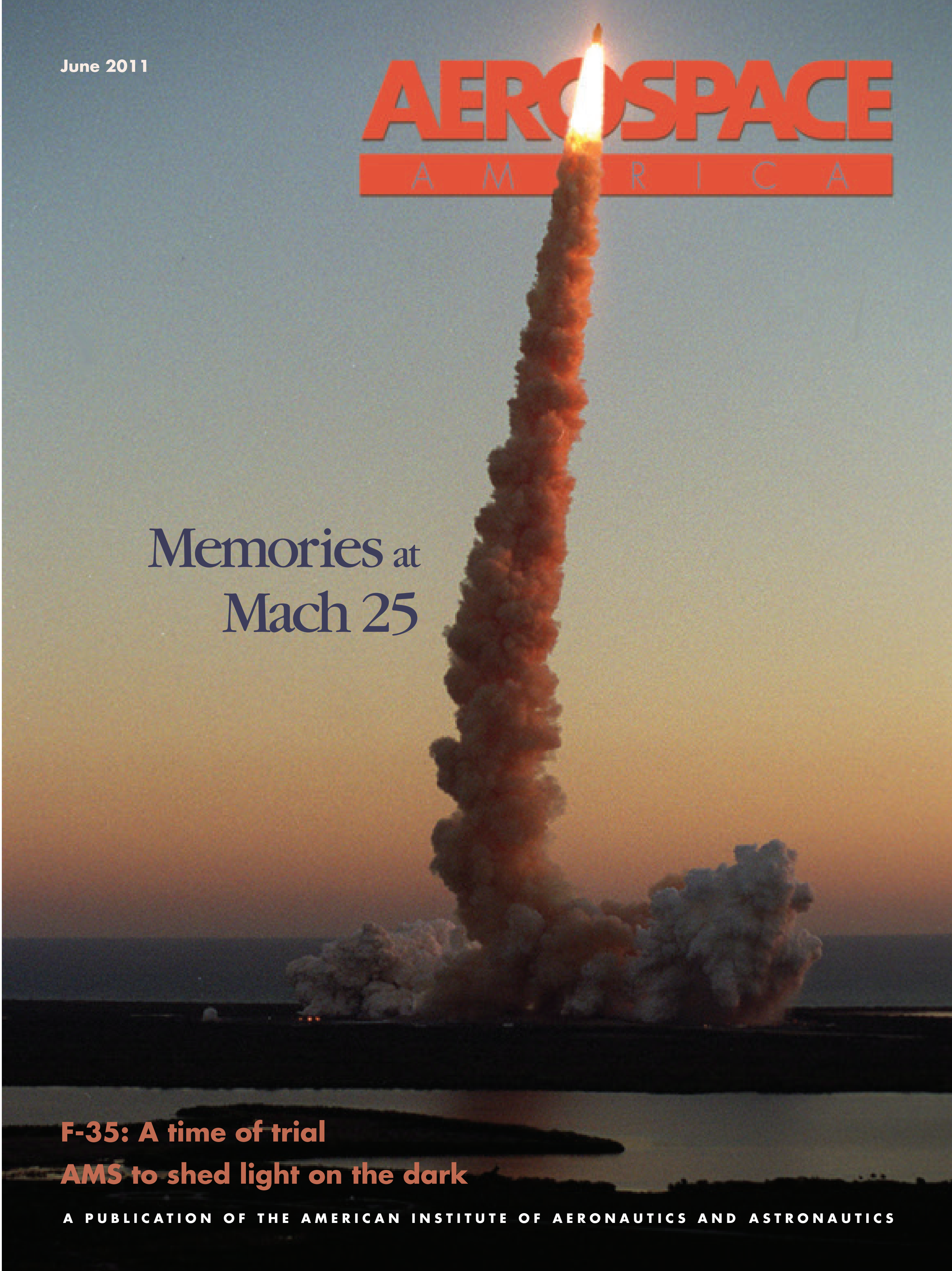
June 2011

AEROSPACE AMERICA



Memories at Mach 25

F-35: A time of trial

AMS to shed light on the dark

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AEROSPACE AMERICA

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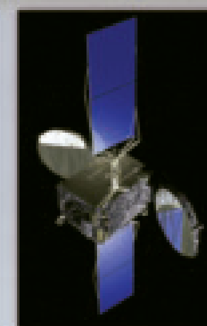

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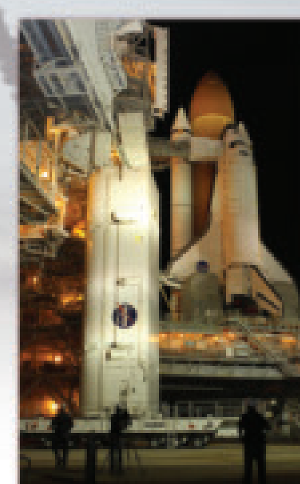

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COVER

After 30 years and more than 130 missions, the space shuttle's historic final launch will bring the program to a close later this month. For one astronaut, the approaching milestone sparks vivid memories of his own spaceflight experiences. See the story beginning on page 20.

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Editor-in-Chief
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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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American Institute of Aeronautics and Astronautics

Editorial

Hail and farewell

Some time in the next several weeks, the space shuttle Atlantis is scheduled to make its last flight—and draw to a close an incredible 30-year history of this remarkable manned space transportation program.

Although the construction contract for the first space shuttle was awarded in 1972, conceptualization had begun decades earlier, even before the Apollo program.

Dozens of configurations and innumerable combinations of airframe, propulsion, thermal protection, and control systems were conceived, assessed, and discarded before the final Space Transportation System design we now know as the shuttle evolved. A key step in every evaluation was an exhaustive analysis of costs based on various mission profile scenarios. Although selection of the final design was based on highly overoptimistic mission plans (for example, more than 50 flights per year), which led to seriously flawed economic projections, the shuttle was indeed an engineering and technological marvel.

The five shuttle orbiters—Columbia, Challenger, Discovery, Atlantis, and Endeavour, plus the Enterprise test vehicle—together have made over 130 flights, with astronauts both domestic and foreign delivering dozens of spacecraft to orbit, conducting invaluable experiments, and performing extravehicular activities to rescue and repair one-of-a-kind assets such as the remarkable Hubble Space Telescope.

The shuttle was also the means by which the international space station was brought into being, delivering the modules and trusses that would steadily take shape under the hands of these same space travelers.

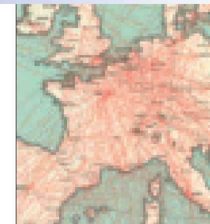
Like the Apollo program before it, public interest in the shuttle's accomplishments seemed to wane over time, as we moved on to the 'next new thing.' And just as the heartstopping drama of Apollo 13's mechanical woes served as a brief reminder of how truly perilous space travel is, it took the tragic losses of life aboard first the Challenger on January 28, 1986, and Columbia seven years later, on February 1, 2003, to remind a mostly unengaged public of the engineering complexity of these flights and the tremendous courage of the participants.

Of course the lessons learned at such great expense are forgotten over time, and launch scrubs and standdowns make us impatient, as if the shuttle were a Greyhound bus with a flat tire just before departure. It is human nature to take these launches for granted—if we thought too long about the difficulty and danger involved we would probably look away.

So let us watch, one last time, as Atlantis streaks across the sky, and think back and give thanks. Not just to those whose faces and voices we have come to know, the astronauts and ground crews, flight controllers and spokespersons, but to the thousands of men and women whose names we will never know, whose faces we have never seen, who began considering a notion in the 1950s, nurtured it, and watched it blossom in the decades since. We can only hope that we shall see their like again.

Thank you.

Elaine Camhi
Editor-in-Chief



Space industry takes root in central and eastern Europe

The European Commission's new space policy, launched in April, contained many ingredients that were familiar, one or two surprises, and three or four important issues that were raised but not answered.

The familiar ingredients were the prioritization of the Galileo satellite navigation and GMES (global monitoring for environment and security) programs, and the development of indigenously owned and operated European Union space systems to support security missions worldwide. The major surprise—especially given the perilous state of many European economies—included a new emphasis on space exploration activities. According to the policy document, "The Union seeks to identify and support the development of essential technologies for exploration, in particular in the fields of energy, health, and recycling (support for life in isolated environments)."

Among the issues raised but not answered is the challenge of developing a space industry policy that fully reflects the needs of the entire EU community—but with the key industry and service providers concentrated in a single demographic area.

For Europe's space industry is centered on three or four major companies based entirely in the west. In eastern and central Europe, where annual economic growth rates for some countries are likely to be over 4% this year, the industry hardly exists at all. This is strange, given the scientific and academic centers of excellence in the region, the close links these countries had to Russia's aerospace industry (with Czech, Polish, Romanian, and Slovakian astronauts having flown on Russian spacecraft), the recent integration of some of these countries within the EU, the low wage demands and high skills of the available workforce, and, finally, ESA's efforts to integrate many of these states within Europe's space infrastructure.

Underlying causes

The Soviet Union concentrated its space industry efforts in Russia, Kazakhstan, and Ukraine. The 'Interkosmos' space exploration program was developed to engage fellow Warsaw Pact states in manned and unmanned programs but focused mainly on placing cosmonauts of neighboring countries into space, rather than on developing a space industrial infrastructure.

As a result, when the Soviet Union collapsed in 1991, there were hardly any space manufacturing capabilities at all in central and eastern Europe, apart from a few academic research institutes. Poland hosted a small industry based on sensors and spectrometers. The Czech Republic built scientific instruments on 23 Interkosmos science satellites (1969-1991), the movable platform for the Vega 1 Halley comet probe, and five Magion microsatellites for magnetosphere and ionosphere research between 1978 and 1996. Romania contributed academic research to more than 30 scientific and technological space missions.

Although ESA offered the opportunity for new EU states to develop their space industries in cooperation with those of Western Europe, the funding and commissioning of work within ESA was not helpful for those countries that wanted to develop their industries but lacked a mature science and industrial base.

Says Pierre Lionnet, research director at the European trade association Eurospace, "The way that ESA works is that every euro generated by France for funding ESA activities is spent within France on space programs. In other words, the funding rule translates directly into a spending rule."

ESA member states contribute to these programs on a scale based on their gross domestic product, which means that countries such as Poland or Hungary would have to make sizeable contributions to the ESA budget even though they have no indigenous industry capable of carrying out the ensuing work domestically. The only central European former communist states that are now full members of ESA are the Czech Republic—which joined as a full member in November 2008—and Romania, which signed its accession agreement to become the 19th member state in January.

New approach, new opportunities

ESA recognized the problem and in 2001 set up a new agreement for central European nations, the Plan for European Cooperating States (PECS), in which countries would spend five years working with ESA with no obligation to become full members. In January 2010, Slovenia became the sixth European Cooperating State (ECS), following Estonia in 2009,

The Czech space industry and ESA

The Czech Republic has committed itself to contributing around €45 million to ESA programs until 2013 and is now integrated into ESA's major projects. By 2010 it had completed 14 projects in cooperation with ESA, was working on a further 36, and planned to become involved in 31 more, the work coordinated through the Czech Space Office.

The country is an active participant in the European program for life and physical sciences, with work taking place on the ISS. In Earth observation, the Czech Republic committed itself to cofinancing the GMES program at the ESA Ministerial Council in 2008. It is also involved in the ESA Earth observation envelope program and the Envisat and Meteosat projects. It is a major partner in ESA's European GNSS evolution program, developing technologies associated within the EGNOS (European GNSS overlay service) and Galileo systems, and is integrated within the ESA advanced research in telecommunications systems (ARTES) program. The Czech Republic has a major financial stake in Iris, a subelement of ARTES that focuses on satellite solutions for air traffic management.

Poland in 2007, Romania in 2006, and Hungary and the Czech Republic in 2003. When Hungary and the Czech Republic became PECS members, the two states agreed to make an annual payment to ESA of €5 million over a five-year period—93% of which has returned to each country in the form of contracts to industry and research institutes, with the remaining 7% as an administration fee to ESA to cover the costs of integrating the participation of these two countries. Other countries are negotiating with ESA about joining the PECS initiative.

In the past few years, however, the space market has seen some changes that will open up new opportunities for those European countries that have only a modest space industry heritage.

"With programs such as Galileo," says Lionnet, "the European Commission (EC) is starting to become a major procurer of space systems without the ESA rule—in other words, there is no direct link between the ESA funding rule and countries obtaining work on such programs."

Although the EC's new direct involvement in space activities is relatively modest, it is allowing several countries to develop space industry expertise from a relatively low baseline. For example, the EC-funded seventh framework project 'Nordic-Balt-Sat' has seen Lithuania, Estonia, and Latvia partner with Sweden, Poland, and the International Space University in France to examine how Baltic states can make a "continuous and sustainable contribution in major ongoing and planned European space programs."

The Slovak Academy of Sciences has participated in the IMPRESS project, a cofunded EC and ESA research effort to understand the critical links between the solidification processes of intermetallic alloys. According to early findings, the research could lead to a 40-50% weight reduction for low-pressure turbine stages compared with conventional nickel superalloys. In Warsaw, the Space Research Center of the Polish Academy of Sciences (CBK PAN) has contributed work to a wide range of NASA, Russian, Ukrainian, and EU space research programs; its latest work focuses on using satellite technology to monitor land surface and land border areas within the EU as part of the EC's GMES program.

And at the very least, the advent of Galileo navigation equipment will allow 'value added' service companies in central Europe to set up operations in the software enhancement sectors, along the lines that already exist there for GPS-derived products.

SPACE INDUSTRY EMPLOYMENT BY COUNTRY

	2003	2004	2005	2006	2007	2008	2009
Austria	263	289	294	279	290	301	318
Belgium	1,123	1,193	1,189	1,187	1,288	1,284	1,523
Denmark	233	153	175	180	200	167	216
Finland	141	136	136	131	129	153	172
France	13,017	12,699	11,157	11,145	11,453	11,641	11,225
Germany	5,065	4,630	4,415	4,481	4,812	4,962	5,270
Ireland	48	48	45	42	42	42	30
Italy	5,100	4,770	3,814	3,738	3,963	3,985	4,490
Luxembourg	N/A	N/A	N/A	N/A	27	27	31
Netherlands	511	543	505	559	491	460	610
Norway	155	312	247	223	205	254	276
Portugal	24	80	55	73	53	109	101
Spain	1,971	2,022	1,896	1,901	1,915	2,095	2,231
Sweden	693	679	699	686	689	641	664
Switzerland	705	683	670	671	707	743	783
U.K.	3,186	3,239	3,287	3,576	3,242	3,437	3,429

Source: Eurospace.

Low wages, high skills

European manufacturers are also starting to exploit opportunities to use highly skilled workforces in the low-wage economies of central European countries. Satellite and spacecraft manufacturer EADS-Astrium set up an op-

Ukraine and Kazakhstan: Looking beyond Russia

The first launch of Cyclone-4, capable of carrying a single or multiple payload of 5,300 kg to LEO or a 1,600-kg satellite to geostationary transfer orbit, is planned for 2012. The launcher, being built by the Yuzhmash State Enterprise in Ukraine, is the latest in the organization's long line of rockets, which include the Zenit and Dnepr launchers.

Although the Ukrainian space sector still relies on the Russian market for around 80% of its overall space business—worth around $254 million in 2009—it has been forging more links with other customers in recent years. In February, Systema JFC and Switzerland's Leica Geosystems signed a collaborative agreement for development and application of satellite navigation systems and spacecraft docking systems.

Ukraine is a partner in the Brazilian Alcantara spaceport program and will provide Cyclone-4 launchers when the complex is finished in 2012. The country participates with China in over 50 space projects, including a joint Earth observation satellite program, implementation of an ionosphere satellite project for earthquake forecasting, and the supply of launcher equipment by Chinese partners.

Ukrainian companies provide assemblies to the Russian Soyuz and Progress vehicles, transporting crews and supplies to the ISS. In addition, they are now producing the first-stage fuel compartment and second-stage propulsion system to the Orbital Sciences Tauris-II launch vehicle.

Other cooperative agreements have recently been signed with Japan and Saudi Arabia. Ukrainian rockets are being employed in the Sea Launch program, which went into bankruptcy in 2009 but has plans for relaunch this year.

Although Yuri Gagarin blasted off on the first manned space rocket in 1961 from the Baikonur cosmodrome center in Kazakhstan, the center is on a 50-year lease to Russia. So Kazakhstan has started building its own space launch complex, a €130-million facility in Astana. Work started on the center in July 2010 under the direction of Kazakhstan Gharysh Sapary (KGS), the company in charge of developing the country's space program. KGS and EADS-Astrium have signed an agreement in which Astrium will provide mechanical, radiometric, thermal, and acoustic testing facilities at the new center and will help in its construction. KGS and Astrium will jointly manage the Astana center and implement Kazakhstan's future satellite programs.

eration in the Czech Republic in September 2010 and in Poland the following December, as part of the Astrium Central Europe program.

Astri Polska is a 50/50 joint venture between Astrium and CBK PAN, Poland's largest space institute. The new company will focus on developing space technologies in the areas of spacecraft electronics, photonics, and materials, as well as in Earth observation, navigation, and telecommunications services. This will involve developing tailored satellite applications for end users, particularly in disaster management and security. Astrium is also working closely with ECS countries such as Hungary, Estonia, Romania, and Poland "to facilitate the development of space programs in these countries as they work towards full ESA membership," according to the company.

It is still very early days in the history of space activity in central and eastern Europe. But the work of the EC and the new cooperative agreements between academic and research institutes throughout the region are creating a building block of space science knowledge on which an industry can eventually develop. With more PECS agreements in the pipeline, and with Romania and the Czech Republic now full ESA members, there will be a rapid increase in space industrial development in these two countries over the next few years.

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

Correspondence

In **Cyberscience and 21st-century education**, **April**, page3), Lyle Long contends, in a provocative and interesting commentary, that the "physics-based" disciplines of aerodynamics, structures, propulsion, dynamics, and control are "fairly mature," and calls for aerospace curricula to deemphasize these in favor of computers and electronics.

As important as these technologies are, they are still only one of a number of subsystems. A Boeing 787 has billions of times more computational capability than a 707, but it is still only about twice as efficient by any measure, and it is not at all clear that the increased efficiency is due to the electronics. Have aerospace engineers failed to take full advantage of the revolution in computing, or is there simply a limit to what computing has to offer aerospace?

A graduate curriculum in systems engineering or technical management might well benefit from more computational content, but most students go into aerospace engineering because they want to build physical flight hardware. And even if they move into management, they will still need a firm foundation in the technologies governing what can be built and flown. There are already too many systems engineers and program managers who are bored or confused by the physics-based subject matter. Aerospace engineers who don't focus primarily on the physics will not be able to effectively manage aerospace projects.

There is also a reach-down effect into the physics-based disciplines themselves. Managers more comfortable with computers than with the mechanical realities often fail to recognize irrelevant solutions or incorrectly posed problems. Those of us who do a great deal of computational modeling know, perhaps more than anyone, that we must always work to capture the physics better and generate results relevant to the messy and uncertain physical world. To borrow from Richard Hamming's famous statement, computing must not become a self-justifying exercise in which numbers substitute for insight.

I was recently at the National Air and Space Museum. Near the Apollo capsule, a young guy showed his girlfriend a cell phone and said the phone "has more technology than that capsule." His comment betrayed a narrow and limiting, though all too common, definition of technology. Limits in material strength, propulsion efficiency, and structural reliability cannot be overcome primarily by computation. Better aerospace systems will still require greasy old test rigs that smell like hydraulic fluid. We can only compute our way around failures if we clearly understand the physics behind those failures.

Grant Henson
Chief scientist
Invariant Laboratories
www.invariantlabs.com

Reply by author I am not advocating drastically reducing the teaching of the physics-based disciplines, but if that is all the students learn then they will not be prepared for the future.

I am advocating that aerospace students learn all they can about cyberscience, not get pure cyberscience degrees. They need to fully understand aerospace systems, and since the systems are roughly 50% cybersystems (and cybersystems are also used in the design and building of them) they need to learn about that.

I had an eye-opening experience about 10 years ago that helps illustrate the problem. When we first started doing UAV research, the first thing we did was buy some large R/C aircraft and an autopilot, and for very little money we had covered aerodynamics, structures, propulsion, dynamics and control. And we quickly realized that the existing aerospace engineering students were of little help in further developing the system. We needed students trained in cyberscience to develop the system into an interesting platform capable of performing useful missions. So we have changed our curriculum to allow them more freedom in choosing courses and in getting minor degrees. They learn a great deal about the traditional aerospace topics and then can easily supplement this with more depth or breadth in aerospace or in other areas.

This increases the credits required, but they get recognition for this additional work (a minor). We also offer a graduate minor in computational science, which has been very successful.

As to the Hamming quote, I agree.

I think computer science programs (in fact, all university programs) need to be revised, too. In fact, I think almost every college student should get a minor in cyberscience (even if they are not in science or engineering).

The F-35 is several years behind schedule, not because of aerodynamics, structures, propulsion, dynamics and control, but because of software problems, and we are not educating enough people to address these issues (or to build systems beyond the F-35).

✈✈✈

Wow! Prof. Long's commentary contains a lot to think about. I suspect that he has intenionally gone a bit over the top to get people thinking about his fundamental premise.

One thing we need to get out on the table right away: Current aerospace curricula **do not deal in technology.** Curricula began to drop such courses in the early 1970s. Curricula were reduced from 160 hours when I was in school to 120 hours nowadays. In addition, to make room for greater liberal arts content, even more technical or scientific content was removed.

These changes took place because a) technology courses are much more expensive than straight lecture courses; b) faculty versed in technology frequently do not have Ph.D.s nor do they write many technical papers—administrators therefore have a hard time evaluating such faculty for raises and promotions; c) industry has never urged universities to provide specific technological content in their curricula; d) without a decent background in the fundamentals of solid and fluid mechanics an engineer is unequipped to undertake the creation of unconventional vehicles or those that must operate in unconventional environments.

Courses in software engineering, systems engineering, electronics, computing, autonomus systems, navigation, etc., are little more than handbook references unless the needed physical and mathematical foundation is provided beforehand.

Long says physics-based teaching is 'mature,' but it is not for new students. Has he looked at what freshmen bring with them from high school?

I for one am reluctant to go back to the 1930s, when engineering education emphasized practical experience and the application of handbook knowledge at the expense of fundamental knowledge. I grew up in such a system and when I was confronted with trying to build systems to operate in a space environment I was completely at sea until I acquired the necessary fundamental background.

The curriculum needs constant updating, but in small steps, not in superman leaps.

Frederick O. Smetana
Professor emeritus, mechanical and aerospace engineering
North Carolina State University

P.S. Here are some projects I undertook during my career. How many of Long's courses would have helped me tackle them: Heat a low-density supersonic gas stream; interpret the indications of a Langmuir probe in a moving plasma; build a low lag, position-error-compensated pitot-static tube to operate successfully from M=0 to M=5 at angles of attack to 30 deg and sideslip angles up to 10 deg; build a 10-kW solar electric system that can be built by the average refrigeration mechanic; build a low-cost 1-kW wind energy system that can be built without using precision milling or casting equipment; design a light airplane that uses only a steering wheel and a foot pedal for controls yet remains at the same attitude for all forward flight conditions; and devise a scheme to find the roots of a 12th-order polynomial accurate to 20 significant digits.

Reply by author I am glad my commentary has stimulated discussion on this topic; it is long overdue.

I don't know if future curricula would prepare someone to address those seven tasks; but that is the point—we should not be educating students to solve yesterday's problems. I agree the number of credits required to graduate has been greatly reduced, which means the entry-level engineering degree should be a master's degree, and these could be in another field such as business, computer science, cyberscience, software engineering, systems engineering, etc. These choices should be driven by what they love, but tempered by what will allow them to have a long and fulfilling career.

Also, mature does not mean easy—calculus is mature but is still difficult to learn. Likewise, classical aerospace engineering is fairly mature but still difficult to learn. However, because they are fairly mature, we essentially know how to do them, and we can teach people how to do it.

Teaching a mature discipline is different than teaching very new material, and it is irresponsible to teach these topics in the same way they were taught 50 years ago.

Fluid dynamics and structural mechanics today are primarily done using CFD and FEM, and the students must know how to intelligently interpret those results; but do they also need to know all the material that was taught 20 years ago too?

While we can teach someone the mature disciplines fairly well, topics such as critical systems software, intelligent systems, etc., are difficult to teach because we do not know all the answers yet. So part of the reason these are not being taught is because it is much easier to teach the mature topics. Why do we teach the students the mature technology and then ask them to learn the less mature information on their own? The changes we have made to our curriculum have had an impact, and other departments can emulate them.

So we have made some small steps that do have a significant impact, which will allow superman to focus on more important problems! Also, keep in mind that my commentary was limited to 500 words; some of my recent papers, curricula descriptions, and webpages discuss these issues in more depth (http://lylelong.com).

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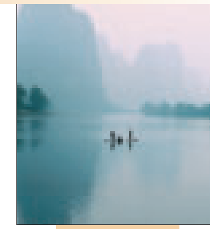


In China, aviation gets back on track

A series of announcements and a change in policy direction at the top of China's government indicate that a measure of realism has been restored to the direction of the country's civil aviation industry, and indeed to its plans for major industrial expansion in general. The announcements indicate that events have forced a reassessment and a cutting back of the massive Chinese effort to build high-speed railways over huge swaths of the country.

Yes, that's railways: If you think high-speed trains have little or nothing in common with making aircraft, you may want to think again. The major factors are money, allocation of precious resources such as experienced designers and engineers, and international credibility.

A planner's dream

For China, building its own large commercial aircraft has long been the dream of planners, principally for three reasons. First is the economic rationale of not having to buy only from foreign manufacturers—both for international routes and for vital links across a huge country. Second is to bring about the technical training and engineering experience that comes from hands-on aircraft production line work, practical learning that goes beyond the theoretical knowledge imparted by universities. Third, and hugely important, is the international mark of respectability that would come from having a Chinese-designed and built airliner certificated by Western regulators.

It is a long-term process, and China has been taking small bites at it since the 1960s, though the effort has been accelerating over the past few years. The country's aircraft makers, which produce both civil and military types, subsisted on a diet of former Soviet designs and subcontract assembly, with just one serious foray into building a four-engined jet airliner in the 1970s—the handful that were built were deemed unacceptable for passenger service within a short time.

A joint project undertaken in the 1980s with McDonnell Douglas (now Boeing) saw MD-80s built in Shanghai to FAA standards from kits. More recently, Airbus has started assembling A320s in China, while China's own designers and engineers have worked with Western companies and individuals to design a regional jet—the ARJ-21, about the size of a Fokker F100 or a DC-9—and a larger aircraft called the Comac 919.

Seal of approval?

Comac is short for the Commercial Aircraft Corporation of China, and the 919 is intended to be certificated jointly with the FAA so that it will have the stamp of foreign approval, which its makers hope will enable foreign sales to boost its manufacturing numbers. How real such expectations might be is a matter for debate: The aircraft's various models are intended to have about 165-190 seats, so they will fall squarely into the marketing brackets now comfortably occupied by Boeing and Europe's Airbus. The C-Series of jets from Canada's Bombardier and planned products from Brazil's Embraer are soon to join the fray as well.

The Comac products are not expected to fly until 2014, with entry into service likely in 2016, so they will be well behind the competition in numbers. Also, because Comac is relying on Western companies to supply systems and many components, the level of technology shown in the C-919 is unlikely to be as good as that in the competition, even if it is using the same engines. Price is another matter, of course, and arguments via the World Trade Organization about subsidies could be interesting.

Comac is hoping to get an FAA stamp of approval for its C-919.

No matter—the project is happening, and it will continue. It can be difficult to appreciate from outside the mainland just how much determination and effort is being put into the C-919—it is a national project with huge amounts of foreign and domestic prestige riding on its success, and it therefore cannot be allowed to fail.

A new path

What is also often not evident from outside the mainland is that, far from its external image, China's government is anything but monolithic. Elsewhere, the democratic process ensures that many major differences over policy are aired in public. In China they are aired behind closed doors, but they are still aired. Factional fighting is the norm, just as it is anywhere else.

In this regard, there has been a significant change of direction very recently. China needs mass transit to shift huge numbers of people around the country during national holidays. It also needs mass employment for a rapidly growing population. Commercial aviation cannot do either: It is considered inherently elitist because of its cost to the consumer in China's low-wage economy, and its employment opportunities are for the top end of the education stream, thus limiting available jobs to a relatively small pool of talent.

So how will China offer an alternative form of transport across the nation, one that would cost the consumer less, absorb large numbers of people building it, and be faster than existing ground-based modes? High-speed rail has been around a long time in Japan and parts of Europe, and in China it quickly became the answer to planners' dreams. They diversified the effort and costs of building it by letting regions be given or borrow large amounts of cash under local control to set up infrastructure such as rail tracks and stations.

At first glance, the idea is hugely attractive. The rolling stock is cheaper than aircraft. Stations can be in or near town centers, cutting total travel times over short distances by so much that rail journeys of roughly 300-350 mi. take about the same time as air trips. Further, baggage is less of a problem because the passenger takes care of it, and security is less intrusive—so far, at any rate.


The CRH3 is a version of the Siemens Velaro high-speed train used in China on several lines.

To sum it up, proponents of high-speed rail say it offers "freedom from airport security hassles, freedom from never-ending flight delays and cancellations, freedom from being forced to spend hours stuck in airports, freedom from having to turn off your electronic devices, freedom from endless traffic jams, freedom from car accidents, freedom from foreign oil dependency and rogue nations controlling us, freedom from oil price spikes, freedom from transferring our wealth (money we spend on transportation) to terrorist-ridden nations that don't like us, and freedom from being pulled into resource wars."

No, that's not what was said in China; it is a statement on the Website of the U.S. High Speed Rail Association, which followed up with, "Promoting HSR for America is promoting freedom for Americans!" And just so you get the message, "HSR is as American as we can get." Unless of course you are in China, where that message or something similar has led to a high-speed rail network that by the end of last year covered more than 5,200 mi., to be extended to 8,125 mi. by 2015 and 10,000 mi. by 2020.

The down side

Unfortunately, contracts associated with China's high-speed rail have been subject to substantial amounts of corruption, and the public exposure has led to changes at the top of the Ministry of Railways. Separately, there is now a realization that high-speed rail is no more viable a means of mass transport than aviation. The proof of this was widely trumpeted in mainland Chinese media after the Lunar New Year national holiday break in February, when literally millions of people all over the nation wanted to take trains home to their families. Many had journeys that were far from easy, and there was an outpouring of ill will about how expensive high-speed rail is compared with the older, slower trains.

These were not the only negatives—short cuts taken in the system's construction were uncovered, in the form of inappropriate and substandard materials used for the rail beds in various places. This was not necessarily because of backhanders at high levels, but because the proper materials were not available, and the pressure to get the job done led to a fall in standards. The potential safety risks were obvious. The country's leadership responded by ordering safety checks across the country, and by announcing a decrease in planned speeds and fares, while planned expenditure on the system has been slashed.

Brazil's Harbin manufacturing line will switch to building Embraer Legacy jets.

Unstated by the aviation faction (at least in public), but almost certainly a major factor in its overcoming the rail faction's sapping of potential funding, is the issue of international monitoring of standards of aircraft manufacture—monitoring voluntarily sought by Comac. FAA and European regulatory approval will be necessary for China's commercial aircraft to have any hope of success in the outside world; having started down that road, it is impossible to go back. No such approval is necessary for the rail system. There is nothing wrong with high-speed rail in the right circumstances, but in China it now has a public black eye both at home and abroad.

Teaming for success

The aviation faction's victory in this instance came through the rail faction shooting itself in the foot. But a handful of other events indicate that Comac and its supporters are pushing hard to ensure the 919 project's success. One major such event is the teaming of Comac with Bombardier to cooperate in technology, marketing, and customer support—the last being the most important, given that China has virtually no experience supporting high-technology products outside its own borders. Another is the gradual shifting of its publicity and marketing to outside hands with experience.

The final major event is a deal with Embraer, which for more than a year had been sweating over possibly having to close its Harbin production line that makes the 50-seat ERJ 145 regional jet. The Brazilian company had wanted to upgrade to making the 90-seat E190, but there were fears that this would be stopped because this is the market the ARJ-21 was intended for. Under the new deal, Embraer will switch the Harbin line to making its Legacy business jets that are part of the ERJ 145 family, while China will buy 35 E190s.

No one has said what is to happen with the ARJ-21. It has been flown, but there is no indication that it is in production. It would not be too surprising if that project has ceased, because it has served its purpose as a development and systems integration laboratory for China's engineers working with foreign companies, enabling all new civil aircraft work to be concentrated on the C-919.

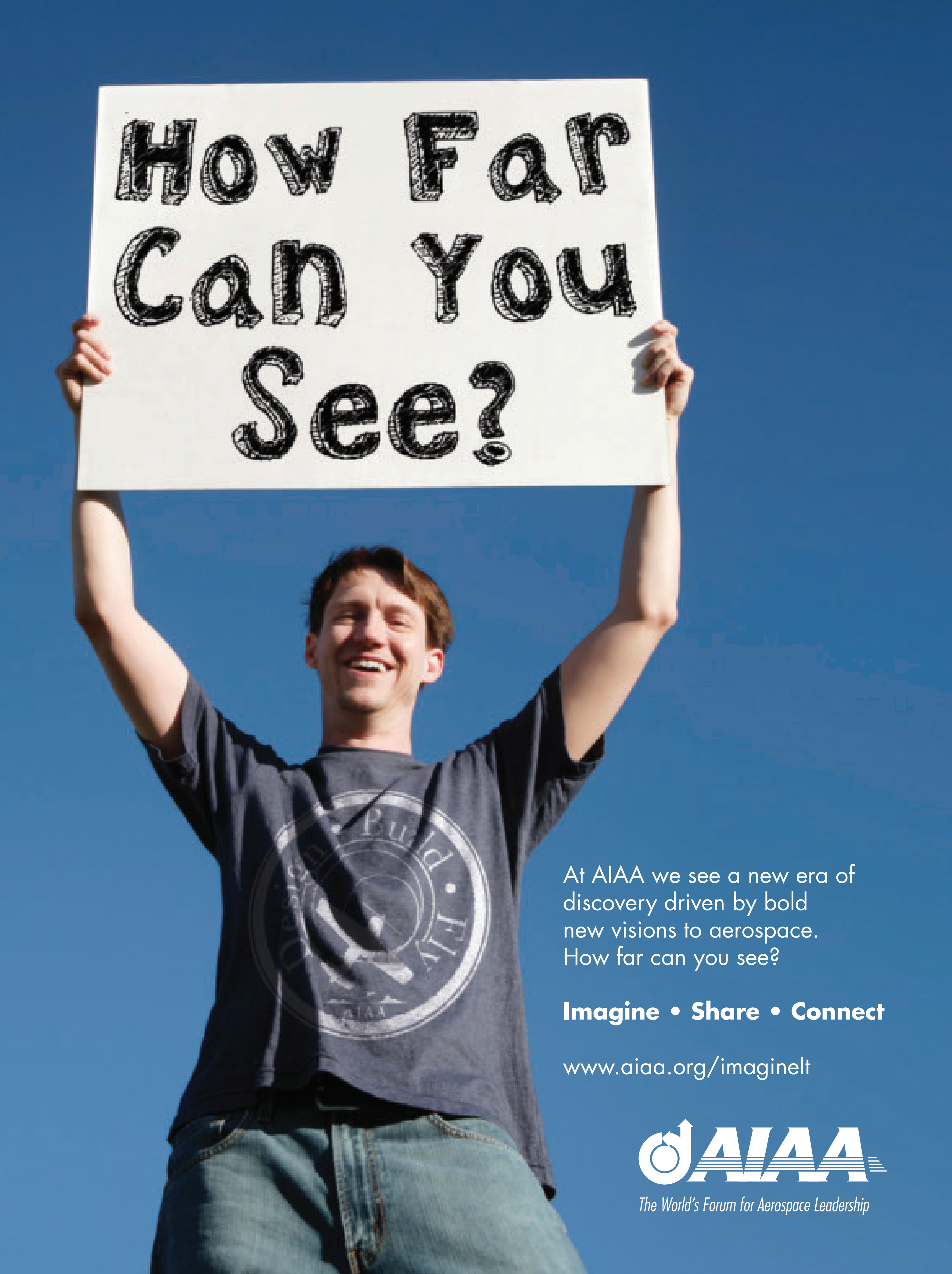
WigetWorks plans to sell its small craft as private transport.

Completely unrelated, and out of left field from Singapore, is an approach being made to China by Singapore company WigetWorks to sell its 'wing in ground effect' craft as a private transport or lake-crossing ferry. The concept has been taken seriously in Russia, where very big 'Wigs' have been seen crossing large expanses of water. Like its Russian forebears, the Singapore craft flies at about 6-20 ft above the water, cruising at 90 kt and carrying eight passengers.

The makers say it is powered by a V8 automobile engine that runs on automotive gasoline and is capable of 'flying' across stretches of coastal waters or large lakes. The Singapore company developed the AirFish after buying out the intellectual property of its German builder in the 1990s, and then spent a long time getting it certificated because it was outside the rules of the time. Now it is certificated by Singapore's maritime authorities, and its manufacturers estimated a six-passenger version made of carbon fiber will cost less than $500,000. It may well be an immensely practical proposition, but getting it licensed in China may be an interesting challenge.

The fate of the ARJ-21 is still uncertain.

Michael Westlake
Hong Kong
michael_westlake@yahoo.com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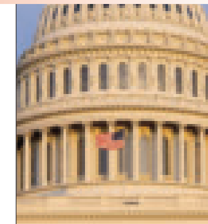


Waking up to harsh realities

WITH SPRING ENDING AND SUMMER AT hand, Washington is debating the future of human spaceflight, problems in the civil aviation arena, and the seemingly endless issue of government spending, deficits, and debt. After reaching a last-minute deal containing $38.5 billion in cuts from 2010 funding levels, on April 15 Congress finally enacted a budget for FY11.

Bolden testimony

NASA's handling of the human spaceflight program drew barbs from lawmakers when Administrator Charles Bolden testified on Capitol Hill on April 11.

Bolden told legislators his agency is attempting to comply with a congressional mandate that bars NASA from canceling contracts in the Constellation next-generation spaceflight program, which the Obama administration wants to terminate. Bolden said NASA can comply with legislation requiring it to develop a 'multipurpose crew vehicle' (MPCV) at reasonable cost by exploiting shuttle infrastructure. He said the Orion crew exploration vehicle (CEV)—part of Constellation—and the MPCV are similar, and that NASA can develop the capsule Congress wants under existing Orion contracts with Lockheed Martin. He cautioned, however, that the scope of work may have to be revised because of lowered funding prospects.

Sen. Kay Bailey Hutchison

Impatient with the pace of MPCV work, Sen. Kay Bailey Hutchison (R-Texas) told Bolden that President Obama "wanted Orion continued, and your staff and managers agree that Orion is the reference vehicle and easily falls within the scope of the authorization law that you have said you are following. Yet it doesn't seem that the contract modifications to achieve this result are happening."

Any delays with MPCV, Bolden said, are about money: "I will tell you that in any of the contracts that we have today, we cannot pay the amount of money that was contracted x-number of years ago. So there will be negotiations among us and all our contractors, because we have got to get our costs down." He added, "We may have to descope the vehicle in some manner," referring to potential changes in the configuration and capabilities of the MPCV.

In early 2010, Obama proposed canceling Constellation, including the then-planned version of the CEV being built by Lockheed Martin Space Systems of Denver. Hutchison asked Bolden whether he intends to proceed with the scaled-back Orion or, "is it just going to be strung out, so that eventually it just can't be revived?" Bolden replied that "the existing Orion contract, as a deep-space exploration vehicle, easily maps to the scope of what we call a multipurpose crew vehicle."

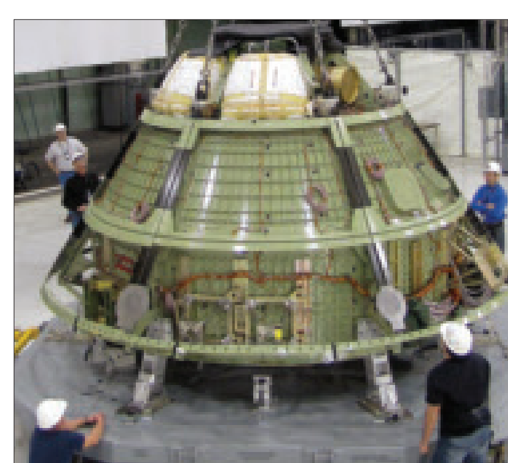
Though it is not clear that Congress and the executive branch will be able to agree on a federal budget for FY12, Hutchison told Bolden the $1 billion in the administration's FY12 spending plan for NASA falls short of the $1.4 billion lawmakers insist is necessary to field an operational MPCV by 2016. She pressed the administrator to seek more money next year for Orion—a prospect few in Washington view as realistic in today's constricted and contentious budget climate.

Under the original plan for Orion, initial models were to carry astronauts to the ISS; later versions would take them to lunar orbit. In April 2010 Obama announced that Orion would be spared Constellation's fate, but only to be scaled back to serve as an emergency lifeboat at the space station—meaning it would launch without a crew. Since then, Congress has enacted the MPCV requirement into law. Bolden will now be under pressure to produce the lifeboat/MPCV without any increase in funding.

Asleep at the FAA

Transportation Secretary Ray LaHood and FAA Administrator Randy Babbitt are conducting damage control—including a nationwide tour of control tower facilities by Babbitt—after eight separate incidents in which air traffic controllers were found sleeping on the job. In a ninth incident, a controller mishandled a landing by a C-40B carrying first lady Michelle Obama.

Although no one has been hurt in an aircraft mishap as a result of con-



The Orion crew module ground test structure is inspected prior to integration with an encapsulating aeroshell. The NASA administrator believes work on the Orion CEV can be integrated with development of an MPCV.


FAA Administrator Randy Babbitt

trollers succumbing to drowsiness, professional associations and lawmakers say the FAA must make a greater effort to ensure that controllers are awake and alert.

With lawmakers looking over their shoulders, officials of the FAA and other agencies are confronting other civil aviation issues as well. Rep. John Mica (R-Fla.) is concerned that the FAA has missed a deadline to develop pilot identity documents that meet a standard set by Congress. In addition, an aerial mishap aboard a Southwest Airlines jet raised questions about government officials' monitoring of the structural condition of the nation's aging airliners.

Babbitt's whirlwind tour of FAA facilities to talk to employees about work practices was accompanied by an order that at least two controllers will be on duty at every facility whenever that facility is in operation. This brings an end to the practice of having a single controller at work during the midnight shift at 29 controlled airports around the country.

Said Babbitt, "We absolutely cannot and will not tolerate controllers sleeping on the job when they're supposed to be controlling airplanes. We're working with controllers to take a good hard look at some of the scheduling practices. Some of the things we've done will provide a better sleep opportunity, rest opportunities for the controllers, so that they can in fact arrive to work rested and ready to go to work."

In the incident involving the first lady, a C-40B (a military derivative of the 737-800) was approaching for a landing at Joint Base Andrews outside Washington, D.C.—where air traffic control is provided by the FAA—when a controller noticed that the plane was following too closely behind a C-17 Globemaster III, a huge airlifter that can create blasts of wake turbulence. The controller ordered the C-40B to make a routine go-around, after which it landed without incident. The controller on duty was not a supervisor.

The agency has since changed its rules to require a supervisor on duty whenever the first lady or vice president is flying, a requirement already in effect when the president is flying.

Rep. Mica, who follows the FAA most closely, so far has not followed through on an earlier pledge to hold hearings about air traffic controller problems. However, he told reporters he is "miffed" about the executive branch's performance in introducing a new pilot ID card using embedded biometric data that Congress first mandated in 2004.

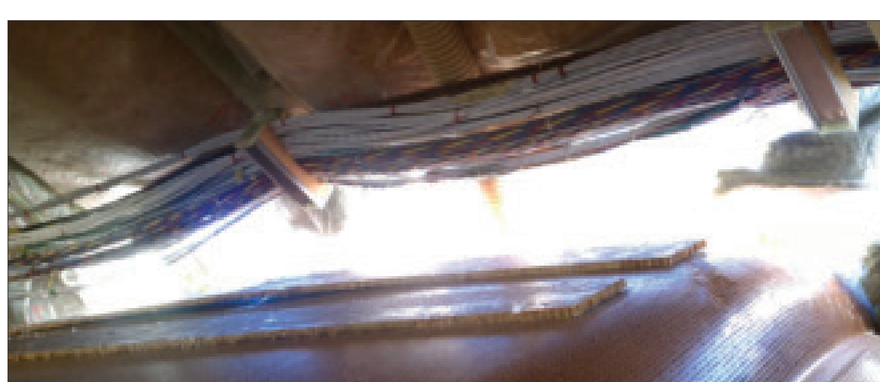
On April 14, in a rare snub of Congress, TSA officials declined to attend a hearing by Mica's Transportation and Infrastructure Committee, leaving the FAA unable to answer legislators' questions on progress, or lack of it, in producing secure pilot ID. "They are not building a good strong fuzzy relationship in working with us," Mica said of TSA. A symbolic empty chair for TSA director John Pistole left Peggy Gilligan, FAA associate administrator for aviation security, on her own and unable to tell lawmakers the status of stalled efforts to issue biometric IDs.


Transportation Secretary Ray LaHood

Mica says he might convene a joint hearing with the House Homeland Security Committee. The TSA comes under that department and would be likely to participate without lawmakers having to take the extreme step of issuing a subpoena.

All these issues were percolating when a 5-ft hole was ripped out of the roof of a Southwest Airlines Boeing 737-300 on April 1 en route from Phoenix to Sacramento. In a public gaffe, the FAA first called it "a purely random occurrence." That did not prevent several legislators from calling for a review of FAA policy on aging airliners. There were lingering memories of an April 1988 mishap in which the cabin roof was torn off an Aloha Airlines 737-200 and a flight attendant was swept to her death.

Despite serious efforts to upgrade and inspect airliners that might be vul-


On April 1 a 5-ft hole opened in the roof of a Southwest Airlines Boeing 737-300 on its way to Sacramento.

nerable, experts say structural cracks from metal fatigue remain a persistent problem on older planes.

The 737 is by far the most widely used airliner in the world. According to Boeing, over 6,000 have been built or ordered. Many flying today are recently built or even fresh out of the factory door. Boeing says, however, that some 570 older models may be at risk for the same kind of fuselage cracks that disrupted the Southwest flight. No one was injured in that incident, and the stress cracks were anticipated, but they were expected to occur only after the plane had made at least 50,000 flights. Acknowledging that a particular joint failed much earlier than expected on the Southwest flight, Boeing said checks were now advisable after just 30,000 flights. Solons on the Hill are expected to insist the FAA make this a requirement.

Defense budget

Secretary of Defense Robert Gates has been telling lawmakers for months that the Pentagon will have to get by with fewer dollars in the near term, and that he "accepts" small defense reductions in the FY11 legislation. In the context of the president's April 13 announcement of a government-wide plan to reduce the federal deficit—the White House's response to larger cuts proposed by deficit hawks like Rep. Paul Ryan (R-Wisc.)—Gates says he is launching a "comprehensive review" to find $400 billion in spending cuts by 2023. In the context of a target date eight years away, that is not a huge sum, but it may prove difficult to attain.

When Gates' acquisition chief Ashton Carter spoke to reporters about the secretary's cost-cutting program in an April 20 speech, he had little to offer that was new. He cited the Navy's Zumwalt-class destroyers and the Marine Corps' proposed new presidential helicopter and expeditionary fighting vehicle (EFV) as examples of high-tech systems the nation might well dispense with.

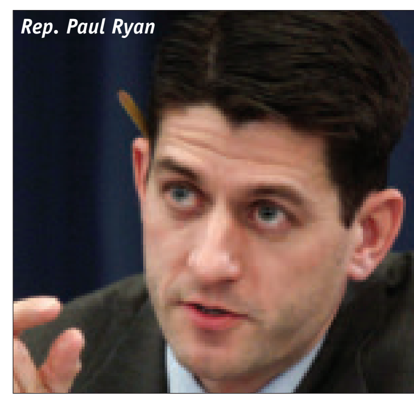
But the Zumwalt-class ships were already facing criticism, almost nothing is being spent currently on a new presidential helicopter, and Gates had already announced cancellation of the EFV months ago. Rep. Duncan Hunter (R-Calif.) and others say they will try to keep EFV alive, but most in the nation's capital believe Gates' decision to cancel the costly, long-delayed ship-to-shore Marine vehicle will stick.

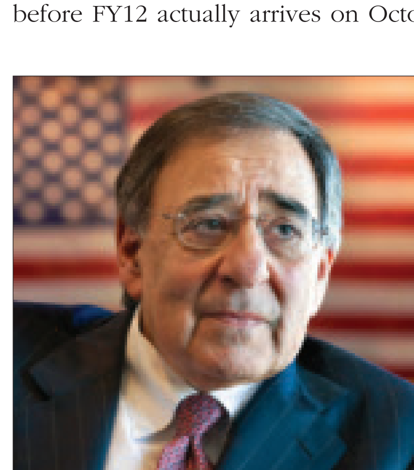
The armed forces today are largely dependent on weapons that date to the 1970s, such as the M1 Abrams main battle tank, F-15C Eagle fighter, and Los Angeles-class submarine. Thus Obama, Gates, and other administration leaders will not easily find a big military program they can cut.

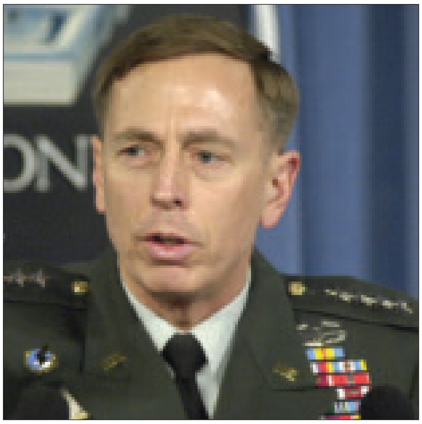
The F-35 Lightning II program has suffered from technical and fiscal concerns and has been restructured—meaning delayed—several times, but leaders in both parties acknowledge that it is needed too badly to be canceled outright. The Air Force's KC-46A air refueling tanker program will have a tab of over $35 billion, but it has been in gestation for a decade, and no one argues it is not needed.

The Navy littoral combat ship program may be costlier than necessary, because the service chose two designs and is developing them along parallel tracks, but experts say the technology is so advanced there is no other way to proceed. It is unclear whether in the current spending climate the Navy will be able to move ahead with its plan to order 20 of the ships, to be built between now and 2012.

Defense spending makes up about one-fifth of the federal budget. Even Capitol Hill's most ardent proponents of spending cuts have mostly steered clear of the Pentagon budget for fear of appearing unsupportive of U.S. troops. That may change this spring and summer if Congress follows the traditional pattern of debating the administration's proposed FY12 budget before FY12 actually arrives on Octo-


Rep. Paul Ryan


CIA Director Leon Panetta


Gen. David H. Petraeus

ber 1. A range of congressional voices, from Sen. John McCain (R-Ariz.) to Sen. John Kerry (D-Mass.), argue that the time has come to include the DOD in any new cuts—to a greater extent than Obama and Gates are proposing.

These cuts will not be Gates' problem much longer. As the secretary's planned retirement date nears, the president has nominated current CIA Director Leon Panetta to step into that office. Other nominees announced were Afghanistan commander Gen. David H. Petraeus as the new head of the CIA; Lt. Gen. John R. Allen, deputy chief of the Central Command, to take over in Afghanistan; and Ryan C. Crocker as ambassador to Afghanistan.

Debt ceiling

With the battle over the current year's budget temporarily out of the way, Congress began to debate raising the statutory $14.3-trillion federal debt ceiling in the near future.

Nothing in the Constitution limits the government's ability to borrow, but Congress established a ceiling in 1917 in response to the fiscal needs of the Great War. In fact, the overall federal debt has been increasing since 1835. Lawmakers will be searching for ways to rein in government excess without allowing the federal government to default. Despite much talk on both sides of the aisle, Congress is expected to raise the cap on government spending because, in the end, it really has very little choice.

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

Events Calendar

JUNE 2
Aerospace Today...and Tomorrow: An Executive Symposium, Williamsburg, Virginia.
Contact: 703/264-7500

JUNE 5-8
Seventeenth AIAA/CEAS Aeroacoustics Conference, Portland, Oregon.
Contact: 703/264-7500

JUNE 6-8
The Space Shuttle: An Engineering Milestone, Atlanta, Georgia.
Contact: Cindy Pendley, cindy.pendley@ae.gatech.edu

JUNE 9-11
Fifth International Conference on Recent Advances in Space Technologies, Istanbul, Turkey.
Contact: 703/264-7500

JUNE 13-17
International Conference on Aircraft and Engine Icing and Ground Deicing, Chicago, Illinois.
Contact: Frank Bokulich, fbokulich@sae.org

JUNE 26-30
International Forum on Aeroelasticity and Structural Dynamics 2011, Paris, France.
Contact: Anne Venables, secr.exec@aaaf.asso.fr

JUNE 27-30
Twenty-ninth AIAA Applied Aerodynamics Conference; 41st AIAA Fluid Dynamics Conference and Exhibit; 20th AIAA Computational Fluid Dynamics Conference; 42nd AIAA Thermophysics Conference; Sixth AIAA Theoretical Fluid Mechanics Conference; 42nd AIAA Plasmadynamics and Lasers Conference in conjunction with the 18th International Conference on MHD Energy Conversion; and Third AIAA Atmospheric and Space Environments Conference. Honolulu, Hawaii.
Contact: 703/264-7500

JULY 17-21
Forty-first International Conference on Environmental Systems, Portland, Oregon.
Contact: 703/264-7500

JULY 31-AUG. 3
Ninth Annual International Energy Conversion Engineering Conference, San Diego, California.
Contact: 703/264-7500

JULY 31-AUG. 3
Forty-seventh AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, San Diego, California.
Contact: 703/264-7500

JULY 31-AUG. 4
2011 AAS/AIAA Astrodynamics Specialist Conference, Girdwood, Alaska.
Contact: William T. Cerven, 571/307-4208, william.t.cerven@aero.org

AUG. 8-11
AIAA Conferences on Guidance, Navigation, and Control; Atmospheric Flight Mechanics; and Modeling and Simulation Technologies. Portland, Oregon.
Contact: 703/264-7500

Christian Scherer

What do you think are the major step changes in new aerospace technologies that will change the shape and operating dynamics of future aircraft?

If you bring it back to basics, the biggest cost of flying is fuel. So our research has always been focused on consuming less energy. There are some step changes available here, beyond the generation of engines we are proposing for the Airbus A320neo. And, assuming that the next generation of engine will still be burning kerosene, that means counterrotating or open rotors. I'm beating the drum very hard on this—the laws of physics suggest we could be looking at a 15-20% improvement over neogeneration engines with an open rotor, so we must try to make this technology work.

But there are two major hurdles to clear—first, they look like a meat chopper, and the stigma of propeller-driven power is still around. Second, there is the issue of noise. Many people equate noise with emission issues, but this is totally wrong. Carbon emissions stay in the atmosphere for a long time, but noise dissipates very quickly.

Do you believe these engines will have applications within the short-haul and long-haul markets?

We would need to start with short-haul aircraft; this is fairly sophisticated technology, employing gears and pitch mechanisms, so we will have to start with small thrust levels. So the first application would be on short-haul aircraft, in our opinion.

But later on, perhaps, there might be some long-haul applications?

As far as we can see, it's a technology that we could master on paper today for thrust levels that we would need for typical replacements for 150-seaters. The time frame jibes nicely with our product strategy, because we think these [open-rotor engines] could be brought to maturity if we clear any show-stoppers that we might face. They could be brought to maturity let's say in the mid-2020s, and that would coincide nicely with the post-A320neo timing that we have in mind. Actually, that is one of the underpinning reasons for why we think the neo strategy is the right one.

So would you say the neo program has met expectations?

It's going really well commercially, and we're extremely agreeably surprised by the market reaction on A320neo—and on the combination of A320s and A320neo, with airlines actually taking both, because they have large fleets and the A320 is still better than anything else until the A320neo comes. In fact it is going so well that we are actually studying whether or not we can accelerate the development timing of A320neo, to hit the market a little bit earlier than the official entry into service of early 2016.

"[The pilot] will be less involved in flying the aircraft or being the guarantor of safety in flight and much more an asset manager of the machine tool."

Apart from new engines, where else do you see major changes to future aircraft performance?

Energy conservation—the electric aircraft is very important for us. More automation and ground operations without aircraft engines are some of the main areas of interest. Then there is biofuel, of course, but the development of that is more or less beyond our control.

Another possibility is the application of laminar flow technology that will help provide a less turbulent flow over the wing. This could lead to an overall drag reduction of 2-5%, which of course translates into further lower fuel-burn rates.

How far ahead do you look when you consider which technology paths you are going down?

We adopt the standard technology readiness level concept developed by NASA as the timeframe to assess the maturity of evolving technologies in materials, components, and equipment prior to incorporating that technology into a system or subsystem. That puts us generally in the 15-20-year time scale, which is why we're looking at open rotors now.

One of the perceived drawbacks of open rotors is that aircraft flying with these engines will generally not be as fast as a conventional jet.

Actually, there are some technical benefits to slower speed; some technologies prefer slower speeds. From our research so far, airlines don't really care as long as their aircraft, their machine tools, are not handicapped in the complex air traffic situation—we don't want to have to fly at lower altitudes, for example.

But there is an issue of how we can offset the time lost through slower flight, and we don't want to be in the business of having to compete with a rival who will be able to arrive at the destination airport 10 minutes ahead. So we may have to look at a way of giving the aircraft some extra speed if it's needed. Of course if we had an air traffic management system which allowed us to fly the most efficient routes, we would save 10 minutes on our current short-haul routes and we wouldn't need the extra speed.

A perfectly optimized ATM system

Interview by Philip Butterworth-Hayes

would give us a 10% fuel saving—but that would be possible only if the aircraft were more directly linked into an ATM system as part of an interactive, real-time management network.

And that would be possible only if there were more automation on the ground and in the air.

Yes—but introducing automation is a double-edged sword because of the social issues involved. From my personal perspective I would say that we will not introduce automation for automation's sake. There would have to be clear financial reasons. On that point I have to point out that labor, in and around the aircraft, is an airline's second largest cost factor, after fuel.

So do you have a roadmap in mind as to how we can introduce more automation into the cockpit, and which technologies will replace which manual operations at certain points in the future?

We have a roadmap to developing SESAR [Single European Sky ATM Research] technologies and a roadmap to developing enhanced systems capabilities. But that is not automation for automation's sake. Our company now has the technologies to fly an aircraft without a pilot in the cockpit. We don't necessarily want to build such an aircraft, but we have the technologies to allow it. We could make proposals to our customers, but it's up to the airlines and certification bodies to make these decisions.

I don't want Airbus to make the same mistakes that we made in the 1970s and the 1980s, when we announced we could reduce the cockpit from a three-person to a two-person operation. The result was that for some time we were initially met with skepticism, even though we developed money-saving technologies, which the rest of the industry has since adopted.

But if you ask, 'How is further automation going to enter the cockpit?,' it is clear that air traffic integration is going to be one important driver.

The role of the pilot is going to change. For an airline, an aircraft is a production tool, which means the aircraft will have to produce more and more and become less and less greedy. That means a change to the pilot's role. He or she will be less involved in flying the aircraft or being the guarantor of safety in flight and much more an asset manager of the machine tool.

Automation is then introduced under the pressure of new technology and economics. So the asset manager will play a great role in maintaining the asset, and we will move away from calendar-based maintenance-cycle overhauls to a self-diagnostic system, managed by the 'manager.'

So how will the new aircraft technologies that you are planning to

Christian Scherer was appointed executive vice president at Airbus in September 2007, with responsibility for strategy and future programs as well international cooperation. Scherer is in charge of defining Airbus's long-term strategic objectives in diverse areas, including analysis of the market environment, research on its trends and evolution, product policy and development of future programs, industrial strategy, and international partnerships and cooperative programs. He reports directly to the Airbus CEO.

Previously, beginning in March 2006, Scherer headed Airbus's future programs and was responsible for driving the vision, genesis, and development of any future aircraft product offerings and programs. His duties extended to development of the processes and industrial structure needed to support these future innovations. He retains responsibility for this activity in his current role.

Scherer began his professional career in 1984, joining Airbus Industrie as a contracts administrator before being promoted to sales contracts manager. In 1987 he became contracts director to Airbus Industrie North America (AINA) in Washington, D.C., and was then promoted to vice president of contracts at AINA, responsible for pricing, financial performance, negotiation, and implementation of all sales proposals and resulting transactions in North America.

In 1994 he returned to Airbus' headquarters in Toulouse as vice president, leasing markets. In 1999 he was appointed vice president for contracts and pricing worldwide, retaining leadership of the leasing markets division. He became Airbus' permanent deputy head, commercial, in 2003.

Scherer was born in Duisburg, Germany, in 1962. He holds an MBA in international marketing from the University of Ottawa, and was graduated from the Paris Business School with a degree in organization and management information systems in 1984.

introduce impact what Airbus will be doing in 10 years' time?

With the decision on the neo now made, we will be building aircraft with energy consumption levels 15% better than today. But neo is part of a wider strategy to supersede what our competitors are going to be doing. And we do have a lot of new competitors.

But what these new manufacturers, from China, Brazil, Russia, and Canada, are doing is not new; they're not inventing anything. In 2015 they will have new aircraft in the market, with fly-by-wire avionics invented by Airbus. For years Airbus and Boeing have been locked into a stable duopoly, and for the first time we are going to be challenged.

"For years Airbus and Boeing have been locked into a stable duopoly, and for the first time we are going to be challenged."

So our strategy is to invest $1 billion [in the neo program], while the new manufacturers will have to invest $10 billion or more, and it will take them years to see any return on this. By then, we will have our next generation of technology-efficient aircraft ready, so that by 2025 we will have a new generation of aircraft, with more automation, new engines, new maintenance capabilities, in place, which will make the aircraft of our competitors obsolete.

Will we have a regulatory regime in place capable of managing the introduction of these new technologies?

Yes, I'm sure we will, for two reasons. First, we are maturing these technologies in a step-by-step way, and we are already engaging with the regulators on some of the issues surrounding these new ideas. Second, if you can bring to the market a technology which improves operating costs by 5% or more, then ways will be found for it to enter the market.

I have no doubts that, in terms of safety, more automation in aviation correlates directly to improved levels of safety; most mishaps are human-induced. Anyway, new open-rotor engines and better aerodynamics should not offer safety challenges.

And how will the passenger benefit from the application of new technologies such as open rotors and more automation?

The 'travel experience' should be made much easier. But first and foremost, the passenger will feel the benefit in his or her wallet, because aircraft will become increasingly cheap to operate, and that means much better connectivity. We are looking at, after all, double-digit improvements in aircraft efficiencies.

What technology improvement 'leaps' have you made on the A350?

The A350 XWB brings together the very latest in aerodynamics, design and advanced technologies to provide a 25% step change in fuel efficiency compared to its current long-range competitor. Over 70% of the A350 XWB's weight-efficient airframe is made from advanced materials combining composites (53%), titanium, and advanced aluminum alloys. The aircraft's innovative all-new carbon fiber reinforced plastic fuselage results in lower fuel burn as well as easier maintenance. The A350 XWB benefits from Airbus's high level of expertise in incorporating composite material into its aircraft.

Robust state-of-the-art systems also help to lower maintenance costs which, combined with the aircraft exceptional fuel efficiency, reduces operating costs by 25% compared to equivalent, in-service long-range aircraft. The A350 XWB's commonality in engines, systems, and spare parts throughout the family helps reduce operating costs even further.

Space shuttle: Memories at Mach 25

THE 30-YEAR FLIGHT HISTORY OF THE space shuttle culminates this month in one grand finale, a microcosm of its 134 previous missions. On STS-135, Atlantis and her crew will deliver the Raffaello multipurpose logistics module, laden with supplies, logistics, and spare parts, to the ISS. The vehicle will also fly a system to investigate the possibility of robotically refueling existing spacecraft. In addition, Atlantis will return a failed ammonia pump module to help NASA diagnose the failure mechanism and improve future pump designs.

The space shuttle's flight history can be summarized neatly with eye-popping facts and figures about satellites launched, cargo upmass hoisted to orbit, and modules delivered to the ISS. But Atlantis' last flight should also remind us of the uniquely human achievements of hundreds of thousands of shuttle engineers, technicians, scientists, managers, and support staff, offered willingly to sustain this amazing fleet of spaceships. This dedicated team—in mission control, at NASA centers, at industries and labs across the nation, as well as in the cockpit—propelled the space shuttle to its successes. On the eve of the shuttle's final mission, here are some personal memories of their contributions.

Vaya con Dios!

Endeavour was my first shuttle, carrying five veteran crewmates and one rookie—me. At T-2 minutes during the STS-59 count, the last call to the crew from the orbiter test conductor was: "Endeavour, close and lock your visors, initiate O_2 flow, and 'Vaya con Dios!'" Commander Sid Gutierrez replied crisply with, "Thanks a lot, Mark, and we'll see you in about 10 days." On the flight deck, pilot Kevin Chilton jokingly asked Sid, a favorite son of Albuquerque, if he could translate Mark's Spanish sendoff.

"Nope, I think I got that one. The real translation is 'God be with you as you go.'"

Endeavour lifts off from launch Pad 39A on April 9, 1994, at 7:05 a.m. on STS-59.

God is who I wanted lying next to me 90 seconds later, when Endeavour's three main engines coughed fire and shivered their way up to full power. My middeck seat rattled and shook along with every fitting in the cabin, until six seconds later booster ignition hit us with a massive crash-bang wallop. Explosives split the eight hold-down nuts clamping the SRBs to the pad, and the shuttle leaped clear of Earth under 7 million lb of thrust. The brutal ride on the solids was like hurtling down a dirt road in a pickup truck at about 50 mph, and Endeavour wasn't backing off the accelerator.

After two minutes of crackling and shaking, the boosters left us with a metallic *Clang!*, and we traded brute power for smoother, sustained acceleration on the main engines. Six-and-a-half minutes later, after a full, chest-squeezing minute of 3-*g* throttling, we were in orbit over the North Atlantic at just over 17,000 mph. For my first orbital experiment, I unzipped and tugged off my left glove, then released it to float and spin lazily, inches from my face. My grin could have lit up the world.

Through the Aurora

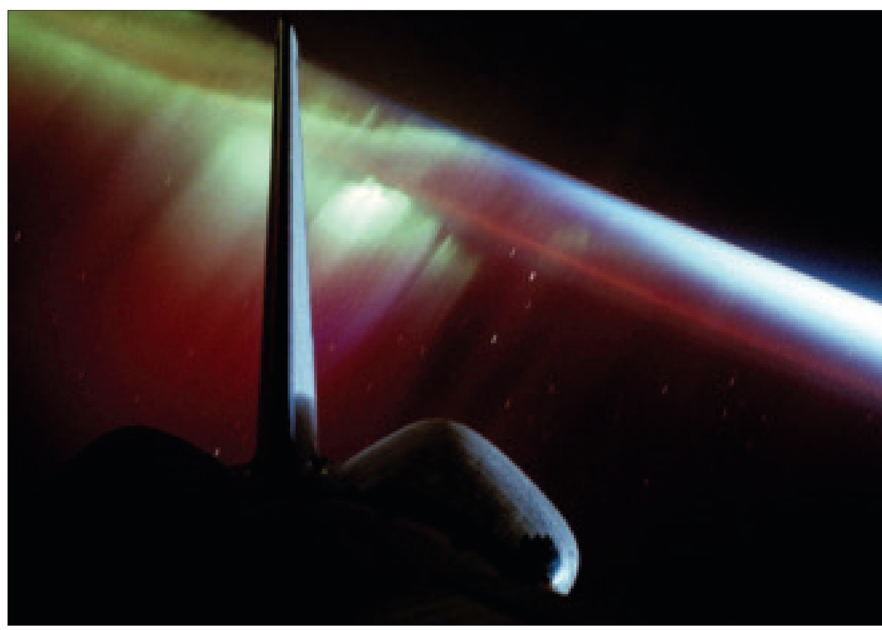
The payloads on my first two shuttle flights, in April and October 1994, were space radar labs (SRL-1 and -2), synthetic aperture imaging radars scanning Earth's changing surface with wide-ranging geological and ecological applications (see http://southport.jpl.nasa.gov/). Endeavour carried us around the globe at an altitude of 121 n.mi., at an orbital inclination of 57°. JPL scientists and Johnson flight controllers had come up with an ingenious steering technique that enabled the shuttle to pirouette delicately through each orbit, aiming the radar beam precisely and canceling out the Doppler error in the echoes caused by the Earth's rotation. The result was a nearly 24/7 swath of crisp, multifrequency radar portraits of our planet, imaged at 20-m resolution.

In April the vehicle carried us on three orbits daily through the autumn darkness, well south of Australia and New Zealand, where we sailed among the glowing curtains of ionized nitrogen and oxygen atoms called the Aurora Australis. My recorded notes reveal sightings on Flight Days 4 and 6:

At times we were flying right through the long thin streamers of the aurora, projecting straight up through the atmosphere, a very ghostly pale yellow green….We could see these long streamers going up above us, but at times we flew right over the long shimmering arcs of the aurora. We could see the shimmering curtain below us, and when we flew over the top of it, it would become edge-on to us, and we could look straight down on this line…just a fantastic sort of ghostly sight…swirling all around the shuttle…pulsating curtains and rippling ribbons of light.

Of course, daytime held even more spectacular sights: On September 30, my STS-68 crew and I roared off the launch pad the day Russia's Kliuchevskoi volcano blew its top. Late on launch day we soared over the Kamchatka peninsula, but could see little of the twin-peaked volcano's summit, entirely shrouded in charcoal clouds of ash boiling up 50,000 ft into the stratosphere. The jet stream threw that vast eruption plume of steam and dust nearly 350 mi. out across the Pacific. Crowding Endeavour's windows, cameras in hand, we captured dramatic, down-the-throat views of this live geology lesson, as explosions from Kliuchevskoi fed the turbulent shaft of steam shot through with dirty-brown ash. The radar was able to penetrate the cloud, revealing active vents, hot lava and mud flows, and melting of the summit's icy hood.

Kliuchevskoi was just one of our 572 science targets, and Endeavour nailed them all: Flight controllers handily developed a software patch to work around a faulty steering jet and restore precise radar pointing. Later in the mission, with the help of payload and in-flight maintenance controllers, astronauts Steve Smith and Jeff Wisoff removed and replaced an oven-sized high-rate digital recorder on the flight deck, restoring full data flow from SRL-2. After 11 days STS-68 glided home with 13,000 still photos of Earth, and enough radar imagery to fill a stack of CDs more than 65 ft high.



STS-68, orbiting just 120 n.mi. up for its SRL-2 mission, cruises through the Aurora Australis in October 1994.

In total, the NASA/JPL, German, and Italian radars imaged 150 million km² of the Earth's surface, observing about 15% of the globe. That's over 100 terabits of data—an imagery collection that would fill a 45,000-volume encyclopedia. We tested radar interferometry (stereo imaging) techniques that in 2000 enabled the shuttle radar topographic mission to generate a precise, 30-m-resolution topographic map of 80% of the world's landmass. These three flights were typical of the shuttle's superb performance as an orbital science platform.

Are you turning the handle clockwise?

The shuttle showed off its scientific versatility again on STS-80 in November 1996. At the outset, KSC launch controllers wrestled with a hydrogen leak in Columbia's main engine compartment that held our count at T-31 seconds. On the flight deck, I was sure we had scrubbed for the day, but within a couple of minutes propulsion engineers had eyeballed the leak rate and determined it was within safety limits. With studied coolness, the console lead announced, "NTD, it appears to me that we're on the edge, but that this is an acceptable condition. My recommendation is that we continue." A few seconds later the NASA test director had approval from his launch director, and intoned, "Copy, resume on my mark: three, two, one, mark!"

My reaction? *Holy smoke, they're going ahead!* Thirty-one seconds later the twin boosters blasted us off the pad, and the five of us were soon safely in orbit. The experts on the Kennedy launch team had saved a scrub and saved our hides. I'm still grateful!

Ten days later Tammy Jernigan and I were floating at vacuum inside Columbia's airlock, ready to rehearse a toolbox full of space station assembly techniques on the first of two EVAs. With a 'GO!' from Houston, Tammy swung the outer hatch handle to crack the seals and open the door to the payload bay. But instead of describing an easy circle, her gloved hand stopped abruptly after 30 degrees of travel, hard against some mysterious resistance. Ten minutes of fruitless shoving couldn't budge the handle further; frustrated, we called in Houston for advice.

Flight controllers scrambled with the hatch schematics while walking us through troubleshooting steps. A quarter of an hour later we were still locked inside by the jammed handle. I couldn't really blame Capcom Bill McArthur for his next transmission: "Tom, uh, forgive us for asking the obvious, but could you please confirm you're turning the handle *clockwise*?" His tone was apologetic—Mission Control had to cover every possibility.

If only that *had* been the problem; after two hours of troubleshooting, we admitted defeat. Our $2-billion space shuttle's doorknob was broken. The jammed mechanism was on the far side of a sealed cover, impossible to reach from the airlock. We were stumped, and our Thanksgiving night spacewalk was scrubbed.

It was a crushing blow to Tammy and me, but my disappointment was salved somewhat by membership in a team that could exercise such cool and thorough decision-making. I later learned that Houston and cape engineers had meticulously examined every branch of the hatch mechanism failure tree, zeroing in on where the failure must be—in the hub gearing.

We could bypass the faulty mechanism only by applying a hammer and chisel. Punching through the hatch might leave us stranded in the airlock with no way to repressurize and get back inside, forcing an emergency landing and abandoning our free-flying ORFEUS-SPAS astronomical satellite. The shuttle team made the right call in canceling: Spacewalks could be (and were) rescheduled. Our disappointed crew took satisfaction in hauling in and berthing a successful ORFEUS-SPAS, its recorder packed with two weeks of high-quality astronomical observations. We also logged the longest shuttle mission ever, including a weightless Thanksgiving dinner I'll never forget.

Columbia's five astronauts launched and retrieved ORFEUS-SPASTelescope as well as the Wake Shield Facility materials processing satellite during STS-80. Mission duration was a record at nearly 18 days.

Destiny in space

Atlantis was our ship for the STS-98 mission, which delivered the U.S. Destiny Laboratory to the ISS in February 2001. On Flight Day 4, Marsha Ivins expertly flew the Canadian robot arm to swing Destiny out of the cargo bay and nestle it permanently into its berth at Unity's forward hatch.

Meanwhile, pilot Mark Polansky had suited up Bob 'Beamer' Curbeam and me, and propelled us out of the airlock for our first EVA—this time, I managed to rotate the hatch handle all the way 'round. We were soon clambering about the station's exterior, releasing launch locks and connecting utility lines to the new lab.

Beamer had to disconnect four ammonia coolant lines from the station's cooling loops and plug them into the new lab's heat exchangers. Within seconds of releasing the first hose from its ISS receptacle, its business end sprayed my partner with a jet of ammonia vapor and ice crystals from a cold-soaked poppet valve. My heart sank: We were venting vital coolant for the new lab.

Backdropped by Atlantis' cargo bay, spacewalker Bob Curbeam peers into the orbiter's airlock to retrieve the Destiny Lab's protective window shutter for installation on Feb. 12, 2001.

"Yeah, I know," Beamer exclaimed. "I've got ammonia…definitely ammonia coming out, and ice crystals forming all over the place." Against the empty black sky, fat ammonia snowflakes tumbled in brilliant sunlight, blasted outward by a barely visible jet of vapor.

But Curbeam had already thought through this failure—back on the ground. Just weeks before launch, station and shuttle payload flight controllers conferred with us about a possible leak. We agreed on a strategy in case one should occur: Cut off the ammonia supply, then seat the connector into the new lab fittings.

Engulfed in an ammonia snowstorm, Beamer muscled open an upstream valve, choking off the leaky connector. Within minutes of the initial leak, he had wrestled the stiff hose and its spewing connector safely into its lab receptacle. His quick thinking and execution, building on thorough contingency planning by the ground team, had preserved 95% of the coolant supply. In the end, the potentially crippling leak merely gave us a glimpse of a spectacular but transient ammonia comet tail.

Another curve ball: Inside Atlantis, Ken Cockrell and Marsha Ivins got word from flight controllers that a faulty thermostat had pushed the lab's interior temperature to over 100 F. Tapping laptop keys on the flight deck, they promptly worked with Houston to step through the module's activation procedures, taking just 45 minutes instead of the planned two-plus hours. Their quick response restored cooling and prevented heat damage to Destiny's avionics and life-support systems.

That was a tense day in orbit, inside and out, but the combined Houston/Atlantis team had dealt with every problem, inaugurating the $1.4-billion lab's operations. Ten years later, Destiny is still the hub of control and research activity at the ISS.

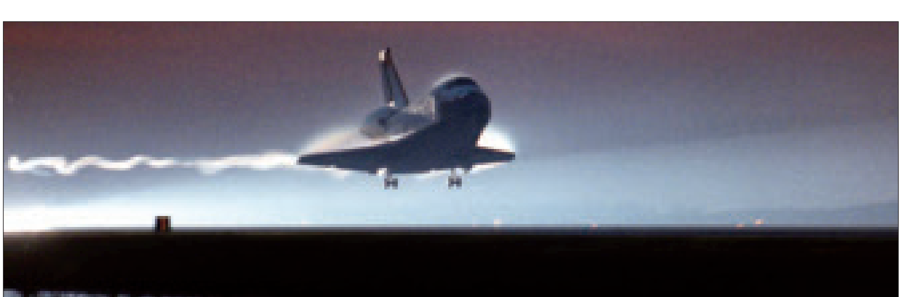
What a privilege you've given me: representing the U.S. on four flights of its marvelous space shuttle. I've seen almost everything the shuttle can do: delivering space station modules, hauling supplies to crews in orbit, serving as a 'workbench' for complex spacewalks and robotics work, observing both Earth and the universe with cutting-edge scientific payloads, and launching and returning satellites for refurbishment and reuse.

We will miss the shuttle's ample lifting power and, even more, its flexibility and versatility. Serving as our classroom in space, the orbiter fleet has taught us invaluable skills: orbital repair, outpost construction, precision rendezvous and docking, complex EVA, and intense, round-the-clock science operations. Even its shortcomings will help us build safer and more efficient vehicles.

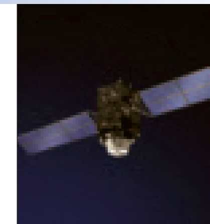
When the shuttle retires, what we will miss most is its human component. That superbly professional team overcame innumerable technical obstacles and recovered from devastating tragedy in compiling an unmatched record of success in Earth orbit. The nation should not surrender their talent, but rather build on their dedication and experience to capture our future in space.

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

Thanks to my crewmates Jay Apt, Mike Baker, Dan Bursch, Kevin Chilton, Rich Clifford, Ken Cockrell, Bob Curbeam, Linda Godwin, Sid Gutierrez, Marsha Ivins, Tammy Jernigan, Story Musgrave, Mark Polansky, Kent Rominger, Steve Smith, Terry Wilcutt, and Jeff Wisoff; ISS crewmembers Yuri Gidzenko, Sergei Krikalev, and Bill Shepherd; and the thousands of shuttle colleagues with whom I had the privilege of working. Your record in 30 years of space exploration is second to none.



Mission accomplished, Columbia nears touchdown at Kennedy Space Center for a dawn landing on December 7, 1996. The next national space system will build on the accomplishments of the space shuttle team's 30-year record of excellence.



Mission model offers snapshot of space payloads

Every year for the past two decades, we have tracked proposed satellites, probes, capsules, space shuttle missions, and ISS assembly hardware around the world to develop a snapshot of known possible future space payloads.

That picture, which we call the Worldwide Mission Model, is the first step in putting together a forecast of the payloads market for the next 10 years. It is meant as a rough draft from which to begin piecing together the puzzle of what we believe the future market may look like, based on certain assumptions about current and upcoming programs, competitors, investors, political priorities, and technology trends, as well as related historical cycles.

We account for all the payloads we know to have been proposed for manufacturing and launching over the next 20 years. We also include those that we believe would have to be built and launched to replace systems currently in orbit, or that we expect will soon be operational—in other words, payloads about which we know nothing yet, but which are based on payloads we view as a 'sure thing' or close to it.

Getting specific

The strength of the mission model is that it contains the specific name of each payload and basic data about it, including its type, its intended orbit, its mass, its host country or region, its primary manufacturer, its owner/operator, and its launch vehicle program.

Unlike a forecast, which by its nature must include unnamed or made-up payloads, the mission model is more straightforward. We simply collect the payloads that governments, companies, universities, and other organizations announce they are developing or planning. We avoid making judgments about whether these will be completed and go up on schedule, or even go up at all. We accommodate only the publicly available information and use it as a starting point to get a sense of 'what is currently out there.'

In last year's mission model for the period 2010-2029, we accounted for 2,229 proposed payloads. That number was up 9% from the previous year's model, which contained 2,033 payloads. This year, for the 2011-2030 time frame, we count a total of 2,315 proposed payloads, or an increase of 4% over our 2010 survey.

More than meets the eye

Nearly two-thirds of the payloads are listed for launch during 2011-2016, which makes it look as though we are expecting a huge drop in the payloads market for the remaining 15 years. But that is not the case, because this is not a forecast, and we are factoring in only the payloads that have been announced or are based on these programs. Since most of the available information is about payloads intended to be launched within the next five years, it is natural that the model will have considerably fewer payloads in the 'out' years.

In a forecast of the market for space payloads, it is likely you would see steady growth in the numbers during the next 20 years, rather than declines, as suggested in the mission model. Most of the growth would probably be attributable to major increases in the number of small, micro-, nano-, and picosatellites. There will also be many new flights into space related to emerging markets such as the commercial resupply of the ISS, crew transport, and space tourism.

Of course, we assume there will be more and more countries entering the market—building, launching, and operating a wide range of payloads. The national space programs and industries of countries such as China and India are still in their relative infancy and appear destined to continue developing for the foreseeable future, until they too produce Earth-orbiting space stations and crewed missions to the Moon. Other nontraditional players in the market, such as Brazil, Iran, and South Korea, also seem determined to invest in their space infrastructures and compete in the payloads market.

Analyzing by type and orbit

What is most useful about the mission model is not the annual totals, which do not tell a story about the market, but rather the totals of the different breakdowns of the data by category. For example, if you look at the breakdown by the type of payload, the narrative begins with the fact that there are more commercial payloads being proposed than any other kind. Of the 2,315 payloads, 38% are commercial, 35% are civil, 20% are military, and 7% are university and 'other' types.

If you then look at the breakdown by orbit, what you see is that most of the payloads, by far, are destined for LEO. Of the total payloads, 63% are LEO, 23% are GEO, 8% are medium Earth orbit, 5% are deep space, and 1% are elliptical.

Given the extremely high number of LEO payloads and the dominance of commercial types, there is a strong indication that a main driver of the mission model is mobile communications satellites. An overwhelming number of all the payloads that have been

PAYLOADS[1]

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021-30	Total
Payloads	351	397	335	198	193	139	89	83	59	60	411	2,315
By Type[1]												
Commercial	59	135	103	68	116	80	42	21	13	25	224	886
Civil	178	152	121	93	39	30	27	44	20	25	90	819
Military	72	57	59	35	35	29	20	17	26	10	97	457
University and other	42	53	52	2	3	0	0	1	0	0	0	153
Total	**351**	**397**	**335**	**198**	**193**	**139**	**89**	**83**	**59**	**60**	**411**	**2,315**
By Orbit[1]												
Low Earth orbit	246	268	245	124	111	95	51	49	32	24	220	1,465
Geostationary	56	94	63	34	58	22	21	21	15	22	126	532
Medium Earth orbit	12	9	13	26	12	16	10	8	9	11	33	178
Deep space	24	24	13	7	6	4	7	5	3	3	11	107
Elliptical	13	2	1	7	6	2	0	0	0	0	2	33
Total	**351**	**397**	**335**	**198**	**193**	**139**	**89**	**83**	**59**	**60**	**411**	**2,315**
By Mass[1]												
1-500 kg	157	172	181	85	50	34	7	6	1	2	3	698
501-2,000 kg	106	118	86	60	78	63	42	36	23	22	166	800
2,001-4,000 kg	28	37	22	19	27	15	18	19	15	14	78	292
4,001-6,500 kg	42	22	31	21	25	14	13	12	12	13	100	335
Over 6,500 kg	18	18	15	13	13	13	9	10	8	9	64	190
Total	**351**	**397**	**335**	**198**	**193**	**139**	**89**	**83**	**59**	**60**	**411**	**2,315**
By Host Region[1]												
North America	114	173	133	85	87	79	41	21	24	12	141	910
Europe	70	87	120	55	38	28	15	30	9	20	82	554
Russia and CIS	58	44	38	22	44	15	13	13	15	10	122	394
Asia and Pacific Rim	81	52	33	34	20	15	16	16	11	14	45	337
Africa and Middle East	19	18	6	0	2	2	1	2	0	2	14	66
Latin America and Caribbean	9	23	5	2	2	0	3	1	0	2	7	54
Total	**351**	**397**	**335**	**198**	**193**	**139**	**89**	**83**	**59**	**60**	**411**	**2,315**
By Owner/Operator[1,2]												
Rosaviakosmos (Russia)	28	22	14	8	9	7	6	7	6	6	61	174
NASA (U.S.)	36	23	40	39	10	4	3	3	2	2	5	167
ESA (Europe)	13	18	19	28	3	4	5	21	1	12	4	128
Air Force (U.S.)	20	21	8	12	15	14	3	4	2	3	17	119
NRO (U.S.)	9	17	37	16	2	2	2	2	2	2	20	111
Ministry of defense (Russia)	14	5	4	4	9	4	7	4	7	4	49	111
Globalstar (U.S.)	6	12	24	0	0	0	0	0	0	0	44	86
Iridium Communications (U.S.)	0	0	0	0	36	29	16	0	0	0	0	81
Orbital Communications (U.S.)	6	6	6	6	6	12	6	0	0	0	28	76
CNSA (China)	13	5	4	5	6	5	7	7	6	9	2	69
ISRO (India)	20	6	9	7	5	0	2	1	1	0	9	60
Von Karman Inst (Belgium)	0	0	50	0	0	0	0	0	0	0	0	50
Intelsat (U.K.)	4	10	3	1	3	0	3	1	2	1	10	38
SES (Europe)	2	3	4	5	4	2	1	1	1	2	13	38
CNES (France)	6	1	15	2	1	1	2	0	2	0	3	33
BMDO (U.S.)	1	0	0	0	0	6	6	6	12	0	0	31
JAXA (Japan)	11	6	0	5	0	0	1	0	1	0	1	25
CMA (China)	6	3	2	2	1	0	1	2	1	1	5	24
GeoOptics (U.S.)	6	6	12	0	0	0	0	0	0	0	0	24
Gazprom (Russia)	2	6	2	0	2	0	0	0	2	0	8	22
Izmiran Institute (Russia)	3	0	10	8	0	0	0	0	0	0	0	21
Loral Space & Comm (U.S.)	1	2	0	4	0	2	1	1	1	1	8	21
Intersputnik (Russia)	0	0	0	0	20	0	0	0	0	0	0	20
O3b Networks (U.K.)	0	0	8	0	0	12	0	0	0	0	0	20
CSA (Canada)	3	8	2	0	3	2	0	0	0	1	0	19
RSCC (Russia)	1	0	7	0	2	3	0	2	0	0	4	19
DGA (France)	5	0	4	0	4	1	0	0	1	0	2	17
CONAE (Argentina)	0	15	1	0	0	0	0	0	0	0	0	16
Satellite Observing Sys (U.K.)	0	0	0	0	16	0	0	0	0	0	0	16
China Satellite Comm (China)	2	1	1	1	1	0	1	0	1	0	7	15
Eutelsat (Europe)	1	3	0	1	0	1	0	1	0	1	7	15
INSA (Spain)	1	0	0	12	0	0	0	0	0	0	0	13
ICO Global Comm (U.K.)	1	1	0	1	1	0	1	1	0	1	5	12
KARI (South Korea)	2	0	0	3	0	2	0	1	0	2	2	12
Other	128	197	49	28	34	26	15	18	8	12	97	612
Total	**351**	**397**	**335**	**198**	**193**	**139**	**89**	**83**	**59**	**60**	**411**	**2,315**

[1]In payload units. [2]Top 25.

PAYLOADS[1] (continued)

By Primary Manufacturer[1, 2]	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021-30	Total
Thales Alenia (Europe)	18	32	37	6	37	46	16	3	0	0	0	195
Energia (Russia)	11	7	7	6	6	6	6	6	6	6	60	127
Boeing (U.S.)	12	13	43	17	7	1	2	5	0	2	7	109
CASC (China)	17	8	5	7	4	3	8	7	5	6	7	77
Lockheed Martin (U.S.)	6	13	5	7	10	5	3	3	4	2	16	74
Reshetnev (Russia)	15	12	12	0	7	3	3	2	3	0	9	66
NASA (U.S.)	5	3	25	25	0	2	2	0	2	1	0	65
ISRO (India)	19	6	10	7	5	1	2	1	1	0	9	61
Von Karman Inst (Belgium)	0	0	50	0	0	0	0	0	0	0	0	50
EADS (Europe)	13	16	8	5	5	1	0	1	0	0	0	49
Sierra Nevada (U.S.)	6	6	6	6	6	12	6	0	0	0	0	48
Surrey Satellite Tech (U.K.)	9	6	1	6	17	0	0	0	0	0	0	39
Space Systems/Loral (U.S.)	8	14	5	3	0	2	0	0	0	0	0	32
Khrunichev (Russia)	2	4	1	1	21	1	0	0	0	0	0	30
Orbital Sciences (U.S.)	10	6	4	2	5	0	1	0	0	0	0	28
OHB-System (Germany)	1	3	2	2	0	1	0	17	0	0	0	26
CALT (China)	2	2	2	2	2	2	2	2	2	2	0	20
Arsenal Design (Russia)	0	0	10	8	0	0	0	0	0	0	0	18
CONAE (Argentina)	1	14	1	0	0	0	0	0	0	0	0	16
INSA (Spain)	0	1	0	12	0	0	0	0	0	0	0	13
KARI (South Korea)	2	0	0	3	0	2	0	1	0	2	2	12
Ball Aerospace (U.S.)	3	0	2	4	2	0	0	1	0	0	0	12
Pumpkin (U.S.)	0	12	0	0	0	0	0	0	0	0	0	12
SpaceX (U.S.)	3	2	2	2	2	0	0	0	0	0	0	11
IAI (Israel)	2	3	1	0	1	0	0	1	0	1	1	10
JAXA (Japan)	6	2	0	0	0	0	0	0	1	0	1	10
Miltec Missiles & Space (U.S.)	2	0	0	0	0	8	0	0	0	0	0	10
Other	178	212	96	67	56	43	38	33	35	38	299	1,095
Total	**351**	**397**	**335**	**198**	**193**	**139**	**89**	**83**	**59**	**60**	**411**	**2,315**

By Launch Vehicle Program[1]	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021-30	Total
Soyuz (Russia)	37	25	45	17	7	18	6	6	6	6	60	233
Atlas V/Delta IV (U.S.)	31	24	10	16	12	12	9	10	14	4	11	153
Long March (China)	29	13	8	14	9	6	10	11	8	10	19	137
Ariane 5ECA/5ESV (Europe)	39	17	25	15	4	4	1	3	0	12	1	121
Proton K/M (Russia)	20	8	9	2	6	1	4	1	5	1	20	77
Falcon 9 (U.S.)	3	3	2	2	38	14	0	0	0	0	0	62
Shtil (Russia)	2	0	50	0	0	0	0	0	0	0	0	52
PSLV (India)	19	6	3	3	0	0	0	0	0	0	0	31
VEGA (Europe)	13	14	3	1	0	0	0	0	0	0	0	31
Dnepr (Russia)	23	5	0	1	0	0	0	0	0	0	0	29
Falcon 1 (U.S.)	15	6	7	0	0	0	0	0	0	0	0	28
Rockot (Germany/Russia)	5	0	1	0	20	0	0	0	0	0	0	26
GSLV (India)	4	4	5	4	4	0	0	0	0	0	0	21
Delta II (U.S.)	16	2	1	0	0	0	0	0	0	0	0	19
H-2A (Japan)	10	3	3	1	0	0	0	0	1	0	1	19
Tsyklon (Ukraine)	4	0	6	0	0	0	0	0	0	0	0	18
Minotaur (U.S.)	10	3	1	0	0	0	0	0	0	0	0	14
Zenit 2/3F (Ukraine)	9	1	0	0	0	0	0	0	0	0	0	10
Taurus II/XL (U.S.)	2	2	3	2	1	0	0	0	0	0	0	10
Pegasus XL (U.S.)	9	0	0	0	0	0	0	0	0	0	0	9
Strela (Russia)	2	4	0	0	0	0	0	0	0	0	0	6
Cosmos (Russia)	3	2	0	0	0	0	0	0	0	0	0	5
Molniya (Russia)	2	0	0	0	2	0	0	0	0	0	0	4
Space Shuttle (U.S.)	4	0	0	0	0	0	0	0	0	0	0	4
Naro (South Korea)	1	0	0	0	0	0	0	0	0	1	1	3
Safir (Iran)	3	0	0	0	0	0	0	0	0	0	0	3
VLS (Brazil)	1	2	0	0	0	0	0	0	0	0	0	3
Zenit 3SL (U.S./Russia/Ukraine)	3	0	0	0	0	0	0	0	0	0	0	3
Epsilon (Japan)	0	0	0	1	0	0	0	0	0	0	0	1
Sea Star (U.S.)	1	0	0	0	0	0	0	0	0	0	0	1
Shavit (Israel)	1	0	0	0	0	0	0	0	0	0	0	1
Start 1 (Russia)	1	0	0	0	0	0	0	0	0	0	0	1
Volna (Russia)	1	0	0	0	0	0	0	0	0	0	0	1
Other	28	246	153	119	90	84	59	52	25	26	297	1,179
Total	**351**	**397**	**335**	**198**	**193**	**139**	**89**	**83**	**59**	**60**	**411**	**2,315**

[1]In payload units. [2]Top 25.

launched to LEO during the past two decades have been mobile comsats, specifically for three major constellations—Globalstar, Iridium, and Orbcomm. Each of these programs is currently in the process of launching replenishment satellites or developing them in preparation for launch within the next 4-5 years.

The only other commercial payloads in LEO tend to be small Earth imaging satellites for systems such as India's IRS, DigitalGlobe's QuickBird/WorldView, ImageSat International's Eros, and the SPOT Image SPOT. But none of these constellations compare in size to those of the LEO mobile comsat programs.

Another narrative can be that, given the relatively high number of civil payloads, and how few of these have traditionally been in either GEO or MEO, many of the civil payloads are scientific and Earth observation satellites in LEO or scientific and exploratory probes in elliptical orbits or deep space trajectories.

The story on the significant number of payloads destined for GEO is self-explanatory, since most payloads in this orbit are medium- to large-sized commercial telecommunications, direct broadcast television, and broadband satellites.

Mass breakdown

When we break down the payloads by their mass, we see that 65% weigh somewhere between 1 kg and 2,000 kg. It is within this range that we find pico-, nano-, micro-, and small satellites, as well as some that are considered on the lower end of medium size. An extremely high proportion of these satellites are destined for orbits other than GEO. Most are destined for LEO, particularly those weighing under 500 kg, which make up 30% of the total payloads.

Those payloads with masses between 2,000 kg and 6,500 kg account for 27% of the total. More than two-thirds of these are satellites intended for launch to GEO, and more than half of them are commercial communications satellites. Payloads that weigh more than 6,500 kg make up 8%, and most of those are crew transport and resupply capsules for the ISS.

The players

In terms of who is building or ordering payloads, the breakdowns by host region and owner/operator clearly show that North America (mainly the U.S.) and Europe together account for nearly two-thirds of the payloads. Russia and the Commonwealth of Independent States (CIS), or former Soviet Republics, account for 17%; Asia and the Pacific Rim, 15%; Africa and the Middle East, 3%; and Latin America and the Caribbean, 2%.

Together, Rosaviakosmos (the Russian space agency), NASA, and ESA account for one-fifth of all the payloads. If you add payloads for the USAF, the National Reconnaissance Office, and the Russian ministry of defense, the percentage goes up to more than one-third. The top 25 payload owner/operators account for three-quarters of the payloads.

We know that 53% of the 2,315 payloads either have been contracted for manufacturing or have named a company or an agency as the primary builder. On the strength of its prime contracts to build dozens of satellites for the second-generation Globalstar and Iridium mobile comsat systems, as well as other commercial, civil, and military satellite business, Thales Alenia Space alone accounts for 16% of the payloads that have a designated manufacturer.

Slightly under two-thirds of the payloads with a designated manufacturer are assigned to the top eight companies or agencies, including Boeing, Thales Alenia Space, Energia, CASC (China Aerospace Science and Technology), Lockheed Martin, Reshetnev, NASA, and the Indian Space Research Organization.

Finally, depending on the way you define a launch vehicle program—for instance, whether you count Long March as one or break it out into its many models and variants—there are at least three dozen of these programs that have payloads on their manifests or have been designated as the likely launch vehicle.

Approximately half the payloads have a firm or tentative launcher. The Soyuz medium-lift rocket accounts for one-fifth of those payloads. During the past few years, Soyuz has consistently been the world's most active launch program and, based on its current manifest, will probably remain so.

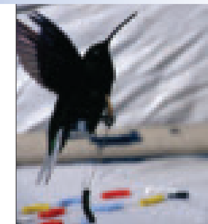
Together with Soyuz, the other four of the top five launch vehicle programs—Atlas V/Delta IV, Long March, Ariane 5ECA/5ESV, and Proton K/M—account for almost two-thirds of the payloads that have an assigned launch vehicle.

Reality vs. fantasy

Now the task is to begin sifting through all of the payloads in our survey and decide which ones are real, or potentially real, and which are merely wishful thinking.

Of our 2,315 payloads, we estimate that at least half will never make it past the drawing board or early stages of development, because of insufficient funding, technical challenges, or the perceived lack of a user market. On the other hand, payloads of which we are not yet aware also will be adequately financed, built, and launched. The trick is to have enough material with which to begin realistically gauging the market, so that it is more than just guesswork.

Marco Cáceres
Teal Group
mcáceres@tealgroup.com



Birds, bees, and nanos

The publicity surrounding AeroVironment's hummingbird-inspired robotic Nano Air Vehicle has injected fresh life into the engineering debate over the merits of flapping versus rotary flight for tiny aircraft.

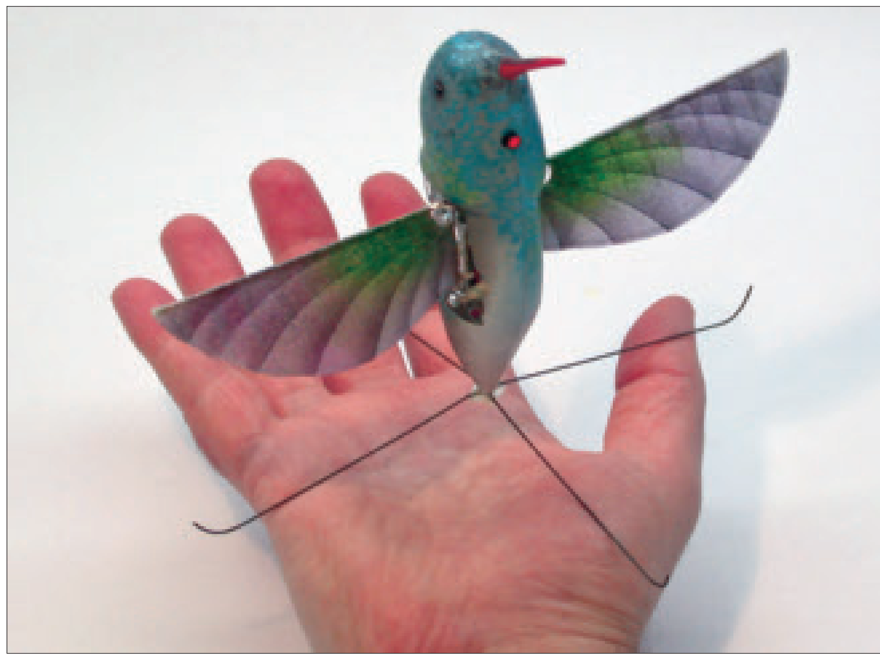
The Monrovia, California, company flew its 19-g, 16.5-cm-wingspan craft in front of reporters in February with permission from its sponsor, DARPA, which had just concluded a 4.5-year, $4-million investment in the project. DARPA tightly constrained what AeroVironment could say about the engineering details. The company also said it wanted to avoid tipping off competitors as it searches for a sponsor to continue the development toward a smaller and more automated operational version.

Some details were provided in the company's December patent application for an "aircraft having flapping wings where angular orientation control is effected by variable differential sweep angles of deflection of the flappable wings." Inside the Nano Air Vehicle, a system consisting of a small battery-powered electric motor and gears flaps the wings. Pivoting each wing at a different angle creates yaw torque, giving the aircraft its life-like maneuverability.

AeroVironment says the vehicle has flown for as long as 11 min. Reducing the weight of the components could double that endurance, or the same endurance could be maintained while reducing the size of the craft.

The vehicle was not as small as DARPA and AeroVironment engineers originally hoped, but it hovered for 8 min with no external power source, flew forward to a speed of 11 mph and returned to a hover, then withstood a 2-m/sec wind gust from the side without drifting more than 1 m.

The Nano Air Vehicle was the culmination of a "bunch of little details that are very important. If I put this into your hand, you wouldn't be able to see them. We want to keep our proprietary edge for as long as possible," says AeroVironment's Matt Keennon, the project manager.



Although it did not meet DARPA's original goal of an 8-g vehicle with a 7.6-cm wingspan, the Nano is about the same size as the largest of the hummingbird species. Courtesy AeroVironment.

Are hummingbirds the key?

Aside from the patent, the spectacle of a remote-controlled aircraft maneuvering and hovering like a hummingbird was enough to spark a torrent of news coverage and a call for a possible fly-off between flapping aircraft, also known as ornithopters, and propeller-driven robotic types. Engineers say quad-rotor aircraft, which have propellers on the tips of plus-sign-shaped frames, are especially worthy competitors because of their maneuverability.

At the heart of the debate is a fundamental question: Are there inherent aerodynamic advantages to flapping devices, or is their only real advantage that they can be disguised to look like birds or insects?

The rotors, including quad-rotor craft, are highly maneuverable, but there is disagreement about whether their maneuverability could ever equal that of a biological hummingbird, or of a manmade craft based on the bird's aerodynamics.

In addition, quad rotors cannot be dressed up as biological creatures. By contrast, the Nano Air Vehicle was outfitted with a fairing painted to look like a hummingbird, although the fairing was not part of its aerodynamic design. "We could have just made it look like a football [with a] winged body, but it's more intriguing to have it look like a biological creature," says Keennon. For the wing design, biological hummingbirds were an inspiration rather than a template.

"We pulled up some high-speed video of hummingbirds in flight, but it was mostly inspirational. We did not try to follow the bone structure, for example," Keennon says.

The fairing and long beak did their job of suggesting the potential for a more advanced version that could serve as spy craft.

The Nano Air Vehicle's maneuverability impressed other engineers in the flapping flight community, but AeroVironment acknowledges that there is a lot left to do. The aircraft as currently designed is about the same size as the largest of the hummingbird species. It did not meet DARPA's original goal of an 8-g vehicle with a 7.6-cm wingspan, which would be closer to the dimensions of the most common breed of hummingbirds.

Although a video feed was available, the vehicle was typically controlled 'heads up,' or visually, by a person equipped with a model airplane controller. An operational version would need more cameras and an onboard processor to control its wings more autonomously. The human controller could then hide a safe distance away and steer the craft by looking at video feeds and sending basic commands, much as operators do today with AeroVironment's fixed-wing military drones, Puma, Raven, and Wasp.

AeroVironment left the automated control issues for another day.

Three synchronized views of a hovering hummingbird were captured during one downstroke. Photo Credit: Doug Altshuler, UC Riverside.

Fixed versus flapping

In the debate between rotorcraft proponents and flapper advocates, the tone was set in 2001 by Kenneth C. Hall of Duke University and Steven R. Hall of MIT. After running a series of aerodynamic calculations, they published a paper concluding that flapping wings were 'probably disadvantageous' except in cases where 'stealth mimicry' was desired.

Their paper formed a chapter in the AIAA book, *Fixed and Flapping Wing Aerodynamics for Micro Air Vehicle Applications*, edited by Thomas J. Mueller.

Flapping enthusiasts have been busy in the years since, especially on the question of aerodynamic efficiency, which for a battery-powered device corresponds directly to flight duration.

"I don't think the efficiency argument has been answered fully yet," says engineer Ron Fearing of the Biomimetic Millisystems Lab of the University of California at Berkeley.

As magical as hummingbirds are to watch, biomechanics and hummingbird expert Douglas Altshuler of the University of California at Riverside is not so sure nature places a premium on efficiency. "For the animals, it's not at all clear to us that their wings are designed to be efficient," he says.

Altshuler videotapes hummingbirds in his lab and regularly advises flapping wing engineers.

As to the question of efficiency, Keennon concedes that a rotorcraft with a diameter about the size of the Nano Air Vehicle's wingspan would be more efficient. He suspects that might not be the case as engineers learn to make smaller and smaller craft.

"The fact is, a fruit fly can fly and hover all day long," he says.

Fearing says engineers are still working to understand the aerodynamics of flapping wings, whether natural or manmade.

Tiny mechanical ornithopters have been around for only about five years, which means engineers have not had much time to fly them and make measurements of lift, drag, and efficiency. After more testing, new advantages could be discovered. For example, flapping craft could turn out to be more maneuverable than rotorcraft, or better equipped to handle wind gusts from open windows or from doors opening and closing. Those are significant challenges for a craft that weighs just grams.

Then there is maneuverability. The flapping community sees hummingbirds and insects as the Holy Grails of flight. "If I compare something like a hummingbird to a helicopter, the hummingbird has such amazing control over its wings," Fearing says. "You can generate huge amounts of control authority there. It's going to be pretty hard for a helicopter to match the maneuverability of a hummingbird," he concludes.

One hurdle is that at this point, engineers understand legged location far better than the aerodynamics of flapping flight, Fearing says. Engineers and biologists have videotaped cockroaches running along and examined them in slow motion. "A cockroach can hit some bump and, because of the way the legs and suspension system are working, just ignore that bump and keep on going. There may be similar things with a flapping flight, where it may be just intrinsically more robust with respect to certain classes of disturbance," says Fearing.

At a minimum, "the jury's still out for helicopters versus ornithopters," Fearing concludes.

Engineers are using a variety of techniques to help them understand flapping ornithopters. Force sensors are sometimes attached to craft in wind tunnels. Motion capture systems can be used to sense the path of free flight. Onboard accelerators and gyros can record movements. Velocimetry and motion tracking systems can be used to understand wing deflection and loading.

A hummingbird begins the initial phase of load lifting. A rubber-band harness around the neck is connected to a string loaded with color-coded beads. Photo Credit: Jim Hamilton.

Limits of evolution

Engineers and biologists have thought hard about why rotary wings are not seen in nature. Could that fact suggest that flapping wings are superior? Even flapping enthusiasts like Altshuler and Fearing do not think so.

"The reason we don't see helicopters in biology is that it's very hard for evolution to make wheels," says Altshuler. "Arguably there's only one true wheel that nature's ever created"—the bacterial flagellum, he says.

It is difficult to imagine how nature, with the need for nerves and blood vessels, could produce rotary motion.

Altshuler says there is an amazing fact of nature that suggests a possible wide range of utility for man-made flappers. Using video cameras, he says, "We've studied the wing motions of hummingbirds and honeybees and fruit flies. It's shocking how similar they are. If you just sort of see a trace of those wing motions, you can't tell whether you're looking at a hummingbird or a fruit fly."

This is true even though a fruit fly weighs only a milligram or two, while a typical hummingbird weighs about 4,000 mg. "Despite that, they flap with almost the exact same wing pattern," Altshuler notes.

Moreover, insects and hummingbirds are surprisingly similar in their biological construction, he says.

If animals of such different sizes and weights can use the same flying tactics, the implication is that unknown fundamentals of fluid could be at play. If engineers can find them, they might be able to tap them for their mechanical designs.

The Biomimetics Millisystems Lab at Berkeley uses an off-the-shelf iBird ornithopter equipped with a processor and camera to test autonomous flight. Credit: Stan Baek, University of California at Berkeley.

Practicality

If nature has a hard time making helicopters, so do engineers who are racing to make insect-sized craft. Aerospace engineers cannot miniaturize every part they need, so they must rely on advances in commercial microelectromechanical systems—MEMS.

"If you want to go really small, you run into bearing problems," says Fearing.

Fearing chose flapping wings for his Micromechanical Flying Insect, whose propulsion system was demonstrated in a bench-top experiment in 2006. "Our device was attached to a force sensor and did not take off," he explains.

The device's wing-drive system flapped at 270 Hz with about a 90-deg flapping angle, and a ±30-deg controllable angle of attack during the stroke. In 2007, engineer Rob Wood at Harvard, who used to work in Fearing's lab, showed how a tethered fly could lift off using external power and use a vertical post for guidance/stabilization. Wood is now working on a craft he calls Robobee.

Flight control

While Wood and others continue to work on shrinking the mechanics of flight, Fearing has shifted his research into flight control technologies. For his experiments, Fearing and his students use a 12-g off-the-shelf ornithopter called iBird. Fearing says iBird is not nearly as aerodynamically advanced as the Nano Air Vehicle, but he chose it so he could focus on the problem of developing miniaturized control processors and algorithms.

In February, one of Fearing's graduate student researchers, Stan Baek, demonstrated autonomous flight with the iBird and its control system.

The iBird senses its location in the air with input from an infrared sensor taken from Nintendo Wii games, plus a three-axis gyro and a three-axis accelerometer. By contrast, the Nano Air Vehicle's patent lists two-axis gyros, one for yaw and one for pitch and roll. Fearing is also experimenting with cellphone cameras for his craft. Inputs from these sensors are turned into control commands by an onboard processor programmed in C language.

"We had to come up with our own processor board. There wasn't anything out there that included all these devices and still met the weight constraint," he says.

Fearing is trying to understand the flight dynamics well enough to perfect the control algorithms. One challenge is that the infrared or cellphone cameras have narrow fields of view, which makes it hard for them to keep a target in sight as the craft's body moves because of the wing flapping. "You may be losing sight of the target for half of every link stroke," he says.

With engineers making good progress on tiny rotorcraft and ornithopters, Fearing makes an interesting suggestion: "At some point in time, we're going to have to have a competition," he says. A 'bakeoff' in a controlled setting could show the aerodynamic advantages of each, once and for all.

Ben Iannotta
biannatta@aol.com

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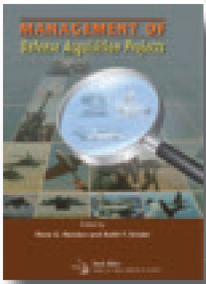

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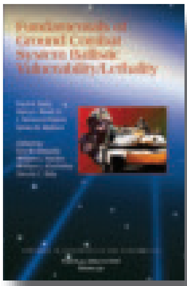

While the focus of this book is on ground combat system vulnerability, many of the principles, methodologies, and tools discussed are also applicable to the air and sea system communities.

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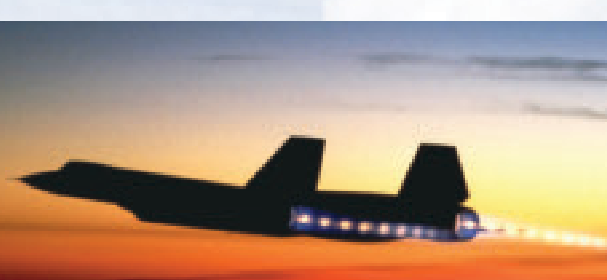

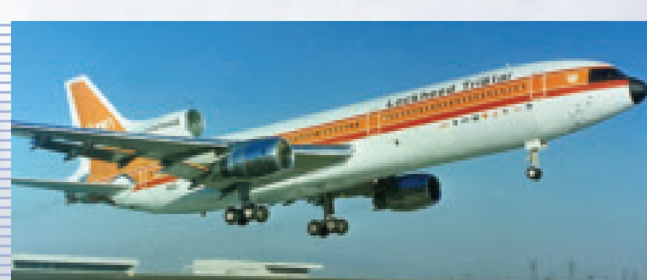

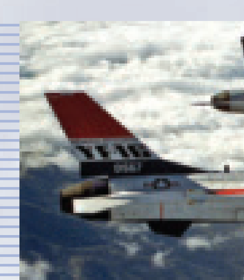

The aircraft is only a transport mechanism for the payload, and all design decisions must consider payload first. Simply stated, the aircraft is a dust cover. *Fundamentals of Aircraft and Airship Design, Volume 1— Aircraft Design* emphasizes that the aircraft design process is a science and an art, but also a compromise. While there is no right answer, there is always a best answer based on existing requirements and available technologies.

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2010, 883 pages, Hardback
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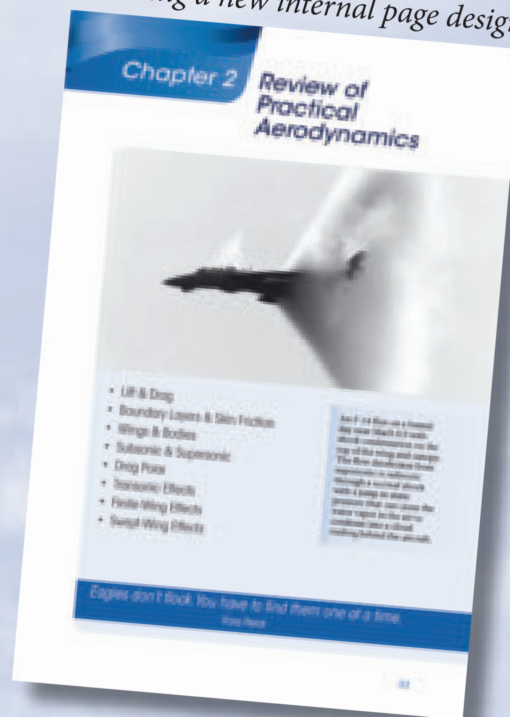

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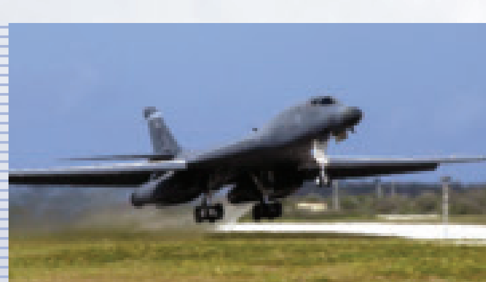


BF-4, the fourth F-35 STOVL test aircraft, flew mode 4 for the first time on April 7, 2011, at Naval Air Station Patuxent River, Maryland.

Despite the F-35's mounting problems with cost, schedule, and performance, the administration is betting on a successful restructuring of the Air Force fighter and its Navy variant. The future is murkier for the Marine Corps version, which the secretary of defense has placed on probation for two years. And that is only one of the issues that continue to plague this joint international program.

On January 6, Secretary of Defense Robert Gates issued his first formal statement on the FY11 defense authorization bill—passed as one of the final acts of the 111th Congress—and how he plans to implement it, especially with respect to the F-35 JSF. For the Marine Corps and the F-35B STOVL (short takeoff/vertical landing) variant, the news was mixed, but leaning toward bad.

"The Marine Corps' short takeoff and vertical landing variant is experiencing significant testing problems. These issues may lead to a redesign of the aircraft's structure and propulsion—changes that could add yet more weight and more cost to an aircraft that has little capacity to absorb more of either," Gates explained at a Pentagon press conference.

"As a result, I am placing the STOVL variant on the equivalent of a two-year probation. If we cannot fix this variant during this time frame and get it back on track in terms of performance, cost, and schedule, then I believe it should be canceled. We will also move the development of the Marine variant to the back of the overall JSF production sequence. And to fill the gap created from the slip in the JSF production schedule, we will buy more Navy F/A-18s."

Marines keep the faith

In keeping with the Marine Corps tradition of taking on whatever challenges it faces,

F-35

A time of trial

Gen. James F. Amos quickly responded with a vow not only to meet Gates' deadline, but to personally see that it happens.

"I am confident that we will field this aircraft in accordance with responsible timelines," the corps commandant told the Congress on March 1. "This matter has my unwavering attention—and I am personally overseeing this program."

However, Amos also demonstrated Marine pragmatism, bowing slightly to the combination of pressure from the defense secretary and the continued opposition of the Navy to having the STOVL variant aboard their carriers. Two weeks after delivering his promise to Congress, the general took a step in direct opposition to long-standing corps desires to build an all-STOVL aviation force. He signed a memorandum of understanding with the secretary of the Navy and the chief of naval operations on "tactical aircraft integration."

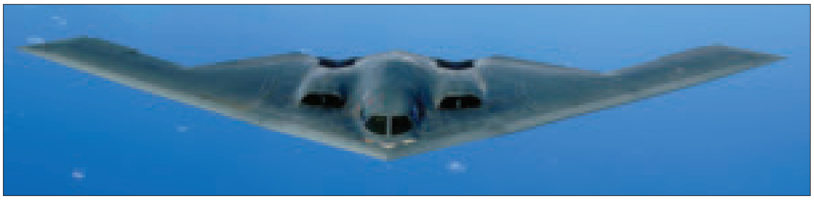
Under the new TACAIR agreement, the Marine Corps will give up 80 of its originally planned buy of 420 F-35Bs, replacing them with F-35C Navy carrier variants. Those aircraft would form five Marine Corps squadrons assigned to Navy carriers, half the original plan, using F-35Bs. The remaining 340 F-35Bs still in the corps acquisition plan would be assigned to corps amphibious flattops, which are being modified to carry them.

"This decision to purchase C-model JSFs is representative of USMC commitment to tactical air integration with the Navy. It is important to note that the continued development of F-35B remains the centerpiece of the USMC TACAIR fixed wing modernization program," Amos said in signing the MOU. "The F-35B STOVL Joint Strike Fighter is vital to our ability to conduct expeditionary operations in the future and the STOVL JSF is still our primary focus.

"We've always been fans of TACAIR integration. It's good for both our service and the naval force. When we set the requirement in for STOVL aircraft, our hope was that we would be able to someday fly those versions off of naval aircraft carriers. In the meantime, it would seem prudent that we would buy some number of C variants—even early on—so that we can begin to transition our force."

By moving the corps into an early position in F-35C production, he added, the Marines can continue to meet their commitment to flying alongside the Navy from the big carriers and, to some degree, respond to congressional concerns there would not be enough F-35s, of either type, available for carrier duty as legacy aircraft were retired. That had led lawmakers to order additional buys of new F/A-18E/F Super Hornets, presumably all for the Navy fleet as the corps has never wavered from its decision not to buy anything but the F-35 for future operations.

by J.R. Wilson
Contributing writer



Two of the previous stealth aircraft were the B-2 (above) and F-117.

Indeed, Amos made that crystal clear to Congress, responding to Gates' threat to kill the F-35B if he was not satisfied with its progress during probation.

A week before his comment that "the Marine Corps remains unequivocally committed to the success of the F-35B program" as part of a "measured transition to a 5th Generation F-35B expeditionary capability," Amos told the Senate Armed Services Committee, "If we lose the F-35B, there is no Plan B for fixed-wing airplanes on the large-deck amphibs."

A month later, Lt. Gen. Terry G. Robling, assistant commandant for aviation, said the corps' continued commitment to and increased oversight of the F-35B program already was showing dramatic improvements. "We completed more than 78 vertical landings [through March 31], almost triple last year already. There have been technical issues—four or five main ones of concern—but nothing insurmountable. We need to get the fixes done and retrofitted into the early lot aircraft as soon as possible, but right now it looks to me like the F-35B is doing everything we're asking of it," Robling said.

"F-35 development will cost more and take longer than reported to the Congress [in 2009]; despite cost and schedule troubles, [the Pentagon] wants to accelerate [F-35] procurement."

Government Accountability Office report to Congress

"We have 29 of these already ordered and I do not plan to slow down the start-up or training.... Our IOC has slipped to early or mid-2014, but I think the aircraft will meet all the requirements we want and will stand up on time."

Navy Secretary Ray Mabus and F-35 deputy program manager Maj. Gen. C.D. Moore (USAF) also have reported major progress on the F-35B since January and indicated they still believe the STOVL variant will be part of the Lightning II family down the line. Moore says the increased testing schedule, especially vertical landings, has given program engineers a better understanding of the impact of the aircraft's unique aerodynamics on the reliability of some F-35B-only components.

As for Gates, he has had little to say about the STOVL aircraft since announcing its probation.

Jointness and other troubles

Gates' statement came on the heels of an announcement by the U.K.—the second-largest expected operator of the F-35B—to cancel its order for 187 STOVL aircraft and instead order a far smaller number of the F-35C carrier-landing-capable variant. With other potential F-35B customers also now wavering, it seems increasingly likely the STOVL variant will be the first victim of the 'joint' program curse.

Whether viewed as conventional wisdom or just dark humor, it has long been held that the fastest way to cripple, if not kill, a major military program is to make 'joint' the first word in its name. Add 'international' and the number of successful major programs is as rare as a unicorn.

Almost every major weapons system—certainly every new military aircraft—has had a more difficult time with funding and critics after, rather than before, being approved as a program. Perhaps the most vilified in recent times were the Navy/Marine Corps F/A-18 Hornet—which one congressman claimed could not land on a carrier—and the Marines' V-22 Osprey, which many claimed simply could not fly.

The F-22 Raptor, the world's first fifth-generation (Gen-5) fighter, seemed to have avoided the worst of such controversies. Nonetheless it faced a production shutdown at the end of 2010, with only a fraction of the originally planned fleet delivered to the USAF. And despite continued campaigns by Australia and other allies, a foreign sales ban remains in effect, eliminating a route that airframers have long used for continued production.

But the F-35 Lightning II has one of the more unusual ongoing histories. As the world's second—and in some respects most advanced—Gen-5 fighter, it has the largest international production team in aviation history, with nine nations cooperating in the funding, development, production, and, presumably, purchase of one or more of its three variants. In short, it is the most ambitious international joint program of record.

Having three distinct versions, for the

land-based (F-35A), carrier-based (F-35C), and STOVL (F-35B) requirements of the Air Force, Navy, and Marines, respectively, also is unique. Multiservice aircraft have been attempted in the past, but one or another service typically pulled out before production began.

In this case, all three variants are available to the international partners, and to any other approved friendly nation that might want to add a superpower superplane to its fleet.

But with that many 'cooks,' not to mention Congress and the secretary of defense, along with their counterparts in the partner nations, it should surprise no one that the F-35 is seriously behind schedule, over cost, and targeted by budget-cutters everywhere. It is also the subject of an intense battle between the Marines, who want the aircraft to replace the F/A-18 and complete their conversion to an all-STOVL force, and the Navy, which does not want the 'B' on their carriers. In short, the program certainly has not escaped the curse of its 'international joint' designation.

As stealth dwindles, orders fall

The JSF also has fallen far short of what the partners and customers had anticipated for the first stealth fighter to be operated by any military service except the Air Force, which has had sole possession of all three previous stealth aircraft—the F-117 Nighthawk (retired in 2008 after 25 years); the B-2 Spirit bomber (just 21 of a planned 132 built, the last delivered in 1997); and the F-22 Raptor, on which Gates ordered pro-

Engine battle

One battle still being waged across Washington is whether to continue production of two separate engines for the F-35: the Pratt & Whitney F135, designated the primary engine for all three JSF variants, and the General Electric/Rolls-Royce F136, developed as an alternative engine. President Obama and Secretary Gates have argued the F136 is an unnecessary expense and ordered it canceled, but the 111th Congress balked, with the House steadfastly supporting continuation of the dual engine track and the Senate less committed to either path.

According to a Joint Explanatory Statement from both congressional Armed Services Committees: "The House bill contained a provision (sec. 802) that would require the Secretary of Defense to designate the F135 and F136 engine development and procurement programs as major subprograms of the F-35 Lightning II aircraft major defense acquisition program, in accordance with Section 2430a of Title 10, United States Code. The Senate committee-reported bill contained no similar provision. The agreement includes the House provision, amended to require that the Secretary designate an F-35 engine development and procurement program as a major subprogram."

In short, the 111th Congress, facing a threatened presidential veto if they funded a second engine, instead wrote language that did little more than punt the issue to the 112th Congress.

"It's a little bizarre at this point, at the tail end of the development process, becoming such political dynamite," said Richard Aboulafia, a senior analyst at Teal Group, earlier this year. It would "make sense to have a second engine. You're trying to preserve what competition you can in a downselect to one prime, and turbine engines are definitely an enabling technology.

"Starting a second engine today would certainly be foolish, but finishing up the last parts of one that already has been around for 10 years makes sense. Why Gates chose to make a battle out of this, knowing Congress would go out on a limb to preserve the GE engine, I don't know."

With Republicans in control of the House and narrowing the power gap in the Senate, the battle was expected to resume. Indeed, on February 16, the House voted 233-198 to halt FY11 funding for the GE/Rolls-Royce alternative engine.

Following what some considered a surprise—as it had been the House that had kept the second engine program alive—Gates immediately called on the Senate to complete the kill when they began debating the issue in March.

Early reactions from the new Republican House leadership to both the FY11 authorization and Gates' January 6 comments made it clear the battle is far from over.

For example, Rep. Buck McKeon (R-Calif.), new chair of the House Armed Services Committee , and Rep. Bill Young (R-Fla.), defense appropriations subcommittee chair, both expressed deep concern about the scope and nature of the Gates cuts. Meanwhile, a number of Republican HASC members met to discuss strategies for modifying or reversing budget cuts impacting the Marine Corps—which was hard hit beyond the F-35B—including ways to ensure the STOVL aircraft survives beyond Gates' two-year probation.

The GE/Rolls-Royce F136 alternate engine for the F-35 has proven to be one of the most difficult "kills" in DOD and congressional history. The Pentagon has been adamantly opposed to continuation of the second engine option for more than half a decade, but Congress kept it alive with continued funding DOD did not want.

After the last Congress, with its seemingly unstoppable Democrat majority, simply passed the issue to their successors—with a Republican majority in the House and closer to parity in the still-Democrat controlled Senate—many expected the second engine to gain even greater strength. They were wrong.

In mid-February, the House, led by freshmen Republicans, voted for the first time to halt additional funding for the F136, which was retained in the House-Senate compromise on a stopgap funding measure in April. That seemed to give weight to a stop-work order the Pentagon had issued a short time earlier, although a spokeswoman made it clear that was not a cancellation order but a 90-day stop during which the Pentagon would give the question further study.

In the end, she added, the engine's fate was in the hands of Congress.

This gave GE enough encouragement to ignore the Pentagon order and continue work on the engine with its own funds, with the expectation that Congress, in passing a final budget later this year, once again would ressurrect the F-35. "We feel so strongly about this issue, as do our congressional supporters, that we will, consistent with the stop-work directive, self-fund the F136 program through this 90-day-stop work period," company spokesman Rick Kennedy said.

GE's position was somewhat bolstered by House Armed Services Committee Chair Howard McKeon (R-Calif.), who criticized Gates for issuing the stop-work order before Congress had finished its debate and made a final, rather than temporary, decision. However, some Senate leaders agreed with Sen. Joe Lieberman (I-Conn.), who called the stop-work order essential to the Pentagon's efforts to save money.

Despite repeating Pentagon opposition to continuing the F136, Undersecretary of Defense for Acquisition Ashton Carter gave GE another reason for hope when he criticized Pratt & Whitney for not adequately dealing with cost overruns already estimated at $3.4 billion—$2.7 billion of which P&W says were due to changes requested by DOD. However, he also said the $2.9 billion the Pentagon estimates it would cost to bring a second engine to the point the F135 already has reached "does not show the payback." But subcommittee member Rep. Jim Moran (D-Va.) told Carter the GE/RR alternate engine is "not a dead issue—it still has substantial support."

duction halted after delivery of fewer than 30% of the original requirement of 650.

The JSF was initially planned as the nation's fourth aircraft to feature stealth (a major aspect of fifth-generation fighters). But much of its stealth capability was lost during structural changes made early in the program's system development and demonstration (SDD) phase.

The F-35 employs structural fiber mat instead of the high-maintenance coatings of previous stealth aircraft. Like the F-22, it also forgoes the multifaceted surface of the F-117 or 'flying wing' design of the B-2, rely-ing instead on a smoother low-observable shape. However, while the F-22 is considered stealthy against all types of radars and from all directions, the F-35's lowest radar signature is directly ahead and primarily intended to defeat the X- and upper S-band radars typically found on fighters, surface-to-air missiles, and tracking radars. From all other angles and against L-band and other surveillance radars, it has been compared to a Gen-4 F-16.

"The Joint Strike Fighter has a complex lower fuselage shape, as well as a wing and fuselage lower join shape, unlike any other aircraft designed with stealth in mind," says an analysis by think tank Air Power Australia. "The result of this design choice is that the beam/side aspect radar cross section will be closer in magnitude to a conventional fighter flown clean than a 'classical' stealth aircraft."

The F-35B was expected to be popular with international buyers, many of whom were planning to build smaller, less expensive carriers specifically for STOVL operations. The U.K. was expected to be the largest of these customers, originally planning to buy F-35Bs as a joint combat aircraft for the Royal Navy and RAF. But the recent release of the Ministry of Defence's Strategic Defence and Security Review (Britain's equivalent of the U.S. Quadrennial Defense Review) called for canceling a second aircraft carrier and canceling procurement of all F-35Bs, instead buying a far smaller number of F-35Cs for use by both services.

Congress will keep the F-18E/F in production to cover any shortfalls from F-35 delays.

The loss of the second-largest order will mean a higher acquisition cost for the Marines, who want approximately 400 of the new supersonic STOVLs to replace their current fleet of F/A-18s and AV-8B Harrier subsonic jumpjets. The extent of that increase will depend on finalization of British plans, along with those of other expected F-35B customers, primarily Italy and Spain.

Betting on restructuring

Even as the future of the STOVL variant grew murky, Gates went 'all in' on the F-35, canceling further production of the F-22 and placing the money saved into restructuring—and extending—the JSF SDD phase.

"The Joint Strike Fighter program received special scrutiny given its substantial cost, ongoing development issues, and its central place in the future of U.S. military aviation. In short, two of the JSF variants, the Air Force version and the Navy's carrier-based version, are proceeding satisfactorily," Gates told reporters.

"The Marine Corps made a compelling case that they need some time to get things right with the STOVL, and we will give them that opportunity."

That was a bit of a surprise, as both the 'A' and 'C' variants of the F-35 had come under considerable criticism in the past year or two for being overweight, over cost, behind schedule, and failing to meet planned capabilities in stealth, maneuverability, range, and so on.

Even so, Gates' decision notwithstanding, the F-35 has accomplished what no other aircraft or air defense system on the planet has been able to do—shoot down 463 F-22 Raptors, the balance of the original Air Force requirement canceled by Gates in favor of the Lightning II. For the record, in nearly 30 years of combat operations, only one stealth aircraft has been lost to enemy fire—an F-117 shot down over Kosovo in 1999, which even the commander of the air defense unit involved called essentially a lucky shot.

Holding on to Super Hornets

Despite Gates' enthusiasm for the F-35, the Congress took a far less sanguine view of the future of U.S. air power in both the Defense Authorization bill and accompanying summaries and explanations. Lawmakers highlighted the list of problems plaguing the JSF—especially the STOVL variant—and made it clear Congress would keep the F/A-18E/F Super Hornet in production to cover any naval aviation shortfall resulting from further JSF delays.

"The bill authorizes $18.9 billion for aviation programs for the Navy and Marine Corps. However, concerns remain about the Navy and Marine Corps managing and accepting an unprecedented level of operational risk within their tactical air force structure while waiting for the completion of the F-35B and F-35C. It is estimated that by FY2017, the Navy and Marine Corps inventory could be at least 250 aircraft short of requirements—the equivalent of five carrier air wings," lawmakers warned.

"This is an unacceptable outcome, and Congress will not support future budget requests that fail to address the factual realities of a naval strike fighter shortfall. Barring a complete reversal of the development and performance failures in the Joint Strike Fighter program, Congress expects future budget submissions to continue the production of F-18s to prevent our naval airpower from losing significance in our nation's arsenal."

In his announcement roughly two weeks later, Gates turned these congressional concerns and threats into official administration policy, moving the F-35B from the front to the back of the production and delivery schedule and directing the Navy to "buy more of the latest model F-18s and extend the service life of 150 of these aircraft as a hedge against more delays in the deployment of the Joint Strike Fighter."

Mandate for measuring progress

Congress did not limit its concerns about the program to the Navy and Marine Corps variants. The House accepted a Senate amendment requiring the secretary of defense to create a system management plan for measuring the F-35 program's progress through the remainder of SDD.

"There is concern that progress on F-35 development and testing is behind a schedule that would warrant planned future production levels. Significant cost risks can result from buying large quantities of the F-35 with only 5% of its flight testing complete," an overview of the amended legislation stated. "To address concerns over the serious delays and cost overruns in the F-35 program, the bill requires the Dept. of Defense to establish a management plan under which decisions to commit to specified levels of production are linked to progress in meeting specified program milestones, including design, manufacturing, testing, and fielding milestones for critical system maturity elements."

In a brief response to both the legislation and Gates' comments, F-35 prime contractor Lockheed Martin took a cautiously optimistic view: "We recognize that long-term confidence in the program must be earned over time by executing and meeting commitments," and the restructuring represents "an essential foundational requirement to ensure future success."

Frozen in time

Despite efforts to keep the aircraft design 'open architecture' for both hardware and software, the F-35 still suffers from the long design-to-production schedule accompanying any major military program, according to Don Bolling. He is senior manager for advanced targeting systems at Lockheed Martin Missiles & Fire Control, which is responsible for the electrooptical targeting system that gives the F-35 its long-range detection and precision targeting.

"We've been at war now since 2001, and JSF has been on the drawing board better than 10 years. Technologically, on our side, we've been frozen in system design and development time. Because of the war, we've had rapid advances in ISR [intelligence, surveillance, reconnaissance] capabilities. At the time our sensor was frozen in the JSF design, it was a leading-edge technology—nobody else was even close," he explains.

"But as we get closer to fielding, that will certainly be less so. Sensors with HDTV, IR pointers, and other things have continued to move along while we have been marking time in place. That has been frustrating, because we know we could make adjustments—which we will in due time with block upgrades to the airplane. That is just the way it is with JSF acquisitions."

Not out of the woods

Despite arguments by some—especially overseas—that F-35 funds should instead go to building more F-22s, it seems highly unlikely that JSF will face the drastic cuts in planned production suffered by its predecessors. Low-rate initial production (LRIP) alone will produce more than twice as many F-35s as the combined total of F-117s, B-2s, and F-22s—and the Raptor cannot replace the aging Navy and Marine Corps fleets of F/A-18s and AV-8Bs. But the most expensive DOD program on the books is far from out of the woods.

(Continued on page 45)

The F-22 stealth fighter is banned from export.

The AMS is positioned in the aft payload bay of Endeavour. Note the manipulator arm at the left of AMS and the bright silver lining of the partially open payload bay doors. The crew cabin is at the opposite end of the payload bay. ©Michele Famiglietti.

AMS: Shedding light on the dark

by Craig Covault
Contributing writer

The Alpha Magnetic Spectrometer (AMS), the largest scientific instrument on the ISS, will conduct an unprecedented search for previously undetectable antimatter and for invisible dark matter, which (along with dark energy) makes up 95% of the universe, theorists believe. Astronauts were to deliver the instrument and attached it to the left end of the space station's 300-ft truss during STS-134, the last flight of the shuttle Endeavour and the penultimate mission of the 30-year space shuttle program.

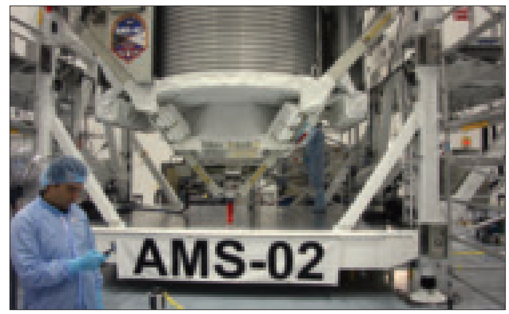
The AMS high-energy particle detector will be gathering evidence concerning two of the greatest mysteries of the universe: What caused the disappearance of primordial antimatter, which was formed in equal amounts with the visible matter that makes up the current universe; and just what is this stuff called dark matter, which neither reflects nor emits light, yet bends light from other sources, and exerts such a powerful gravitational force that it has shaped galaxies and formed them into giant linked structures up to 10 billion light-years across?

Bone of contention

But while the AMS science team probes momentous issues governing the universe, political controversy in Congress and elsewhere could arise over the 4,000 lb of Chinese hardware that has finally made its way onto the ISS as a critical element of the station's most historic instrument. This has occurred in spite of NASA, White House, and congressional opposition to Chinese participation in the ISS program.

The 15,000-lb AMS is a Dept. of Energy project, and most of its $1.5-billion cost has been borne by multiple European and Asian participants, including China.

The two tons of Chinese components include 4,000 permanent magnets. These comprise the inner walls of the barrel-shaped instrument through which AMS scientists hope to track cosmic particles from the Big Bang so that detectors can measure their properties. The researchers hope that finding key particles and atoms will prove the existence of dark matter, dark energy, and antimatter.

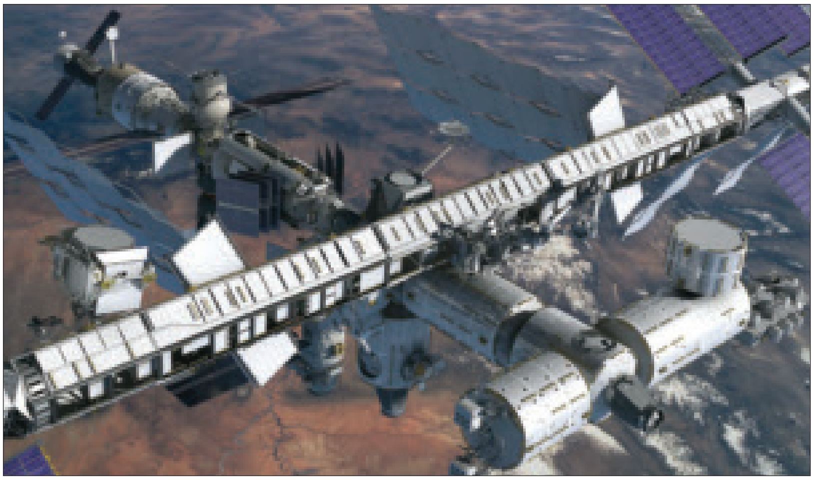


The AMS-02, loaded with 2 tons of Chinese magnets, undergoes final processing at the Kennedy Space Center before its launch to the ISS.

The Chinese magnets are important from a U.S. policy standpoint. These magnets and support hardware were retrofitted in place of a canceled multimillion-dollar U.S./European cryogenically cooled electromagnetic system that AMS project leaders determined would not perform as well as hoped. The heating needed to run the electromagnets was greater than expected and would consume roughly double the planned amount of liquid helium, reducing useful life to less than two years. Thus the cryogenic system in the works for 10 years was removed and replaced with the permanent magnets, which can keep the AMS functional through the remaining 20-30-year life of the station.

Now mounted on the ISS, the Alpha Magnetic Spectrometer will probe cosmic mysteries, seeking evidence that dark matter, dark energy, and antimatter do exist. Such a discovery could explain what occupies most of the known universe. However, political controversy involving China's participation in the effort could cast a shadow over this exciting prospect.

The retrofit of this unique space instrument with such a large amount of Chinese equipment comes face-to-face with strong debate—and some outright hostility—in congressional and policy circles about whether the U.S. should engage in space cooperation with the Chinese, given their internal human rights record and a surging military space program aimed at countering the U.S. There had been congressional



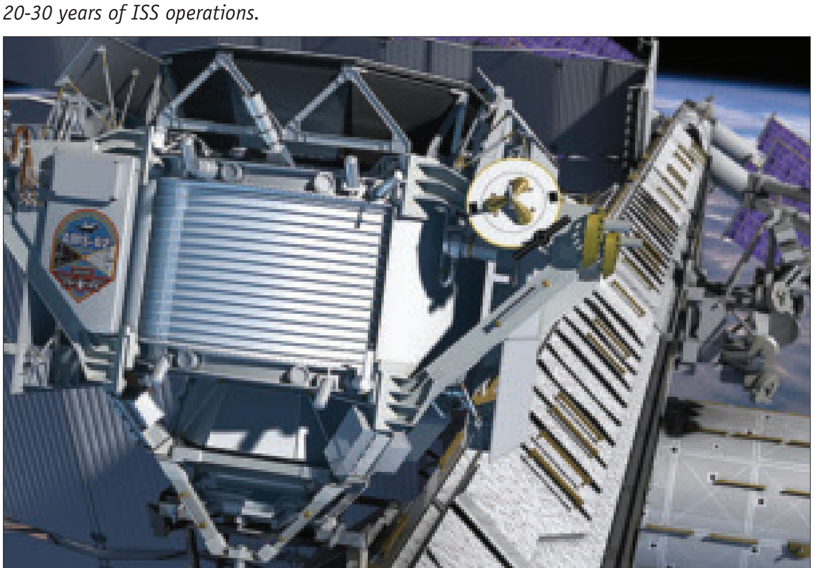
After delivery to the station, the AMS will sit atop the far left truss.

oversight and, in 2008, approval to fund delays. However, this came before the decision to replace the cryogenic system with magnets that had been used for a short proof-of-concept flight on STS-91 in 1998.

AMS-02, as large as an automobile, is to be attached to the exterior of the station's port truss—a large instrument in a prominent place. That is ironic, because for more than 10 years NASA has rejected all Chinese overtures seeking involvement with the space program in general and the space station specifically.

The head of the Chinese National Space Administration (CNSA) even used this author, during one of six trips to Beijing, as an intermediary between himself and then-NASA Administrator Dan Goldin in an attempt to open talks on Chinese participation in the station effort. "Without China's participation, the ISS is not a true international program," said CNSA Administrator Luan Enjie. Goldin rejected the Chinese overture, as has every administrator and administration since. But now, with AMS-02's thousands of pounds of critical Chinese components, China's technology has made it onto the station as a key aspect of ISS science operations.

The AMS will wait for signs of antimatter and dark matter to pass through it for the next 20-30 years of ISS operations.



Breakthroughs in detection

The 7.5-ton instrument could detect direct evidence of the dark matter that scientists believe forms the framework of the universe, holding galaxies together, forming them into groups, and then linking those groups into mammoth cosmic structures, including one that spans 10 billion light-years. Once analyzed at the cosmic particle level, dark matter could also help to prove whether antimatter indeed makes up entire galaxies that could be part of an unseen parallel universe, and whether that antimatter could annihilate everything in the known cosmos.

The key technological theories and components making dark matter and antimatter detection possible result from Chinese breakthroughs, according to Samuel C.C. Ting, a 1976 Nobel Prize-winning scientist at MIT, where one AMS Payload Operations Control Center will be based. Ting has spent most of the past 20 years building a coalition of 500 scientists from 60 institutions in 16 countries, to develop, build, and test AMS-02. All the international agreements involving the instrument are the responsibility of DOE, says NASA. However, the DOE connection may not make much difference to members of Congress.

The key to solving the performance issue that brought about the need for China's technology is that the Chinese magnets use a neodymium, iron, and boron alloy from Germany. Says Trent Martin, AMS project manager at NASA Johnson, the Chinese took this raw, unmagnetized material to shape, magnetize, and fit into the instrument's structure. "The latest development of the Chinese technologies for making permanent magnets has made AMS experiment possible," said Ting in a letter to DOE.

Assembly and testing of the Chinese hardware have taken place at some of the most important defense plants in China, including the Institute of Electrical Engineering and the Chinese Academy of Launch Vehicle Technology in Beijing. Lockheed Martin engineers traveled to these Chinese plants to ensure components were assembled precisely and safely—the magnetic force between adjoining blocks is 4 tons.

Difficult timing

Sharp restrictions against any NASA relationship with China were levied just as the AMS-02 instrument has been in final development. NASA tries to avoid any controversy by noting that the international aspects of AMS are managed by DOE.

But the agency's new FY11 budget just signed by the president precludes cooperation with China. The bill specifically bans NASA and the White House Office of Science and Technology Policy from spending any funds to discuss or arrange space cooperation with China unless specifically authorized to do so by Congress.

In June 1998 a prototype version of the instrument, AMS-01, including the same 2 tons of Chinese components flew for 10 days as an attached payload on board the orbiter Discovery's STS-91 mission. But it carried more than a test version of the instrument. With NASA and DOE concurrence, the orbiter carried 'Chinese souvenirs,' according to a history of the AMS-01 mission, including a gold-plated memorial tablet with an inscription by 'Comrade' Deng Xiaoping' and a copper tablet engraved with the name of the Chinese Academy of Sciences and the Institute of High Energy Physics in Beijing, a facility tied closely to the Chinese military. The sprawling complex is the biggest and most comprehensive fundamental research center in China, according to U.S. defense analysts.

Other Chinese facilities that had a hands-on role in the assembly and test of the AMS hardware include Beijing's Satellite Environmental Engineering Institute.

A closer look

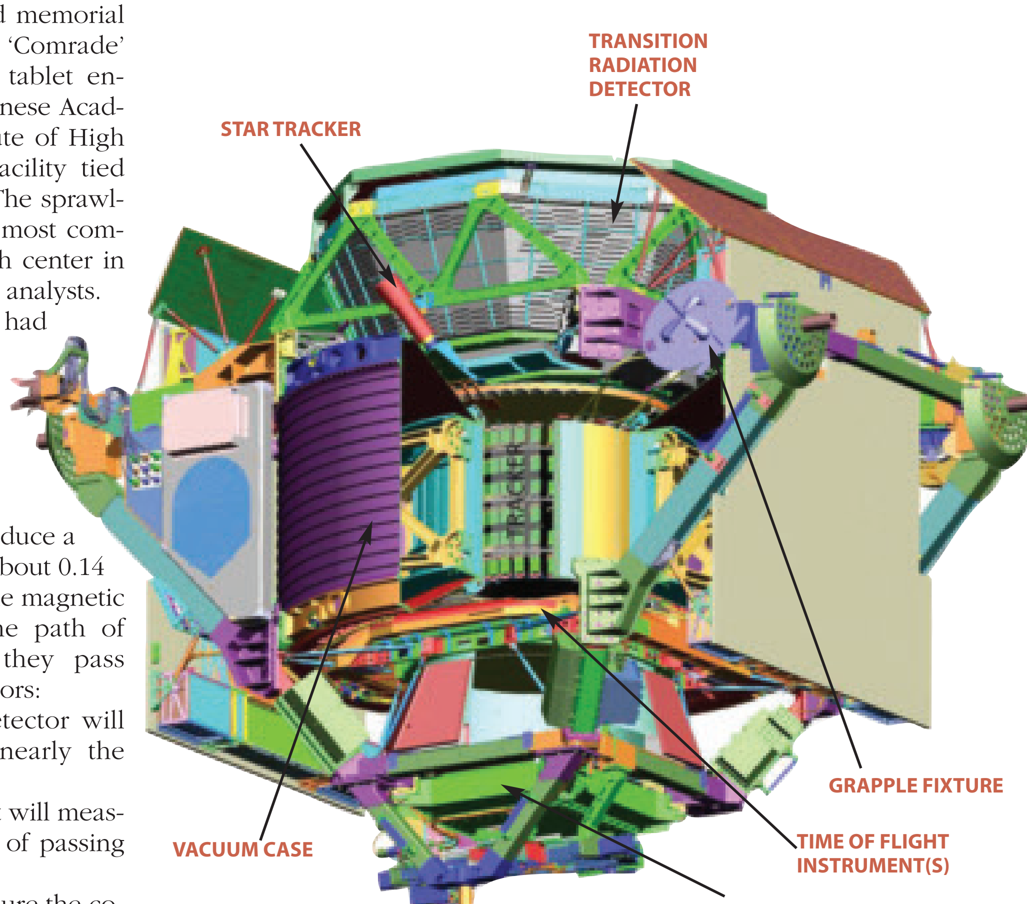
The permanent magnets will produce a strong, uniform magnetic field (about 0.14 Tesla) over a volume of 1 m^3. The magnetic field will be used to bend the path of charged cosmic particles as they pass through different types of detectors:

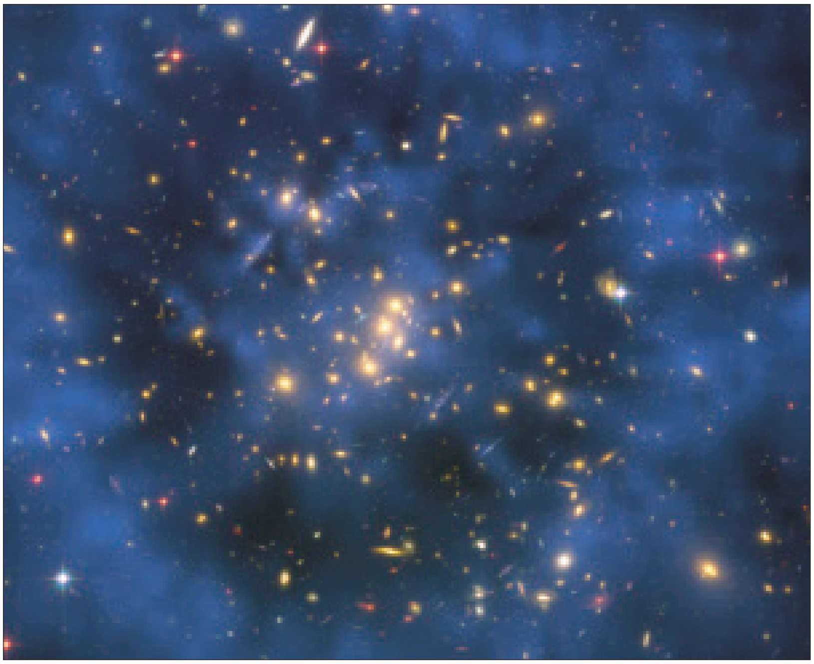
- The transition radiation detector will measure particles passing at nearly the speed of light.
- The time of flight instrument will measure the charge and the velocity of passing particles.
- The silicon tracker will measure the coordinates of charged particles in the magnetic field.

MIT Nobel Laureate Samuel Ting stands in the middle of the covered AMS-02 that he conceived.

- The electromagnetic calorimeter will measure the energy and coordinates of electrons, positrons, and gamma rays.

With over 300,000 data channels, the AMS-02 instrument will gather an extremely large amount of data that will be processed and sent to Earth using the ISS power, communication, and data infrastructure.





The Hubble Space Telescope images a ghostly ring caused by the gravitational pull of dark matter. The 2.6-million-light-year-wide ring was formed long ago during a titanic collision between two massive galaxy clusters. Though astronomers cannot see dark matter, they can infer its existence in galaxy clusters by observing how its gravity bends the light of stars, and that is what is seen here. The features are 5 billion light-years from Earth.

The AMS instrument, located in the large white cargo transfer canister, is elevated for transfer into Endeavour several weeks prior to launch.

The critical invisible

Particles of dark matter and its associated dark energy are the most enigmatic, invisible, yet critical elements in the cosmos. This is because they totally dominate the structure of the universe.

The visible matter in the universe adds up to less than 5% of the total mass that is known to exist, based on many other observations. The other 95% of the mass is dark—either dark matter (which is estimated at 20% of the universe by weight), or dark energy, which makes up the balance. The exact nature of each is still unknown. The AMS-02 detectors are geared to solving major questions about them.

According to AMS researchers, one of the leading candidates for dark matter is the neutralino particle. If neutralinos exist, they should be colliding with each other and giving off charged particles that can be detected by AMS-02. Any peaks in the background positron, antiproton, or gamma flux could signal the presence of neutralinos or other dark matter candidates.

The detection of antimatter would also be a major cosmological discovery. All evidence currently indicates that the universe is made of matter; however, the Big Bang theory requires equal amounts of matter and antimatter. Theories that explain this apparent asymmetry violate other measurements. Whether or not there is significant antimatter is one of the fundamental questions of the origin and nature of the universe. Any observations by AMS-02 of an antihelium nucleus would provide strong evidence for the existence of antimatter, AMS researchers believe.

Finding a flight

AMS-02 successfully completed final integration and operational testing at the European Organization for Nuclear Research (CERN), where it was tested with powerful nuclear particle beams generated by CERN particle accelerators. The instrument was then shipped to ESA's European Space Research and Technology Center in the Netherlands, where it underwent thermal vacuum, electromagnetic compatibility, and interference testing. Then, after another round of testing at CERN, it was delivered to Kennedy Space Center on board a USAF C-5M Super Galaxy.

For several years it was uncertain if AMS-02 would ever be launched, because it was not manifested to fly on any of the remaining shuttle flights. After the 2003 Columbia reentry accident, several flights, including that of AMS-02, were removed from the manifest. But in May 2008 a bill was proposed to launch AMS-02 to ISS on an additional shuttle flight in 2010 or 2011. The bill was signed into law by President George W. Bush in October 2008, well before the AMS team decided to fill AMS-02 with 2 tons of Chinese magnets divided into 4,000 components.

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At the Kennedy Space Center prior to launch, Ting said he did not know exactly what to expect, but that he had several ideas of what he hopes to find using the AMS. One hope is that the AMS data will open up an entirely new field of particle physics. Up until now, he said, the study of cosmic rays has been limited to measuring light using telescopes and instruments like those on NASA's Hubble Space Telescope. "The AMS is to be the first to study charged particles in space," he noted.

Ting also hopes that the particles recorded by AMS prove the existence of a parallel universe made up of antimatter, or particles that are, in electrical charge and magnetic properties, the exact opposite of ordinary particles. Such a universe has been theorized but not proven. The discovery of massive amounts of antimatter could answer fundamental questions about the origin of the universe. "Unless you do the experiments, you don't know who is right," Ting explained.

F-35

(Continued from page 39)

As the new decade dawned and the 10th F-35 entered flight tests, reports out of Washington indicated Gates was prepared to extend the SDD phase by up to two years beyond the 13-month extension it received in a restructuring last year. That in turn would trigger the congressional vow to buy additional F/A-18E/F Super Hornets to keep Navy carriers stocked through 2020.

Adding to the muddle as JSF moves into its first major LRIP is that the Pentagon is essentially wagering everything on the successful completion and integration of three F-35 variants into the U.S. fleet, even as the international side grows murkier than ever.

"Everybody is justifiably nervous about the future acquisition of JSF. The U.S. Air Force, Navy, and Marines have not backed off their stated numbers, but we've seen a recent slide to decouple concurrence, and international customers back off because there is no incentive to buy an aircraft early in production when they can wait a few more years and get a less expensive—and likely more capable—later block airplane," Bolling says. "But that is a slippery slope; they invested for the business case, but if they start backing off, the costs will go up, and Congress wants to reduce the buy due to rising costs. So you get into an affordability question our competitors will take advantage of, as Boeing is doing with the Navy now on what they term their 'good enough' 4.5-generation solution.

"And clearly the administration has made it known we need to get away from elegant, gold-plated solutions to get to 'good enough' with a rapid acquisition cycle. But I can tell you there is no way to take something designed with an entirely different threat in mind, make it perform the missions this aircraft will do, and survive," says Bolling. "But as the economies of several countries force scalebacks in defense expenditures, a naturally cut-throat defense industry will increasingly see the F-35 as a huge target to attack and attempt to take money away from; so everyone is justifiably leery."

The Marines will replace some of its STOVL aircraft buys with the F-35C Navy varient.

25 Years Ago, June 1986

June 9 The Presidential Commission on the Space Shuttle Challenger Accident releases its final report. It states that the cause of the Jan. 28, 1986, accident was a failure in the joint between the two lower segments of the right solid rocket motor. The specific failure was the destruction of the seals that were designed to prevent hot gases from leaking through the joint during the propellant burn of the rocket motor. NASA History Program Office Web site, www.history.nasa.gov/rogersrep/v1ch4.htm.

50 Years Ago, June 1961

June 1 Capital Airlines is merged into United Airlines, which becomes the largest airline in the world. Capital started in 1926 as the Clifford Ball Airlines, which delivered mail. By 1928 it began carrying passengers. In 1948, after several mergers, it became Capital Airlines and was based in Washington, D.C. United Airlines eventually has a fleet of 267 aircraft and serves 116 cities. D. Baker, *Flight and Flying*, p. 376; *The Aeroplane*, May 11, 1961, p. 512; *Aviation Week*, June 5, 1961, p. 39.

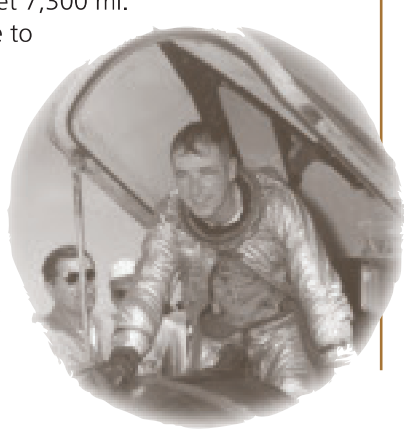
June 3 A 500,000-lb-thrust segmented solid-propellant rocket motor is successfully test fired by Aerojet General. The most powerful solid-fuel rocket motor fired to date, the 30-ft-long, 8-ft, 4-in.-diam motor contains more than 100,000 lb of propellant. The three segments of propellant are manufactured separately and assembled on site. *The Aeroplane*, July 13, 1961, p. 32; *The 1962 Aerospace Year Book*, p. 471.

June 16 The Discoverer XXV satellite is launched from Vandenberg AFB, Calif., with reentry set for June 18. However, the aerial retrieval fails when the capsule misses the drop zone near Hawaii and falls too far into the sea. Air Force parachutists trained in skin diving are flown to the new landing area, then jump into the water and successfully haul the capsule aboard a 20-man life raft. The data are later retrieved. *Aviation Week*, June 26, 1961, p. 32.

June 17 India's Hindustan HF-24 Marut, the first supersonic fighter designed and built in Asia, makes its maiden flight. Powering the plane are two 4,850-lb-thrust Rolls-Royce Orpheus 703 turbojet engines. D. Baker, *Flight and Flying*, p. 376.

June 22 An advanced Atlas E test missile explodes 2 min after launch at Cape Canaveral, Fla. It had been aimed for a target 7,300 mi. out in the South Atlantic. The missile did not have to self-destruct. *The Aeroplane*, July 6, 1961, p. 6.

June 23 The North American X-15 rocket research aircraft sets a new world speed record of 3,603 mph (Mach 5.30), the first time a manned aircraft exceeds Mach 5. Flown by Air Force Maj. Robert White, the mission beats the previous record of 3,370 mph, also set in the X-15. D. Jenkins, *X-15: Extending the Frontiers of Flight*, p. 618.



June 25 Aviation pioneer John Alexander Douglas ('J.A.D.') McCurdy, regarded as the first in the British Empire to fly a controlled powered aircraft, dies at age 75. Born in Nova Scotia, he spent 1907-1909 developing an aircraft in close association with Alexander Graham Bell, as a member of Bell's Aerial Experiment Association. Eventually, McCurdy flew his own machine, the Silver Dart, at Baddeck Bay, Nova Scotia, on Feb. 24, 1909, for 1.5 mi. The plane featured ailerons for control and had a 35-hp Curtiss engine. This was the first controlled flight of a flying machine in Canada. The Canadian Aeronautical Institute's premier award was later named the McCurdy Award in his honor. *The Aeroplane*, June 29, 1961, p. 739; C. Gibbs-Smith, *Aviation: An Historical Survey*, p. 130.

June 25 BOAC inaugurates the first nonstop air service between London and Ghana. *The Aeroplane*, June 29, 1961, p. 742.

June 26 The Navy announces it will give up using airships for antisubmarine work, except for two that will continue operating for another year. One stated reason for the decision is economy, although airships are cheaper to operate than conventional planes and can fly when other aircraft are grounded. Another reason that is offered is a review of the accidental loss of one of the airships, the ZPG-3W, with its 12-member crew. *The Aeroplane*, July 20, 1961, p. 59; D. Baker, *Flight and Flying*, p. 376.

Past

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

June 26 Hélène Dutrieu, the famous Belgian-born aviatrix who was one of the first women to obtain a pilot's license, dies at age 84. A cycling world champion, stunt cyclist, stunt motorcyclist, and automobile driver, she became qualified to fly in 1910. She made her first flight on a Demoiselle of Alberto Santos-Dumont. Prior to WW I, Dutrieu won numerous awards for speed, and altitude, attaining endurance aviation records as well. Hélène Dutrieu file, NASM; *The Aeroplane*, July 6, 1961, p. 7.

And During June 1961

—X-15 pilots A. Scott Crossfield, Joseph A. Walker, and Air Force Maj. Robert A. White are named the 1960 winners of the Harmon International Aviation Trophy, the first time three pilots are chosen as joint winners. *Aviation Week*, June 26, 1961, p. 67.

75 Years Ago, June 1936

June 6 Sacony-Vacuum Oil of New Jersey begins production of 100-octane aviation gasoline by the catalytic cracking method. This technological breakthrough paves the way for increased engine performance and provides the Allies with a significant advance over the Axis powers during WW II. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 34.

June 6 London's new Gatwick Airport opens with an air show featuring a wide variety of civil and military planes, ranging from a Pou-du-Ciel to D.H. 86s, a Vildebeest, and the Monospar S.T. 18. *Flight*, June 11, 1936, pp. 616-619.

June 7 Major Ira C. Eaker, Army Air Corps, makes the first transcontinental blind flight, from New York to Los Angeles. E. Emme, *Aeronautics and Astronautics, 1915-60*, p. 34.

June 8 Capel W. McNash, president of the newly formed American Institute for Rocket Research, requests the affiliation of Robert H. Goddard, the nation's leading rocket pioneer, and proposes that a convention of "all the rocketeers in the country" be held in Chicago to decide, by consultation, the best plans for 'one great experiment.' Goddard, however, refuses on the grounds that his work is not yet complete so he cannot share his results. E. Goddard and G. Pendray, eds., *The Papers of Robert H. Goddard, Vol. II*, pp. 1007-1008.

June 9 The Dutch mail rocket experimenter, known as 'Professor' Dr. Adam J. de Bruijn, begins a nine-year period of mail rocket flights in his country, with his first attempt at Ijsselmonde, the Netherlands. De Bruijn is later jailed for the falsification of 'rocket stamps.' J. Ellington and P. Zwisler, *Ellington-Zwisler Rocket Mail Catalog*, p. 105; F. Winter, *Prelude to the Space Age: The Rocket Societies 1924-1940*, p. 109.

June 11 The first of the Handley Page 42s, known as Hannibal, completes five years of service between London and Paris. The giant all-metal biplane has flown 5,950 hr and has covered 565,000 mi. at its modest speed of 95 mph. *The Aeroplane*, June 17, 1936, p. 773.

June 29 An Army Douglas OA-5 type amphibian sets a world nonstop distance record for such aircraft by flying 1,425 mi. from San Juan, Puerto Rico, to Langley Field, Va., in 11 hr 9 min. Leading the flight and its crew of six are Maj. Gen. Frank M. Andrews and Maj. Gen. Frank R. McCoy. Andrews, commander of the General Headquarters Air Force, is seeking to keep the Army Air Corps in the public eye to generate good publicity and more congressional funding. *Aero Digest*, Aug. 1936, p. 76.

100 Years Ago, June 1911

June 26 In Germany, Zeppelin rigid airship LZ 10 Schwaben completes its maiden flight. A. van Hoorebeeck, *La Conquete de L'Air*, p. 91.

June 28 From western New York, famed stunt pilot Lincoln Beachey flies his Curtiss biplane over Niagara Falls without incident. A. van Hoorebeeck, *La Conquete de L'Air*, p. 91.

And During June 1911

—In Britain, F.T. Nettleingham claims to have originated flight insurance there as a result of articles he had written in *Aeronautics* magazine on the subject. *Aeronautics (London)*, June 1911, p. 89, and May 1912, pp. 117-118.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