the way it is structured, is not acceptable to this community."

In Florida and elsewhere around the country, supporters of a robust space program believe that even if the White House does not change policy, Congress will force a change. Many in Washington view the agency and its administrator, Bolden, as performing a difficult balancing act in order to satisfy both Capitol Hill and the White House as well as the conflicting requirements of FY10 and proposed FY11 legislation.

As the state's *Orlando Sentinel* put it, "NASA is…caught in a tug of war" between President Obama's budget, which ends the program, and congressional legislation preventing the program from ending without its approval.

Some NASA engineers are continuing to develop components of the program, while other NASA staffers are canceling solicitations for components for which contracts have not yet been written. NASA is still working on Ares I,

Delays in the JSF program have the services looking at upgrades for the older fighters.

arguing that it may have applications for undefined future programs.

At press time, the agency was awaiting the April 18 return of the space shuttle Discovery on STS-131, with Navy Capt. Alan Poindexter leading seven astronauts to the ISS. The 13-day flight delivered supplies, a new crew sleeping quarters and science racks that will be transferred to the station's laboratories. A Russian TMA-18 Soyuz mission to the ISS also took place in the first week in April. The final flight in the shuttle program, STS-133, is scheduled for a September 16 launch, but an analysis by the agency office of the inspector general indicates that delays may extend shuttle operations.

Fighter shortfall

With the F-35 Lightning II Joint Strike Fighter (JSF) confronting significant cost overruns and schedule delays, some in Congress and industry are arguing for an increased buy of F/A-18E/F Super Hornets, the Navy's current, carrier-based strike fighters. Production of 493 Super Hornets was scheduled to end next year, when it was expected that the F-35C would begin replacing them on carrier decks. Now, four senior members of the House Armed Services Committee have warned Defense Secretary Robert Gates that the Navy and Marine Corps face a much larger shortfall of fighter jets than expected. The Marine Corps never invested in the F-18E/F but is counting on the F-35B version of the JSF to replace its older F/A-18C/D Hornets.

In a letter to Gates that was also sent to Adm. Michael Mullen, chairman of the Joint Chiefs of Staff, the legislators said the Pentagon expectation of a looming "fighter gap" of 100 aircraft is "too optimistic." Armed Services Chairman Rep. Ike Skelton (D-Mo.) signed the letter along with ranking Republican Rep. Buck McKeon (R-Calif.) and Reps. Gene Taylor (D-Miss.) and Todd Akin (R-Mo.). Analysts have long spoken of a Navy-Marine fighter shortfall that could leave the sea services with 300 fewer fighters than their force structure calls for. Boeing assembles the Super Hornet in Missouri and uses components built by Northrop Grumman in California.

Gates called a Boeing proposal to supply an additional 124 Super Hornets an "interesting offer." Previously, the Pentagon boss was opposed to any purchase of fighters that would be perceived as interfering with the JSF program. The Pentagon is also considering upgrades to 150 older F/A-18C/D Hornets—used by both the Navy and the Marine Corps—and reducing the number of fighters in expeditionary squadrons. So far, no funds have been appropriated for a life extension of the Hornets, estimated at $3.5 billion.

The fighter shortfall is not limited to the Navy and Marine Corps. In what outsiders call a pending "fighter gap"—officials say they do not use the term—the Air National Guard and Air Force Reserve F-16 Fighting Falcons that provide 80% of the air defense of North America will exhaust their airframe hours by 2017. In the FY10 defense appropriations bill, Congress halted plans to retire about 250 F-15 Eagles and F-16s until a review of the situation could be completed and a report issued. That report, once scheduled for April, "keeps slipping to the right," an official tells this author. But even without retiring its so-called "legacy" fighters, the air defense mission (officially called air sovereignty alert) may suffer unless a decision is made to purchase new aircraft.

FAA funding

It may take months for the Senate and House of Representatives to reconcile differing versions of a $34.5-billion two-year authorization bill for the FAA following the Senate's passage of its version on March 22. In a situation not atypical in Washington, the FAA's statutory authorization expired on September 30, 2007, and the aviation agency has continued to function since then under a series of temporary extensions passed by Congress.

A key provision in both versions of the new bill would provide funding for the FAA's NextGen (next generation) program to update the nation's air traffic system. A new navigation system for the nation's airways has been stalled for years, but the measure would require "key elements" to be in use by 2014 at the busiest airports.

The bill funds NextGen in part by an increase in general aviation jet fuel taxes—21.9 cents to 36 cents a gallon—but does not impose new user fees. Supporters of the general aviation community say they have done their part and


Sen. Byron Dorgan

Sen. Jay Rockefeller IV

that any additional taxes or fees would harm small operators at the nation's smaller airfields. Sen. Byron Dorgan (D-N.D.), chair of the aviation subcommittee, told the Senate floor of the value of small aircraft—"to travel around the state and the country to do commerce, to haul parts, to haul people." Sen. Jay Rockefeller IV (D-W.Va.), chairman of the Senate Commerce Committee, said "airports are economic engines for many small communities, and everyone, everywhere, needs to be connected to our national air transportation system."

Missing from both bills is language that mandates installation of monitoring cameras on the flight decks of airliners. Several recent incidents, including one fatal crash, have been blamed on pilot inattentiveness, and safety officials favor cameras that would supplement existing voice recorders. Pilots and privacy advocates oppose installing cameras, and the idea is on hold for now.

The biggest difference between the two bills relates to an ongoing debate about unionization within the airline and air cargo industry. The House bill would make it easier for FedEx employees to organize locally into union chapters. FedEx opposes this language, while their rival UPS supports it. The conflict is expected to set up a difficult conference between the two branches of the legislature, because the Senate bill contains no language on the issue.

The Senate measure includes provisions aimed at improving cockpit safety, including pilot rest rules and a law against pilots using laptops, cell phones and hand-held devices while piloting. The measure also strengthens a federal rule, scheduled to take effect April 29, forbidding planes in most situations from sitting unmoving—and loaded with passengers—for more than 3 hr on the tarmac. Major airlines object to the 3-hr federal rule, citing backups at New York-JFK when a runway is down. Critics say the rule is the wrong approach to the problem of being stranded on the runway: Airlines simply cancel flights to keep from breaking the rule, adding to crowding and frustration at airports.

Robert F. Dorr
robert.f.dorr@cox.net

Andrew Brookes

Every time there's an important military aircraft acquisition decision, in either Europe or the U.S., it always seems to end up in a major controversy. How can we manage the process better?

It's the law of unintended consequences. In the U.S. and here at one time there were quite a few manufacturing companies. People could choose and competition could reign. But after consolidation, we arrived at one or two companies in the U.K. and not many more in the U.S. So when a really big contract is opened up to tender it might only involve a single company—which means if you lose that contract it suddenly looks as though Boeing, or whoever, is going to opt out of the fixed-wing market. Soon there will just be two major facilities in the U.S. for making military aircraft—Fort Worth and Seattle. Ten or 15 years ago they were everywhere.

So you start by looking for efficiencies, but you end up with just one or two market players. When the C-17 closes down in Long Beach, who will be left in the heavy-lift transport business in the U.S.? I can see the A400M becoming the great transport aircraft of the USAF.

There are better ways of doing it—but it's not easy to do when you are trying to save money and give value to the taxpayer.

And with globalization you have the ridiculous situation where Boeing is trying to be the U.S. tanker leader against the wicked Europeans, when Boeing is widely subcontracting across the Pacific. Boeing is arguably not much more American when it comes to components than the EADS/Northrop Grumman aircraft. It's just that one is trading on its past and the other is trying to make up ground.

But it's not just the recent tanker bid—it seems we still don't know how to procure military aircraft in general.

It's because everything now is a system. The temptation is to hang more and more bells and whistles on the system. You can now hang so much capability on an aircraft in the 10 to 15 years it takes to develop it.

How do you get around that? You can't set the program in aspic. In many ways the capability of the Eurofighter Typhoon, for example, was set in 1986. If you bought all the components for the aircraft in 1986, and we bought quite a few Motorola chips then for Eurofighter, they would now be totally useless. So you have the dilemma about when to buy, as over 10 years there is so much change. For example, the F-22 is a good example where there is so much obsolescence built in that you end up with not the aircraft you planned in the first place.

But a military tanker isn't like that.

If there is anything that should be easy to do, it's an A400M. I remember being briefed at the start of the A400M program by EADS staff. "We can design it like an airliner," they said. "We'll agree on the design on the computer—where you are going to place the doors, for example—and 48 months later you will have your aircraft." But of course it isn't like that. Because it's then that the politics come into the program—from the politics of "you mustn't close the aircraft factory in my state" to the politics of "you mustn't have a Pratt & Whitney engine on it." Even though it's not high technology it's the political interference that stops these programs from progressing as they should.

So the answer to the question is to take politics out of the equation and go to the marketplace and buy what you want. But I'm not naïve enough to think that's how the business works.

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Politicians have a duty to protect the country's strategic industrial base and technical know-how. By going to the open market you can lose valuable skills and knowledge—some would argue that has already happened in the U.K., where we have lost our space technology capability, for example. So is there a better way to protect a skills base without distorting the market? The current system is not working—with the Joint Strike Fighter, for example, there are still client countries trying to access the software they will need to operate the aircraft in the way they want.

If you look at what's happened in the U.K. with the helicopter sector, you had a government minister, Lord Drayson, respected by everyone in the industry, who said that in exchange for receiving major orders the U.K. manufacturer would have to set up centers of excellence in the U.K. at Yeovilton. This was an idea that was also agreed to by the Italian partner who brought over the design office from Rome. But look what happens. The minister leaves and the whole strategy falls apart. If you look at the major international helicopter orders recently, they've gone to Sikorsky, to everybody, in fact, apart from those based in the U.K.

It's back to joined-up thinking. The folks who are issuing the contracts for search and rescue aren't necessarily the military who have signed up to the defense industry strategy—the Treasury [the U.K.'s government finance department] aren't signed up either, they just want value for money. So how do you get all the stakeholders to sign up to the strategy? If the strategy is to keep all these core skills within your country, it will only work as long as people keep buying the kit. And as we haven't had any money to keep buying the kit, we

Interview by Philip Butterworth-Hayes

have not been keeping the strategy going. It's fallen flat on its face.

Are we becoming more protectionist, on both sides of the Atlantic?

The U.S. certainly—all this ITAR waiver issue is nothing to do with technology issues; it's to do with keeping jobs. I've been somewhat appalled, as someone half American, that there is this perception in the U.S. that it's not the American way to do the terrible things we do in Europe such as subsidizing our industries. But everyone does it. The loss by EADS/Northrop Grumman of the tanker contract was a classic piece of *dirigiste* policy—the French could have done it, but with much more panache.

It's not the way to do business. The B2 contract keeps going because the government has deliberately contracted out work on the B2 to each of the 50 states. So you know you have 50 states signed up to the program. It might make political sense but it does not make any industrial sense—the best suppliers might be in just five states.

It's a great shame because increasingly protectionism will now rise in Europe as a result [of the KC-X tanker decision], which for someone like me, dedicated to moving on, is very sad. It will give ammunition to those Europeans who should know better but who will now say: "We tried the American market, with the presidential helicopter, with the tanker, but when we win fair and square suddenly the goalposts are changed." They will now start saying "why bother?" That worries me because as taxpayers we will all lose and the vested interests will win out.

So where does that leave the global aerospace industry, especially in the wake of the recent World Trade Organization ruling [on European government grants to Airbus]? Will it mean that every contract will now become even more political, even more influenced by government-to-government relations and less about what the end user really wants? Is that where we are heading?

We are heading to a world which we in the West have not really thought through. We're really Western focused—the U.S. vs. Europe—and in the meantime the real advances are being made in the Far East. While we are squabbling over these matters there are remarkable advances being made there.

"We're really Western focused—the U.S. vs. Europe—and in the meantime the real advances are being made in the Far East."

The received wisdom is that China is just very good at copying and that's it. The reality is China is very, very good at copying. The latest Chinese helicopter gunship is powered by a Pratt & Whitney engine they acquired via Canada. This will continue to happen, irrespective of any embargoes.

Airbus has already given China Airbus wing technology for the older Airbus wings, but as I said to Airbus: "If you are giving them the technology, don't you think that in 15 years' time they will be beating you in composites?" Once you give away the technology, even older technology, they will soon be adding the new technology themselves.

What worries me is that we will become too involved in these trade issues between the U.S. and Europe. Chinese military aircraft and the weapons they carry are becoming awesome, and they have acquired them through throwing money at the industry. China plans to put a man on the Moon by 2020. There

After graduating from Leeds University in the U.K., Andrew Brookes completed Royal Air Force pilot training and then logged 3,500 flying hours on reconnaissance and strike tours. He then joined the triservice policy and plans staff of Commander British Forces, Hong Kong. After serving on the HQ Strike Command Plans staff, and then in charge of the multiengine, training and rotary wing desks in the Inspectorate of Flight Safety, he was appointed as the last operational RAF commander at the Greenham Common cruise missile base.

He spent a year studying international relations as fellow commoner at Downing College, Cambridge, before becoming a group director at the RAF Advanced Staff College and then coordinator of air power studies at the Joint Services Command and Staff College. He earned an Open University MBA in 1995 and was trained in management consultancy at the Civil Service Staff College. His final tour was in Ministry of Defence Consultancy and Management Services.

From 1999-2009 Brookes was an aerospace analyst at the International Institute for Strategic Studies in London before being appointed as director of the Air League, an organization that seeks to influence U.K. government policy on behalf of the aviation industry.

will also be superb long-range fighters, supported by all the necessary infrastructure and support assets, over the Taiwan Straits by 2020.

If you are in the market for a new fighter you will soon be asking: "Do I really want to buy a JSF with all the caveats or should I get one from Beijing at half the price?" The U.S. is becoming too prescriptive in what it does with U.S. technology.

Was there any way EADS/Northrop Grumman could have won the deal?

They did win it—it was taken off them. I was talking with U.S. chiefs of staff and they said it was their job to give the U.S. public the best product. They said they were not beholden to any company but that their job was to pick the best product for the U.S. Air Force. They went through an exhaustive procedure and concluded that this [the EADS/Northrop Grumman KC-45] was the best product for the Air Force, at a time when they really needed the asset as soon as possible.

The same thing with the presidential helicopter—no one gave that contract to the Europeans because they owed the Europeans anything. They gave it to Europe because it was the best aircraft. Still, what happened? They wanted to strap new equipment on the aircraft. They said, "You've doubled the price," but that only happened because they wanted to strap new equipment on it. So it then became an issue of how can you have an American president flying an Italian helicopter?

But the WTO issue didn't help EADS in the tanker contract.

But that's just a smokescreen to me. There are subsidies all over the place. No one would live in California if the water wasn't subsidized. There are vast subsidies going into communities in the U.S. that would otherwise be unsustainable; I don't see anything wrong with that. But the idea that somehow subsidies only happen in Europe is wrong.

In terms of the WTO, it is true that the Europeans were at fault, but the idea that the pristine U.S. had just been taken to the cleaners is wrong.

But these trade issues have to be properly regulated. In Europe we are moving toward a more openly regulated defense market with the development of the European Defence Agency and the commission's increasing involvement in this area. Would it be possible to set up an organization to regulate transatlantic trade, an open and fair market—or is that just not possible?

No, it's possible. The market should be the market. The market should rule—the winners should survive and the losers should go to the wall. Airbus started off with a great deal of help but it did get to the stage where it was winning against Boeing on its own merits. You can argue: Would it have got that far without government support? Well maybe not. But once it was up and running it was winning contracts on merit and continuing to win on merit.

Everyone subsidizes, but the idea of bringing bureaucrats to try to regulate it is pure Soviet Union. It doesn't work.

But my point is that we should learn from what has happened and try to put in place a new regime that would look at issues such as the ITAR waiver and what constitutes fair and unfair subsidies. There must be a better way of organizing it.

The WTO is the way. That's where it should be, through processes such as the Doha rounds, which develop procedures we can all sign up to. Unfortunately, the Doha round proved that we are getting poorer at sorting out these issues, not better, because of all the other baggage that comes into world trade talks.

Until recently, far from there being more cooperation since the fall of the Berlin Wall, there seem to be more arguments on issues such as missile defense—an area very conducive to a level playing field—which is a great shame, because we could all end up chasing just one aircraft contract because the process has become so expensive.

What is slightly strange about all this is that operationally we are becoming much better at sharing assets, especially tankers, which are being used in Afghanistan and elsewhere. For example, Australian tankers are fueling aircraft from many of the different coalition forces. At an operational level we're much more advanced, and at the acquisition level we seem to be retreating.

Defense is the last pork barrel in town. As a politician the only lever you have left to pull is defense.

If you were running a European aerospace company now, the biggest market will still be in the U.S., but there are new threats coming from the Far East. How would you align the business to exploit the opportunities and defend yourself against threats? The selling opportunities are narrowing.

The BAE Systems answer is that you opt out of making aircraft and concentrate on systems. In many ways that's a very creditable argument—but to me that means that after Typhoon we will no longer make an aircraft in the U.K. I find that rather sad. But the trend is that manufacturers in the Far East will make the aircraft, and it's pointless trying to undercut them because they will always be able to beat you.

But that's not where the value is in the supply chain.

No, there's no value in that; the value-added is in the systems. The aircraft will be increasingly made outside

"But the trend is that manufacturers in the Far East will make the aircraft, and it's pointless trying to undercut them because they will always be able to beat you."

and they'll be shipped to the U.S. to be riveted. But that won't last for long.

How long will that last?

Once Far East competitors learn how to make the whole wing they will make it themselves and sell it. Now the competition for the U.S. tanker is between the U.S. and Europe, but in 20 years' time there could well be a Chinese competitor. And it won't just be a tanker, it will have all the latest fittings—like the latest tanker for the United Arab Emirates, which will be delivered with an Etihad airline interior. This will be their value-added. They will also fit it out as an aerial communications and command post aircraft—so suddenly it won't just be a tanker, it will be a tanker, transporter and communications platform as well.

Is one of the problems for politicians that the technology is now becoming so complex—the strategic thinking required for buying network-enabled capabilities is so difficult and the platforms themselves are becoming less important in the overall scheme of delivering a capability? Understanding that and putting it in a political context is very difficult.

The problem is, politicians are fighting next year's war the whole time. They are fire-fighting immigration issues or health care and the only money left, in the U.K. at least, is for the current war in Afghanistan. People like me are saying "don't forget the next war, which will come as sure as God made little eggs."

What wise people need to do is set up a structure that will tick over until you need it, which means you buy things as they do in the civil world, on the open market. I think we've gone too far in the U.K. in not having a strategy that says to the local police chief, "I'm sorry but you have to give preference to European or U.K. assets to maximize the industrial base until the time it is really needed."

But isn't that what is happening in the U.S.?

Yes, but not in the U.K.

And in France, too?

Yes. They wisely worked out that they need to invest in an infrastructure that can expand when the war comes. No one knows what it's going to be—but we need to have in place the right people to make the right decisions.

Space shuttle: An astronaut looks at its legacy

THE SHUTTLE COUNTDOWN CLOCK STOOD at "L-minus-three," three launches remaining—as engineers were able to deal with the helium isolation valve leak found in Discovery's right maneuvering system pod in time for an April launch, and President Obama had not yet announced whether an additional launch, or launches, would be scheduled.

Reports of the orbiter fleet's retirement may still be premature. I have a feeling that this year and next we'll see several "final" shuttle launches.

We are nevertheless nearing the end of the shuttle's long career, an appropriate moment to examine the craft's historic and complex legacy. Even after 30+ years of atmospheric tests and orbital missions, the shuttle's outstanding characteristics have yet to be matched by other space vehicles. The shuttle orbiters expanded our human capabilities in space a hundredfold.

But the spacecraft, built by human hands, is an imperfect creation. Compromised by tight budgets and conflicting requirements, its career has been twice marred by terrible tragedy. By recognizing how it has fallen short of its promises, and building on its many successes, we can make the next generation of spacecraft safer, more efficient and better suited to the demands of future exploration.

Born in compromise

During its 30 years in service, the shuttle has averaged about four launches per year. Its large crews (up to eight astronauts) have made it the initial route to space for about 61% of the 509 human beings who have left the planet. But at its conception in the late 1960s, its future was by no means assured.

President Richard Nixon, swayed by his budget director, Caspar Weinberger, approved the shuttle's development early in 1972. The project was underfunded from the start (a $5-billion budget target eventually swelled to nearly four times that), and NASA struggled to find a design that was both affordable and attractive to the widest spectrum of launch customers.

Carrying just two passengers, Columbia lifted off for the first time on STS-1, on April 12, 1981.

To get the Pentagon to designate the shuttle as the sole launcher for the largest national defense payloads, NASA agreed on an orbiter with a 60x15-ft cargo bay, far larger than necessary for most scientific or commercial satellites. Air Force requirements were also responsible for the orbiter's expansive delta wings. They delivered the hypersonic cross-range performance for a first-orbit, high-inclination satellite deployment from Vandenberg AFB, California, followed by an immediate reentry and landing back at the base.

Although the larger wings and payload bay required a bigger (and more vulnerable) heat shield, the orbiter could then haul impressively large payloads to orbit. The shuttle can launch 15,900 kg to the 51.6°-inclination orbit of the space station, and routinely returns 9,400 kg of cargo from the ISS in the Italian-built MPLM. By contrast, the ESA-built automated transfer vehicle delivers 7,385 kg to ISS; the JAXA HTV, 6,000 kg; the Russian Progress, 2,350 kg. The cramped Soyuz can return a mere 60 kg of cargo from ISS. Even when commercial cargo services debut in 2011, the shuttle's truck-like hauling capacity will be sorely missed.

The shuttle has been the classroom in space for two generations of NASA's engineers, scientists and managers. Its frequent flights, steadily advancing capability and long career have built a bridge that has supported the nation's space operations talent pool until the agency's path could match its long-held ambitions.

Carrying just two pilots on its first four shakedown flights, each lasting only a few days, Columbia and its companions gradually expanded NASA's experience base in LEO. Beginning with relatively simple launches of commercial communications satellites, the fleet expanded its capabilities to national defense payloads and satellite rescue and repair. Commercial cargoes were dropped from the STS manifest after Challenger's loss in 1986, but the orbiters stayed busy with a wide array of scientific missions, everything from planetary probe launches to repeated flights of ESA's long-duration Spacelab module.

Flexible, reusable science platform

In the nearly 20 years between its debut and the start of ISS construction, the shuttle served as a versatile science platform, hosting an astounding array of experiments and major payloads, both in-cabin and in the cargo bay. With launch costs approaching half a billion dollars per liftoff, science customers could have found a cheaper route to space. But the orbiters did offer a reliable platform with robust power, pointing and communica-

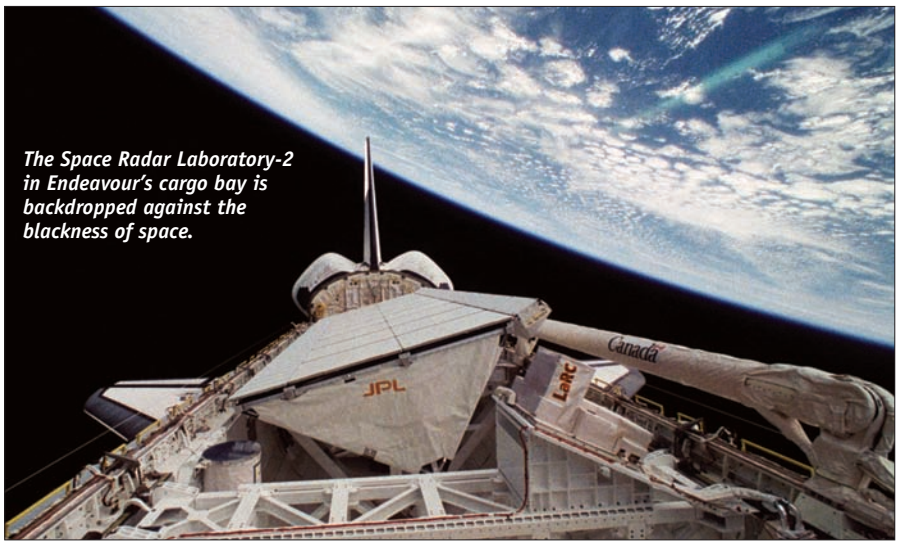
tions budgets, and they could return science payloads to Earth for refurbishment and reflight. A purely robotic space science program would not hire the shuttle as a launcher. But the shuttle's expansive capabilities for meeting national security and human spaceflight priorities allowed it to be made available for science.

My two flights with the Space Radar Lab in 1994 were good examples. SRL included an advanced, multifrequency imaging radar (http://www.jpl.nasa.gov/radar/sircxsar/) to map the changing face of our planet. Its 40x12-ft antenna weighed 21,380 lb; if flown as a free-flyer it would have required a maneuverable satellite bus, 10-kW solar arrays, and a high-bandwidth communications system. On STS-59, however, Endeavour provided pointing, power and communications; the crew conducted over 400 separate target-tracking maneuvers and captured the avalanche of digital imagery on high-capacity tape cassettes.

Best of all, the shuttle enabled the radar to fly twice more, each mission more capable than the last, culminating in the shuttle radar topography mission (SRTM) in 2000. SRTM created a near-global high-resolution digital terrain map of Earth's land masses, a product still being used by our military forces and in civil aviation cockpits.

The list of high-value science and security payloads carried by the shuttle is a long one, including Spacelab for long-duration science investigations in LEO; planetary probes such as Magellan, Galileo and Ulysses; the unmatched Hubble Space Telescope; and military payloads such as the Defense Support Program satellites. (In addition, 11 classified shuttle missions launched a variety of defense or intelligence collection craft.)

The astronauts accompanying these cargoes were also capable of dealing with balky payload systems that might have threatened loss of mission. The crew on STS-37, for example, freed the Compton Gamma Ray Observatory's stuck high-gain antenna, and the STS-51I astronauts brought the circuitry of the comatose Leasat-3 satellite back to life after the four months it spent adrift in LEO. On-orbit repair capabilities culminated in complex "catch and release" operations such as the 1992 Intelsat VI rescue and the stunning recovery of Hubble's optical performance. STS-61 in 1993 restored the telescope's flawed optics, while four subsequent visits replaced its failing systems and upgraded its scientific capabilities to a level never imagined by its designers.



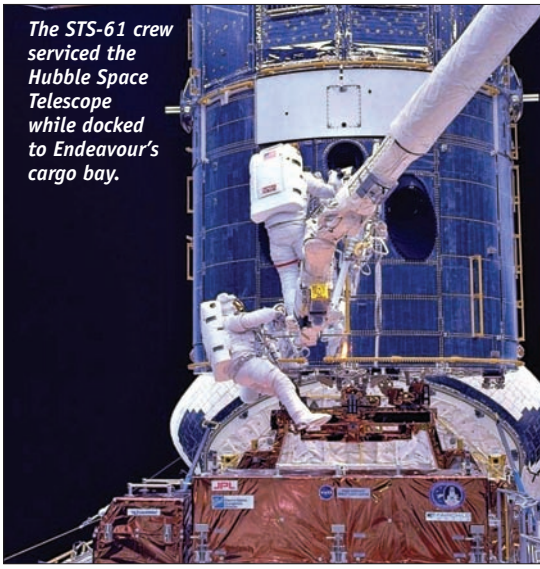
The Space Radar Laboratory-2 in Endeavour's cargo bay is backdropped against the blackness of space.

Not your father's space shuttle

Seventeen years of robotic, EVA and rendezvous experience positioned NASA to begin space station construction in December 1998, when Endeavour joined America's Unity docking node to the Russian-built Zarya module. Building an orbiting station was one of the earliest tasks envisioned for the shuttle, but not until nearly two decades after its first flight did ISS construction actually begin. During those decades when the nation's future in space was not at all clear (a situation in which we find ourselves again today), the shuttle nurtured larger ambitions while providing a stream of research results and invaluable operations experience.

From its inception in 1984, the ISS project depended on the versatile skill set of the shuttle fleet. The orbiters delivered, using all their unique capabilities—large upmass, precise proximity operations and complex robotics and EVA functions—to tackle this ultimate mission.

With construction now more than 90% complete, the station incorporates three active research laboratories and a six-person crew. Shuttles delivered the bulk of the structure, most of its supplies (including tons of fuel-cell-derived water), all manner of experiments and outfitting hardware, and a steady stream of multinational astronaut crews. The end product is an outpost that now tops 800,000 lb in mass, spans 356 ft, and encloses 12,000 ft^3 of pressurized volume, equivalent to a five-bedroom house.


The STS-61 crew serviced the Hubble Space Telescope while docked to Endeavour's cargo bay.

Astronaut Nicholas Patrick participates in the mission's third and final spacewalk as construction and maintenance continue on the international space station. During the spacewalk, Patrick and astronaut Robert Behnken completed all of their planned tasks, removing insulation blankets and launch restraint bolts from each of the Cupola's seven windows.

There are many ways to build a space station, but without the shuttle, the one circling 200 mi. above Earth for the past 11 years would never have materialized. As the ISS approaches 10 years of continuous occupancy, the shuttle is arguably the one tool whose existence was essential to the permanent habitation of humans off the planet.

Brilliant but flawed

In 30 years, no nation has matched the space shuttle's capabilities, adaptability and flexibility. But after two horrifying accidents that claimed the lives of 14 crewmembers, shuttle astronauts take an "eyes-open" approach to the vehicle's shortcomings. The design compromises of the 1970s gave the shuttle large delta wings (protected by thousands of brittle heat shield tiles) and stacked the orbiter next to millions of pounds of explosive liquid and solid propellants. The crew escape system, a minimal bailout capability added after the 1986 Challenger accident, ties the crew's fate to that of the orbiter itself.

In 1986, and again in 2003 after Columbia's loss, NASA examined proposals for an escape "pod" that could rocket the crew clear of a crippled orbiter. But the cost of such a major modification was deemed prohibitive. Post-Columbia, the shuttle would fly for at most five more years, NASA thought, so forgoing an upgraded escape capability seemed an acceptable risk. Ill-informed congressional talk of adding shuttle missions to close the LEO access gap consistently skirts this life-and-death issue. The U.S. owes its astronauts a better chance at survival than the current orbiter can offer.

The shuttle has other shortcomings as well. The external tank thermal insulation and orbiter tiles are vulnerable to severe weather damage on the launch pad, and to debris impacts during ascent and orbit. The orbiter's inability to withstand the impact of raindrops in flight (without suffering severe tile damage) has caused months of cumulative launch delays. Although NASA has been recertifying critical orbiter systems over the past few years, the aging of the fleet means thorny problems are sure to keep turning up, from corrosion and damaged wiring to balky valves and propellant system leaks. The shuttle's Achilles heel has always been the intensive (and expensive) maintenance required for turnaround; that factor is bound to worsen if extension becomes reality.

Each time I flew in space, I believed—I think correctly—that I was strapping into the best maintained, most thoroughly vetted vehicle that human beings could ready for launch. In 2010, I believe the machine is in even better shape, with respect to the operations team's corporate knowledge and the skill of its maintainers. But shuttle managers are aware that the storied spacecraft is always just one serious in-flight anomaly away from being grounded in its tracks.

Learning from the shuttle

Even if it stopped flying tomorrow, the shuttle has written volumes full of hard-won lessons advancing the science of human spaceflight. Some of the "Do" lessons: Do design for crew safety and robust escape capability. Split cargo and crew when feasible, to enhance crew survival. Design for minimum life-cycle costs, anticipating a service life measured in decades. Do enable your human crew with provision for robotics and EVA. Design for ease of future upgrades to computers, communications and human interfaces.

The "Don't" lessons are even more valuable: Don't expect multiple users to guarantee cost savings or streamlined operations. Don't assume reusability is a cost saver—it can limit upgrades and raise turnaround costs. Don't carry landing gear and wings to orbit and back unless a runway landing is truly a mission requirement. Don't keep your vehicle sitting exposed on the launch pad for weeks. Don't retire your sole downmass capability until you have a replacement payload return system ready.

Spacecraft designers will use the shuttle as a case study for decades to come.

Into the orbital sunset

Today, the space shuttle approaches its final missions at the top of its game. For

STS-59, the author's first shuttle ride, began on April 9, 1994.

30 years, albeit at great human and economic cost, it has provided unmatched capability for U.S. ambitions in space. On the day it retires, the nation will lose a significant portion of its preeminence in space. When we will see its equal in orbit again is impossible to predict.

Of greater importance than the loss of specific capabilities will be the question of whether we can retain the talent pool and collective experience that built and maintained the orbiter fleet. The near-term answer from the administration seems to be no.

Whatever direction the nation adopts for human spaceflight, we should not assume the capabilities lost at shuttle retirement will be easy or cheap to resurrect. NASA will not have the budget to build a beyond-LEO transportation system *and* replace the shuttle's many capabilities. Instead, the commercial sector should be asked to provide some mix of the shuttle's attributes, as part of a broad LEO services contract.

This new orbiter would take on EVA and robotic operations that cannot be performed at ISS. Ideally, the successor would reside on-orbit, robotically serviced and refurbished. Its crews would visit only temporarily (bringing their reentry vehicle along) to carry out high-value repair, rescue or assembly tasks. This orbital work platform could be reconfigured for various tasks, then upgraded and expanded as new technology makes economic and operational sense.

The first time I felt the three main engines roar to life under me, the first time I felt twin solid rocket boosters jolt and rattle my body to the bone, I was in awe of the space shuttle. Indeed, I felt somehow indebted to this machine—and the people who designed, built and operated it—for enabling ambitious tasks to be tackled in space, and for bringing me home at mission's end. Perhaps I overlooked its shortcomings too easily. But when Americans see these magnificent vehicles up close at Udvar-Hazy and other museums across the country, we should swell with justifiable pride.

The shuttle gave us incredible competence and sophistication in space operations. It seasoned us with the maturity needed to take on the space challenges of a new century. The shuttle's matchless legacy should inspire us to craft machines even more versatile, able to carry explorers far beyond the orbiters' lofty reach. Their lasting record of accomplishment, and that of the team that made it possible, deserves nothing less. The final call of "*Houston, wheels stop*" should be only the beginning of an exciting new story in space.

Thomas D. Jones
Skywalking1@gmail.com
www.AstronautTomJones.com

Trainer aircraft: Long-term hopes for growth

For years, the trainer market has been the smallest segment of the world aviation industry, with annual deliveries in the $1 billion-$2 billion range and few hopes for growth. The introduction of new products and the appearance of new requirements for light attack and advanced jet trainers provide some hope, but only one program offers genuinely impressive numbers.

A difficult market

While the fighter aircraft market grew at a compound annual growth rate of 5.7% between 2003 and 2009 (in value of deliveries), the trainer market registered no growth at all. Several factors have kept the trainer market from growing along with combat aircraft demand.

Although force structures and training requirements have remained intact, air forces inevitably give trainer acquisitions the lowest priority. Combat and surveillance assets always come first, and trainers are at the bottom of the list. As a result, trainer fleets are kept in service for a very long time. There are plenty of Saab 105s, Cessna T-37s, Northrop T-38s and myriad other old planes still in service. Even Israel, with its top-class air force, relies on ancient Fouga Magisters and TA-4s. In 2008, the country decided to rely more on T-6 turboprops, a low-cost departure from its traditional reliance on more capable jet trainers.

Also, as simulators have improved (largely through software advances), they have taken over a greater percentage of the pilot training regime. As modern fighter aircraft have become more "forgiving," pilot training increasingly emphasizes information and systems management, rather than aerial flight skills. This too means more simulator work for pilots, and less actual trainer flying.


T-6


Hawk

Meanwhile, more countries are outsourcing their training requirements, sending pilots to private schools, other countries or shared trainer services such as NATO Flying Training In Canada (NFTC). Of course, shared fleets like these have much greater aircraft utilization rates than national fleets, considerably reducing aggregate demand. Since shared trainer programs offer a commodity service, they do not care what plane does the job, just so long as it meets the requirement. They are more likely to use secondhand aircraft such as AlphaJets or Impalas.

Despite all these downward pressures on the market, one positive catalyst for growth has emerged. Like its forebear the F-22, Lockheed Martin's F-35 Joint Strike Fighter is distinguished by a purely single fighter configuration. Unlike almost all jet fighters built, the F-35 does not come as a "B" model, with room for two pilots. Therefore pilots now need to transition directly from an advanced jet trainer to an F-35 solo flight. This increases the need for a truly superior high-end advanced jet trainer with a relatively seamless transition capability. That means, among other factors, a cockpit that is compatible with the F-35's.

Yet even before the other downward pressures impacted the market, trainers were the smallest turbine-powered aircraft segment—worth between $1 billion and $2 billion a year. Over the next 10 years, the market will stay at about this level. Teal Group forecasts a world market for 1,550 turbine-powered trainers worth $14 billion over the next 10 years, up (and down) from 1,383 worth $14.4 billion in 2000-2009 (all in constant 2010 dollars). However, this excludes the T-50 and any supersonic trainers that may be delivered. We include these in our jet combat aircraft forecast.

A high-end resurgence?

For years, the high end of the trainer market was dominated by BAE's Hawk. Since 1989, over 50% of the jet trainer market has been controlled by the Hawk and Boeing's T-45 Goshawk, a license-built derivative used by the Navy for carrier training.

However, Alenia's Aermacchi unit has introduced the M-346, an advanced jet trainer aimed directly at the Hawk's share of the market. Launched by the Italian air force, the M-346 has also been selected by the United Arab Emirates for its longstanding 48-unit trainer requirement. As of this writing, the UAE contract has not yet been firmly signed, and has been delayed by negotiations over price.

Meanwhile, South Korea has begun manufacturing and operating the T-50A


T-50

Golden Eagle, the first dedicated supersonic trainer built since Northrop's T-38 ended production in 1972. Designed by Korean Aerospace Industries and Lockheed Martin, the T-50 is also being derived into two combat versions, the A-50 attack jet and the FA-50 fighter. So far, the only firm customer is South Korea.

Since the UAE is technically still up for grabs, the T-50 might have a chance there (although the M-346 remains the likely winner). Beyond the UAE, Singapore has an imminent competition between the M-346 and T-50, a supersonic trainer built by Korea. Also looking at a new trainer buy is Saudi Arabia, whose large Hawk fleet will need replacement sometime this decade.

Europe has the biggest problem with aging trainers, and 12 European countries have been contemplating a shared trainer fleet. In December 2001 they agreed to create an Advanced European Jet Pilot Training program, also known as Eurotraining. Aircraft selection had been scheduled for 2009 but has been delayed. Funding for this effort is highly uncertain, despite big plans to couple it with a new Eurotrainer aircraft.

This year the situation seems as hopeless as ever, with the U.K. purchasing additional Hawks and Italy going with M-346s. In the interim, European nations will continue to coast on legacy fleets, joint training with U.S. services (through the original shared fleet, the Euro-NATO Joint Jet Pilot Training program) and other training services (such as NFTC). This may prove difficult as Eurofighter and F-35 come on line, increasing the required level of sophistication.

Meanwhile, even Russia is boosting the high-end market: After decades of relying on an aging fleet of Czech-built Aero Vodochody jet trainers, it has begun procurement of the Yakovlev Yak-130. The first production Yak-130 was delivered to Lipetsk air base in February.

USAF: LAAR and beyond

While high-end training offers some limited opportunities for aircraft primes, the USAF has announced plans to buy a few squadrons of turboprop light attack aircraft for counterinsurgency warfare. In July 2009 the Air Force announced a CRFI (capability request for information) for its Light Attack and Armed Reconnaissance (LAAR) program. A contract is expected this year. The program will involve procurement of 100 aircraft, with deliveries beginning in 2012. Additional LAAR aircraft could be procured for National Guard units, especially as older fighters are retired.

Meanwhile, similar smaller requirements have emerged for the Iraq and Afghanistan air forces. Afghanistan will take six firm and 14 option planes under the light air support requirement. Iraq took delivery of the first of eight Hawker Beechcraft T-6s in December 2009. It will likely take additional T-6s, including the AT-6 attack version. The AT-6 prototype first flew in September 2009.

Also in September 2009 Hawker teamed with Lockheed Martin to pursue the LAAR competition with the AT-6. The other leading candidate is Embraer's EMB-314 Super Tucano. Boeing proposed restarting production of its OV-10 Bronco, which had ended in 1976.

It is important to note, however, that LAAR and its cousins will provide only an incremental level of market demand. Production of 200 light combat aircraft over five years means just $500 million a year in business. This will barely compensate for the conclusion of USAF T-6 procurement.

The return of T-X

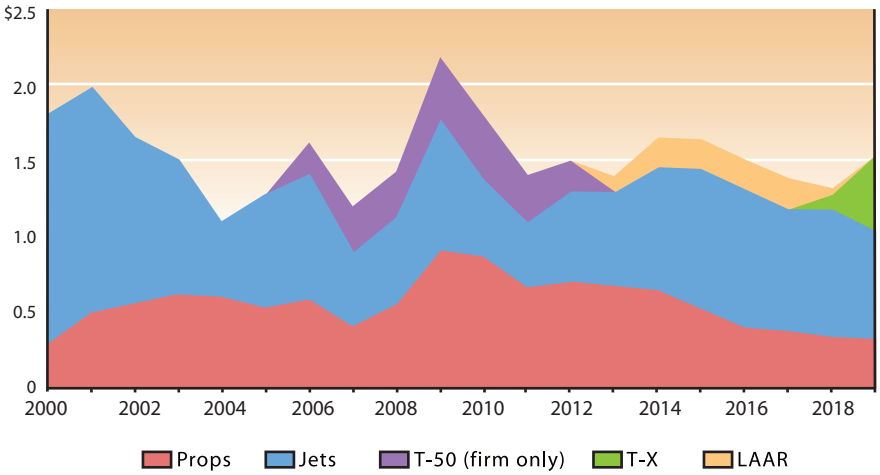
The one possible catalyst for significant trainer market growth is the USAF's T-X program. For years, the service maintained that it did not need new advanced jet trainers until after 2020. While the last T-38 had been built in 1972, the service's fleet of over 500 T-38s had received a steady stream of upgrade work over the past 15 years. This involved new wings, major engine and engine housing work, and a digital cockpit upgrade. The planes had been redesignated T-38Cs, and looked set to enjoy 50+ year lifespans.

However, there have been serious problems with these fixes, and with T-38 reliability in general. After five safe years, two T-38s were lost in crashes in May 2008, followed by an Air Force decision to ground the fleet temporarily. Another T-38 crashed in May 2009.

Because of these incidents and other factors, the service has decided to accelerate the T-X, which will replace the T-38. New plans call for a request for proposals in February or March 2011, with a downselect to two teams scheduled for September 2011. This will be followed by prototype demonstrations, culminating in an award to a single contractor in October 2012. The plan calls for T-X initial operating capability with 12 aircraft in late 2017. Our forecast, however, calls for an 18-month schedule slip,

(Continued on page 25)

WORLD TRAINER/LIGHT ATTACK MARKET SHARES
Share by 2010 $billion value



Israeli UAVs find a competitive edge

ISRAELI UAV COMPANIES HAVE RACKED UP an impressive series of victories in recent months, demonstrating their competitive strength even when large U.S. budgets and procurements should bolster their American competitors.

A number of U.S. allies recently have turned to Israeli companies to meet their UAV urgent operational requirements in Afghanistan. Poland announced in February that it would buy

Aeronautics Defense Systems' Aerostar UAV for a $30-million contract to provide reconnaissance and surveillance in Afghanistan. In winning the contract, its competitive field consisted of only two other Israeli companies—Elbit Systems and Israel Aerospace Industries (IAI).

In October Germany rejected a purchase of General Atomics' Aeronautical Systems Predator B in favor of leasing IAI's Heron. The Netherlands signed a $50-million agreement in March to lease Aeronautics' Aerostar system.

With these most recent agreements, at least eight armed forces in Afghanistan will be using Israeli UAVs they have either purchased or leased. The Canadian, French, German, Australian and Spanish militaries will be using IAI's Heron. The Dutch and Polish armed forces will be using the Aerostar and the British military is using the Elbit Hermes 450.

Germany's Heron agreement was only the most recent lease of Israeli systems for urgent operational requirements in Afghanistan. Five of the European militaries are now using leasing of Israeli systems to meet their needs.

Innovative services

In focusing on the export market, Israeli companies have come up with innovative leasing services that offer customers rapid access to UAVs. This has been extremely important recently in light of urgent operational requirements in Afghanistan. While Boeing has been active in doing leasing for tactical UAV services, unlike IAI no U.S. company has been offering leases of large tactical and MALE (medium-altitude, long-endurance) systems.

Aeronautics signed the first leasing contract with the Israeli Defense Force in 2001, says Itay Sherman, director of marketing communications for the company. That three-year contract for UAV services enabled the IDF to use Aeronautics' Aerostar UAV as needed. IAI had its own leasing contract with the IDF. That early experience enabled Israeli companies such as IAI to refine the concept, says Uzzi Rozen, president of IAI International, the U.S. arm of IAI.

This innovative marketing approach is only one element of the way Israeli UAV companies are succeeding in being competitive against a larger and better financed U.S. industry.

A head start

Israeli UAV executives point to their early presence in the market and three decades of experience. "We were the first," Rozen points out. "Being without any competition [for a long time] is a big advantage."

Israeli companies came into the market before U.S. and European companies could develop their own systems. Early on that even led to sales of Israeli systems such as the Pioneer and the Hunter to the U.S. military. This head start has enabled Israeli companies to build up impressive lists of international customers. For example, IAI has customers in 20 countries.

Elbit, Israel's other UAV giant, also cites Israel's long experience as a key advantage. Israel and Elbit understood the advantage of UAVs long ago, says Haim Kellerman, executive vice president and general manager of Elbit's Unmanned Aerial Systems Division. "We started fighting the war of terror long ago, and UAVs are a good tool."

Sharing technology, funding R&D

Israeli companies also began gearing early for the export market. While U.S. manufacturers have a windfall of orders to meet the demands of U.S. forces in Iraq and Afghanistan, the Israeli armed forces cannot support three companies contending for the domestic UAV market—IAI, Elbit Systems and Aeronautics Defense. Export orders are essential if all the Israeli companies are to survive.

Thus they have often been more willing than U.S. companies to be more aggressive in their pricing and provide technology transfer to customers, according to Israeli executives. Israeli companies also pursue joint research programs with foreign customers to bolster their own research funding. "Since UAVs are a strategic asset, each country wants to have the technology," and does not want to have to rely on another country for it, says Kellerman. So Elbit works to help each customer become self-sufficient.

"We understand that without sharing our capabilities with local industry, we are dead," says IAI's Rozen.

The Israeli approach to remaining competitive involves generous amounts of company-funded R&D money, often considerably more than their U.S. coun-


Skylark

terparts spend. IAI targets 4% of revenues for its research funding. Elbit spends 8% of its revenues on R&D, an exceptionally high level for a defense company.

Company strengths

Each Israeli company has a different strength. IAI is tremendously strong in the MALE market through its Heron. Elbit has considerable clout in tactical and small UAVs through its Hermes family and Skylark I and II UAVs. Aeronautics, the smallest of the three, has focused on tactical UAVs.

Yet each company is using its robust UAV funding to introduce products that would enable it to compete across the spectrum of UAV capabilities. Elbit has just developed its new Hermes 900 to address the MALE market. It is also looking at larger vehicles, says Kellerman. As customers seek to use UAVs for different missions such as electronic intelligence, communications intelligence and maritime patrol, it is important to develop larger UAVs.

In addition, Elbit has been improving its current tactical and small UAVs. Over the past several years it has introduced the Hermes 90 tactical UAV and the Skylark long-endurance small UAV, and is continuing the Hermes 450 upgrade by adding new engines.

IAI, which builds the Search III tactical UAV, is developing the I-View, a new family of tactical UAVs, as well as the Mosquito, a micro air vehicle weighing only about 1-2 lb, depending on its configuration, says Rozen. In addition, the company has a mini-UAV that comes in three versions.

Even Aeronautics, a much smaller private company, offers a mini UAV and a tactical UAV and is also in the process of developing its own MALE UAV, the Dominator.

Strangely, this intense competition between Israeli companies has strengthened the country's UAV industry, say several Israeli executives. There is no sense of having an indefensible market niche when another Israeli company is always trying to penetrate it. Having such expertise in multiple companies provides synergy as well as the competitive edge to drive a very competitive industry, Sherman says.

Variety and completeness

Creating a broad array of UAVs also gives Israeli companies an advantage in marketing their products. For example, once a customer has bought a Skylark UAV from Elbit, the company can develop the customer intimacy to aggressively market Hermes 450, or vice versa.

"It is important to have the full range to give the customer a variety of UAVs for different missions," says Kellerman. IAI offers the full array, from 1 lb to 10,000 lb, says Rozen. This is fundamentally different from the approach used by U.S. companies that generally specialize in one or two niches in the market rather than offering a broad choice of UAVs.

Israeli firms also offer complete UAV systems. There is no need to go to separate companies for the air vehicle, avionics, electrooptical and/or radar payloads, datalinks and ground station. Elbit and IAI both offer integrated solutions. This approach offers advantages for optimizing the performance of each unmanned aerial system, says Kellerman.

Cost advantages

This approach of having one company do everything, with the vehicle and the payload viewed as a single package, also translates into greater affordability, says IAI's Rozen. Systems such as the Heron emphasize affordability in other ways, he adds. In addition to cost, there is a benefit to having only one supplier to go to for system support.

Elbit's family approach allows the use of a common infrastructure such as a ground station between different UAVs.

WORLD UAV EXPENDITURES FORECAST ($Millions)

R&D	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
U.S.	1,520.0	2,200.0	2,100.0	2,300.0	2,250.0	2,100.0	2,100.0	3,600.0	4,100.0	4,700.0	26,970.0
Rest of world	510.0	590.0	650.0	725.0	770.0	805.0	850.0	910.0	1,100.0	1,300.0	8,210.0
TOTAL R&D	2,030.0	2,790.0	2,750.0	3,025.0	3,020.0	2,905.0	2,950.0	4,510.0	5,200.0	6,000.0	35,180.0
Procurement	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**Total**
U.S.	2,020.0	2,775.0	2,435.0	2,045.0	2,160.0	2,620.0	2,545.0	3,030.0	3,320.0	3,370.0	26,320.0
Rest of world	877.4	1,172.4	1,341.4	1,584.0	2,055.8	2,286.9	2,185.6	2,456.2	2,431.5	2,181.9	18,572.9
TOTAL procurement	2,897.4	3,947.4	3,776.4	3,629.0	4,215.8	4,906.9	4,730.6	5,486.2	5,751.5	5,551.9	44,892.9
Total expenditures	**4,927.4**	**6,737.4**	**6,526.4**	**6,654.0**	**7,235.8**	**7,811.9**	**7,680.6**	**9,996.2**	**10,951.5**	**11,551.9**	**80,072.9**


Heron

Israeli companies also recognize the need to compete aggressively in the U.S. market, the world's largest. Teal Group's newly issued *World Unmanned Aerial Vehicle Systems 2010: Market Profile and Forecast* estimates that from 2010 to 2019 the U.S. will account for $30 billion of the $35.2 billion spent worldwide on UAV R&D. The U.S. will also account for $26.3 billion of the $44.9 billion spent on UAV procurement worldwide.

Targeting the U.S. market

The importance of the U.S. market is particularly pronounced now. The U.S. will spend $2 billion of the $2.9 billion spent worldwide on UAV procurement in 2010, according to the Teal Group study. It also will spend $1.5 billion of the $2 billion spent on UAVs in 2010.

That makes it essential for Israeli companies to be present in the U.S. market. Elbit has established itself there through Elbit Systems of America, a business that has been developed through a string of acquisitions in the U.S. dating back more than a decade. Last year Elbit also set up a joint venture with General Dynamics Armament and Defense Products, targeted at penetrating the U.S. UAV market. That venture put in its first bid as one of the competitors in a hotly contested Navy and Marine Corps small tactical UAS competition. For the competition, Elbit introduced the Hermes 90, a robust, deployable UAV.

IAI also has a history of teaming in the U.S. to win competitions, having worked, for example, with Northrop Grumman on the RQ-5 Hunter UAV. IAI established its Stark Aerospace subsidiary in Starkville, Mississippi, so that it would have the presence it needs to win U.S. military and homeland security programs. In particular, it is interested in competing with General Atomics Aeronautical Systems' Guardian variant of the Predator B for a Coast Guard maritime requirement. IAI also demonstrated the capabilities of its Heron for a possible antidrug role in Central and South America, the Caribbean and the Pacific in trials for the U.S. Southern Command in El Salvador during a month-long demonstration that ended in May 2009.

Despite these successes, there have also been setbacks. IAI and Elbit recently paid a steep penalty for Heron deliveries being two years behind schedule. They attributed the problems to the contractual requirement that they integrate a heavy Turkish payload on the UAV that


Hermes 450

was incompatible with the system. In September 2008 a team of IAI and Boeing Australia lost a contract with Australia to provide the I-View 250 following technical problems and a delay of more than two years.

Still, the Israeli companies appear to have resolved their problems. IAI and Elbit paid a penalty to the Turkish government. Moreover, Australia was sufficiently interested in IAI's UAVs that it contracted with the company to provide its MALE services in Afghanistan.

Despite massive UAV budgets in the U.S., Israeli firms believe that continuing their current strategy will enable them to survive growing U.S. competition.

Israeli companies recognize the difficulties ahead in the market. U.S. firms are increasingly focusing on the export market, and one or two European UAV competitors will likely emerge in coming years. "We used to be the only ones in the world," says Rozen. "The main challenge [now and in the future] is to operate in such a saturated market."

Focus on selling points

The approach Israeli UAV companies are adopting is to continue to elaborate strategies concentrating on performance, affordability and customer needs. "We have to excel in order to succeed," says Kellerman.

While U.S. industry is now competitive, European industry continues to lag, offering a larger market that Israeli firms have been very successful in exploiting. Indeed major European countries have often turned to Israeli industry for their UAV development needs. In a joint venture, Thales and Elbit are developing the Watchkeeper tactical UAV system for the U.K. army. France turned to IAI in its development of the Eagle 1 system, now deployed in Afghanistan.

IAI argues that part of its competitive appeal comes from its focus on reliability and safety. The same engineering group that developed manned aircraft for IAI also developed its UAVs. That has helped reassure customers about the safety of the aircraft. Indeed the company was the first to get the approval to operate its UAVs at a regular airshow, the Singapore airshow, six years ago, Rozen says.

Elbit Systems' approach has been to focus on the UAV as a tool for gathering information. That makes the command, control, communications, computer and intelligence system critical. Elbit's approach is to make the system easy to use, to ensure that operators are able to focus on actual operation of the system to exploit its intelligence. With a very smart platform with autonomous systems, operators can focus on the payload.

Philip Finnegan
Teal Group
pfinnegan@tealgroup.com

(Continued from page 21)

based on reasonable expectations of budget availability.

Beyond the baseline T-X requirement, which will cover 350 aircraft, the Air Force might buy another 150 T-Xs to replace its T-1 fleet. The T-1s are relatively new Hawker Beechjets procured in the 1990s to train tanker and transport pilots. However, if the Air Force decides to merge training of transport/tanker and fighter/bomber pilots, T-Xs would be tapped to do the job.

There is also the potential for a light attack adaptation, a kind of follow-on to LAAR, but more robust and capable. This could even be used to help maintain the USAF combat aircraft force structure

M-346

as older types retire and if the F-35 proves too expensive to be purchased at the currently planned rate. Also, the Navy may purchase a navalized carrier version to replace the T-45 Goshawk.

The total requirement for T-X and those notional adjunct programs could be as high as 1,000 planes. This includes the 350-500 baseline T-X trainers, 200 carrier versions for the Navy, and 200-300 light attack versions.

If the Air Force adheres to the new schedule, T-X will be filled by an existing aircraft. This is particularly true since the Air Force budget has no money for new trainer aircraft development.

Therefore, unless the Air Force delays the program to make way for a new competitor, there are basically three (somewhat predictable) candidate T-X designs: the Hawk, M-346, and T-50. While the Hawk cannot be ruled out, it is a rather old design and will probably be eliminated from the competition fairly quickly. The two remaining competitors have very different strengths and weaknesses.

The T-50 has two great strengths. First, it is the only new supersonic trainer on the market. However, there are no clear indications that the Air Force wants supersonic flight training to be part of the post-T-X training syllabus. The second T-50 strength is that it already has an important U.S. backer, Lockheed Martin. In addition to a significant Washington presence, the company has access to possible manufacturing sites across the U.S. It can decide to put its line in any politically expedient location.

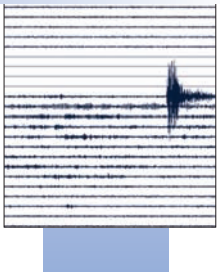
The M-346, by contrast, would likely need a U.S. partner for domestic assembly. However, it does offer considerably lower acquisition and operating costs. Alenia Aermacchi is also gaining considerable experience creating an M-346-based training system for the Italian air force. Also, as a subsonic plane, the M-346 might be more appropriate for any light attack requirements. This is particularly true since current plans call for the integration of an active electronically scanned array (AESA) radar, which would be useful for combat missions. The M-346 is the world's first trainer/light attack aircraft to be offered with AESA.

As a subsonic plane, the M-346 would be far more appealing to the Navy for carrier training, while the T-50 may not be suited for this role at all. However, T-X is not a joint program, and the Air Force is under no obligation to take note of Navy concerns when making an aircraft selection.

Over the next few years, the trainer market offers several respectable prizes, both in the U.S. and international markets. If nothing else, it offers actual undecided new programs, and most defense primes are hungry to bid on any kind of new platform. And at a procurement rate of 48 planes a year, T-X has the potential to add $1 billion-$1.5 billion a year to a $1 billion-$2 billion a year market. That represents nearly 100% growth.

However, until USAF T-X procurement begins, there are no real drivers behind sustainable market growth. The industry continues to be hobbled as well by overcapacity, particularly at the high end of the market.

Richard Aboulafia
Teal Group
raboulafia@tealgroup.com



Measuring change in Earth's wobble

PICTURES OF WIDESPREAD DEVASTATION leave no doubt: The 8.8-magnitude earthquake that struck coastal Chile on February 27 was strong. How strong? NASA scientists say it might have shifted the axis of Earth itself.

"If our calculations are correct, the quake moved Earth's figure axis by about 3 in. [8 cm]," says geophysicist Richard Gross of JPL in Pasadena, Calif.

You might think you would have noticed the Earth suddenly tilting 3 in. But that is not how the "figure axis" works. "The figure axis defines not how Earth is tilted, but rather how it is balanced," explains Gross.

Consider the following: The planet is not a perfect sphere. Continents and oceans are distributed unevenly around the Earth. There is more land in the north, more water in the south, a great ocean in the west, and so on. Because of these asymmetries, Earth slowly wobbles as it spins. The figure axis is Earth's axis of mass balance, and the spin axis wobbles around it.

"The Chilean quake shifted enough material to change the mass balance of our entire planet," Gross says.

A shifting figure axis is nothing new. On its own, the figure axis moves about 10 cm per year as a result of "Ice Age rebound." After the last great glacial period some 11,000 years ago, many heavy ice sheets disappeared. This unloaded the crust and mantle of the Earth, allowing the planet to relax or "rebound" back into a more spherical shape. The rebounding process is still under way, and so the figure axis naturally moves.

Measuring a seismic shift

The February Chilean quake may have moved the figure axis as much in a matter of minutes as it normally moves in a whole year. It was a seismic shift.

So far, however, it is all calculation and speculation. "We have not actually measured the shift," says Gross. "But I intend to give it a try."

The key is GPS. "Using a global network of GPS receivers, we can monitor the rotation of Earth with high precision," he says. He explains that changes in Earth's spin and the orientation of Earth's axes affect the phase and timing of signals we get from the satellites in Earth orbit.

GPS already monitors the seasonal changes in the planet's spin. Factors such as tides, winds, ocean currents and circulation patterns in the planet's molten core modulate its rotation on a regular basis. For instance, a typical day in January is about 1 msec longer than a typical day in June. The roughly six-month variation is driven mainly by seasonal winds. There are also changes on time scales of weeks, years, decades and centuries.

Earthquakes throw a "spike" into GPS signals, and Gross believes he can find it. "I have to take the GPS Earth rotation measurements and subtract the effects of tides, winds and ocean currents," he says. "Then the earthquake should stand out."

In addition to GPS, researchers use VLBI (very long baseline interferometry) to monitor Earth's rotation and figure relative to the quasars at the edge of the universe.

The real news

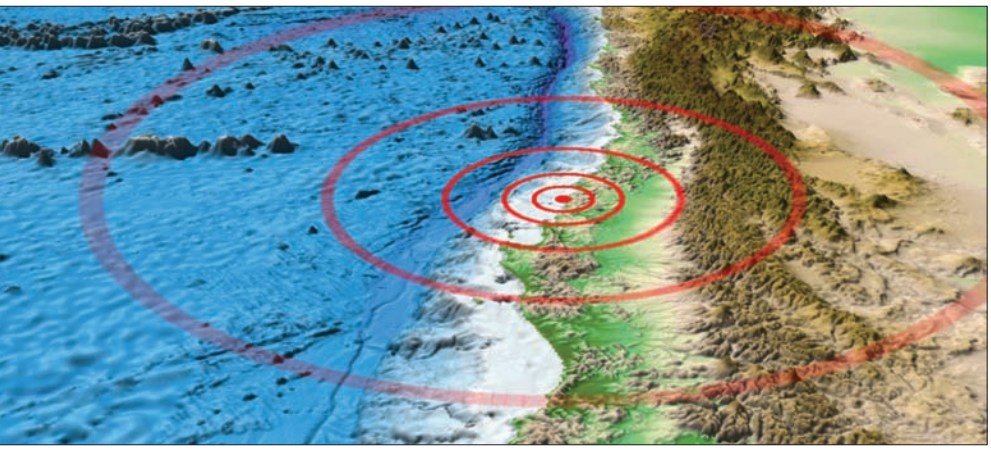
Recent news reports have focused on Earth's length of day, noting that the Chilean quake might have shortened days by as much as 1.26 microsec out of 24 hr. That is true. But it is also negligible compared to the normal effect of wind and tides, which can lengthen or shorten days a thousand times more than earthquakes can.

The real news, as Gross sees it, is the possible shift in Earth's figure axis. The geophysicist has a very "JPL perspective" on the issue: "The antennas we use to track spacecraft en route to Mars and elsewhere are located on Earth. If our tracking platform shifts, we need to know about it."

No one has ever measured a shift in Earth's axis due to an earthquake before. Back in 2004, Gross looked for a shift from the magnitude-9.1 quake in Sumatra, but failed to find a signal. The Sumatra quake was less effective in altering Earth's figure axis because of its location near the equator and the orientation of the underlying fault. The Chilean quake, albeit weaker, may have produced a bigger shift.

The stage is set for discovery. "Computing power is at an all-time high. Our

Scientists will map the rupture site of the 8.8-magnitude earthquake in Chile. Credit: Jared Kluesner, David Sandwell, SIO/UCSD.



The research vessel Melville will take advantage of an unprecedented opportunity. Credit: SIO/UCSD.

models of tides, winds and ocean currents have never been better. And the orientation of the Chilean fault favors a stronger signal."

In a few months Gross hopes to have the answer.

A century-old mystery

In 2000 Gross offered a solution to one of the wobbles manifested by the spinning Earth: the century-old mystery of Earth's "Chandler wobble." The phenomenon is named for its 1891 discoverer, Seth Carlo Chandler Jr., a U.S. businessman turned astronomer. The Chandler wobble is one of several wobbling motions exhibited by Earth as it rotates on its axis, much as a top wobbles while it spins.

Scientists have been particularly intrigued by the Chandler wobble, whose cause has remained a mystery even though it has been under observation for over a century. Its period is only around 433 days, or just 1.2 years, meaning it takes that amount of time to complete one wobble. The wobble amounts to about 20 ft at the North Pole. It has been calculated that the Chandler wobble would be damped down, or reduced to zero, in just 68 years, unless some force were constantly acting to reinvigorate it.

But what is that force, or excitation mechanism? Over the years, various hypotheses have been put forward, such as atmospheric phenomena, continental water storage (changes in snow cover, river runoff, lake levels or reservoir capacities), interaction at the boundary of Earth's core and its surrounding mantle, and earthquakes.

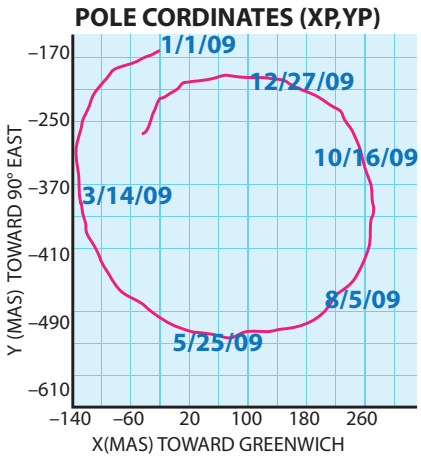
Writing in the August 1, 2000, issue of *Geophysical Research Letters*, Gross reported that the principal cause of the Chandler wobble is fluctuating pressure on the bottom of the ocean, caused by temperature and salinity changes and wind-driven changes in the circulation of the oceans. He determined this by applying numerical models of the oceans to data on the Chandler wobble obtained during the years 1985-1995. These numerical models had become available only recently through the work of other researchers. Gross calculated that two-thirds of the Chandler wobble is caused by ocean-bottom pressure changes and the remaining one-third by fluctuations in atmospheric pressure. He says the effects of atmospheric winds and ocean currents on the wobble are minor.

Monitoring Earth's rotation

Gross credits the wide distribution of the data that underlay his calculations to the creation in 1988 of the International Earth Rotation Service, based in Paris. Through its various bureaus, he writes, the service enables the kind of interdisciplinary research that led to his solution of the Chandler wobble mystery.

The International Earth Rotation and Reference System Service (IERS) is tasked with monitoring the irregularities of the Earth's rotation.

The variability of the Earth-rotation vector relative to the body of the planet or in inertial space is caused by the gravitational torque exerted by the Moon, Sun and planets, displacements of matter in different parts of the planet and other excitation mechanisms.



The normal wobble of Earth's axis since January 2009 is reported by the International Earth Rotation Service. The grid is scaled in milliarcseconds, one of which equals 1/3,600,000 deg.

The observed oscillations can be interpreted in terms of mantle elasticity, Earth flattening, structure and properties of the core-mantle boundary, rheology of the core, underground water, oceanic variability and atmospheric variability on time scales of weather or climate. Understanding the coupling between the various layers of our planet is also a key aspect of this research.

Several space geodesy techniques contribute to the permanent monitoring of the Earth's rotation by IERS. For all these techniques, the IERS applications are only one part of their contribution to the study of planet Earth and the rest of the universe.

The measurements of Earth's rotation are under the form of time series of the so-called Earth Orientation Parameters. Universal Time (UT), polar motion and the celestial motion of the pole (precession/nutation) are determined by VLBI. The satellite-geodesy techniques, GPS, satellite laser ranging and DORIS (Doppler orbit determination and radiopositioning integrated on satellite) determine polar motion and the rapid variations of UT.

The satellite-geodesy programs used in the IERS give access to the time variations of Earth's gravity field, reflecting the evolution of the globe's shape, as well as the redistribution of masses in the planet. They have also detected changes in the location of the center of mass of the Earth relative to the crust. This discovery makes it possible to investigate global phenomena such as mass redistributions in the atmosphere, oceans and solid earth.

UT and polar motion are available daily with an accuracy of 0.5 mas (milliarcseconds), and celestial pole motion data are available every five to seven days at the same level of accuracy. This estimation of accuracy includes both short-term and long-term noise. Subdaily variations in UT and polar motion are also measured on a campaign basis. Past data, going back to the 17th century in some cases, also are available.

Exploring the rupture site

JPL's researchers are not the only scientists interested in the consequences of the Chilean earthquake. Others, funded by the National Science Foundation (NSF) and affiliated with the Scripps Institution of Oceanography (SIO) at the University of California at San Diego, are undertaking an expedition to explore the rupture site of the 8.8-magnitude quake, which was one of the largest in recorded history.

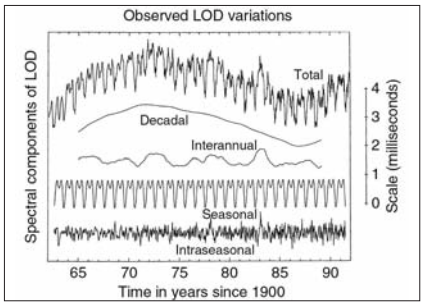
The scientists hope to capitalize on a unique scientific opportunity to capture fresh data from the event. They will study changes in the seafloor that resulted from movements along faults and submarine landslides.

The "rapid response" expedition, called the Survey of Earthquake And Rupture Offshore Chile, will take place aboard the research vessel Melville. The Melville was conducting research off Chile when the earthquake struck.

"This rapid response cruise is a rare opportunity to better understand the processes that affect the generation and size of tsunamis," says Julie Morris, NSF division director for ocean sciences. "Seafloor evidence of the quake will contribute to understanding similar earthquake regions worldwide."

The rapid response mission includes swath multibeam sonar mapping of the seafloor to produce detailed topographic maps. Data from mapping the earthquake rupture zone will be made public soon after the research cruise ends, Morris says.

The new information will be compared with prequake data taken by scientists at Germany's Leibniz Institute of Marine Sciences (IFM-GEOMAR).



The chart shows observed changes in Earth's length of day caused by tides, winds, ocean currents and other factors. (From Treatise on Geophysics, *2007, section 3.09, "Earth Rotation Variations—Long Period" by Richard Gross.)*

Several years ago IFM-GEOMAR researchers conducted a detailed multibeam mapping survey off Chile. Their data will be valuable for comparisons with the new survey to expose changes from the earthquake rupture.

"We would like to know if the genesis of the resulting tsunami was caused by direct uplift of the seabed along a fault, or by slumping from shaking of sediment-covered slopes," says Dave Chadwell, an SIO geophysicist and chief scientist of the expedition. He says they will look for disturbances in the seafloor, including changes in reflectivity and possibly shape, by comparing previous data with the new rapid response data.

The rapid response cruise is possible because Melville is currently in Chilean waters, where a research team has been conducting an investigation of the geology and biology of the Chilean margin.

"This is a unique case in which we have the shipboard assets, the scientific agenda and the funding all in place," says Bruce Appelgate, associate director for ship operations and marine technical support at SIO. "The earthquake was a tragedy for the people of Chile, but we hope this opportunity enables important new discoveries that can help us plan for future events."

The logistical details of undertaking the expedition are enormous and constantly evolving because of uncertainties regarding transportation infrastructure in Chile. Port facilities are limited by widespread earthquake devastation, which has made fueling and provisioning the ship difficult.

Chadwell and SIO scientist Peter Lonsdale, plus graduate students Jared Kluesner and Ashlee Henig, and Scripps Geological Data Center analyst Aaron Sweeney will be aboard Melville for the eight-day expedition.

The scientists, along with Scripps researchers Mike Tryon and Mark Zumberge, also will deploy depth sensors on the seafloor to record possible abrupt vertical motions over the next year.

Joining the U.S. scientists will be Chilean researchers Juan Díaz and Matias Viel González from Universidad Católica in Valparaíso, as well as scientists from IFM-GEOMAR.

Edward D. Flinn
edflinn@pipeline.com

NextGen

A slow transformation

The technologies needed for making the Next-Generation Air Transportation System a reality are already available, says the FAA. But real progress, which so far has been frustratingly slow, will depend on cooperation by all stakeholders—and, as always, on funding.

The past two decades have seen the rapid evolution of several new technologies that are already having an impact on commercial air traffic management. In 2004, the Dept. of Transportation announced the Next-Generation Air Transportation System (NextGen), an effort to transform U.S. air traffic management (ATM) by bringing those technologies together in a unified new system.

NextGen, a partnership of the FAA, industry, NASA and the Departments of Defense, Commerce and Homeland Security, calls for a three-phase program, in the near term (through 2013), midterm (2013-2018) and far term (2018 and beyond). These efforts also are to be coordinated with the Single European Sky ATM Research (SESAR) program of the European Organization for the Safety of Air Navigation (Eurocontrol) and other international ATM organizations and modernization programs.

"The aviation industry—from the makers of planes to the people and companies who fly them, from foreign air navigation service providers to local airports—all agree that, with adequate resources, we, government and industry can work together to bring NextGen to implementation in 3-5 years instead of the 10-15 years that is currently pegged," Aerospace Industries Association president and former FAA administrator Marion Blakey told a symposium on ADS-B (Automatic Dependent Surveillance-Broadcast) last fall.

"So, what is holding us back? Funding. Not an inconsequential barrier when you consider the economy, the state of the airline industry and multiple priorities weighing on the administration and Congress."

Changing conditions

When NextGen was inaugurated, air travel was at a peak, with growth expected to continue at a significant pace. Boeing and Airbus had new jetliners under development to help airlines increase and modernize their fleets. That influx of new aircraft was expected to help speed NextGen implementation by incorporating required airborne capabilities with the initial purchase rather than as retrofits.

Anticipating such developments, some airlines had begun including GPS and other advanced system capabilities in aircraft they purchased as early as the mid-1990s. According to the Air Transport Association (ATA), some aircraft already are being retired with equipment the airline was never able to use.

"The industry has spent hundreds of millions of dollars on NextGen already. All the aircraft developed in the last several years had NextGen technology built into them. At one point, that was probably optional equipment; today it is standard, so it is hard to calculate that cost," says ATA vice president for operations and safety Basil Barimo, the association's NextGen technology lead.

"And airlines are investing in upgrades to existing aircraft, such as new displays, flight management systems and GPS capability. I don't have a specific number, but it is probably north of $1 billion when you add in new deliveries and retrofits."

Estimating costs

From the beginning, estimates for the total cost of NextGen were roughly $40 billion, split about evenly between government and industry—half for ground infrastructure, half for airborne equipage. With changes in both

by **J.R. Wilson**
Contributing writer

"The operators are saying, before they equip with the next generation of technology, they would like to see some benefits from what they've already invested in, which will go a long way toward making the case for further investments."

Margaret Jenny, president, RTCA

technology and political leadership, however, the estimates have become somewhat murky.

"Those numbers were created several years ago, and I really don't have any new numbers to cite, but I don't think we want to rely too heavily today on that $20 billion," says Michael Romanowski, the FAA's director of NextGen Integration and Implementation. "We're continuing to refine the expenditures required, but they will be significant on both the government and industry side. If you look at the 2010 budget request, that is somewhere around $6 billion-$7 billion in the next five years."

Industry is concentrating on near-term costs, trying to ensure that what is spent now puts both sides on the right path and schedule. As a result, a primary focus is on ADS-B and Area Navigation (RNAV), considered NextGen front-end components.

Gauging results

But progress to date, Barimo says, has been "a huge disappointment" to the airlines, aircraft manufacturers and the business and general aviation communities. "We saw an investment of several billion in NextGen as really smart, when you consider the benefits associated, the jobs that would be created and the fact it would put us at the leading edge of this new capability compared to the rest of the world—and so in a position to export the technology and services," he says.

"It made perfect sense, so the airlines were absolutely frustrated that the government spent tens of billions on high-speed rail development that, if it ever brings real benefits, is decades away, while we had something that could generate real benefits, add capacity and remove a lot of delay and frustration to the flying public in a few years."

A helicopter takes off from a Gulf of Mexico platform.

The airlines are even more unhappy about increasing tariffs and taxes to pay for the government's side of NextGen.

"That is not an acceptable way to fund our nation's aviation system. We should have a funding mechanism that is equitable and reliable and provides for investment in new capacity and capability," Barimo argues. "The key there is equity. The system today collects money from airline passengers to subsidize the use of the system by others. If we use 70% of the FAA's services, we should pay for 70%, not 94%, as it is today."

Romanowski says NextGen is on schedule and on budget for nationwide deployment of major components by 2013, with ADS-B now installed and operational in south Florida, performing aircraft separation in the terminal phase for the first time in Louisville, Ky., and, as of January 2010, in the Gulf of Mexico.

"Any equipped aircraft flying at altitude, but more significantly the helicopter community [servicing offshore oil rigs], will have surveillance coverage in the gulf for the first time, interfaced with the en route host system," he says. "In February, we will go operational with ADS-B in the Philadelphia area, a terminal environment integrated with STARS [Standard Terminal Automation Replacement System]. And in April, we have Juneau integrating ADS-B with MicroEARTS." (Philadelphia is now live.)

Commenting on those plans in mid-January, Blakey expressed the mixed feelings that have begun to permeate the industry's view of NextGen: "While we are greatly encouraged by the progress demonstrated so far, there is still much to be done. Congress has opportunities in the jobs bill and the FAA reauthorization to promote accelerated implementation of NextGen and incentivize further investment in our aerospace infrastructure. We estimate the total number of direct and indirect jobs generated by an approximate $6-billion investment in NextGen equipment at more than 150,000 through 2012, with 30,000 jobs generated the first year."

Among the most outspoken critics of the FAA's efforts in general and NextGen in particular is aviation consultant Michael Boyd, president of Boyd Group International: "We

get the same speech from the FAA every year, see no results, then say we're making progress. But at the end of the day, we're no further ahead than we were in 2000, when Bill Clinton dragged airline presidents to the White House and said we're going to end delays."

"We have a new FAA administrator, new Transportation secretary, RTCA report—but no results. They point to ADS-B—which is late. Where are the results to give the nation the air transport results it needs? There aren't any. The one iron-clad, unshakable truth is they haven't made any progress in 20 years. None," Boyd notes.

Task Force report

Boyd was referring to the final report of the RTCA Task Force on NextGen Mid-Term Implementation, issued on September 9, 2009. The task force was created in January 2009 at the request of the FAA to develop a community-wide consensus on NextGen operational improvements to be implemented through 2018, with a focus on how to maximize benefits to justify industry investment.

"We came up with a set of recommendations that are very airportcentric, starting at the surface and making traffic safer and more efficient on the runways, then using the existing capacity of the runways—focusing on airports with closely spaced parallel runways—and using those to the full extent before trying to do new things," RTCA president Margaret Jenny tells *Aerospace America*.

Next would be "moving out to metro areas with multiple airports and using technology to let them operate independently, so problems at one airport don't affect the others. If you can reduce delays at the airports, you go a long way toward reducing problems system-wide," says Jenny.

The report says an incremental implementation of en route procedures and data communications (datacom) would allow for more direct, user-preferred routes, increase air traffic controller productivity and reduce errors associated with voice communications. For example, controllers would be able to reroute multiple aircraft around weather with a single push of the button rather than dealing with each individually.

"Every piece of technology must be linked to an operational capability that delivers new capacity. So it isn't just putting in new equipment on the ground or on the plane, but being able to fly differently—better routes, reduced separation among aircraft, etc. You have to go all the way to the operational capability and not just have infrastructure programs. That was a pretty loud, clear message from the task force," Jenny says.

Next Gen technologies are under test in many different labs. Image courtesy Lockheed Martin.

"The big focus is on RNAV, in which some have invested heavily. That requires new routes, procedures, training, potentially even some changes to airspace, all of which are beyond technology—if we can't get them done, we don't get benefits. [Airlines] are saying they already have some of this equipment and so far are not seeing all the things that need to be accomplished for them to get full benefits."

"Things are going forward aggressively, with a lot of progress on the ground infrastructure side."

Michael Romanowski, director, NextGen Integration and Implementation, FAA

The report also concludes that the FAA already is well positioned, from a budget perspective, to implement its recommendations, which Jenny says require little, if any, new infrastructure. "A lot of what is being asked for is procedures, streamlining processes, training, potential airspace modifications, etc. That's step one," she says. "As we move into midterm and beyond, they need to finish what is currently planned, such as the en route automation system to accommodate Datacom. In accommodating the recommendations, they may need to reprioritize what they are doing, but it doesn't call for any new programs.

"The airlines might be looking at some upgrades to their flight planning system to take advantage of some of this, which would be the major ground infrastructure investment. For airborne, the majority of near- and midterm really depends on how a carrier's fleet is currently equipped. Some already have RNAV, some Datacom. Getting to midterm is a minimal investment for the airlines, while getting to long-term is a substantial investment."

NextGen will provide controllers the tools they need to safely handle the projected steady increase in air traffic forecast through 2025 (operations are expected to increase 1.2% a year at TRACON facilities, 1.3-1.9% a year at towers, and 2.4% a year at ARTCCs, according to the FAA Aerospace Forecast, Fiscal Years 2009-2025).

Next steps

The primary short-term goal is to map the task force recommendations into the FAA's current plan. This may involve what RTCA terms slight modifications within each time frame. The most significant of those would be moving to an airport-centric approach, implementing as much NextGen technology as possible—with accompanying procedural changes and training—within a few major metropolitan areas, rather than following the original national deployment plan.

"This may be a tough challenge, but really—what are we waiting for? The challenge is clear and the way forward is plain; we have the technologies and we can garner the resources if we have the political will."

Marion Blakey, president, Aerospace Industries Association, and former FAA administrator

Collaboration with the airlines is considered critical to success. This would include the development of technical standards to be followed, not only for the FAA NextGen system, but worldwide.

"We [in RTCA] work, often on joint committees, with our counterparts in Europe and with ICAO," Jenny says. "At the concept level, there also is work between the FAA and Eurocontrol to come out with harmonization between NextGen and SESAR. A lot of work has been done to compare those two and keep them in synch."

Because the RTCA report focused on near- and midterm issues, in which new standards were not an issue, it did not really address harmonization, despite a large number of international carriers on the task force. While standardization has always been a driver in global aviation, she notes, the seven months the group had in which to complete its work was not enough to permit a thorough mapping against international efforts.

"We want to ensure what we deploy is fully interoperable with what is being deployed in other regions of the world," Romanowski adds. "It doesn't make sense to have systems that are incompatible and force aircraft to be dually equipped. So we are spending a great deal of effort to develop harmonized standards for elements of NextGen and SESAR.

"We work very closely with our partners, from the regulatory environment for national standards to a broader international framework, such as ICAO. We also use groups like RTCA and EUROCAE [European Organisation for Civil Aviation Equipment] to help us develop the technical standards for avionics, for example."

Keeping up with Mongolia

In some ways, having no major legacy ATM system has been an advantage for certain nations in developing NextGen-like systems of their own. "While we have a great infrastructure that has worked well, it also makes it more challenging for us to transition to a new system. China and India don't have that extensive infrastructure in place, so it is relatively easy for them to embrace some of this new technology and capability," Barimo explains. "Frankly, Mongolia has a more advanced system than we have in the U.S.

"We're anticipating those nations will continue to move aggressively on this and will have a system we envision as NextGen in place before us. It's not really who gets there first, but that we are all heading in the same direction. A major concern by the airlines is we end up with different requirements in different parts of the world. So we want to make sure whatever way nations move, we all move toward the same objective." Barimo believes that is happening at this point, with the world embracing ADS-B and RNAV, which are significant for global harmonization.

Maintenance, money and politics

Another concern for ATA is the cost of continuing to pay for upkeep on the current ATM system even as it is being replaced.

"We have a network that is, in some cases, nine layers deep in the U.S. that we won't need when we complete this transition," Barimo says. "Today, the vast majority of the money the FAA spends goes to maintaining the current system instead of investing in new capability. And that is part of the chal-

lenge, because it will become political.

"These [legacy] installations are in all 50 states, in almost every congressman's district, providing high-paying jobs for their constituents. So when we talk about consolidation of facilities, we've already seen politics come into play. For the military, the BRAC [base relocation and closure] process has provided an answer to a similar type of process; that might be valuable at some point."

Many in industry were concerned by the slowness of the administration in naming its new secretary of transportation and FAA administrator—and even more so by the lack of funds devoted to NextGen in the president's trillion-dollar economic stimulus plan. Randy Babbitt, who was the original RTCA Task Force chairman before being named FAA administrator, has pledged to make NextGen his number-one priority, but some in industry are not sure he has sufficient backing from the administration or Congress.

"I think the fact the stimulus money did not come pouring into NextGen has a lot to do with us failing to make our case on what the return on investment might be," Jenny says. "I agree things could be expedited, accelerated; but we have to accelerate the delivery of benefits, not just programs or equipage. So it is a complex, integrated problem.

"I would agree we need to have much more explicit, measurable near-term goals than we have had. So far, NextGen has been too far out in the distance in actually being able to deliver benefits to those being asked to invest; 2025 is pretty hard for an airline losing money today to care about. What is important to focus on is getting the first phase done, which will help incentivize investment in the next phase."

Romanowski says NextGen has "incredibly strong support from the administration and Congress and the stakeholders," but while some technologies have been available for a decade or more, it is essentially a new program.

"It is a large-scale integration issue, integrating technology into a system that is operating at an extremely demanding pace today. We have to have the right policies, the right procedures, the right technologies, the right commitment—not just from the FAA, but from the operators, manufacturers, airports—and the right political environment. But," he contiues, "it is achievable."

The role of industry

Making NextGen a reality also depends heavily on how the airlines approach whatever changes they must make, in areas including pilot training and on-board equipment.

"If we have an 85% solution with existing technology, we should go ahead and implement that and not wait until we have the 100% solution, even though that might require a lot bigger investment in the next increment of that technology," Jenny says. "We have to stop getting halfway down the road, seeing a new technology coming around the corner and waiting for that instead of implementing what we've already got.

"A lot of people say you don't want to open the airplane infrastructure more than once, because it is very expensive to upgrade an airplane. But the task force said if you have a positive business case every time you open the airplane, you shouldn't worry about it."

While the ADS-B installations will dramatically improve operational efficiency and safety, especially in the gulf, Romanowski says, the airlines still need to make additional investments to take full advantage of NextGen capabilities as they are brought online.

"We are getting the new technologies faster than anticipated and hope to gain most of the benefits in the next five years."

Randy Babbitt, FAA administrator

"We see three capabilities the aircraft will have to have to get NextGen benefits—ADS-B, Datacom and RNAV. Currently, most aircraft are not equipped for ADS-B. With Datacom, the task force said, there is tremendous ability to leverage installed—but not turned on—communications capability from FANS [Future Air Navigation System]," he says.

"They asked us to accelerate deployment of Datacom capabilities for departure clearances, revisions and moving to some en route services. We can do that very effectively by turning on and leveraging that FANS capability, which will provide operators with a benefit they already have installed. A very high percentage of the fleet also is already equipped for RNAV, so we can take advantage of that right away."

Incremental, or intolerably slow?

Given the wide range of capabilities involved—and continued technological evolution—NextGen and its counterparts such as SESAR will never be completely finished, the FAA notes. Nor will it have a specific start date.

"The systems will not turn on at the throw of a switch anywhere. What you will see, wherever capability is being implemented, is a staged, incremental approach. So saying when NextGen becomes operational really means when various parts of it become operational in various locations," Romanowski says.

An aircraft equipped with ADS-B (a moving map display showing FIS-B and terrain) flies over Alaska.

"The FAA is delivering NextGen, in a number of areas, a number of ways—from systems deployment to demonstrations of capability to providing operational capability in the field today, moving forward with future deployments and delivery of procedures. In the coming years, we will see significant capability brought to bear that, when installed, will result in a fundamental change in how ATC is done and a new foundation on which we will be able to grow our continued infrastructure to even greater capacity in the long term."

But critics like Boyd remain unconvinced.

"NextGen does not look at the needs of America, but at what the FAA can or cannot do. And that approach is fatally flawed," he argues. "We have to start from scratch—not what the FAA can do or has done or wants to do. Why do we have separation gaps when we are only dealing with 4% of the sky? The free flight system we outlined 15 years ago showed we don't need separation gaps.

"We have to stop trying to modernize the buggywhip. The horse is dead. You have to clean out the current system and start using all the sky; put in a sat-based conflict probe free-flight system, where the airplane takes the best route for its purpose. The FAA is now irrelevant to the solution. They can't do it. The airlines are going to have to work harder to adjust and manage their own production line."

Capability, not technology

Boyd's position marks the harshest criticism facing NextGen. But even those who support it as the best solution for airports, airlines and a critically strained ATC system often reflect some of his central concerns.

"Historically, FAA and industry have been very much technology focused—buy some piece of equipment and put it on the airplane, buy some infrastructure on the ground and magically something good would happen," Barimo says. "What we found is the benefits never really surfaced and, while we had new technology in the airplanes and on the ground, we didn't invest in the development of the procedures and new standards and policies that enable us to take advantage of that.

"So today, rather than talk about new technology, we talk about new capability. That may seem a subtle difference, but it is extremely important. We built a lot of slop into the system due to limitations in place; now we want to change the protocols that govern how we space traffic, using the new precise information we have to move aircraft closer together while maintaining the same level of safety. That would translate into additional capacity, which translates into fewer delays."

Jenny agrees. "At this point, NextGen is not a technology issue," she concludes. "You probably could characterize it as an institutional issue. We have to find a way for all of us to work together and couple the technology with all the other things we need to do to make this whole system work better. That will take some pretty skilled leadership, continued collaboration and openness to doing things differently by almost everyone.

"We still have a little work to do on the operator side to further prioritize what we do first and, on the FAA side, to figure out ways to do these very complex, integrated implementations that require working across multiple organizations. Somehow all that has to coalesce and get people focused on the end implementation. And that is not going to be easy."

"I have no confidence this is going to work. The public is simply being bamboozled by the FAA about how this is working."

Michael Boyd, president, Boyd Group International, aviation consultants

SESAR faces nontechnical hurdles

EUROCONTROL's Maastricht Upper Area Control Centre is a hive of activity.

For many reasons, 2010 will be a decisive year for Europe's $30-billion Single European Sky ATM Research (SESAR) program.

With the technology development phase of the effort well under way, it should start to become clear this year how the mature technologies will be deployed throughout the continent in 2014 and beyond, and where the main synergies and differences lie between the European SESAR and U.S. NextGen ATM programs.

The real challenges facing SESAR are not technical but institutional. When Europe decided it would develop its new ATM system on a transnational rather than state-by-state basis, it loaded several layers of complexity onto the program.

Implementation and other challenges

"The technical challenges are relatively easy to solve," says Patrick Ky, executive director of the SESAR joint undertaking, responsible for implementing the development phase of SESAR. "The real difficulty is finding the right compromise to make those technologies implementable—the compromise between the cost and the return on investment, and the compromise between the needs of specific stakeholders and other stakeholders. In Europe we have 27 member states, and that means 27 regulators, 27 air navigation service providers (ANSPs) and 27 air forces. This compli-

by
Philip Butterworth-Hayes
Contributing writer

The Single European Sky ATM research program faces key challenges, most of them institutional and policy-related. Harmonization of all SESAR elements—both among European countries and with the U.S. NextGen system—is a major issue facing this $30-billion program.

cates the issue of decision-making. So SESAR is about 20-30% technical challenges, and the rest is about decision-making and finding the right compromises."

Every European state has a different way of defining the role of the regulator—a government function—and the role of an ANSP, which may be a government function but may also be a corporatized organization. That means that in some countries, functions such as safety-critical aeronautical information services are seen as primarily the responsibility of the state, while in others they are ANSP obligations. In some European countries (such as Ireland), airports and ANSPs are linked in the same organization, while in others (like the U.K.), airports are mainly privately owned and their ATM functions put out to tender. And every country has its own way of coordinating military and civil ATM functions.

This fragmentation is a major cause of the relative inefficiency of Europe's ATM system com-

SESAR: Goals, scope and methodology

The SESAR goals are to triple airspace capacity by 2020 in Europe, halve the costs of providing air navigation services, reduce the environmental impact per flight by 10% over 2005 levels and improve safety by a factor of 10.

A new concept of operations

SESAR plans to overcome the problems of Europe's fragmented ATM system by introducing a new concept of operations. The new architecture will be designed to enable the aircraft of the future to choose the safest and most efficient route from origin to destination by building a "network-enabled" ATM capability, linking aircraft operators, ANSPs, airports and others. Many of the current functions will be automated. Data-link messages will replace voice messages in many areas, and automatic dependent surveillance broadcast technologies will be widely employed to broadcast aircraft identity and altitude positioning information, greatly increasing the scope for "self-separation." This implies the development of new technologies that would support:

- *4D trajectory management, introducing a new approach to airspace design and management*
- *Collaborative network operations planning*
- *Integrated airport operations, contributing to capacity gains*
- *New separation modes, allowing increased capacity*
- *System-wide information management (SWIM), integrating all ATM business-related data*
- *A shift in the role of controllers from operators to managers*

Funding

The overall cost of SESAR will be around €30 billion, with the deployment phase responsible for most of this. Most of the costs will come from installation of new SESAR-compatible airborne systems—which will cost €15 billion-€20 billion. The total estimated cost of SESAR's development phase is €2.1 billion, shared equally between the European Union, Eurocontrol and industry—each providing €700 million.

The SESAR joint undertaking

The founding members of the SESAR joint undertaking are:

- *Aircraft manufacturers: Airbus, Alenia Aeronautica*
- *Airport operator: SEAC*
- *ANSPs: AENA, DFS, DSNA, ENAV, NATS, NORACON*
- *European bodies: EUROCONTROL, EC*
- *Ground-based technology suppliers: Frequentis, Honeywell, Indra, NATMIG, Selex*
- *Airborne systems manufacturers: Thales, Honeywell*

Since June 2009 the joint undertaking has been launching, on average, one new research project a day and now has 1,000 employed on SESAR work, rising toward 3,000 in 2011.

How the research is being organized

The development of appropriate technologies is being researched in the following work packages:

- *WP 3 Validation Infrastructure Adaptation and Integration involves all ATM stakeholders in looking at the benefits of employing existing expertise, tools and validation platforms for use in the SESAR development phase.*
- *WP 4 En-Route Operations provides and then validates new operational concepts of en-route operations.*
- *WP 5 Terminal Maneuvering Operations provides and then validates new operational concepts of the arrival and departure phases of flight.*
- *WP 6 Airport Operations is developing new collaborative decision-making, safe taxiing and efficient use of runway concepts.*
- *WP 7 Network Operations prepares and supports trajectory-based operations including airspace management and collaborative flight planning.*
- *WP 8 Information Management is developing a European-wide SWIM "Intranet for ATM."*
- *WP 9 Aircraft Systems is planning the evolution of the aircraft platform to progressively introduce 4D trajectory management functions in large, regional and business aircraft.*
- *WP 10 En-Route and Approach ATC Systems designs, specifies and validates en-route and TMA systems evolution, encompassing trajectory management, separation modes, controller tools, safety nets, airspace management supporting functions and tools, queue management and route optimization features.*
- *WP 11 Flight Operations Centre System develops airspace-users operations systems to support the implementation of SESAR components.*
- *WP 12 Airport Systems outlines R&D activities to define, design, specify and validate airport systems needed to support the SESAR ATM target concept.*
- *WP 13 Network Information Management System (NIMS) is developing a technical strategy for implementing the NIMS, AAMS (Advanced Airspace Management System) and AIMS (Aeronautical Information Management System).*
- *WP 14 SWIM Technical Architecture provides a link between the European Commission-funded work on SWIM concepts and aligning them with SESAR.*
- *WP 15 Non-Avionic CNS System assesses requirements for CNS technologies development/validation and their compatibility with military and general aviation user needs.*
- *WP 16 R&D Transversal Areas defines the improvements needed to adapt the Transversal Area (safety, security, environment, contingency and human performance) management system practices to SESAR.*
- *WP B Target Concept and Architecture Maintenance provides strategic and conceptual guidance for the entire work program, including all operational, technical and SWIM concepts, to ensure the consistent development of SESAR improvements.*
- *WP C Master Plan Maintenance.*
- *WP E: SESAR Long Term and Innovative Research outlines priorities in these two research areas.*

Timetable

The definition phase (2004-2008) has already delivered the ATM master plan defining the content, development and deployment plans of the next generation of ATM systems. The development phase (2008-2013) will produce the required new generation of technological systems, components and operational procedures. The deployment phase (2014-2020) will see the large-scale production and implementation of the new ATM infrastructure.

The flight control room screens in Maastricht show how complex the flight patterns are. (Photo copyright Paul Veronique.)

pared to that of the U.S.—but there have been major improvements in efficiency over the past 10 years in Europe. Between 1999 and 2007, according to the International Air Transport Association (IATA), performance improvements to the European ATM network led to a 66% drop in flight delays despite a 25% increase in traffic, together with a shortening of around 4 km, on average, in routes flown.

But recently these performance gains have stalled. According to the latest Eurocontrol Performance Review Report for 2008, only in the safety domain—where there were no ATM-induced accidents that year—has there been a marked improvement.

The capacity of the European ATM system is measured by the number of delays directly attributable to ANSPs. This figure is on the rise. In 2008 the number of ATM-related delays rose for the fourth consecutive year and exceeded the agreed target by 90%. The target was an average of 1 min delay per flight due to ATM causes; the actual figure was 1.9 min per flight.

Costs, capacity and emissions issues

Costs too are increasing. Eurocontrol measures the cost of ATM service performance in three ways—en-route charges to aircraft operators (€6.5 billion in 2008), delays as a result of ATM en-route inefficiencies (€0.9 billion) and the number of extra miles flown by aircraft operators beyond their optimum flight profiles ($2.6 billion in 2008). While charges to airlines have been decreasing since 2004 at a rate of 1% a year (though many ANSPs had to raise their air navigation charges in 2009 as a result of traffic declines), the savings have been more than canceled out by an increase in delays and inefficient routings (called "route extensions" by Eurocontrol). And as aircraft are flying farther than their optimum route, their fuel burn and greenhouse-gas-forming emissions are also rising.

This is particularly worrying as 2008 was the year that traffic numbers started to stall—there were just 0.4% more aircraft flying in Europe in 2008 over 2009, so capacity issues should not have been a major problem for the continent's ANSPs. While most ATC centers

have been increasing their capacity, there were a number of highly congested centers—mainly outside the busiest traffic areas—where staffing and systems problems contributed to many of the delays.

Small improvements in the ATM network can have large impacts. According to an ATM efficiency improvement plan drawn up in September 2008 by IATA, the Civil Air Navigation Services Organization (CANSO) and Eurocontrol, a potential reduction of 0.1% in distance flown is equivalent to 4 million n.mi. per year, generating potential savings of €20 million per year. A 1-min reduction in taxi times at Europe's 50 busiest airports, for example, would save €120 million annually.

The short-term measures introduced by IATA, CANSO and Eurocontrol were aimed at reducing annual fuel consumption in European airspace by 470,000 tonnes, saving an estimated 1.55 million tonnes of CO_2 emissions per year and trimming their fuel bills by around €390 million. The plan is seen as having little overlap with SESAR "and yet is expected to achieve nearly 10% of SESAR's emissions-reduction target within 18 months," according to the three organizations.

So is a $30-billion program like SESAR really necessary? After all, there are now next-generation technologies available—automatic dependent surveillance, satellite-based precision landing systems and data-link communications—that provide many of the technical solutions to the problem of developing new capacity, and these are already being implemented on a state-by-state basis.

"The larger the area you cover with a single ATM system, the more efficient it is," according to Andrew Charlton of Geneva-based ATM consultants Aviation Advocacy. "You only have to look at the relative costs of providing ATM services in Europe compared to those in the U.S. to see how much more efficient it is to cover a large area with a single entity. Apart from that, Europe has for many years now treated aviation as a single market with a single regulator for airlines and airports. There is no reason to treat ATM differently."

Hurry up and wait

Thus the ATM problems of Europe are only partly technical issues. One of the biggest bottlenecks is a chronic lack of runway space at Europe's busiest runways.

"When you look at airports, the biggest challenge will be to increase the capacity of runways," according to Ky. "In SESAR we are talking about trebling the capacity of the overall system—but I don't think we will be able to treble the capacity of runways. We can significantly improve runway capacity by working on wake vortices to have actual separations based on actual occurrences, rather than theoretical occurrences, as today. I think we can decrease runway occupancy time by having more rapid exits from the runway, and I also think we can be much better in coordinating arrivals and departures."

Here is the problem: If three or four highly congested European airports are constraining the capacity of the total European ATM system, then all SESAR will achieve will be to move traffic more swiftly and efficiently between the bottlenecks. Identifying the bottlenecks is a tiny part of the problem—increasing capacity by adding new runways may not be an option, as local and national government planning regulations could prohibit the building of new runways without a 10-year public inquiry. In which case, the efficiency of the whole European ATM system could be compromised by local government planning regulations.

The European Commission has recognized that this is a major issue and in 2008 set up a "Community Observatory on Airport Capacity," which advises the commission what measures will be needed to improve the capacity of the overall European airport network. According to the EC, "It will issue non-binding opinions, either at the commission's request or on its own initiative, which will serve as a basis for producing guidelines or regulatory instruments. The commission will therefore be able to seek its opinion on methods for assessing airport capacity….All the member states, Eurocontrol, the SESAR JU [joint undertaking], academia and the commission will be represented, as will airports, airlines, the local authorities concerned, airport coordinators, environmental groups and people living or working near airports."

The airport capacity problem has, for the moment, dropped out of the limelight as traffic

has declined in the wake of the global fiscal crisis. For the moment at least, Europe's airports are not facing an immediate capacity crunch—but this is an ongoing issue that will need to be resolved if SESAR is to reach its goals.

It is also indicative of why the SESAR architects have had to take a different approach to introducing a next-generation technology system to that of the U.S. In Europe, agreement in detail on new systems and procedures has to be reached between all stakeholders—airports, airlines, ANSPs, governments, industry, civil and military authorities and so on—before programs can be implemented. NextGen is deploying baseline technology and then, if it is successful, rolling out the new systems nationwide as soon as possible.

"There are pros and cons of doing it the U.S. way and the European way," says Ky. "The main benefit of the European approach is that we have a system-wide view of what we need and a system-wide consistency. The big paradigm shift in SESAR is that we are developing components which can be shared and distributed between the air and the ground, so it makes sense that we have a system-wide view....The drawback to this is that it takes a longer time, especially in the implementation of the components. This is where the U.S. approach is better, because when the FAA decides to implement a new technology such as ADSB, it goes all the way through to implementation. We are more R&D and system-wide focused than the FAA."

Compatibility and coordination

Ky acknowledges that the difference in approaches could possibly lead to a problem of "desynchronization," especially where new technology programs are led by different operating priorities. Establishing common data-link protocols, for example, is complex, because in Europe the new data-link concepts have been driven by the challenge of VHF congestion, whereas in the U.S. the priorities are different.

"The only way to deal with this is to have the proper level of coordination between the U.S., Europe and other parts of the world," Ky says. "The European Commission has started to negotiate with the FAA a more political agreement that will ensure these difficult decisions will be supported by the political authorities. The new paradigm is called 'trajectory based operations,' and the really difficult issue is to define what 'trajectory' means. I would expect those issues to be covered in 2010 and 2011."

One simple way of solving the issue would be to have U.S. industry teams integrated within the SESAR JU and European teams integrated within NextGen. After all, the SESAR research philosophy is to develop two parallel technology platforms so performance can be measured and compared.

"We are in process of trying to see how we can enlarge the industrial base of SESAR to see how we can include new companies, including U.S. companies," says Ky. "I hope through the negotiation between the FAA and the commission on reciprocal arrangements we'll be able to make progress in this area."

Procurement and planning

The one big unknown about the program, which should become clearer during 2010, is who will implement the mature technologies throughout the continent in the deployment phase of SESAR. There are a wide number of options, from the creation of a new, centralized European ATM systems procurement office to evolving the role of current European bodies in order to harmonize technology procurement—more or less a planning role.

SESAR research contract winners

Candidate members	Number of projects	Millions of euros
Airbus	51	€79.4
Alenia	30	32.1
Frequentis	30	26.3
Honeywell	24	39.7
INDRA	99	119.3
NATMIG	29	35.3
Selex	64	77.3
Thales	128	237.3

Table compiled December 2009. Source: Thales.

At the start of 2010 the SESAR program was keeping to schedule, despite the turbulent times in the aviation market. Europe's airlines have been pushing for such a program for decades—although their priorities have changed in recent years from reducing delays to cutting air navigation charges.

The next few months and years will be critical to the program's success; this is the time when political details will be worked out on how to implement the new technologies on the ground and in the air. The task is tough enough within the European context—but given that most expenditure on new ATM systems will take place in the cockpit rather than on the ground, it may be that integrating SESAR with NextGen and other new ATM technology programs emerging around the world will prove the toughest task of all.

Out of the

25 Years Ago, May 1985

May 6 STS 51-B, the17th space shuttle flight and the seventh flight of Challenger, lands at Edwards AFB, Calif., after 111 orbits and seven days in space. On board for its first operational flight is ESA's Spacelab 3, where astronauts performed delicate experiments in materials processing and fluid mechanics during the mission. Also on board are two monkeys and 24 rodents for studies of weightlessness and its physiological effects. NASA Space Shuttle Launch Archive.

50 Years Ago, May 1960

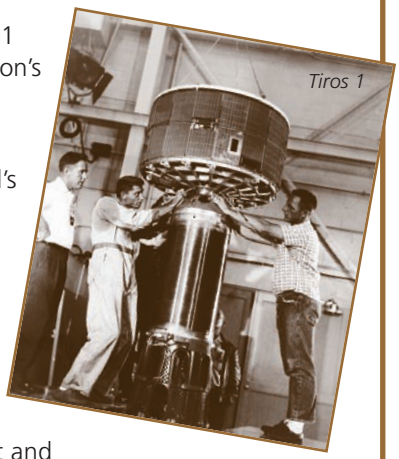
May 9 The first production model of the one-man Project Mercury spacecraft is successfully launched from NASA's Wallops Island, Va., facility, for testing of the escape, landing and recovery systems. This unmanned test version of the spacecraft reaches 2,540 ft when it is parachuted into the Atlantic Ocean and retrieved by a Marine helicopter. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 123.


Joseph A. Walker

May 12 X-15 No. 1, flown by Joseph A. Walker, reaches a speed of Mach 3.2 and a 78,000-ft altitude before landing at Edwards AFB, Calif. This is the first remote launch of the plane, 100 mi. from its carrier "mother" aircraft. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 123.

May 14 The International Astronautical Federation and the Florence Guggenheim Foundation announce the founding of the International Academy of Astronautics. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 123.

May 17 Members of Parliament witness an SR-N1 Saunders-Roe Hovercraft demonstration near London's Westminster Bridge, on the River Thames. *Flight*, May 20, 1960, p. 674.


Tiros 1

May 19 The recently launched Tiros 1, the world's first weather satellite, tracks a tornado storm system around Wichita Falls, Texas. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 123.

May 24 The Midas II (missile defense alarm system), an Air Force reconnaissance test satellite designed with infrared sensors to detect and provide an early warning of long-range missile launches, is launched by an Atlas-Agena launch vehicle. However, it operates for only two days. When it is fully operational the Midas system is designed to give the U.S. 20-37 minutes' warning of an attack. *Flight*, June 3, 1960, p. 746.

May 24 Britain's two-stage version of the Black Knight rocket is launched at the Woomera test range in Australia to test hypersonic reentry. The second stage is a separable solid-fuel rocket with an instrumented nose cone for measuring reentry conditions. *Flight*, June 3, 1960, p. 746.


Black Knight

May 27 An Office of Naval Research (ONR) Aerobee-Hi sounding rocket is launched from the White Sands Proving Ground, N.M., to an altitude of 135 mi. It carries eight telescopes for mapping the sky by ultraviolet light. ONR scientists expect the analysis of the results to provide the most complete mapping of the stars to date. *Flight*, June 10, 1960, p. 784.

May 28 The Soviet Union sets a new flight speed record of 2,910 kph (1,298 mph) over a 1,000-km (62-mi.) closed-circuit course for a single-seat turbojet aircraft. *Flight*, July 1, 1960, p. 3.

May 31 NASA chooses the Rocketdyne Division of North American Aviation to develop a 200,000-lb-thrust liquid oxygen and liquid hydrogen rocket engine. This engine becomes the J-2. In upgraded versions, five are used to power the second stage of the Saturn V launch vehicle, while a single J-2 powers the third stage. The Saturn V later launches the first men to the Moon under Project Apollo. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 123.

75 Years Ago, May 1935

May 3 Large-scale Navy air and sea maneuvers are conducted in the Pacific in Fleet Problem XVI, which covers 5 million mi.^{2}. The exercise, which lasts until June 10, involves 520 naval aircraft and four aircraft carriers, as well as battleships and cruisers that also carry two to four catapult seaplanes each. It is prompted by Japanese military

Past

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

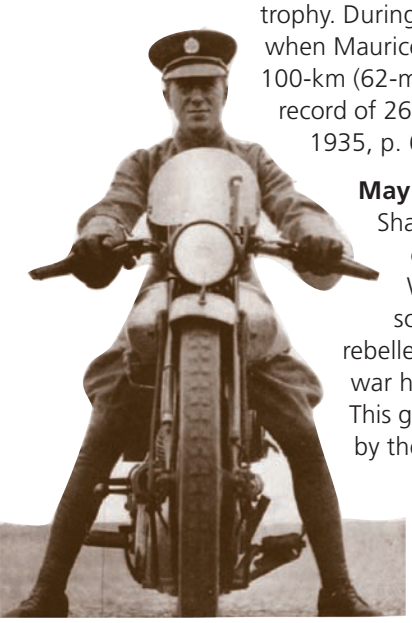
buildups and aggression in Asia. One of the problems is to determine whether naval and air forces based in Hawaii can fend off an enemy attack on the U.S. *The Aeroplane*, June 12, 1935.

Eagle

May 3 A British Aircraft Eagle airplane, baptized the Costa Esmeralda by the Spanish ambassador to England, leaves Hanworth, England, for a 9,000-mi. flight to Mexico City. The pilot, 21-year-old Spaniard Don Juan Ignacio Pombo, reaches Bathurst, Gambia, by May 17. On May 20 he makes a 17-hr flight over the sea to Port Natal, Brazil. This is the eighth successful Atlantic crossing by Gipsy-powered aircraft. When taking off from Port Natal on May 26 for Mexico City, the aircraft crashes and is destroyed, but Pombo is unhurt. *The Aeroplane*, May 29, 1935, p. 639.

May 18 The world's largest airplane, the Soviet Union's ANT-20 Maxim Gorki, crashes at an airport near Moscow, killing the crew of 11 and 36 passengers. A small single-engine airplane, whose pilot is also killed, had been performing stunts near the Gorki until it hit the bigger plane. The smaller craft is later identified as an I-5 fighter. The ANT-20, designed by A.N. Tupolev, had a 207-ft wingspan, a gross weight of 92,594 lb and eight 900-hp engines. An improved version, the ANT-20 bis, flies later. *The Aeroplane*, May 22, 1935, p. 610; *Air Britain*, April 1966, p. 151.

May 19 At Etampes, France, Raymond Delmotte wins the Coupe Deutsch de la Meurthe in his Caudron C, powered by a single 460-hp Renault engine. He covers the 2,000 km (1,242 mi.) at an average speed of 276 mph. France thus becomes a three-time winner of the coveted trophy. During the contest a new world's speed record is broken when Maurice Arnoux in his Caudron C flies at 291.5 mph over a 100-km (62-mi.) stretch of the course. This breaks the previous record of 268.235 mph set by Delmotte. *The Aeroplane*, May 22, 1935, p. 608.



May 19 T.E. Lawrence, also known as Aircraftsman Shaw when he joined the RAF, dies as the result of a collision between his motorbike and a pedal bicycle. World famous as "Lawrence of Arabia," the scholar-soldier-adventurer was a leader of the Arabs who rebelled against Turkish rule during WW I. Following the war he continued to work toward their independence. This goal did not succeed and Lawrence, who felt betrayed by the politicians, wrote *The Seven Pillars of Wisdom* and *Revolt in the Desert*. Still in despair that his cause was lost, he first joined the Royal Tank Corps under the name Ross, then transferred to the RAF as Shaw, a name he legally adopted later. *The Aeroplane*, May 22, 1935, p. 588.

May 30 Donald W. Douglas, president of the Institute of the Aeronautical Sciences and Douglas Aircraft, delivers the 23rd Wilbur Wright Memorial Lecture before the Royal Aeronautical Society in London. He discusses the development of civil aviation in America from its beginning in 1926, when the Post Office handed the carrying of mail over to private operators. The mail revenue and a government subsidy allowed the new airlines to grow and prosper. *The Aeroplane*, June 5, 1935, p. 653.

May 31 An 84-lb gyroscopically controlled rocket reaches the highest altitude of any rocket yet built by Robert H. Goddard. It lands 5,500 ft from the launch tower in the desert near Roswell, N.M., and then digs a hole 10 in. deep. E. Goddard and G. Pendray, eds., *The Papers of Robert H. Goddard*, pp. 921, 1664.

100 Years Ago, May 1910

May 21 Frenchman Jacques de Lesseps, piloting his Bleriot XI, Le Scarabee, makes the second crossing of the English Channel. For this achievement de Lesseps wins the London Daily Mail Cup. A. van Hoorebeeck, *La Conquete de L'Air*, p. 83.

May 25 At Huffman Prairie outside Dayton, Ohio, Orville and Wilbur Wright fly together for the first (and only) time. A. van Hoorebeeck, *La Conquete de L'Air*, p. 83.

DEPARTMENT OF AEROSPACE ENGINEERING
WICHITA STATE UNIVERSITY
Position in Aerodynamics and/or Aerospace Propulsion

The Wichita State University (WSU) Aerospace Engineering department has a position available in aerodynamics and/or aerospace propulsion. The tenure track position, at the Assistant Professor rank, includes teaching, research, scholarship, and service responsibilities.

Applicants must hold a doctorate in aerospace engineering or a strongly related engineering discipline. Additionally, applicants must have at least one degree in aerospace engineering or have notable aerospace industry/research lab experience. Teaching and research experience, a good publication record, appropriate communication skills, and a demonstrated commitment to diversity are also required.

WSU, located in the Air Capital, has a proud history. The department's undergraduate and graduate (MS & PhD) programs are strong and play an important educational and research role in the city, region, and nation. In fact, the National Science Foundation ranked WSU third among all U.S. universities in aerospace research and development expenditures (for fiscal year 2007). Furthermore, the department and National Institute for Aviation Research (NIAR) are home to an outstanding collection of wind/water tunnel, aircraft icing, composites, structural testing, fatigue/fracture, crash dynamics, and computational laboratories.

The WSU campus is an attractively landscaped architectural showplace with approximately 15,000 students. Wichita, a community of approximately 450,000 people, is home to aerospace leaders Cessna Aircraft, Hawker-Beechcraft, Bombardier Learjet, Boeing IDS, Airbus, and Spirit AeroSystems.

U.S. citizens or permanent residents with an undergraduate degree in aerospace engineering are preferred. Applicants must clearly state their status: US citizen, permanent resident or qualified foreign national (including current visa status). Salary is commensurate with qualifications and experience.

If interested, mail a printed resume, letter of application, curriculum vitae, and discussion of teaching philosophy to Professor L. Scott Miller, Department of Aerospace Engineering, Wichita State University, Wichita, Kansas 67260-0044. Include the names and contact information for three references located in the United States. The closing date for these positions is April 30, 2010, or the end of each successive month until the position is filled. WSU is an EEO/AA employer. Offers of employment are contingent upon completion of a satisfactory criminal background check as required by Kansas Board of Regents policy. Candidates must also go on line at http://jobs.wichita.edu to apply for the position.

DEPARTMENTS OF AEROSPACE ENGINEERING & ELECTRICAL ENGINEERING AND COMPUTER SCIENCE
WICHITA STATE UNIVERSITY
Joint Position in Controls

The Wichita State University (WSU) Aerospace Engineering and Electrical Engineering and Computer Science (EECS) departments have a joint position available in the area of controls. The tenure track position, at the Assistant Professor rank, includes teaching, research, scholarship, and service responsibilities.

Applicants must hold a doctorate in aerospace or electrical engineering or a strongly related engineering discipline. Additionally, applicants must have at least one degree in aerospace or electrical engineering or have notable related industry/research lab experience in both the electrical and aeronautical engineering disciplines. Research experience, a good publication record, appropriate communication skills, and a demonstrated commitment to diversity are also required. Teaching experience is preferred.

WSU, located in the Air Capital, has a proud history. Each department's undergraduate and graduate (MS & PhD) programs are strong and play an important educational and research role in the city, region, and nation. In fact, the National Science Foundation ranked WSU third among all U.S. universities in aerospace research and development expenditures (for fiscal year 2007). Furthermore, the departments and the National Institute for Aviation Research (NIAR) are home to an outstanding collection of laboratories.

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To ensure full consideration, the complete application package, consisting of a detailed resume, letter of application, discussion of teaching and research philosophies, and a list of three references, must be received by May 1, 2010. Applications are to be submitted on-line at http://jobs.wichita.edu. Applications will be continuously reviewed after that date until determinations are made with regard to filling the positions. Offers of employment are contingent upon completion of a satisfactory criminal background check as required by Board of Regents policy. Questions can be addressed to the co-chairs of the search committee, Dr. L. Scott Miller (scott.miller@wichita.edu) or Dr. John Watkins (john.watkins@wichita.edu). WSU is an EEO/AA employer.

University of Central Florida

Department of Mechanical, Materials and Aerospace Engineering Department Chair

The College of Engineering and Computer Science at the University of Central Florida solicits applications and nominations for the position of Chair of the Department of Mechanical, Materials and Aerospace Engineering. A doctorate in an appropriate engineering discipline or a closely related field is required, as is a distinguished record of scholarship, teaching, research funding, and professional visibility that would warrant an appointment as a tenured full professor. Administrative experience is highly desirable.

UCF is located on a beautiful, modern campus in a suburban setting outside Orlando. Enrollment is approximately 53,000 at the 3rd largest university in the U.S. The MMAE Department is home to 30 full-time faculty (including 4 NSF CAREER awardees and several fellows of professional societies), over 1500 undergraduate students, and nearly 200 graduate students. The department's annual research expenditures exceed $5 million. Opportunities abound for research and partnerships with local high-tech industries, governmental agencies, the military, and other academic and research units at UCF, including UCF's new College of Medicine. Many departmental faculty have joint appointments with research units such as the Advanced Materials Processing and Analysis Center, the Center for Research and Education in Optics and Lasers, the Institute for Simulation and Training, the Florida Solar Energy Center, and the NanoScience Technology Center.

The MMAE Chair will provide leadership and vision that builds on the department's strengths; identifies promising new programs and initiatives; and encourages innovation, creativity, collaboration, and professional growth for the faculty, staff, and students. Under the Chair's direction, the department is expected to participate in cutting-edge, multi-disciplinary projects and to contribute substantially to the College's growing reputation for excellence in research, education, and professional service.

Applications must be submitted electronically at: **www.jobswithucf.com/applicants/Central?quickFind=74737** and should include a cover letter; a complete CV; a one-page statement on the role of a department chair at a major research university; and a list of at least three references, with addresses, phone numbers, and email addresses.

Nominations may be sent to: **Dr. Charles H. Reilly Associate Dean for Academic Affairs**
College of Engineering & Computer Science
University of Central Florida
P.O. Box 162993
Orlando, Florida 32816-2993
creilly@mail.ucf.edu

Screening of applications will begin July 1, 2010. Applications must be received by October 1, 2010, in order to be considered for this position. The position is expected to be filled January 2011, or as soon thereafter as the right candidate can assume the position.

The University of Central Florida is an Equal Opportunity/Affirmative Action employer.

Department of Mechanical and Aerospace Engineering
University of Dayton
Assistant/Visiting Assistant Professor

The University of Dayton seeks qualified candidates for a full-time faculty position in the Department of Mechanical and Aerospace Engineering at the Assistant or Visiting Assistant Professor level beginning in August, 2010. Candidates must possess a Ph.D. in Aerospace or Mechanical Engineering or a related field. Knowledge and scholarship in computational aerodynamics or computational fluid dynamics is essential. The preferred candidate must have an interest in teaching courses in fluid mechanics, aerofluids, and computational aerodynamics/fluid dynamics, and must be committed to education achieved through learner-centered teaching approaches. Preference will be given to a scholar with demonstrated experience in teaching and mentoring students from diverse backgrounds, especially those from traditionally under represented groups and to a candidate who has demonstrated a commitment to service within profession.

As a Catholic and Marianist University, the University of Dayton espouses education and scholarship which is transformational and which serves society directly. Finally, the Dayton area affords an outstanding opportunity to engage in collaborative research with the University of Dayton Research Institute and sponsored collaborative research with the Air Force Research Laboratory at Wright-Patterson Air Force Base.

See the department web site for more information:
http://engineering.udayton.edu/programs/mechanical/default.asp

Application materials must include: vita and a list of three references. Please apply at http://jobs.udayton.edu. Deadline for applications is May 31, 2010 or until position is filled.

The University of Dayton, a comprehensive Catholic University founded by the Society of Mary (the Marianists) in 1850, is Ohio's largest independent university and one of the nation's ten largest Catholic universities. The University of Dayton is firmly committed to the principle of diversity and is an Affirmative Action/Equal Opportunity Employer.

THE AIAA SUGGESTION PROGRAM

AIAA welcomes suggestions from members on how we can better serve you.
All comments will be acknowledged. We will do our best to address issues that are important to our membership.
Please send your comments to:

Mary Snitch
VP Member Services
AIAA
1801 Alexander Bell Drive
Suite 500
Reston, VA 20191-4344

AIAA

Faculty Positions Available at the Faculty of Aerospace Engineering, Technion -Israel Institute of Technology, Haifa, Israel

During the coming years the Faculty of Aerospace Engineering at the Technion is looking to fill tenure track faculty positions. First class applicants are invited in the following preferred areas, as well as in all Aerospace-related fields:

- Space engineering and space systems
- Experimental fields: experimentalists with a strong background in use of advanced experimental methods in one of the following fields: Aerodynamics, Propulsion, Aerospace Structures, Aerospace Control
- Innovative areas relevant to Aerospace Engineering
- Computational Fluid Dynamics, preferably with emphasis on compressible aerodynamics for aeronautical configurations.

Candidates should hold a Ph.D. in Aerospace Engineering or an allied field with a proven record of research excellence. Candidates at all ranks will be considered but applicants for junior faculty positions are particularly encouraged.

The Faculty of Aerospace Engineering at the Technion is the only one of its kind in Israel. It has about 400 undergraduate students and about 170 graduate students. There are currently 26 full time faculty members and 20 adjunct lecturers from industry.

Candidates should have a good command of Hebrew. They will be expected to conduct independent advanced research, supervise research students (and postdoctoral researchers), teach undergraduate and graduate courses and acquire research funding. The language of instruction is Hebrew.

Review of applications will be ongoing until available positions are filled. Applications consisting of a cover letter, curriculum vitae, names and addresses of five references (including email addresses) and a statement of future research plans should be submitted to Professor J. Barry Greenberg, Chair, Search Committee, Faculty of Aerospace Engineering, Technion – Israel Institute of Technology, Haifa 32000, Israel ; email: aer9801@aerodyne.technion.ac.il