7 AEROSPACE AMERICA JULY-AUGUST 2010

July-August 2010

AEROSPACE AMERICA

Human rating for future spaceflight

A roundtable discussion

Emerging regionals crowd a flat market

T minus 15 years...and holding

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AEROSPACE AMERICA

July/August 2010

DEPARTMENTS

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BULLETIN

COVER

Whatever the next generation of human space transportation systems look like, human-rating requirements will be a driving force in their development. Follow the discussion on human rating, beginning on page 26.

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Editorial

The human factor

As has been noted before, in February 2010, President Obama released his NASA budget proposal calling for the cancellation of the Constellation program, which was developing a series of launch vehicles and crew modules to replace the space shuttle. Instead, he called on private industry to provide the next generation of rockets and crew vehicles that would enable the continued human exploration of space.

Now, several months later, the battle over this proposal is still being waged in the Congress. Some of the fight is no doubt political, driven as much by the determination to save local jobs as by a passion for space exploration. Some congressmen, and other interested parties, have registered their belief that NASA is the only appropriate venue for developing the tools by which the U.S. will be able to maintain its leadership position in manned space exploration.

But even as the debate roils, some commercial enterprises are continuing their development of systems meant to provide paying customers, perhaps including the U.S. government, transport to the space station and elsewhere. Other ventures are at a crossroads, unsure that a sound business case can be made for moving beyond hauling cargo. No doubt economic and technical questions will both weigh heavily in determining whether their efforts should extend to providing human transport.

Regardless of the outcome of the congressional skirmishes, and whichever companies determine that they should proceed, it is the human factor that will dominate the design decisions for the next generation of rockets. Whether built for or by NASA or private enterprise, no matter how sound the launch vehicle is, it must be taken the extra mile to be human rated.

On May 24, AIAA held a roundtable to discuss what human rating the next-generation space transportation system will entail, along with a look back at what lessons can be gleaned from the space shuttle and the Russian Soyuz. That discussion, which has been captured within these pages, is just the beginning of the dialogue. NASA's request for information, which may have rolled out as you read this, will set some fundamental requirements for human rating, but will invite all interested parties to offer comments, questions, rebuttals, and alternatives as the industry tries to move forward.

In this roundtable you will find a deeply thought out discussion about how the criteria for human rating are established, what the requirements should be, and who the players are who will make the final decisions. One point that quickly emerges is the importance of the partnership between the public and private sectors in establishing the various paths to achieving human rating.

In this conversation, all of the interested parties—NASA; the FAA, which must license any commercial launch; private industry—have made it clear that safety must be their number one priority. The twin space shuttle tragedies are never far from the thoughts of everyone involved. However, it becomes equally clear that safety issues cannot be allowed to overwhelm the process. Overregulation can easily lead to stasis.The safest launch vehicle may indeed be the one that never leaves the ground, but it also serves no one's interests.

Elaine Camhi
Editor-in-Chief

Flying gets personal in Europe

In February of this year, the European Commission announced the launch of a €4.4-million 30-month research program examining the development of a personal air vehicle. The Personal Plane (PPlane) program involves 13 European research organizations looking at the technology and infrastructure challenges in developing small automobile-size aircraft able to deliver the benefits of speed and routing efficiencies possible only via a direct-to-destination flight.

It is a small but significant piece of research work, and fits within a much larger concept being evaluated within the continent for developing new transport links, primarily within central and eastern Europe, much along the lines of NASA's Small Aircraft Transportation System of a few years ago.

EPATS and general aviation

This European equivalent is EPATS, or European Personal Air Transport System (http://www.epats.eu), a study group that has developed a long-term road map for the development of a personal air transport system based on new-technology light aircraft. The EPATS group has studied the challenges and implications of growing Europe's general aviation fleet by up to 90,000 new personal aircraft by 2020—56% of which would be piston engine aircraft, 18% turboprops, and 26% jets—and flying 43 million flights a year, to meet the transport needs of central Europe.

Much of the rationale behind the personal aircraft initiative has derived from a study the EPATS group compiled showing that, for many countries, developing a transport system based on small personal aircraft will be cheaper, more efficient, and less environmentally damaging than building huge new networks of motorways. But as Krzysztof Piwek, EPATS study project coordinator and a member of the Polish Institute of Aviation, pointed out in a presentation at the 2008 Berlin ILA air show, this will only be possible through the development of a high-density network of airports, the

availability of new air traffic management (ATM) technology, and technically advanced aircraft.

According to the EC, "Some recent studies conclude that smaller aircraft exhibiting individual characteristics will play a greater role in air transportation in order to avoid increasing congestion on European roads. The PPlane project emphasizes environmentally responsible design, including noise and gas emission reduction, green propulsion, and energy efficiency, and is expected to increase savings and sustainability on one hand, and decrease overall traffic environmental impact on the other, resulting from a more efficient travel."

PPlane research will examine affordability, technology availability, social acceptance, and regulatory issues. For many in Europe's beleaguered general aviation industry, the involvement by the European Union in efforts to promote general aviation concepts is a welcome change. There are around 50,000 motor-powered general and business aviation aircraft in Europe, with a further 180,000 microlight and non-motor-powered aircraft. But in many parts of the continent the industry is in trouble, with pilot numbers falling and small airfields facing closure.

The EC added general aviation to its portfolio of interests in early 2008, integrating the industry within its transport agenda. However, despite the prospect of the commission promoting the sale of 90,000 new general aviation aircraft in the continent over the next nine years, there are still some concerns about the involvement of state bodies in general aviation aircraft programs.

"I'm skeptical," notes Guy Lachlan, chief executive of the British Business and General Aviation Association. "Governments should concentrate on developing programs such as the Single European Sky and solving airport access issues rather than involving themselves in industrial issues. After all, very light jet [VLJ] developments have all been undertaken by private companies."

However, the development of personal transport vehicles is now firmly on the EC's agenda. According to commission project officer José Hernandez, PPlane is part of the agency's brief within its aeronautics strategy of "pioneering revolutionary" projects that will pave the way for future European based air transport systems.

PPlane project partners

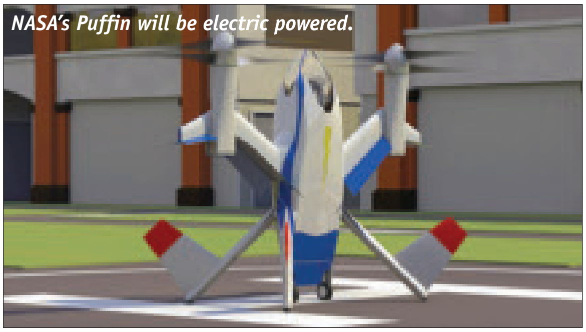
The PPlane project is being led by Claude Le Tallec of ONERA (France), assisted by Moshe Harel of Intergam Communications (Israel). PPlane's consortium members comprise Israel Aerospace Industries (Israel), AIRNET (Slovenia), Bologna University and CIRA (Italy), Brno University (Czech Republic), Warsaw University of Technology (Poland), German Aerospace Center DLR (Germany), Instituto Nacional de Técnica Aeroespacial (Spain), National Aerospace Laboratory NLR (Netherlands), University of Patras (Greece), and REA-TECH Engineering (Hungary). The research will last 30 months.

TRANSPORT PROPERTIES COMPARISON

Travel of more than 200 km, Polish road conditions

Properties	***Units***	***Automobile***	***Light propeller aircraft***	***Single-engine jet-driven aircraft***
Empty vehicle weight	Kilograms	1,300	800	1,500
Average travel speed	Kilometers/hour	70	300	600
Average effective fuel consumption per 100 km	Liters/100 km	9	14	40
Average fuel consumption per passenger-km	Liters/pass.-km	6.4	5	14
Operational life	Years	15	20	25
Fatalities rate per 100 million pass.-km	Number of fatalities	0.460	0.055	0.045
Vehicle price	U.S. dollars	25,000	50,000	400,000
Vehicle-km cost	Dollars per vehicle-km	0.4	0.6	0.9
Passenger-km cost	Dollars per pass.-km	0.3	0.2	0.3
External costs	Dollars per pass.-km	0.06	0.01	0.01
Time of training to achieve the skill to control vehicle at the level necessary to individual trips	Hours	25	50	50
Percentage of adult population able to drive the vehicle		80	50	40
Operational availability: annual number of trips realized as % of planned trips		98	80	90
Average distance to the vehicle parking area	Kilometers	0	20	20
Stress level on a 1-10 scale (10 = high stress)		9	6	7
Daily radius of action	Kilometers	150	600	1,400
Time of a 500-km business trip	Hours	60	12	8
Number of vehicles needed to realize 1 billion pass.-km		60,000	1,900	680
Additional ground area, occupied by roads and car parks needed to realize transport work of 1 billion pass.-km	Hectares	81,000	No additional area needed; underused airports will be used	No additional area needed; underused airports will be used
Saved pass. time on 1 billion pass.-km hours	Hours	0	9.7 million	11.4 million

Source: EPATS.



NASA's Puffin will be electric powered.

The project is based on the findings of previous European research and development projects, including Out-of-the-Box, a study funded by the EC as part of the Advisory Council for Aeronautic Research in Europe initiative; the Single European Sky ATM Research program; and the Innovative Operational UAS Integration work program.

Some of the EPATS concepts have already been analyzed by the Eurocontrol experimental center in Bretigny. Eurocontrol's work to analyze the potential impact of VLJ operations on European ATM was an important factor in paving the way for VLJ start-up in operations in the continent—it concluded that even if VLJs accounted for 10% of air transport movements within Europe they could still be accommodated safely.

Institutional hurdles

But the industrial, commercial, and technological trends are not favorable to the concept in Europe. "Flying car" notions have been around for many years, but to produce these aircraft on an industrial scale a number of breakthrough technologies and procedures will need to be matured.

According to a recent study by the Dutch National Aerospace Laboratory, TNO Defence, Security and Safety, and Aerospace Software and Technologies Institute (http://evts.nlr.nl/index.html) into introducing an enhanced VFR (visual flight rules) transport system (EVTS), based on slightly larger aircraft than the PPlane, the challenges will be more institutional than technical.

Researchers from the three organizations concluded that noise generation and emissions of the aircraft suitable for the EVTS concept are acceptable and will be improving in the future. With the onboard technology of EVTS it will be possible to fly complex approach and departure routes, avoiding populated areas. There would be enough airport capacity; each GA airport could handle around 140,000 passengers annually, based on 1.4 passengers per aircraft—and there are about six times as many airports available for EVTS compared to airliners.

The researchers are also optimistic about the availability of an appropriate airborne collision avoidance system. "When an aircraft is equipped with an ADS-B transceiver, the pilot is able to see all ADS-B-equipped aircraft and TIS-B [Traffic Information Service-Broadcast] aircraft. Therefore it is very easy to make separation more autonomous and go to the next ASAS mode: ASAS-spacing. ATC is still responsible, but aircraft can do separation tasks. When ASAS has proven itself, higher levels of autonomy can be allowed so that eventually VFR flights can be combined with ASAS-Separation or ASAS-Self-separation," according to consortium findings.

The major hurdles will involve aircraft certification and regulation. Automating the aircraft cockpit will imply that, under the present rules, the EVTS will be considered an IFR (instrument flight rules) operation and therefore must be controlled by ATC. In reality, EVTS sits somewhere between IFR and VFR: The pilot is flying on instruments under VFR. This will require a rule change. So will pilot licensing rules; current European private pilots licensing procedures do not require an instrument rating capability, which would be needed for a highly automated ETV cockpit. And access to airfields without an ATC presence would also need a rule change.

But it is a good time to consider changing the rules. As part of the Single European Sky initiative, Eurocontrol is considering moving toward redefining the airspace usage above Europe from seven to three levels, including an airspace level where aircraft unknown to ATC authorities would be allowed to operate on self-separation principles, perhaps using data-link for 4D navigation and more automated sense-and-avoid procedures being developed for UAS traffic. This would be the level in which personal air vehicles could operate.

"It is easy to dismiss these ideas as nothing more than science fiction—the '50s vision of life in 2020—but the benefits for those that need access to Western Europe are huge, and the payback in terms of that access immediate," according to Andrew Charlton, a Geneva based aviation legal consultant to the ATM industry.

"The rate-determining step will be infrastructure, not aeronautics. These plans will call for a huge investment in airspace management. But that need not just be a question of money. There is, as ever, also a need for intelligent regulation. It is worth remembering that the explosion in car usage called for rules and regulations, some of which we continue to fail to harmonize, long before we needed to build more roads. We have the chance here to put in place practical solutions to address the regulatory issues alongside the technical issues—but the project needs to address these concerns fully," says Charlton.

✈✈✈

A few days before the commission announced its PPlane research program the NASA Puffin (http://www.nasa.gov/topics/technology/features/puffin.html) concept of a personal air transport vehicle reached the virtual world. This is an electric powered, 3.7-m-long, 4.4-m-wingspan personal air vehicle that will take to the air—in a one-third-scale form—later this year. It has been developed by a team from the Massachusetts Institute of Technology, the Georgia Institute of Technology, the National Institute of Aerospace, and M-DOT Aerospace in the U.S.

The timing was significant. Although entirely unrelated to PPlane, it was further evidence that there is growing interest in a new type of personal aviation technology on both sides of the Atlantic. Perhaps this is not just a new market opportunity for legacy technology suppliers but a new type of aviation concept to rekindle the interest of a next generation of engineers in the aerospace industry of the future.

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Correspondence

Working toward compromise (April, page 3) suggests using the Atlas V and the Delta IV EELVs as what? Manned vehicles to carry crew to the space station, or to replace the Constellation heavy lift capability? I'm not sure about the Atlas, but Delta uses the same RS-68 rocket engine as the Constellation program. The RS-68 is a very inefficient rocket. It has a specific impulse of 415 sec compared with the space shuttle main engines, which operate at an I_{sp} of 454 sec. As an example, the shuttle using the RS-68 engine would use 17% more fuel which would make each shuttle flight cost in excess of $20 million more. Inefficiency is the reason the Constellation program was cancelled and it is a reason not to use the Delta vehicle as a compromise space vehicle. The proper way to have efficient space transportation is to develop advanced performance rocket engines having an I_{sp} of 470 sec.

Dale Lawrence Jensen
JENTEC

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This is in response to **Wind Tunnels: Don't count them out** (April, page 38). In the discussion of prospects for the future, here is part of the quote by Ed Mickle, manager of aerodynamics test facility planning at AEDC, Arnold AFB: "I think this is where you will see more merging of large-scale computations with testing. Not in spite of, or in replacement of, but the two will meld more to each other."

This reminded me of the Minta Martin Lecture at MIT in 1975 or 1976 by Dr. Hans Mark, then director of NASA Ames. The title of his presentation was "The Future of Computational Aerodynamics," and was based on the AIAA 1975 paper "Computers vs. Wind Tunnels for Aerodynamic Flow Simulations."

Dr. Mark made the point that wind tunnel usage was increasing exponentially in new programs and, with considerable prescience, he made the same point as in the quote above that computational methods would be used, in conjunction with testing, for future developments. His paper went into detail on the further improvements that were necessary for computational methods to be able to give useful results.

In the 35 years since that lecture, computational aerodynamics, now called CFD, has been validated for many applications and can be used to reveal fundamental flow behavior. An engineer of today having the remarkable insight of Richard Whitcomb may well recognize some new phenomenon from the results of CFD studies, as Whitcomb did from wind tunnel tests. There will always be the need to validate CFD results from tests, but inspiration will come from both.

Hubert I. Flomenhoft
Palm Beach Gardens, Fla.

Events Calendar

JULY 10-15
Twenty-seventh International Symposium on Rarefied Gas Dynamics, Pacific Grove, Calif.
Contact: Deborah Levin, 814/865-6435, dalevin@psu.edu

JULY 11-15
Fortieth International Conference on Environmental Systems, Barcelona, Spain.
Contact: 703/264-7500

JULY 18-25
Twenty-eighth Scientific Assembly of the Committee on Space Research, Bremen, Germany.
Contact: www.cospar2010.org

JULY 25-28
Forty-sixth AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Nashville, Tenn.
Contact: 703/264-7500

JULY 25-28
Eighth International Energy Conversion Engineering Conference and Exhibit, Nashville, Tenn.
Contact: 703/264-7500

JULY 27-28
2010 RAeS Aerodynamics Conference, Bristol, U.K.
Contact: Emma Brown, emma.brown@aerosociety.com

AUG. 2-5
AIAA Conferences on Guidance, Navigation, and Control; Atmospheric Flight Mechanics; Modeling and Simulation Technologies; and Atmospheric and Space Environments; AIAA/AAS Astrodynamics Specialist Conference. Toronto, Ontario, Canada.
Contact: 703/264-7500

AUG. 7-13
2010 International Heat Transfer Conference, Washington, D.C.
Contact: Avram Bar-Cohen, 301/405-3173; abc@umd.edu

AUG. 30-SEPT. 2
AIAA SPACE 2010 Conference and Exhibition; 28th AIAA International Communications Satellite Systems Conference. Anaheim, Calif.
Contact: 703/264-7500

Gearing up for budgetary battles

Whether, and how, U.S. astronauts will venture into space in the postshuttle era is rapidly evolving into a head-on dispute between the Obama administration and members of Congress—in both parties—who want NASA to field the nation's next generation of space vehicles.

Fighting over Constellation

The administration wants to cancel the Constellation program for postshuttle spacecraft. Lawmakers who want Constellation to proceed—including representatives from Florida and Alabama, states containing key NASA sites—are expected to oppose the White House policy vigorously during debate and legislative markup sessions this fall. Between now and October 1, as the differences between the two sides fester, NASA employees and field centers are caught up in a time-warp paradox: Legislation for the current fiscal year authorizes them to work on Constellation's Ares I rocket booster, the Orion crew exploration vehicle, and other hardware. The administration's plan for the new fiscal year calls for them to halt work on nearly all components of the Constellation program.

"It's a strength of government to develop and field the hardware for manned spaceflight," says author and analyst Edward Martin. "Everybody likes the all-American idea of entrepreneurship, but putting astronauts into orbit may be a task that's beyond private industry."

Sen. Bill Nelson

NASA Administrator Charles Bolden

Those with an opposing view note that in 2005 the private sector launched 18 unmanned spacecraft, and several companies are close to developing vehicles to carry astronauts.

The looming debate is creating rifts, even between close allies. NASA Administrator Charles Bolden was not President Barack Obama's first choice to head the agency, but he got the job because of close ties to Sen. Bill Nelson (D-Fla.). Bolden and Nelson once flew in space together—Nelson is the only serving lawmaker to have been in orbit—and they are friends. But now Bolden is charged with implementing the Obama plan, while Nelson wants to continue developing Constellation.

The shuttle Atlantis, commanded by Navy Capt. Kenneth Ham with six astronauts aboard, landed on May 26 after a 12-day mission (STS-132) that installed a Russian module on the international space station. That left only two more shuttle flights on NASA's official schedule, one each by Endeavour and Discovery. However, NASA plans to keep Atlantis in operating condition in case a rescue mission is needed during the two remaining flights.

Even without an emergency, observers believe Atlantis may be used for another ISS supply flight, if the White House approves the add-on of one last sortie, which would be the 135th for the shuttle fleet since 1981. Nelson told the Associated Press that he is encouraging one more flight for Atlantis and noted, "There's a good chance the president will approve it." Astronaut Thomas D. Jones predicted on these pages ("Space shuttle: An astronaut looks at its legacy," May, page 16) that we may very well see "several 'final' shuttle launches" before the program wraps up months later than planned.

But even if no more flights are added to the existing schedule, the once-firm cutoff date for shuttle operations, October 1, is now being moved to the right: The last flight by Discovery is slipping to at least November and possibly later.

Defense authorization debate

It will be a long, hot summer—perhaps even a "nasty" one, suggested one observer—as Congress debates the FY11 defense authorization bill. Defense Secretary Robert Gates is a deficit hawk who says he will trim $10 billion from planned defense spending. Just where the cut will occur is unclear, and it is a token figure in the view of critics who seek a more significant decrease in Pentagon expenditures.

The secretary faces opposition on the Hill over such issues as an alternate engine for the F-35 Lightning II Joint Strike Fighter and continued production of the C-17 Globemaster III airlifter. He says he will "strongly recommend" that the president veto the DOD budget if it includes the extra engine or more C-17s. Gates also faces legislative opposition to his plan for retiring aging ships and aircraft, a process that would reduce the size of the armed forces but leave some communities without hometown bases.

Altogether, the House of Representatives version of the defense authorization bill would spend $760 billion, including $567 billion in the DOD budget and the nuclear weapons programs of the Dept. of Energy, $159 billion for "overseas contingency operations" (Iraq

Rep. Adam Smith

Defense Secretary Robert Gates

and Afghanistan), and $34 billion in overseas commitments left over from last year (including relief work in Haiti). At this writing, the Senate had not passed an authorization bill but was expected to join the House in opposing Gates on key issues.

Those who worry about the U.S. national debt and about deficit spending are attacking Gates from the opposite direction, insisting that the DOD's civilian chief is not being tight-fisted enough.

Gates acknowledges that the U.S. will spend more on defense than the rest of the world's nations combined. When adjusted for inflation, the total is the largest defense outlay since the Korean War. The secretary is "merely seeking to slow the growth of defense spending, not to reduce it in absolute terms," wrote William D. Hartung, director of the Arms and Security Initiative at the New America Foundation. "Everything needs to be on the table, from delay or cancellation of the F-35 to deeper cuts in missile defense spending to elimination of spending for new aircraft carriers and ballistic missile submarines."

To remove one roadblock to reaching the spending level he seeks, Gates backed away from an issue that Washington observers say is too hot to handle. He initially wanted to cap this year's pay raise for military members at 0.5%, but quickly saw that it couldn't be done. "I want change, but I'm not crazy," he told reporters after a House panel approved a 1.9% pay increase for service men and women. Personnel costs, including "retirement pay," or pensions, make up the largest chunk of the military spending.

But Gates is not budging on the extra JSF engine or on additional C-17s.

"I believe the defense budget process should no longer be characterized by business as usual, within this building or outside of it," Gates said at a press conference. He added, "We will strongly resist efforts to impose programs and changes on the department that the military does not want and cannot afford, and that take dollars from programs and endeavors the military services do need."

The JSF is under close scrutiny from Congress because of scheduling delays and cost overruns. No aspect of the program is more controversial than the House Armed Services Committee's decision to include $485 million in continued funding for the aircraft's General Electric/Rolls-Royce F136 engine. The administration wants to proceed with just one engine type, the Pratt & Whitney F135. Rep. John Larson (D-Conn.), in whose state Pratt & Whitney is headquartered, says the House funds should be shifted to the F135.

By supporting the F136, which is more than 70% through development, the House committee is demanding an annual, head-to-head competition for a JSF powerplant, avoiding a decades-long, $100-billion engine monopoly that otherwise would go to the F135. Rep. Adam Smith (D-Wash.) says the DOD's own study on JSF engine options indicates "it would cost no more to reduce operational risk and achieve the benefits of a competitive engine program than to fund a sole-source engine program."

Many supporters of the alternate engine are Republicans like Rep. Roscoe Bartlett (R-Md.), who says a competing engine is "warranted and critical and costs nothing more, according to the Government Accountability Office." The GAO estimates that competition between engine makers could lead to long-term savings of up to 21% for ongoing programs.

Getting JSF on track

As for the F-35 itself, all parties agree that the aircraft has fallen behind schedule and gone over cost, but supporters say they are taking strong measures to bring the fighter back on its flight path.

There is strong support on the Hill for purchasing additional Super Hornets while waiting for the F-35.

"We're reducing the time it takes to build an F-35 by half," Lockheed Martin's Steve O'Bryan, vice president of business development and customer engagement, tells *Aerospace America*. In addition, says O'Bryan, "We are reducing parts shortages from over 300 to about 10."

He also notes that, despite setbacks, the F-35 delivery schedule "remains unchanged." He says the Air Force, not the planemaker, must decide when to seek initial operating capability (IOC) for the F-35A land-based version. Gen. Norton Schwartz, Air Force chief of staff, has slipped IOC from 2013 to 2015.

The House Armed Services Committee wants to limit current JSF production to just 30 airframes until the Pentagon completes a study certifying progress in the restructured procurement program. Smith told reporters, "It's a critical program. It's replacing almost all of our fighter attack aircraft over the course of the next five to 20 years. We have to make sure that it works and functions."

Rep. Todd Akin

In addition, sea power panel ranking member Rep. Todd Akin (R-Mo.) points out that "even if JSF suddenly meets schedule and cost, the Navy and Marine Corps will continue to have a strike fighter shortfall." He describes the shortfall as "closer to five carriers' worth of aircraft," calling that "a pretty big deal" despite Pentagon assurances otherwise. One alternative to the JSF would be further "new build" production of the F/A-18E/F Super Hornet, manufactured in Akin's home state.

Expressing support for continued procurement of the Super Hornets "barring a complete reversal of the development and performance failures in the Joint Strike Fighter program," the House committee added eight additional F/A-18E/Fs to the administration's FY11 request for 22 aircraft. Moreover, the Navy now says that over a period of years it will order 124 additional Super Hornets beyond the 493 that constituted the program of record for many years. It must fill in a projected "fighter gap" on aircraft carrier decks, says the Navy, which also says it is not bucking Obama and his administration or their unwavering commitment to JSF. Rear Adm. Mike Manazir, head of naval aviation programs, says the Navy needs almost 700 F-35s to upgrade aircraft carrier power projection capabilities starting in April 2016.

From its inception, the JSF program was intended as a giant multinational effort to provide more than 5,000-6,000 fighters over 30 years, in three versions, to a dozen countries. A similar program, the F-16 Fighting Falcon, was undertaken in the 1970s, with the Netherlands taking the lead in the plane's overseas development and with all customers offered two engine choices. U.S. forces, among other users, operate F-16s with two different sets of engines.

Now, the Dutch parliament has voted to end participation in the operational test phase of JSF and cancel an earlier order for one aircraft. The Netherlands contributed $800 million to JSF development and had planned to purchase up to 85 fighters, but political opposition on the home front has always been strong. While observers in Amsterdam were saying that some of the anti-JSF rhetoric is merely election-eve posturing, at press time it appeared that JSF critics would gain strength in June 9 Dutch elections.

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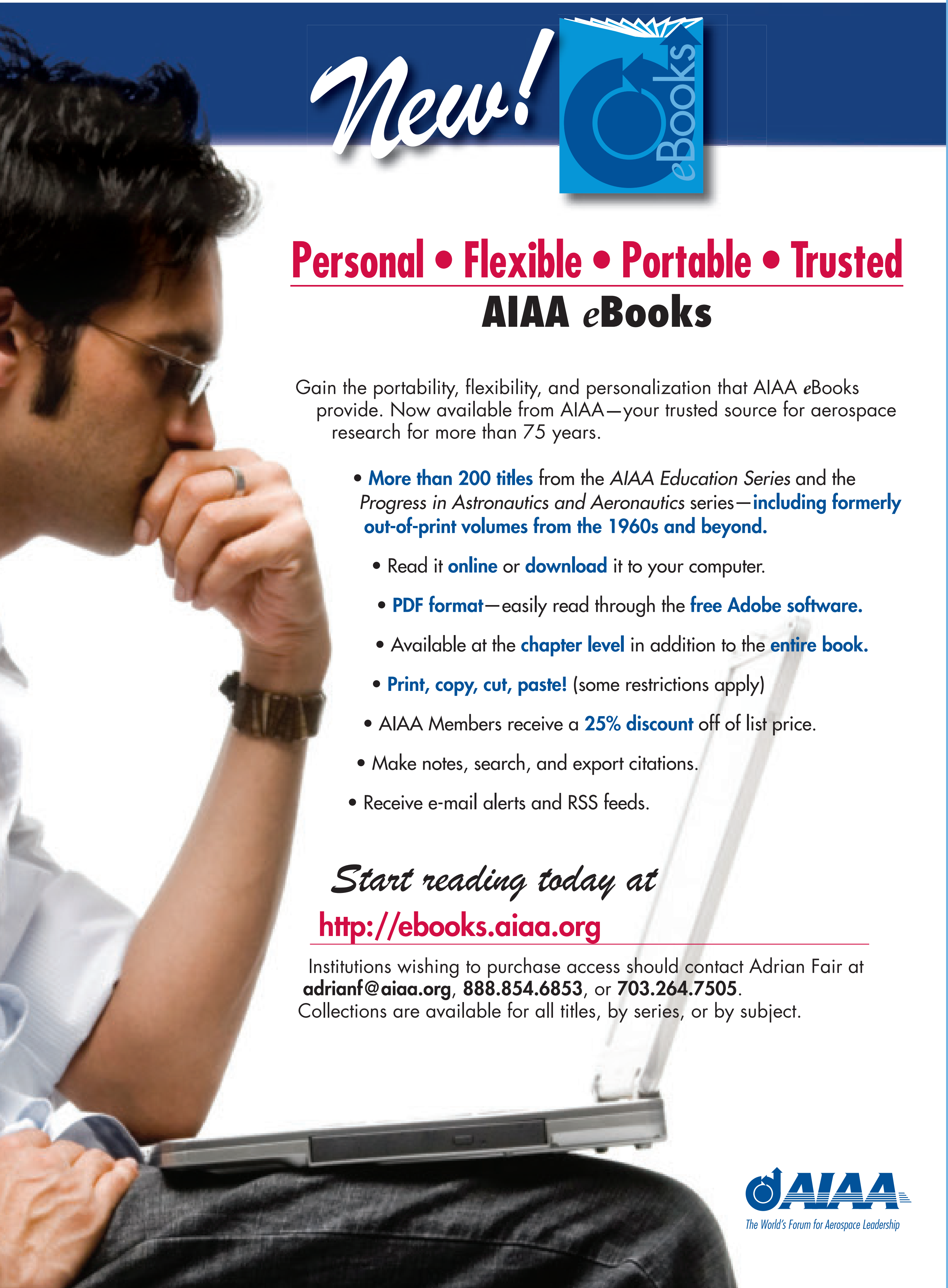
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T minus 15 years...and holding

IN 2001, AS MY CREW AND I WERE ABOUT to set off for the ISS on my last shuttle mission, we had a brief conversation with the executive in charge of NASA's space operations. Fidgeting in crew quarters, we shot the breeze about our STS-98 Atlantis mission and the future. When I asked when he thought astronauts would once again move beyond the station into deep space, his answer startled me.

"Not until 2012 or 2013 at the earliest." He was nonchalant, but the idea of still being mired in LEO a dozen years hence bowled me over. Here I was about to strap into a 4.5-million-lb rocket, surrounded by about 2,000 tons of chemical explosives, all to further the cause of human exploration. Yet my boss was telling me we were going nowhere fast. The only thing on his plate was the status quo: shuttle, station, and LEO.

What a difference a decade makes.

Despite President Barack Obama's April speech at Kennedy Space Center, the nation's future in space remains mired in political debate. To address critics of his FY11 budget proposal (released in February), the president directed NASA to resurrect a version of the Orion spacecraft for use as an ISS lifeboat, promised to choose a design for a new heavy-lift booster by 2015, and pledged to send explorers to a near-Earth object (NEO) around 2025. Still slated for cancellation, however, are the Constellation lunar landing program and Ares boosters. Commercial launch services would provide access to the ISS, and the president made clear his disinterest in the Moon as an objective.

Congress took up Obama's proposals with increased skepticism through late spring, against a backdrop of significant activities in space. On May 6, NASA conducted a successful inaugural test of the Orion launch abort system, or LAS, at White Sands, N.M. The 90-sec flight showed the LAS could blast an Orion capsule clear of a launch pad emergency, hurling the spacecraft "a mile high and a mile long," followed by parachute deployment and safe landing. With Orion slated for cancellation, it is unclear whether the sophisticated LAS will ever fly again.

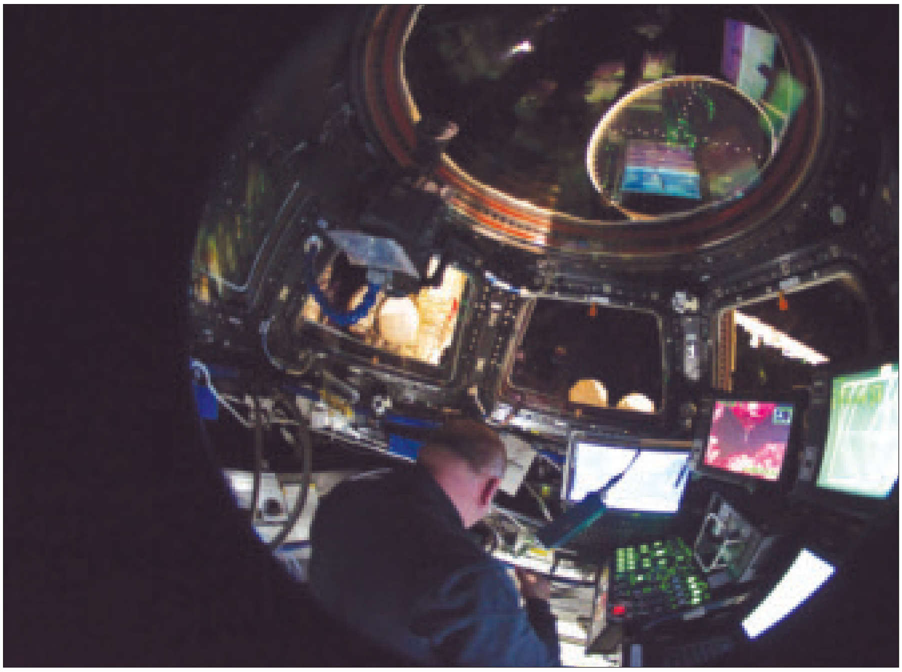
On May 14, Atlantis (STS-132) was launched on its final flight, as NASA continued winding down the space shuttle program. Reaching the ISS on May 16, Atlantis' 32nd crew delivered the Rassvet miniresearch module, or MRM-1, to a nadir-facing docking port on the Russian Zarya module.

With Rassvet's installation, the ISS is 93% complete by mass and 98% complete by habitable volume. The orbiting complex spans more than a football field and currently weighs in at 816,349 lb. The six-person Expedition 23 crew now inhabits more than 29,500 ft^3 of pressurized volume, about the size of a five-bedroom house.

Following Atlantis' final landing rollout, two shuttle missions remain. After the orbiters Discovery and Endeavour head into the barn this fall, the U.S. will see its human spaceflight capabilities undergo the deepest reduction since the end of Apollo in 1975. Gone will be the heavy upmass and downmass capacity of the orbiter fleet, along with the flexible robotics and EVA capabilities that serviced Hubble, retrieved satellites, and enabled an array of scientific expeditions to LEO. Renting seats on Russian Soyuz transports will allow NASA to send only four Americans and two partner astronauts annually to the ISS.

But the retiring orbiters will also take with them the high costs of shuttle operations. By contracting out astronaut transport to the Russians and then commercial companies like SpaceX, Orbital Sciences, and others, the Obama admin-

STS-132 mission specialist Garrett Reisman is surrounded by windows and computers in the ISS Cupola during his mission's flight day five activities. Credit: NASA.



SpaceX's Falcon 9 booster stands on launch complex 40 at Cape Canaveral Air Force Station. Falcon 9's first stage generates more than a million pounds of thrust.

istration hopes to cut LEO transportation costs further. Elon Musk, the SpaceX founder whose Falcon 9 rocket made a successful test flight on June 4, has vowed to have a human-rated spacecraft bound for the ISS three years after inking a NASA contract.

Impasse

That plan was on hold in May, along with other major elements of the president's FY11 NASA budget, as Congress enacted legislative language directing full 2010 funding of Constellation. On May 12, a Senate committee heard from former astronauts Neil Armstrong and Gene Cernan, who with other Apollo and shuttle veterans were clearly skeptical about both the vetting of the Obama plan and its impact on the nation's future in space. In calm but direct phrasing, Apollo 11 commander Armstrong observed, "As I examine the plan as stated …I find a number of assertions which, at best, demand careful analysis, and at worst, do not deserve any analysis."

With November's elections looming, the Congress may avoid deciding on NASA's future this year altogether, by funding the agency at last year's levels in a continuing resolution. The resulting limbo will certainly extend both the policy turmoil surrounding NASA and the length of time the agency will be unable to put its own astronauts in orbit. After Apollo-Soyuz flew in 1975, even with shuttle development in full swing, it took NASA six years to launch Columbia. Today, NASA does not even know which LEO-access system—if any—it might be authorized to build, let alone when a new system might fly.

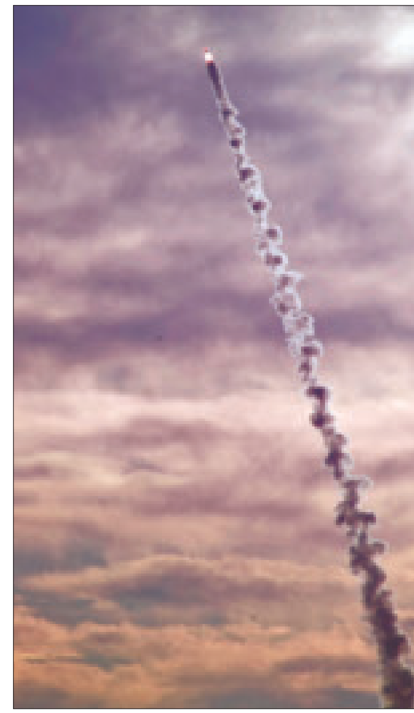
Unavoidable impacts

Even as this White House and Congress spar over policy, the standoff's impacts are already being felt. The shuttle program will likely end this year, with all the attendant workforce layoffs at Kennedy, Johnson, and Marshall. Employees—from Mission Control personnel to booster, main engine, and external tank engineers, to orbiter maintainers and technicians—will be shown the door, with few transition opportunities available in the industry.

Given the space sector's uncertainty, they are very likely to leave the industry altogether. The $40 million the administration has promised for Florida space coast workers is rightly perceived as a political band-aid. As Cernan told Congress, "…these technicians, engineers, scientists, a generation removed from Apollo, yet reinspired by the prospect of going back to the Moon and on to Mars, will be gone—where I don't know—but gone."

The nascent commercial launch services firms, even given a congressional "Go," are unlikely to take on shuttle and Constellation workers in anything like the necessary numbers. To ease home-state impact, Sen. Bill Nelson (D-Fla.) has proposed a continuing series of Ares I test flights at Cape Canaveral, perhaps one per year, with the results feeding the evolving design of the president's promised heavy-lift booster. The administration, however, is unlikely to keep Ares I lurking in the wings to undercut its favored commercial launch partners.

"Orion Lite"



The Pad Abort 1 flight test on May 6 was the first integrated flight of the Orion launch abort system meant to whisk the crew away from a failing booster during launch. Credit: NASA.

During his Kennedy Space Center visit on April 15, President Obama dropped by the Falcon 9 launch pad at Complex 40. He spoke to a hand-picked VIP crowd at the operations and checkout building, once home to Apollo spacecraft and recently refurbished for Orion assembly. There he announced Orion's new role as ISS lifeboat. Launched unmanned, it would serve successive six-month tours berthed at the station to provide emergency escape capability.

The rationale for an Orion lifeboat crumbles under programmatic, fiscal, and engineering scrutiny. ISS partner Russia already maintains two Soyuz transports at the ISS for emergency escape. Orion would merely duplicate this capability at the considerable cost of development and two launches annually. Unless it is intended to serve as NASA's hedge against commercial failure, something the White House will not discuss, Orion's reprieve seems intended more to preserve jobs than to meet any ISS demand. Armstrong assessed the proposal as "a very expensive project with limited usefulness."

On May 14, Atlantis lifted off from KSC pad 39A for its final mission. Astronauts Ken Ham, commander; Tony Antonelli, pilot; Garrett Reisman, Michael Good, Steve Bowen, and Piers Sellers, all mission specialists, delivered the MRM-1 research module and a fresh set of solar array batteries to the ISS. Credit: NASA.

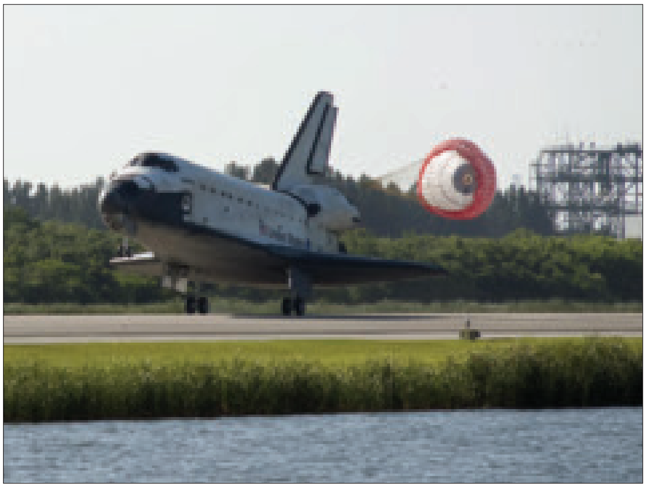
Serious about deep space?

The president emphasized in April his commitment to sending astronauts beyond the ISS: "The bottom line is, nobody is more committed to manned spaceflight, to human exploration of space, than I am.…Early in the next decade, a set of crewed flights will test and prove the systems required for exploration beyond low Earth orbit. And by 2025, we expect new spacecraft designed for long journeys to allow us to begin the first-ever crewed missions beyond the Moon into deep space.…We'll start by sending astronauts to an asteroid for the first time in history."

NEOs are worthy exploration goals for our nation's continued progress into space (see "Why asteroids beckon: NASA and near-Earth objects, March, page 12). NEOs are accessible, rich in scientific interest, and chock full of water and other resources for human exploration. They offer an excellent (and "flexible") path to increase our deep space experience toward Mars, and studying them in detail will help us head off a future destructive impact with Earth. Such a disaster is a certainty, unless we learn how to deflect a NEO. A series of piloted human missions to NEOs would be an affordable and rewarding first move into deep space, before moving on quickly to lunar or Mars exploration.

The Moon still warrants our attention, and the president too quickly dismissed its value. His statement, "We've been there before; Buzz [Aldrin] has been there," while correct, is hardly an argument for overlooking a nearby world with a surface area the size of the Americas. Buzz, after all, explored only a patch the size of a baseball diamond. We should reconnoiter it first with robots, then send humans when the resource and scientific attractions are worth the cost.

After 32 missions and a cumulative 120 million miles in orbit, Atlantis flared over Runway 33 at KSC to bring STS-132 to a close on the morning of May 26. This was the final scheduled mission for Atlantis. Credit: NASA.



But the NEO announcement was welcome, Obama reiterating President Bush's commitment to send American explorers into deep space. NASA has a long-term goal worthy of the risks of spaceflight. But the 2025 target date is far beyond this administration's political horizon, at most six years away. The president thus escapes any serious budget commitment to meeting the deep space goal. Politically speaking, America's journey to deep space is infinitely flexible—and endlessly deferrable.

A path forward

Critics of Obama's 2010 plan have had a thorough hearing in Congress, and the debate continues today. Instead of another year of uncertainty in space, the White House, legislators, NASA, and the aerospace community should seek a path forward that recognizes the urgency of restoring our waning capabilities and the past failure to fund the nation's space goals. The solution should leverage near-term commercial innovations and longer term R&D programs, and should provide a budget sized to deliver real achievement.

First, NASA's sponsorship of commercial launch services should go forward, first with cargo, then with astronauts, when performance, cost, and safety goals are met. Because the commercial cargo effort is already two years behind schedule, establishing that record might take as long as five years. We thus face an unacceptably high risk of having no LEO access well beyond 2015.

To address this risk, then, NASA must field, test, and fly its own near-term crewed spacecraft, perhaps a stripped-down, fast-tracked Orion, providing assured LEO access until the commercial industry matures. The chosen booster should be one that most quickly achieves this interim capability. This is bound to be costly, but long-term disruption of LEO access, and the possible loss of ISS, would be even more so.

NASA's retention of LEO-launch capability will also ease workforce transitions over the next few years. To free funds for deep space exploration, the agency must commit to phasing out its LEO operations as soon as commercial suppliers are ready.

Accelerate deep space

Other nations are aggressively pursuing human spaceflight, and they will not stand still until 2025. To ensure U.S. leadership, the White House should move up the goal of sending astronauts to deep space by at least five years, to 2020. Work on the heavy-lift launcher should begin now. There is nothing sacred about Ares V. NASA should pursue a design course aimed at low life-cycle costs and a true heavy-lift capability. That probably means a move away from shuttle technology, away from solid rocket boosters and toward a new, kerosene-fueled first stage, as discussed by the Augustine committee.

Clearly focused, vigorous R&D on the new booster should aim at providing a vehicle ready to fly well before 2020. Open-ended "breakthrough" R&D is illusory: History shows that unfocused R&D programs are all too easily pirated away by the OMB and congressional earmarks. NASA needs a specific exploration objective, schedule, and budget to match. Managers need all three to assess performance and stay accountable to taxpayers.

Without acceleration of the U.S. deep space goal, there is a real danger that the nation's human spaceflight effort will end when the ISS reaches the end of its useful life circa 2020. (Some see this second "gap" as an opportunity.) Only a vigorous budget commitment to moving beyond ISS, with one program phasing smoothly into another, will demonstrate the nation's long-term commitment to space exploration and an expanding space economy.

Budget realities

The White House has based much of its public rationale for cancelling Constellation on its "unsustainable" costs. Yet had NASA been funded as planned between 2005 and today, the agency would be well on its way to flying Ares I, and Ares V would be ready before 2020. Past budgetary neglect, however, is no reason to shortchange the future.

The president's FY11 budget increase for NASA is welcome but by no means extravagant. If the administration allotted one $3-billion "cash for clunkers" windfall to NASA annually, by 2015 we not only would achieve robust access to LEO, but would also be within tangible reach of mounting our first human deep space expeditions since 1972.

Last April, the president declared that, "Fifty years after the creation of NASA, our goal is no longer just a destination to reach. Our goal is the capacity for people to work and learn and operate and live safely beyond the Earth for extended periods of time, ultimately in ways that are more sustainable and even indefinite. And in fulfilling this task, we will not only extend humanity's reach in space—we will strengthen America's leadership here on Earth."

The declaration was welcome, setting forth a commitment worth pursuing with ingenuity and passion. As the last shuttle astronauts suit up, we will be looking to the future, hoping that the nation's space policy makers match their words with sustained action.

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Emerging regionals crowd a flat market

A new crop of regional aircraft has appeared on the horizon. Most of them reflect the aspirations of government-directed national industrial policies rather than new business ventures created by private-sector companies. The history of national aircraft, along with the flat regional market, suggests industrial carnage ahead.

A legacy of disaster

In the 1980s and early 1990s, no fewer than 10 countries harbored ambitions to enter the regional aircraft business. Nations such as Argentina, Taiwan, and Malaysia had plans for regional turboprops or jets. All planned to use state-owned and funded industries to meet perceived local needs and perhaps tap into a broader export market. Yet all of them failed. In fact, since 1960, only one new country and company—Brazil and its Embraer—successfully entered the aircraft business.

Indonesia's IPTN provides the best illustration of the pitfalls of such an undertaking. Technically, the company succeeded. Along with Spain's CASA, it codeveloped the CN-235 and built dozens for Indonesia's military, several local airlines, and a few export customers. It designed and built a prototype of its N-250/270 50/70-seat turboprop, and had plans to move on to the N-2130, a 130-seat jetliner. All the while, however, it was losing hundreds of millions of dollars. This resulted in bankruptcy in 2007, after the political will to keep funding a money-losing enterprise gave out.

A big problem affecting the viability of all these programs concerns aircraft manufacturing costs and pricing. New market entrants typically tout low labor costs as a way of creating lower cost aircraft. But since most of an aircraft's systems and components come from established providers, the majority of any aircraft's costs are at established producer prices. As for the airframe itself, aviation workers in countries entering the market are likely to be considerably less productive than those at established companies with decades of experience, obviating much of that cost advantage.

Meanwhile, the new entrants do not have the established mechanisms in place to finance aircraft sales, a key part of market development. This is a particularly big problem, because their products have no residual value track records, complicating efforts to arrange third-party financing. Also, establishing customer sales and support networks is as big a barrier to market entry as aircraft design and integration.

Another problem faced by new market entrants concerns the World Trade Organization. WTO's Agreement on Trade in Civil Aircraft (ATCA) signatories are required by the treaty to let their airlines choose jetliners without government interference. This means emerging aircraft producers cannot rely on the protection of a guaranteed home market (China is not a signatory, but it does retain observer status; more important, it has lived up to the agreement). Industry trends have been heading in this direction for some time, even without the WTO. In the 1980s and 1990s, for example, McDonnell Douglas established a production line for the MD-80 narrowbody jetliner. Yet without active government promotion, this airplane enjoyed a notably low market share in China, with production totaling a mere 35 planes, including five exported back to the U.S.

Even if ATCA did not play a role in limiting mandated sales to national carriers, simple airline economics might do the same job. Russia has had to relent on its efforts to mandate sales of local aircraft to national carriers for the simple reason that they would have been at a tremendous competitive disadvantage if they could not purchase the right planes for their needs.

Meanwhile, as new players failed, numerous legacy players that had been around for many decades also were forced to exit the market. The Netherlands' Fokker, Spain's CASA, Sweden's Saab, the U.K.'s British Aerospace, among others, all left the regional aircraft market behind, concentrating instead on military or jetliner work, or on component production.

CN-235

A flat market

All of these new entrants attempted and failed to break into the regional market when it was actually growing. Yet for the past decade, the market has actually been flat, or declining.

In 1989, regional aircraft deliveries were 15% of the total world transport market. In 2009, they were under 11%. High aircraft seat mile costs, persistent scope clauses, and problematic relations between major and regional carriers all portend continued market flatness.

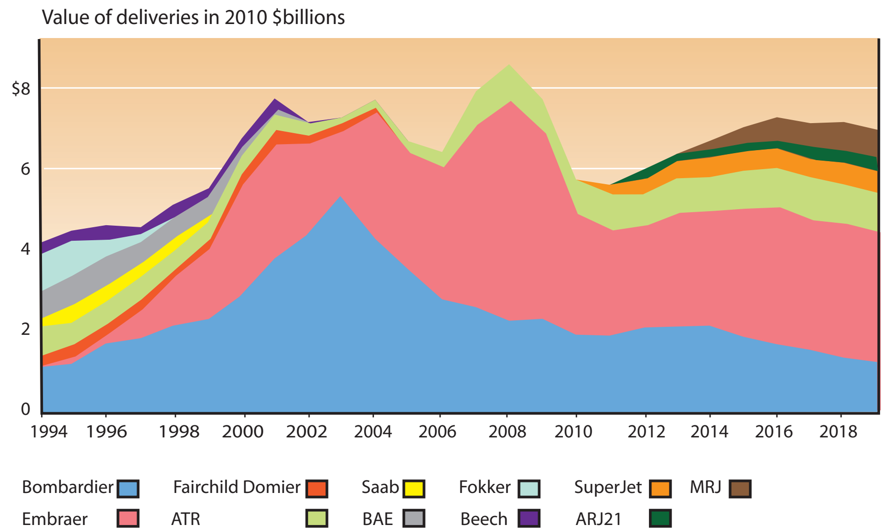
Regional aircraft were the one segment of the aviation business that did not grow during the great 2003-2008 boom market. Large jetliner deliveries grew at a 7% annual rate during that period, and continued at a 13.5% rate in 2009. Yet regional aircraft grew at a mere 1.4% rate in 2003-2008, and even this was completely due to turboprop deliveries growth (in point of fact, regional jets actually shrank). Worse, in 2009 the regional sector declined by 5.7%. Between 2009 and 2010 Embraer, the biggest regional player, saw its backlog drop from 375 jets to 229.

Though the market may stop shrinking this year as traffic returns, the most likely forecast scenario offers a flat market, a far cry from the great days of 1997-2001, when the industry went from $4.5 billion in deliveries to $7.7 billion in deliveries.

Not only is this market flat, it is also stunningly concentrated. The 2,000 jets based in North America represent about 60% of the world's fleet. Asia, which has become the biggest single market for large jetliners, has a mere 230 regional jets, or 7% of the fleet. In short, there is no sign at all that these new aircraft producers were or are being established to meet local market needs. IPTN's efforts to sell CN-235s to its local carriers almost collapsed, with threats of prison sentences needed to coerce airline managers to accept the planes.

Despite this cash-destroying legacy of failure, and despite a very challenging market, there is a new and large crop of government-funded players seeking to enter the regional aircraft business. The first, unsurprisingly, is China.

REGIONAL AIRCRAFT MANUFACTURERS MARKET SHARE



China leads…kind of

In 2002 China announced that it would develop its 90-seat ARJ21. This project, fronted by AVIC (Aviation Industries of China) and Comac (Commercial Aircraft Corporation of China), is the latest in a long line of China RJ proposals. Notably, 2002 also saw an agreement between AVIC-II's Harbin unit and Embraer to coproduce ERJs. In terms of orders, this agreement has produced a mere handful of planes, and the line looks set to close in 2011.

Originally scheduled to enter service in 2007, the ARJ21 is now still slowly going through flight testing. The fourth aircraft flew in April, but the earliest possible delivery date is now late this year.

Unfortunately, the ARJ21 does not look at all like a promising product. It is 15% heavier on a per-seat basis than any of its competitors. That assumes the manufacturer's specifications stay as-is, an optimistic assumption. In overall dimensions, it looks very much like the DC-9—a classic example of reinventing the wheel. The engines and avionics are pretty much identical to any other RJ designed 10 years ago. The basic problem is that because of weak intellectual property laws, Western suppliers needed to make this project work are using last-generation equipment. Nobody wants to give Chinese industry access to their very latest technology.

In short, the ARJ21 now looks as though it will be used as a learning experience for Chinese industry, with very limited commercial appeal. Priority is now being given to designing the C919, a 150-seat mainline jet.

While the ARJ21 struggles, China continues to produce several turboprop regional aircraft. Since 2000, Xian has built about 40 of its 60-seat MA60s, but most have gone to marginal markets. In March, China's government announced that it had sold four MA60s to the Sri Lankan air force and three to the Myanmar air force. Both of these deals will be financed, predictably enough, from China

MA60

government loans. China is also introducing a new, larger, improved turboprop, the MA700. It might arrive in 2014.

From military to civil…maybe

The other countries attempting to break into the regional aircraft game all share one thing in common: They represent an effort to leverage military aerospace knowledge, assets, and experience into a commercial program. Russia, Japan, India, Turkey, and South Korea are all attempting the big jump to the civil world, and all are looking at the flat regional sector as their target market.

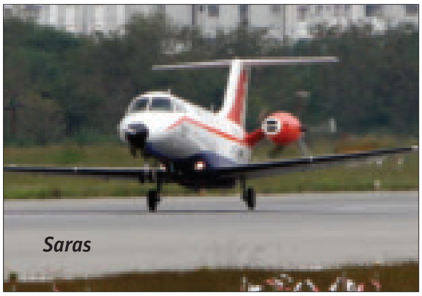
While Russia has a technically respectable legacy of building jetliners, all of the country's civil aerospace work has faded into a mere shadow of its former self. There are numerous mainline and regional models either in production or ready for production, but only a handful are built each year, and most feature aging technology.

Notably, Russia's one hope for preserving this legacy comes from a company that has so far worked exclusively in military markets. Sukhoi's Superjet, to be built in cooperation with Italy's Finmeccanica (as Superjet International), is scheduled to enter service later this year, about two years after the original plan. As of May, there were five Superjet 100s in final assembly.

Superjet actually has one key attribute the other regional players do not enjoy: A potentially strong home market. There are hundreds of aging regional aircraft in Russian airline service, and if the Russian government can help finance replacement aircraft for just a third of the fleet, that is a respectable home market. Although this would violate ATCA, Russia's resource extraction economy is far less dependent on world trade agreements than are the export-driven economies of China and India.

As Sukhoi moves forward with Superjet, its Ukrainian rival, Antonov, is also proceeding with its An-148, a 68/85-seat design. While only about five of these have been built, in May the company flew a 99-seat stretch, the An-158.

In Japan, a very serious collapse of military aircraft production has led the country's government to help fund a long-awaited national regional jet. In the 1990s Japan's Ministry of Economy, Trade, and Industry announced plans to develop an indigenous 30-seat regional jet. The Japan Aircraft Development Corporation (JADC) also proposed an 80/110-seat regional jet family. Known as YS-X, this effort was effectively a reincarnation of the YS-X proposal that was active in the mid-1990s and was canceled in Japan's FY97. This YS-X, in turn, was distantly related to the joint Boeing/JADC 7J7 proposal of the 1980s.



Saras

But the latest Japanese regional aircraft development is actually from the private sector, albeit with government support. At the 2007 Paris Air Show, Mitsubishi began promoting its own RJ in the YS-X class. Since its F-2 fighter jet is about to end production, the company perceived the need for continued diversification into civil markets to keep its prime contractor skills intact. ANA has provided a launch order. In October 2009, the MRJ scored a notable breakthrough with a tentative order for 50 firm and 50 option planes from Trans States Holdings, the parent company of Trans States Airlines and GoJet Airlines.

As for South Korea, it has coproduced jet fighters and helicopters, and created its own jet and prop trainers and transport helicopters (with Western assistance). However, it has also revived its long-dormant plans to get into the civil sector. Predictably, the government is now considering a proposal to fund a 90-seat turboprop airliner. No firm go-ahead has been provided.

India wants to travel the same path. While the country has yet to succeed with its multidecade Light Combat Aircraft, the government's National Aerospace Laboratories (NAL) want to move on to design and develop 70/100-seat commercial aircraft. The latest proposal is the 70-seat RTA-70. Since 1991, NAL has also worked on its Saras 19-seat turboprop program. It first flew in 2004 and may enter service in the next few years. In March 2009 the second Saras prototype crashed, killing two pilots and an engineer.

Meanwhile, military work has sustained IAe, as Indonesia's IPTN is now known, at least in a much smaller post-bankruptcy position. In May the company launched a three-year program to create a new 19-seat turboprop transport. The market for planes in this class basically collapsed in the 1990s, and at least six production programs died as a result. IAe has not indicated any technological enablers or market changes that will allow its new project to avoid the same fate.

The most unexpected potential new market hopeful is Turkey. After decades of building aircraft components and license-built versions of foreign military aircraft such as the F-16, the country's transport ministry has announced plans for a 50/70-seat regional jet. The notional budget is $1 billion, with an equally notional in-service date of 2023.

Given the tiny size of the country's regional airline sector, and the relatively free market economic system to which Turkey normally adheres, this proposal is the most highly improbable new regional aircraft so far proposed.

Transitioning from military to civil work is a difficult process owing to the wildly differing market dynamics, aircraft design parameters, and customer needs. Yet no matter how difficult it is to enter the civil aircraft arena by leveraging military work, the world will continue to see a steady stream of countries moving on that path.

In fact, if evidence is needed that emerging regional producers represent state-directed cluelessness about market needs, there is one looming worst example yet: Iran. The country is already building Antonov's 52-seat An-140 turboprop under license, and in May Defense Minister Ahmed Vahidi said the country had designed a 100-150-seat jet.

In short, there may be a new emerging producer that somehow manages to make the others look good.

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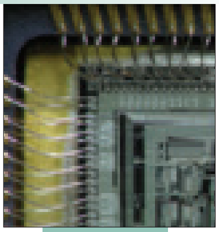


Defense electronics: The spigot is not closing

A CLOSE LOOK AT TOP-LINE INDICATORS IN the defense electronics market over the next 10 years shows that, contrary to stories of "the tap closing" or a newfound spending conservatism, defense electronics funding will almost certainly not decrease at all. Our market forecast shows slow growth every year this decade, for several reasons.

The 2010 Quadrennial Defense Review (QDR) argues the U.S. still needs the capability to fight two major wars simultaneously and to combat terrorism: This is not a cost-cutting QDR. Five-year funding plans in the FY11 budget, released in February, show continuing increases: There is no downturn for electronics. Updating legacy platforms has taken over from all-new procurements, so even if overall defense budgets decrease, electronics will not. Every canceled F-22 may mean radar or electronic warfare upgrades for 25 F-15s. And, although today's open systems and commercial architecture programs are advertised as cheaper to buy and upgrade, in practice this has rarely been the case. Instead, expect continually improving capabilities for similar or greater costs.

Equipment was rolled out at the WIN-T Increment Two Engineering Field Test at Fort Huachuca, Ariz., in December.

As with all forecasts that have appeared in this column, funding is built from the bottom up, from dozens of cumulative individual program forecasts in each market sector (hundreds in the overall market), *not* top down solely from Pentagon R-1 (RDT&E) or P-1 (procurement) lines, which offer little precision or discrimination for electronics programs.

All funding is for U.S. and international markets *available* to U.S. manufacturers. Thus, for example, we have not included funding for Russian or Chinese markets, and very little for French markets. Programs included are primarily U.S. systems. Sales of international systems (such as the Ericsson fighter radar for Gripen) are not included unless there is a significant U.S. component, which is rare. International systems are included only when they have made major sales in U.S. markets, such as the Saab/BAE Systems BOL chaff/flare dispenser, and the Rafael/Northrop Grumman Litening targeting pod.

Market sectors

The largest defense electronics market sector, overall, will be C4I (command, control, communications, computers, and intelligence), followed by radar, EW (electronic warfare), and EO (electrooptics). The highest growth rates—perhaps surprisingly—will be in electronic warfare. In a major turnaround from the past two decades, EW will offer many of the best opportunities for both growth and value, which is perhaps not so strange when the U.S. is again faced with real threats and real casualties; as in the Vietnam War, funding has turned toward protection, which means EW.

The second fastest growth rates (and the largest total market value) will be in C4I. Networked ISR (intelligence, surveillance, and reconnaissance) and an overall growth in the importance of interconnected electronic systems will offer constant new opportunities in C4I, both for established defense primes and new electronics subcontractors.

Although threats have changed since the Cold War, intelligence, protection, and connectedness will grow faster than direct shooter electronics over the next 10 years. Mature markets for radar and EO will remain large, but with moderate CAGRs (compound annual growth rates).

The C4I market will grow steadily over the next decade, as network-centric warfare and U.S. doctrine focus increasingly on making sensor and other data available to all. There are many new business possibilities here, for nearly all major sensor programs—and many options.

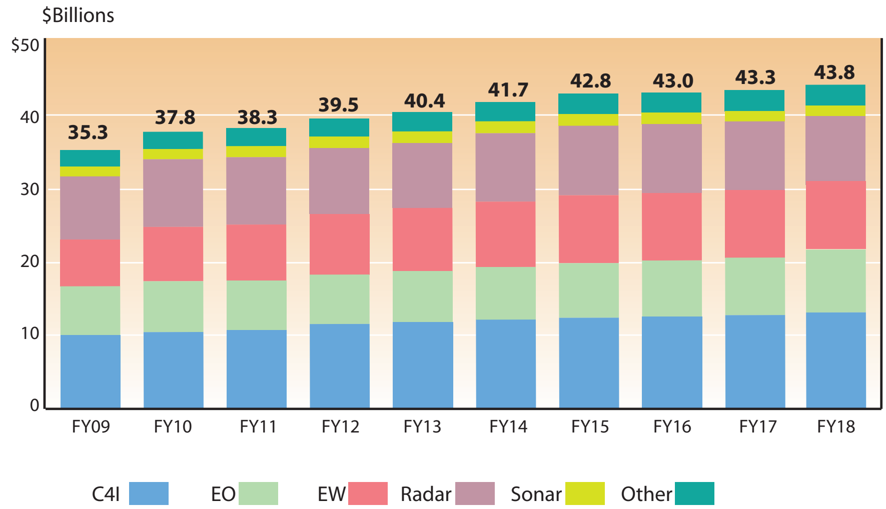
The two biggest coherent market

MARKET SECTOR FUNDING TOTALS

Sector	Value (FY09-18)	CAGR (FY09-14)	CAGR (FY09-18)
C4I	$117.2B	3.7%	2.6%
Radar	$91.6B	1.6%	1.0%
EW	$84.0B	7.0%	4.3%
EO	$72.1B	1.4%	2.2%
Other	$26.0B	2.8%	2.7%
Sonar	$15.0B	4.1%	0.6%

TOTAL DEFENSE ELECTRONICS MARKET FORECAST

RDT&E+procurement



segments will be data links (primarily airborne) and tactical radios (primarily ground). One area that requires all-new equipment and capabilities is C4I for ground sensors; this is the realm of the war on terror, and Cold War systems are *not* adequate (while they remain overqualified at sea and in the air). Examples of programs that will earn massive funding include the Army's ground/air WIN-T (Warfighter Information Network-Tactical) and JTRS (Joint Tactical Radio System).

EO sensor markets have steadily risen for several years, as a number of major programs entered full-rate production following years of delays. With supplemental procurements for the wars in Iraq and Afghanistan already well established, and possibly ending soon, the biggest market surge is over. Teal Group forecasts growth in FY10, primarily because of continuing wartime ground system refits and new UAV production, but then sees a slight decline until the next generation of airborne systems (especially on the Joint Strike Fighter) enters full production.

If the new administration makes major budget changes, or JSF funding is cut back, the uptick after FY12 could be delayed, resulting in a further decline, especially if EO is increasingly supplanted by RF (radio frequency) systems.

EO is a mature market, but new areas are developing, especially for the global war on terror, to detect and counter irregular opponents: networked ground sensors, hyperspectral sensors, UAVs, and naval sensors. There will be billions spent for EO sensors, and hundreds of millions for C4I.

Electronic warfare CAGRs of 7.0% and 4.3% from FY09-FY14 and FY09-FY18 will lead all market sectors. Very strong growth in signals intelligence, airborne infrared countermeasures (vs. infrared-guided missiles), and naval ECM (electronic countermeasures)—each area with a 10-year CAGR above 7%—will lead solid growth expected throughout the EW market.

The airborne market will dominate, earning 84.2% of prime contract value. The only airborne EW market segment that will decline significantly is chaff/flare dispensers and expendables, largely because we forecast less use if the current shooting wars taper off in a few years.

Radar warning receivers, RF decoys, missile warning systems, and RF ECM are all mature market segments, but even these will increase strongly.

In some ways similar to the EO market, the even more mature radar market will see declines in many segments, with

The AN/SPY-1 radar antennas can be seen on the front and starboard side of the superstructure of USS Lake Erie.

The AN/AQS-22 Airborne Low-Frequency Sonar will equip the Navy's MH-60R multimission helicopters.

synthetic aperture radars for ISR the strongest growth area. AEW (airborne early warning)—think the Boeing 707-based AWACS—will increase slightly, because of the new E-2D Advanced Hawkeye's AN/APY-9 radar. Other airborne radar segments, including fighters, have already shrunk, despite the current surge of digital upgrades and active electronically scanned array antenna retrofits, although the JSF will turn this around once production ramps up. Indeed, as the importance of ISR of ground-based targets takes over from the Cold War AEW and fighter fire-control-radar emphasis, the amazing thing is how much will *still* be spent on air-to-air radars, to prepare to fight the thousands of Soviet fighters that will now never come swarming across the border.

The ground radar market will decline somewhat, despite a strong ballistic missile defense segment.

The naval radar market will probably peak in a few years and then shrink, as BMD spending decreases; over 70% of naval radar funding will go to one program—Lockheed Martin's AN/SPY-1 Aegis for more than 100 cruisers and destroyers.

Often overlooked as an airborne market, helicopter and aircraft-borne dipping sonars and sonobuoys will retain their importance as the Navy operates more often in shallow water littoral environments, and helicopters will play an increasing role as ASW (antisubmarine warfare) assets. The airborne sonar market segment has grown quickly as AN/AQS-22 ALFS production has ramped up, but when ALFS tapers off near the end of the decade the overall market will decline.

The ship and submarine sonar market will remain more stable, but will now be buoyed by the increasingly strong growth of Lockheed Martin's dominant AN/BQQ-10(V) Acoustic-Rapid COTS Insertion (A-RCI) program.

TOTAL DEFENSE ELECTRONICS MARKET SHARE
FY10 $Millions, FY09-FY18

Raytheon	$62,793
Northrop Grumman	$52,522
Lockheed Martin	$51,701
BAE Systems	$18,114
General Dynamics	$9,640
ITT	$9,014
Boeing	$7,232
L-3 Communications	$6,897
FLIR Systems	$4,157
Harris	$3,487
Thales	$3,329
DRS Technologies	$3,066
Other	$55,676
Available	$118,240
Total	$405,868

Manufacturer shares

Our market share prediction for the next 10 years shows 29.1% of the market will be available for new primes (a value of $118.2 billion), when considering that continuing production for most current programs is locked up by the incumbent (for example, most future JSF radar funding will likely go to Northrop Grumman, despite theoretical recompetes). A much higher share than this 29.1% will be available for subcontractors.

In making this prediction, for most programs we have allocated manufacturer share funding in full to the prime contractor, not split between subcontractors, as this is often difficult to break out. For really big programs, such as AWACS and JSF, we have sometimes allocated percentages to "other" and "available." Uncontracted programs, as well as speculative programs in the out years, we allocate as "available." Out-years of forecasts may be slight underestimations: We do forecast "undetermined" future programs, but try to be conservative.

Raytheon, Northrop Grumman, Lockheed Martin, and to a lesser extent BAE Systems, will dominate the defense electronics market from FY09-FY18, with nearly 50% of prime contracts. Raytheon will lead by a substantial margin, with $62.8 billion, leading radar and EO markets, placing second in C4I and sonars, and third in EW.

Northrop Grumman will place a reasonably close second, with $52.5 billion in total funding, based on leadership in EW, a strong second in radar (half Northrop's total forecast funding), third in EO, and fifth in C4I. In airborne systems, Northrop will be number one, ahead of Raytheon, with a large lead in airborne radars and EW.

Lockheed Martin will show a very close third with $51.7 billion, absent from many market sectors but dominant in others, especially airborne fighter and attack helicopter EO targeting systems, and naval radar. Lockheed will lead in C4I and sonar (with its dominant A-RCI program), place second in EO, and third in radar (because of the naval AN/SPY-1 Aegis system).

BAE Systems will follow in fourth at $18.1 billion, little more than one-third Lockheed's value, due primarily to its strength in EW (a fairly close second to Northrop), and a growing fifth in EO.

Only two other primes will exceed 2% of the total market: General Dynamics, with $9.6 billion total (third in C4I), and ITT, with $9.0 billion total (fourth in EW and sixth in EO). Just two more will earn more than $5 billion—Boeing ($7.2 billion) and L-3 Communications ($6.9 billion).

Note, however, that many of these prime contractors, especially outside the Big Three, will earn considerable additional funding as subcontractors. There will be many new opportunities in all fields of defense electronics.

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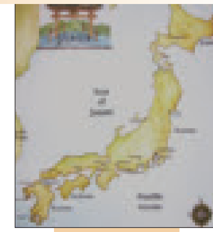


Japan's solar sail heads starward

FORGET THE AMERICA'S CUP YACHTING battle of Valencia in February this year—what's happening in space now may be the sailing event of the century. But we probably will not know the final result for about six months.

On May 21, Japan launched into space a minisatellite with a thinner-than-gossamer sail, to be powered by photons from the Sun. Been there, done that, you say? Agreed, part of the idea may seem old hat—until you take a closer look. This 667-lb, 59-in.-tall, 15-in.-thick cylindrical minisat is to show its paces by heading past Venus and the Sun rather than trying to demonstrate top performance in Earth orbit. No previous satellite has used light pressure as its primary means of propulsion—this is what's new, and it is why this experiment is so important to the future of space exploration.

There is nothing new about the idea of a space sail in itself—Japan deployed one on a suborbital flight to prove the unfurling technology in 2004; the U.S. has tried them in Earth orbit; India and Russia have tried the same. None of the orbital trials succeeded.

The idea has been around in science fiction since 1865, when Jules Verne briefly mentioned the notion of using light pressure to drive a spacecraft. Scientists, engineers, and writers have pursued the idea over a good many years, including, in 1964, scientist and writer Arthur C. Clarke. (The invention of the solar sail is often incorrectly attributed to Clarke, who did conceive the idea of the geostationary communications satellite.)

Interplanetary trial run

Weight and how to get sails to unfurl without tangling or tearing in space have always been problems. But materials science has come a long way since the previous U.S. experiments (of which another is scheduled for later this year by the Planetary Society, a nongovernmental group). So Japan has bitten the bullet and decided to try for an interplanetary trial run, adding the space sail experiment to four other minisats piggybacking aboard its own HII-A F11 rocket, which was already due to launch the Akatsuki (Dawn), a more conventional Venus Climate Orbiter observations satellite.

Weather delays held the launch back by a few days, but then the rocket left from the Tanegashima Space Center in southern Japan with no problems, and rapidly deployed all six of its payload components. The space sail minisat is named Ikaros, which stands for interplanetary kitecraft accelerated by radiation from the Sun. (Never mind that the acronym has unfortunate connotations because of the ancient Greek legend of Icarus: He and his father flew with wings made of feathers held together with wax, but Icarus went too close to the Sun and crashed because the wax melted.) Going for an interplanetary run with a space sail is new, and that is why this technology demonstrator is important to the future of space exploration.

The sail expanded fully on June 9. Pressure exerted by photons—minute "packages" of light energy emitted by the Sun—are now pushing the sail along in much the same way that wind drives maritime sailing craft. The rate of acceleration created by such tiny bundles of energy is very small, but it is constant, and although it takes a while, the sail should accelerate to a reasonable speed, an estimated 100 m/sec, according to Ikaros' creator, JAXA (Japan Aerospace Exploration Agency)—and should be able to reach Venus within about six months.

Slowness and patience

Such a slow speed is hardly useful for manned spaceflight, at least over relatively short distances like those within the solar system, considering the weight of people and stores to be accelerated. But for long-range unmanned probes, it is fine: In theory, at least, a light sail should be able to accelerate up to 10% of the speed of light. If there is a problem with this, it is how to slow down at the end of the trip.

In practice, a great deal of patience will be needed; at the Earth's distance from the Sun, the acceleration of the space sail should be one-sixtieth the force of gravity. Beyond that distance, the inverse square law applies, so the number of photons producing acceleration reduces as the sail gets farther away. Various solutions have been suggested, such as aiming giant laser beams into space to give space sails power, or using a "slingshot" trajectory past the Sun.

In this application of science and engineering, size matters. Ikaros's sail is a technology demonstrator, and is a modest square measuring 46 ft on each side, made up of four triangular petals that unfurled from a drum. To avoid having to provide bracing struts to pull the sail out, JAXA opted for small weights on lines, and centrifugal force from spinning the minisat to throw the weights outward and pull the sail petals off their storage drum. A later version of Ikaros, many times larger, is intended to head for Jupiter in about 2020.

Deployment of the sail occurred over several days. With Ikaros spinning at 25 rpm, the membrane was pulled from its container by guide weights. The four sail petals were released, extending outward as the weights exerted centrifugal force. In the final phase, holders restraining the sail petals' bundled material were ordered released and the petals unfurled. JAXA performed the delicate maneuvers slowly to avoid tearing the fragile membrane. As planned, the sail's expansion slowed the craft's spin rate, just as an ice skater slows a pirouette by extending arms outward. Ikaros should continue to spin at about 1-2 rpm. JAXA confirmed the full expansion of the sail and electric generation with the thin film solar cells at about 7.7 million km from Earth.

Material breakthrough

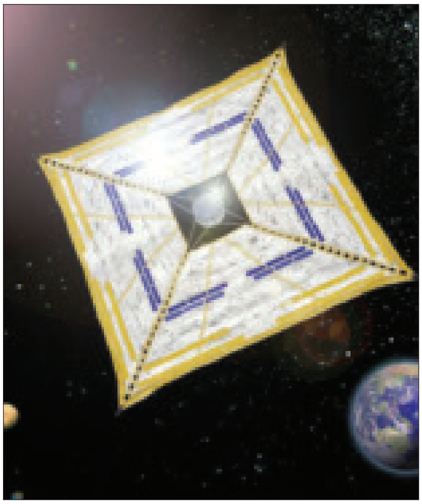
The sail itself is a masterpiece of design and technology, comprising several different elements. The basic sail is an aluminized polyimide film only 7.5 µm thick. Ikaros project leader Osamu Mori describes the material: "This film has to be made from a material that's not just lightweight but can withstand extreme radiation and heat in space. The material that meets these conditions is polyimide resin, which is used as a foam insulation for satellites. Once such a high-quality material became available, the development of a solar sail came much closer to reality.

"Today, Japan has the largest market share in the world for polyimide resin. We are currently leading the race to develop applications for this technology, and it would mean a great deal to us to be the first in the world to build a working solar sail. Polyimide resin allows us to create a much lighter sail. As well as being extremely strong, it doesn't need glue, because it can be joined using heat sealing.

"Polyimide resin is originally yellow, but one side of Ikaros's sail is silver. This is because aluminum is vapor-deposited on one side of the film, in order to reflect sunlight more efficiently. In addition, the film is reinforced in such a way as to prevent it from splitting all the way if it is ripped. If the solar sail is torn, its performance will decline slightly, but it can still continue its space travels."

The sail is also providing electrical power. About halfway up each sail petal are thin-film solar array strips; collectively all four sets of strips occupy about 5% of the sail's area and produce about 500 W of power. Assuming it works as planned, this will take care of Ikaros's "housekeeping" reports and computing needs. Sail shape is fixed; changing course is a matter of using the steering device in each petal—two reaction control device strips near each edge contain liquid crystal cells whose reflectivity can be changed.

Says Mori, "It works just like frosted glass. Normally, the entire area of the sail will reflect sunlight, but by 'frosting' part of the film, we can reduce the reflectivity of that area." This, in turn, cuts the force exerted by the photons on that part of the sail, and so can change the direction of flight.



It has not been an easy trip to the launch pad. The sail's deployment was a particular headache, said Mori before takeoff. "The sail film doesn't have a supporting frame," he said, and for storage at launch it was folded and wrapped around the main body of the spacecraft. Because the spacecraft continues to spin following the deployment of the sail, it will maintain centrifugal force and thus keep the sail open. "This eliminates the need for a supporting frame for the sail film, so the spacecraft can be very light."

Goals and outlook

Looking ahead to future missions, Mori continued: "Using the centrifugal-force method, a bigger sail is easier to unfurl. Ikaros's sail is small for a solar sail, but I think sails with a diameter of 50-100 m will be developed in the near future."

The Ikaros Venus/solar mission has four main objectives:

•Demonstrating deployment of a large membrane sail in space by mechanical means—this is described as an "enabling technology."

•Generating power through the solar cells on the sail.

•Demonstrating photon propulsion or "light power" and measuring and analyzing the results.

•Demonstrating guidance and attitude control by the sail's reaction control devices to show that a particular flight path can be achieved and maintained.

The first two are regarded as minimum objectives and have now been achieved, according to JAXA.

Assuming all goes well, showing the solar power system to be capable has implications for the Jupiter mission in the next decade. Says Mori, "The plan is to equip the probe with an ion engine, as well as a solar sail approximately 50 m in diameter. The larger the sail, the larger the solar cell area, so the probe will be very efficient, with no need to carry fuel.

"But it is very difficult to use only solar power for acceleration and at the same time control the probe's attitude, so we are planning to use a fuel-efficient ion engine along with the solar sail. However, the weakness of an ion engine is that it consumes a lot of electricity, so how do we give it a power source without carrying fuel? Jupiter is five times farther from the Sun than Earth is. At that distance, solar cells will be only 4% as efficient in generating power.

"For that reason, other countries' missions that ventured past Jupiter have all used isotope batteries. But we are determined to go to Jupiter using solar cells, so we invented a way to generate electricity using the thin-film solar cell on the sail. We would like to use Ikaros to evaluate it, and share the technology with the next near-Jupiter exploration mission."

Japan has a history of setting up very reasonably priced scientific efforts. JAXA previously announced plans to set up an unmanned lunar base by 2020 with a wheeled robotic lunar rover to explore the surface and report its findings back to Earth. Achieving that is expected to cost around $2 billion. Against that, the cost of the Ikaros experiment was a bargain at $16 million (yes,$16 million)—a small price for a potentially huge scientific and engineering reward.

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HUMAN RATING

"A human-rated system accommodates human needs, effectively utilizes human capabilities, controls hazards, and manages safety risk associated with human spaceflight, and provides, to the maximum extent practical, the capability to safely recover the crew from hazardous situations.…The overall objective is to provide the safest possible design that can accomplish the mission, given the constraints on the program, mass, volume, schedule, and cost."

NASA NPR 8705.2

On May 24, AIAA held a roundtable to discuss the ramifications of human rating spacecraft for commercial space transportation.

ROBERT DICKMAN Last December, John Marshall, who's on the NASA Aerospace Safety Advisory Panel, told the House Science Committee, "Because it's illogical to rely on commercial providers to provide their own requirements for contractual services on human spaceflight to NASA, the ASAP strongly believes that specific criteria should be developed to establish how safe is safe enough for these services, including the need to stipulate directly the acceptable levels of risk for various categories of activities."

Our goal is to identify the processes necessary to get to the point where commercial providers are certified by the government to carry NASA astronauts, and then anyone, because these will be commercial launches licensed by the FAA. Let's start with Bryan O'Connor.

BRYAN O'CONNOR When we talk about how we're going to deal with commercial human transport to the international space station [ISS], we're reminded of guidance in the 2008 Appropriations Act and Authorization Act that encouraged us to continue looking at what we call COTS [Commercial Orbital Transportation Services], which encouraged us to move further along in allowing for use of commercial assets in transporting cargo and people to LEO.

The business is coming along, maybe not quite as fast as people thought when the Commercial Space Act came out, but still coming along. Rockets are being designed and human transport ideas thrown around that NASA will eventually need to depend on to reach the ISS.

How will we do that? Even though the government is trying not to overregulate commercial human space transport, we don't believe we have the flexibility to back off too much. In fact the Augustine commission had the expectation that NASA would have strong, proactive mission assurance and oversight of commercial human transport. We've got it in our budget for the next few years. In the president's budget words, "To contract with industry, to provide ISS transport to and from the ISS for NASA astronauts as soon as possible to reduce the risk of dependence on foreign transport." It has a sense of immediacy. But it's a proposal, we can't just jump on this right away.

One of the things I am involved with is how we're going to acquire this service. Now, there isn't one to acquire right now; there is a lot of work to be done in developing this capability. We did acquire a transportation service in 1995. We put NASA astronauts, Norm Thagard was the first, on the Soyuz. And we didn't do anything like what you'd think of as human rating. Here was a government operation that had already flown cosmonauts on about 60 flights. The question was, how does NASA get comfortable enough to put our folks on there? We spent about three years on this.

We had a human-rating document on the books in 1995, but we didn't look for compliance with the Soyuz. This was a system with a very good track record—two fatalities in 60 flights, the last inside the first 10. They'd had some mission failures, aborts, and we looked into all of that. This was at a time when there was a lot more openness in discussions with the Russians.

We camped engineers there to learn how they designed, how they operated, their weaknesses and strengths. And once the books were opened we got comfortable enough to fly Norm.

When you're developing a system like Constellation, that's when we put the normal NASA acquisition process in place, and that's what our human-rating requirements are based on—NASA development. When I think of human rating, I think, "This is a NASA development. We're going to put our requirements on this system. We'll have an acquisition and a procurement approach with our contractors; we'll have roles for the program, the

for future spaceflight

projects, the various center oversight organizations, and so on."

In carrying out that acquisition, there's an assumption that you're doing a standard NASA-type development activity, and our standards and mandatory requirements would be incorporated. Much of that would then flow from program to project to contractors. That's how human rating is defined in our policy.

Now, if we say, "What if we're going to do something between a standard NASA acquisition and buying an existing service?" Well, we're going to tailor it.

That's what we're discussing right now. How do you take what we would do for a full-up NASA acquisition, back off a notch, and say, "If we're not quite as involved at the project or system level, but we're managing a program, and the program is dealing with contractors who are doing development work to our requirements, and we need the insight to see how they are doing it, and the appropriate oversight for risk management and to engage our own technical authorities as appropriate, how would we do that?"

First, we'd send out an RFI and say, "These are the requirements we would use if we were doing something like this." We'd take the requirements that apply to human rating, trim off those that might not be applicable, look at those that are actually mandatory, and start there. We are talking about contractors who have good processes and requirements in place. And if we haven't decided to call something mandatory, let's not create it as mandatory if we don't need to.

It will go to all interested parties for comment, and it's basically a first cut at what our human-rating requirements and standards would look like.

And we will accept ideas on equivalents. There are very few mandatory standards that we will not accept ideas on tailoring. There are some we don't have authority to tailor, in the safety and medical areas, but there are hardly any in what I call the basic engineering requirements and standards.

As far as the acquisition approach, we are not sure exactly how to set up a program like this; it's a little unusual for us. I know a lot of people would like to hear all that now, but we're still working it.

But remember, we believe that we are accountable for their safety when we put our astronauts on something. We felt that way on Soyuz. We learned as much as we could and felt a comfort level that allowed us to do that, and we'll do the same thing here. It may have a little different form, and I anticipate it'll be something between those two extremes.

DICKMAN A few Soyuz reentries were non-nominal. Did you take a different approach to looking at the systems and process?

O'CONNOR For the off-nominal entries, our engineers felt they needed to know a little more about what was going on. The Russians set up an independent commission to investigate. We weren't involved, but we got the results. We weren't the decision-makers other than, "Do we want to continue to fly on this." We did some independent assessments on things we could model to see if we'd get about the same answers we were hearing.

By and large, I was happy with the information we were getting. In both cases, we came out saying, "Okay, we've got enough understanding and trust here that we're going to continue."

DICKMAN You have a clear contractual relationship with the two COTS contractors and different contractual relationships with a few others. Is there any barrier for a company talking to NASA about how things would go forward?

O'CONNOR No. We want to hear from potential bidders, should we get a go-ahead next year, on how they see our human-rating plan making sense for them and us, and ideas on tailoring some of the technical requirements.

We will find that, when we issue what we call mandatory requirements we'd impose on ourselves if we were starting this from scratch, some of the response will be, "We've already built a rocket to this other standard." And that's fine. Let's get some feel for equivalents. Does it make us feel as comfortable as it would if we had done it our way? If not, is anything missing? Is there something we can do instead? That's using Soyuz thinking—there's not a chance in the world that we're going to have the Soyuz redesigned.

It was a matter of, "Does it give us a comfort level?" And if it's not the way we would do it and it does impose some risk, is that a show-stopper, or is that just a little residual risk we're willing to accept? I'm sure we'll find some of that. But we've also worked with some of these folks flying cargo. We understand their systems, so we won't be starting from scratch.

Another point, though, is that we've got to integrate the escape and abort capability. That'll be something different for everyone, whether they're starting from scratch or from an existing rocket. Integrating that capability—we have a requirement for abort capability from 0-0 on the pad all the way to orbit insertion—is not a trivial engineering thing. It will probably be more difficult than any of us anticipate.

DICKMAN Let's move to George at the FAA.

GEORGE NIELD We're working very closely with NASA on both current and planned programs, because we have complementary missions. NASA's job is to pioneer the future in space exploration, to extend human presence throughout the solar system. The FAA's job is to be the government regulator.

Under current U.S. law, any U.S. citizen or entity that wants to conduct a launch of a vehicle anywhere in the world needs to have a launch license from our office. The only exceptions are for launches the government carries out for the government. For example, if NASA were to develop a new vehicle to launch its astronauts to the ISS, it could do so without any involvement by the FAA.

On the other hand, if NASA were to engage private industry to carry out those launches, the requirement for licensing would come into play. And even for FAA-licensed commercial launches, NASA is free to establish mission-unique requirements. They can be imposed as part of the Space Act Agreement or in the contract NASA negotiates with the launch operator. So, there is no incompatibility there with the two systems. In fact, that's exactly what NASA has done for the COTS and Commercial Resupply Service programs set up to supply the ISS. All those launches will be FAA-licensed.

My second point concerns the relationship between safety and risk and human rating. The key point is, in my opinion, that safety is not an absolute.

Statements have been made recently that implied that all of our history to date on human spaceflight has been carried out by government civil servants, and that what is being proposed is just turning everything over to an inexperienced contractor. I think that's somewhat disingenuous. From before Alan Shepard's flight 49 years ago, industry has been closely engaged with NASA in conducting the design, development, and operations of our human spaceflight programs.

But even if NASA were to design, build, test, operate, and certify the human rating of a launch vehicle without industry involvement, it would not be guaranteed to be safe. Because all forms of transportation involve risk. According to the National Transportation Safety Board, in 2007, over 41,000 people were killed on our highways, over 800 in rail mishaps, and nearly 1,200 in boating and general aviation accdents.

As Congress observed in the Commercial Space Launch Amendments Act of 2004, space transportation is inherently risky. The shuttle program itself has had two fatal accidents in 132 launches. So, just because a vehicle has gone through the human-rating process does not necessarily mean it's going to be safe. Conversely, just because a vehicle does not satisfy all of NASA's human-rating requirements, doesn't mean we shouldn't necessarily be operating it.

As a reminder, the shuttle doesn't meet the latest version of the human-rating requirements. If they really were mandatory, maybe we need to think about the next two launches. Should we proceed?

The bottom line is, launching people into space is risky. And you need to understand those risks before you fly.

What does the way ahead look like? I think it makes a lot of sense to talk about certifying these vehicles the same way we certify aircraft. But for certification to be successful, you need to have a lot of experience with the systems in question. In aviation, we gained that experience over more than 100 years of flight, with hundreds of companies building thousands of different aircraft, allowing us to learn which approaches work, which systems are safety-critical, and what the best practices are. And although NASA has developed tremendous expertise, we don't have that depth of experience in spaceflight. Over 49 years, that experience is based on only a few hundred launches of just a handful of designs.

The danger is, if we're too rigid or too prescriptive on the requirements for future vehicles and future operations, we may inadvertently prevent the kind of innovation and creativity we need if we're going to end up with safer, more cost-effective systems. If we stick with current design philosophies and operational practices, it's likely we'll end up unable to significantly improve upon our current fatal accident rate for human spaceflight, which is on the order of one in 100, about 10,000 times worse than the current rate for commercial aviation.

Where do we go from here? Based on direction from Congress, we have in place an informed consent process. We have the statute; we have regulations for ELVs, RLVs, spaceports, and human spaceflight and crew. So, if a company were to show up at our office tomorrow with a complete application package, we are prepared to start reviewing it. And if it meets existing requirements and regulations, we'd be good to go to grant that license for a commercial human spaceflight.

Starting in 2012, we'll be able to issue additional regulations, if needed, to further protect spaceflight participants. But in the meantime, I'd really like to see a dialogue within the aerospace community, with the goal of coming up with what are really industry consensus standards, even if the first draft is provided by NASA through an RFI, that would lay out some top-level principles and practices we can all agree on that would provide a basic safety foundation. The FAA could reissue those as guidance documents, we could refer to them in a safety approval that we would grant, or we could start down what is a fairly lengthy road for eventual adoption as official regulations.

Remember, when an accident occurs, and we know it's going to occur some day, there's likely to be a fairly strong reaction by the media, on the Hill, and in the public. And that could be extremely harmful to the entire industry.

DICKMAN Some of you have launched

for the government before, not under license, for DOD. And all of you would like to be launching for NASA in the future, but it's going to be under license. What do you see your companies doing differently under license?

GEORGE SOWERS From our perspective, we launch for the DOD and NASA without a license, but we have to meet Range safety requirements. We have to create a lot of data and prove that we are protecting the public's safety.

We deliver the same data package to the FAA for commercial launch for a launch license. So, from our perspective, the process to launch for DOD or NASA and to launch for the FAA is essentially the same. It's just who we deliver the data to that changes. We'd like to see a very similar thing for commercial spaceflight, that there aren't new requirements imposed by the FAA. If it meets NASA's requirements, it would meet the FAA's.

NIELD That's right. And looking at ELVs over the years, we've tried to do exactly that. We worked very hard with the Air Force on the Eastern Range to develop common safety standards, so that even if it wasn't word for word, the intent of every requirement for launching off the Range is equivalent, so there wouldn't be conflicting standards whether it was a launch for the Air Force or a commercial vehicle. After a long time we finally captured current practice. There are improvements we can and want to make, but that at least has been documented in our FAA regulations as a starting place.

We've seen the benefit of this cooperation to the extent that we believe it makes sense to have NASA as one of the partners. We'll be talking with NASA about having a three-person partnership, if you will, for that common standards working group on the Ranges to ensure government consistency across the board.

DICKMAN So, for the unmanned vehicle, the vehicle's the same, the safety's the same, the processes are the same, the eventual decision authority changes, but it's really a change in acquisition approach rather than how you think about the launch vehicle. Is that fair?

FRANK CULBERTSON Well, that's part of it. Whether we're launching commercially or for the government, we go through the same processes, reviews, safety assessments. And yes, a lot depends on who's involved as to where you deliver the data. But, it's pretty much the same data, and it is the Range in addition to NASA and FAA that you've got to satisfy.

The boundaries kind of cross in various places, depending on where you launch from, but the basic process doesn't change that we can see. You're going to have the same level of diligence on the part of all four parties, no matter what the flavor of the launch is. I don't see FAA license or no license as a major factor.

We're working through the process with both the FAA and NASA leading to our readiness for our first launch. They're both in the room, and they're both giving us feedback and discussing what issues need to be resolved. I think it's working very well in terms of being a partnership.

KEN BOWERSOX You end up with a process in parallel. All the decision authorities try to work together if you're doing it efficiently. It gets a little complicated, because sometimes they'll have different levels of acceptance on the rules, and that can be tough for the person trying to get approval because it's a little less predictable, but any one of the parties could tell you to stop. So the change from going all-government to including FAA is one additional decision authority.

MICHAEL BLOOMFIELD If we do have an accident, there's going to be a presidential commission, and it's going to be a really big deal. That's happened twice so far. For Columbia, I served as the ex-officio member to the Columbia Accident Investigation Board [CAIB], and I walked away from that a different person. And part of what I learned was how passionately that board felt about history being a cause just as much as the foam. They were very clear. They said, in no uncertain terms, that the foam did it.

But they were just as clear when they said, "History is a cause." That's the second half of the CAIB report. They spent a lot of time talking about early decisions that put smart people in this untenable position of trying to manage the system and keep the risk down where we could do it safely. On two occasions we were unable to do that. The risk got too high. Despite the efforts of some really smart people, we ended up losing a vehicle.

They'll tell you, "Well, we made the decisions early on in the process that we're not going to do crew escape because we think we can be reliable enough. We're going to put wings on this vehicle so we can meet some other requirements that came from the DOD as far as ability to launch and to quickly land." And that gave us this vehicle.

When they were done with the report, they added Section 9.3, which gave us guidance about what we as a nation should do. And one of the things is that you need to have a compelling national vision. They used the words, "A lack of national leadership."

They talked about not relying on breakthrough technology, not mixing cargo and crew. And then they said, "The design of the system," talking about the shuttle replacement, "should give overriding priority to crew safety rather than trade crew safety against performance criteria such as low cost and reusability or against advanced space operations other than crew transfer."

That's completely in line with what we have heard here today, that we cannot trade safety away. It must be there at the very beginning. How do we put human-rating requirements in place such that we can do what has been asked by the CAIB? And those requirements should come out as quickly as possible, so you can build the vehicle from the ground up with crew safety in mind rather than trying to go back and fix it.

I agree with the thought process about not being too restrictive in law, allowing innovations to take place. Since Columbia, the probabilistic risk assessment [PRA] has become a very valuable tool for the shuttle program. PRAs allow you to look at what scenarios are likely to happen, so that we can rank order them to understand where to apply resources.

It might be very useful for NASA or FAA to take a look across all the systems and come up with a rigorous process, because PRAs allow us to make direct comparisons between systems from a risk perspective, so that we can try and eliminate it. And if we're smart enough to look 15 or 20 years down the road, then whoever holds all this data could pick the systems that offer the least risk, so that if we are going to do something beyond LEO we can pick the best systems.

DICKMAN It strikes me that the bar they set may be so high that you can't do exploration beyond Earth orbit. You might be safe enough to go to the Moon, but going further than that, if safety is the overriding consideration, you may not ever be able to do a mission.

BLOOMFIELD That's a great point. In Section 9.3, they're very careful to point out that wherever you decide to go, the first thing you have to do is get to Earth orbit, and the last thing you have to do is get back from Earth orbit. And they would contend that that's where, right now, a large part of the risk is.

We've been going to and from Earth orbit for 40 or 50 years. We ought to be able to take something that maybe we understand a little bit more and reduce the risk down. The crew office would suggest one in 1,000 based on that memo they came out with right after Columbia.

DICKMAN One in 1,000 would be an incredibly difficult number. How could you certify something you believe is one in 1,000? That's an incredible flight test program.

O'CONNOR I remember when we were looking at operational requirements documents for aircraft. The tradition there was reliability requirements that could be verified by flight test. Ground test was good, but flight test is where you did operational evaluations, and enough flights in the appropriate environment with real operators to show at 50% confidence that you actually had met the thresholds—maintenance man-hours per flight hour, flight hours between failures, flight hours between critical failures.

We don't have that luxury in spaceflight.

We tend to fly our missions on top of what I call operational flight test. We have to think about what we do as verifying by analysis, verifying by ground test, doing what verification is conceivable and appropriate and can be done with our budget in flight tests, first unmanned and then manned if you need them.

If you need people in a flight test, fly them. If you don't need them, don't fly them. You'll probably need some flight tests just to certify that you've met your technical requirements, but no way in the world can we certify with any level of confidence what our actual safety is by flight test until way downstream.

You can compare systems, look at different risks and how they rank with the same set of assumptions, how the different risks line up with one another and see which ones you need work on. That's a good use of PRA.

BOWERSOX One thing that comes to mind when people talk about commercial space activities is this idea that commercial means you're trying to do it for as little money as possible, that your priority is cost. At SpaceX, our mission statement says that we're trying to build the safest, most reliable, and economical transportation to LEO. It's that way on purpose, because we believe making safety the priority is good business. If you're perceived as unsafe, nobody is going to buy your vehicle no matter how cheap it is.

When you talk about safety, the struggle is finding where that fuzzy line is—safest, or safest within performance and cost limits, etc. Where are those lines? The truth is, they change constantly, with technology, with cultures. If you look at how Soyuz is designed, it's not the way we would necessarily design a crewed vehicle. That's where the human-rating standards can be really valuable to everyone trying to build vehicles.

They can distill the experience of years of development into a set of requirements that will help focus and maximize the probability that companies will have a good outcome in their designs.

We started with Dragon and Falcon 9 looking at NASA human-rating requirements five, six years ago, and they were very prescriptive. We tried to get at the requirements that would be most difficult to implement later and put them in the early designs, so when we moved to a human rating, the major items would be taken care of.

Along the way, NASA changed its requirements to more of a process-based approach, based on building trust between the group approving the design and the one trying to build it. That's very important. Those prescriptive requirements are very helpful, though it's possible to go too far. If you set requirements that are so aggressive and so biased toward safety and performance that they are impossible to do within whatever the cost limits are, it doesn't help anyone.

It helps for the organizations building to human-rating requirements to have examples from the past—shuttle, Gemini, Apollo, Mercury. And Soyuz, too, since in all likelihood, until we have a new U.S. spacecraft, that's what U.S. astronauts will be riding on. And it's important that we build standards that will enable companies to build alternatives to Soyuz and not set up roadblocks that guarantee that we'll be flying on Soyuz forever.

An example of that from the human-rating requirements that were given to the Constellation team is the requirement for Ares and Orion that the crew have the capability to monitor and control the vehicle's trajectory up until the point that they separate from the booster.

There was some relaxation of that, but what a lot of people don't know is the Soyuz doesn't have that capability. You are along for the ride until you separate from the booster. At that point, the crew has some control over trajectory, but before that, it's all taken care of by computers. There's not even a display to see how fast you're going or what the attitude is. There's also no big red button the crew can push to try and abort when they're going uphill.

All of these things, from the point of view of an American astronaut, would be critical. Before I got trained on Soyuz, I would have considered them mandatory. But after having experienced the Russian way of doing business, I realize it's been very reliable over the years. So, maybe I need to open up my thinking a bit and consider other options.

The last thing is that trust issue. As we work through human-rating requirements, the primary goal of that process is building trust between the customer using the service and the company providing it. If you have that trust, the outcome will be what everyone needs, and we'll get the safest, most reliable, economical transportation service, and it will be something that's good for our country.

DICKMAN I didn't understand that shuttle did a whole lot of controlling between launch and the time it got to orbit by somebody moving a stick.

BOWERSOX Auto's the primary mode, but you have the option to fly, outside the first 90 seconds. First 90 seconds there are other things going on, so for the crew to try and fly could damage the vehicle. But the crew has the option of taking over and steering, though it has never happened.

DICKMAN Would that kind of requirement make any sense as you build your vehicles? In the ELV world, you don't put extraneous commands into the vehicle. It's pretty smart. It knows where it's going, it goes pretty fast, pretty far, and gets within a fraction of a kilometer of where it's trying to go at the right speed. So other than trying to get out of an unsafe posture, I'm not sure you want a whole lot of controls.

BREWSTER SHAW We're talking about a commercial crew here, going somewhere like ISS, which means you have to insert into orbit very accurately or you'll never get there. And the chances of a human hand-flying during powered flight and being accurate enough to achieve alignment with the ISS orbit is pretty small. So what you're really talking about with human interaction is not loss of mission but loss of crew. And when you have a system that is comprised of a fairly reliable launch vehicle, a very reliable human-rated spacecraft, and a launch abort system [LAS] that will get that spacecraft away from a problematic launch vehicle to recover the crew intact, you've got a good system that we all ought to be happy to fly.

But asking someone to try to hand-fly powered flight and accomplish the mission is unreasonable. And if you're not going to do that, then what you give them is the red button that gets you away from the rocket when things start to go south.

BLOOMFIELD You're exactly right. The point is, it's hard to take one requirement, like you just threw out on the table, and answer that one requirement without looking at the whole system. That's the dilemma of this whole thing, that it's wrapped up in this big ball of yarn, and how do I just pull one piece out and talk about it without looking at the entire system.

KEN REIGHTLER I agree. The classic argument always comes down to, if you've got a crew on board who are capable and trained, have good processors between their ears to be able to supplement what's in the system, why not use them? Because the day will come when you will need to take over.

The other side of that argument is, we have reached the point where avionics are good enough and reliable enough and robust enough to be able to not require some tertiary level of redundancy to be able to achieve the mission.

DICKMAN It would seem like a very expensive process to put real control in.

SHAW From a safety standpoint, if you were going to use one of George's vehicles to get your spacecraft to orbit, the risk trade-off of going into the guts of his rocket to in-place the capability to hand-fly, it would insert a lot higher risk than it would be to trust that system. And if the system does not work, you push the red button.

CULBERTSON In addition, if you're going to put a human in the loop, training issues have to be addressed. People vary, and making sure they're really ready is a challenge. The Russians put you through a very rigid exam on everything that has to be done manually in the Soyuz. We're a

little different here, but we'd still have thousands of hours of training to make sure people are ready to do the manual things they're called on to do.

BOWERSOX One reason possibly for including manual capability is when you think about Range safety. I've been told that, for shuttle, one of the reasons that some of the Range safety aspects are relaxed compared to an ELV is that the crew can take action, for example, to turn the engines off and terminate thrust. The Soyuz doesn't have that capability during ascent. We could give our crews that capability, and it might change the need for an explosive packet on the rocket.

DICKMAN NASA's plan was, or is, to fly astronauts on the second full-up orbital flight of Ares I. That seems like a pretty low number of flights.

O'CONNOR There's an asterisk that says there's some chance that we may want to do two of those unmanned test flights. In fact, that argument was still going on when the budget came out.

There are various types of test flights, and one of them is when you get beyond prototypes like the Ares I-X. I'm past that now. I'm into the full-up test flight, and we need to do some flight tests to finish the certification that this meets the design intent. And when you do that, you line up all your objectives. These are the things we watch happen in a real environment on a flight test, because we can't do it any other way.

You line those up and ask, "Do we have to have people on board in order to do that?" We went through this on shuttle, and I wondered how we got to the point where we flew people on the first orbital test flight. We hadn't done that on earlier programs. They didn't know how many flight tests when this decision was made, but knew there'd be some flight tests.

The question was raised as early as 1974, and they decided then to plan on people going on the first test flight, because they felt they needed them. The hypersonic risk was the real issue. It was not ascent; it was the hypersonic entry that drove this decision. When you've got a model this big in a hypersonic wind tunnel, there's a lot of uncertainty on the stability derivatives that come out. And some of those uncertainties overlapped, and there were questions about how this thing would actually operate when it came through hypersonic flight.

The decision was the probability of saving the first flight, which was going to have a 13-minute blackout during reentry and therefore you couldn't save the day with people on the ground. And they said, "If we have people on board, and give them some capability to handle dynamic instabilities that could show up, and give them switches to change gains and train them to handle all the various things that could come up, that could actually save the flight and save the orbiter and save the program."

DICKMAN NASA could say, "We'll issue your abort system and you'll screw it on top of your capsule." Does that make sense from the view of the companies, or should that be an integral part of the design process?

O'CONNOR It's going to depend on the system. Each system will have slightly different answers to its abort analysis, its trigger analysis, its trajectory, its mass allocations, its crew interventions, and all those other things. I'd hate to say that this piece of hardware is going to be GFE [government-furnished equipment] and you've got to make it work for your system. It's best to tune your escape system to your system. It's a real integration issue.

KEN REIGHTLER Given what we learned on the LAS for Orion, I'd absolutely agree that trying to retrofit that into some other vehicle would be extremely difficult.

CULBERTSON There is another way to look at this, though, if NASA were to establish itself as the technical authority on LAS and do the requisite evolutionary design evaluations, testing, set some standards, then make that available to industry to choose and tune appropriately for their system. This might be an area where you could get some commonality, at least in design approach and in when's it appropriate to use a pusher, when's it appropriate to use a tractor, and what kind of control authority you need, etc. There's room for some innovative thinking here.

O'CONNOR That might be worth getting some input on when our RFI goes out.

We did a lot of analysis, which I'm proud of, as part of Constellation integration team. The abort trigger analysis folks at Ames helped us with that integrated design. And that feeds right back into the design of the system itself.

My guess is, that process they went through, the kind of tools they used, the way they posed the accident scenario questions might be something everyone could benefit from. Rather than putting GFE on everyone, something in the way of some standard process for coming up with the right answer might be useful.

SHAW There's a basic business issue with GFE LAS. That system puts the highest loads in the spacecraft of any loads during its mission. So if you wait for the government to provide a LAS, it goes to the very structural design of your spacecraft. You have to have the loads going in the right place, so the LAS design is hugely important and a driver in the structural design of the spacecraft, and a big schedule driver. So from a business standpoint, that would be an undesirable path.

DICKMAN Is the person driving the Dragon, for example, going to be one of NASA's?

O'CONNOR Part of that just depends on what we give them as the mission. Until recently, we were talking about a system that would go up, stay at the ISS for six months, then come down. Now if all we need is an up and down, that totally opens up a new concept for crew operations. The taxi mode looks much more feasible and reasonable than it would have if you're going to leave your taxi up there. Maybe that's a rental car concept.

BOWERSOX The way it's going to work is what makes the most sense from a business case. And typically, you can sell the pilot seat for more money. If the customer wants the pilot seat, you get more money to train them and prepare them.

I think there's going to be less piloting involved, but especially in the early missions we'd see folks with flying backgrounds in the seats. You can build a vehicle

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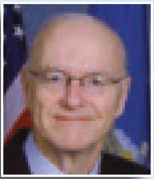

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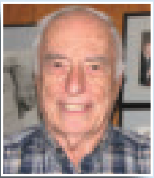

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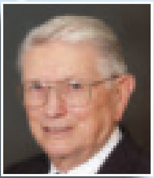

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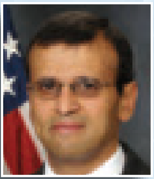

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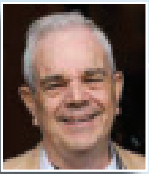

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that's so easy to fly that it doesn't necessarily require someone with a pilot background, and we're hoping that the Dragon would be that simple.

REIGHTLER If you're designing the mission to be completely autonomous and you have full capability and reliability and redundancy, etc., to achieve that mission, why do you need a pilot? Do you really need to have somebody with all that capability and provide all the controls and displays, etc., or do you use that weight and space for other things?

Or do you try to put another level of redundancy by allowing people to take over manually? It will probably be a hard sell to get there initially, but I think eventually that's where we'll be. The astronaut office had weighed in that they wanted the rental car model. That may have changed with some decisions lately, but there is an official document out there that lists pretty clearly the pros and cons of doing that. It's pretty convincing to me that that's the direction to go.

CULBERTSON You have to have, in your requirements, the ability to download to the point where you know you're going to get the crew back safely. And whether that's a LAS or a ballistic reentry—and I agree those are the two riskiest parts of the flight—you've got to have that as a basic part of the design.

The issues we've been discussing, crew involvement in the mission and the flight in order to ensure no loss of life, mission assurance, etc., have evolved over time a great deal. Most of us started flying when autopilot and autorendezvous and autoland were seen as pretty cool things but you never really trusted them. You always had your hand by the stick. The shuttle was designed with that in mind; a lot of stuff was automated, but you had to have manual backup.

One of the things we were working on really late in the process was a concern about whether the SRBs were going to separate. They talked about whether they could put a software patch in. But because software was what it was in the '80s, they also had a crew workaround. In my 18 years at NASA, that became one of the favorite ways to solve design problems.

But that's the least desirable approach. What that means is you've got to design your system so that from a system safety standpoint you are addressing all these things from the very beginning and not relying on the crew to save you.

The ability of computers and control systems to control spacecraft accurately or maintain their own systems integrity is far superior to what it was when a lot of our legacy systems were designed, and I think we need to take advantage of that when we are human-rating our vehicles. What that leads you to is, how much crew do you need to have involved, and do you have pilots on board, or do you have operators on board. I don't think a whole lot of piloting is going to go on in many future spacecraft operations, except for very rare cases.

It's not as simple as, what's your level of redundancy, how many backup systems do you have; it's how the whole system plays together. So we need to make sure that our requirements and our safety standards are written with that in mind.

That brings you to, why are we flying humans? We're not flying humans to ensure that we hit a target or that we're getting passengers to a destination. We are flying humans because we want to get humans into space and do it the safest way possible, which means keeping the crew safe is the number one priority by far, over and above the mission.

There will come a time, as we get further away from LEO, where things will change to a certain extent, where achieving the mission will be the only way to keep the crew alive, but I think keeping that separate in our minds is extremely important. And the country has to make some hard decisions. Do we want to keep flying people or not?

And if we want to maintain our ability to explore space, we do have to keep flying humans. That means we have to put the level of priority on their safety that it deserves, and that means you can't take shortcuts. And none of us here are going to worry about profit over safety.

I think you can count on industry to do what needs to be done to meet the requirements, but we have a customer in NASA who's been doing this for 50 years. And we're eager to work with them to make sure we understand what their requirements are, what the probability of success on the missions is, what reliability levels are necessary.

That's a hard thing to agree on. One in 1,000, one in 400, one in 100. What's the right number? We'll have to reach agreement on that, and we'll have to achieve that in order to satisfy the customer, and also to do the right thing for the country and for the people who are flying.

O'CONNOR One thing we've mentioned several times is the priority of safety. Someone once said to me, "I'm a little concerned about your emphasis on safety. Shouldn't your job over there be exploration, not safety?" And I realized that we may not be making the right choice of words to the public.

When Brewster Shaw was the program manager for the shuttle, he reminded his troops that the priority of the shuttle program was, first, fly safely. Not safety, but fly safely. And when you look at safety at

NASA you'll find it's a core value, not a priority. It's not a mission. It doesn't compete with the mission. But sometimes people think that's what we're saying.

Safety, reliability, quality, integrity, those kinds of things that show up in our core values and so on, I think of as adverbs, and the verbs are our priorities. The verbs are explore, operate, discover, but the way we do those verbs is by attaching the adverbs of "safely" and "reliably," and "with integrity."

They shouldn't be seen as competing with but modifying our mission. And if our first priority is to fly safely rather than safety, that explains why we actually fly, because if it were safety, we could meet that priority very easily by not flying.

REIGHTLER There's that quote we've all heard: "Ships are safest when in the harbor, but that's not what ships are for."

DICKMAN I worry about the one in 400 and one in 1,000 number. They're so much higher than anything we have achieved before. We could keep ourselves on the ground trying to achieve them, and that's where I think your challenge is going to come to play.

O'CONNOR One of the problems we have when we talk about numbers like that is, we don't necessarily include the verification piece. For example, if we're going to require that a design meet some number like that, we need to explain how we're going to verify that and what the uncertainties are, and include the assumptions, because what we're talking about is comparing the results of a model to the results of that same model applied to some other situation or design. It's not meant to say we know exactly what the probability of failure will be on the system when it's operational. There's no model that'll do that. Models, as you know, by definition are wrong.

If we use a PRA that does a certain type of accident scenario analysis using similar kinds of assumptions, and from that PRA we want to see something that looks like it's an order of magnitude better than that other thing we did the same analysis on, now you're getting to where these things can be useful. But some of our engineers really don't like to use that PRA, because they know it's just a single tool in a big toolbox.

DICKMAN One of the challenges with PRA is that it focuses on design and to some extent ignores process. In a very real sense, Challenger was a process problem. It should never have been launched at that temperature.

As NASA goes through the oversight/insight in terms of certifying, what's the continuing process for watching the processes? George, once a license is issued, do you step back?.

NIELD We develop and issue regulations. We issue licenses, permits and safety approvals, but we also maintain a cadre of safety inspectors present at every licensed launch. We oversee the launch operators, whom we hold responsible for safety, to ensure they are following their promises and established regulations.

SOWERS I think human rating is really an attribute of a system—it's a system-level property. I've heard talk about human-rated valves or engines or components, and that doesn't really make a lot of sense to me. It's at the system level.

From a rocket guy's perspective, it starts with a reliable rocket. That's where the mission assurance part comes in. We talk about mission success, which is delivering the payload to the right orbit. I don't think that is in any way in conflict with loss of crew. The best way to have safety is to have a successful mission.

With our history of dealing with the NRO and its culture of mission assurance, which is very rigorous, and talking now with the NASA human spaceflight community, we are finding that the jargon may be different, but the values are closely aligned.

But, starting with a reliable rocket, adding an emergency detection system enables us to perceive whether the rocket is sick or healthy. And if we get a signal of sickness, the spacecraft decides if and when to abort.

That gets the safety element, but providing that intact abort capability is a big system integration exercise, and part of that is the environments you abort into. Those are the elements of a human-rated system at the system level.

DICKMAN Your vehicles were clearly not built with the level of health monitoring and real-time transmission of that information and ability to act on it that would be required if it was carrying a human. I'm pretty sure we didn't put that kind of requirement on either the Delta IV or the Atlas V. That health monitoring to the point where you could know within a fraction of a second that you needed to abort wasn't part of the design requirement placed by the government.

SOWERS That's true. We're working on the emergency detection system under a NASA contract right now, so we're getting into it pretty deeply.

In our first cut at what measurements, what instruments we'd need to detect failure across the board, we've done a fault coverage assessment, which is looking comprehensively at all the potential failure modes and what measurements you'd need to detect those modes in time to effect an abort. That assessment has not revealed any instruments that weren't already on the vehicle.

The level of redundancy and the quality of the instruments may need to be enhanced, because now they're in a critical function vs. just being instrumentation, but we instrument a rocket so that we can tell after the fact, if they fail, what happened, so we can fix it. So the coverage has been there.

DICKMAN Frank, I don't know where you were in the Taurus II process when you started thinking about adding crew, but are you having to change much?

CULBERTSON A crew was not really contemplated for the Taurus II when we started that design. There would have to be modifications to make it suitable.

DICKMAN I guess SpaceX was thinking that mode early on.

BOWERSOX Yes, that was part of the plan from the beginning with Falcon 9; you can see it in some of the design features.

REIGHTLER NASA and Lockheed Martin have learned a lot about this in the four years of working together. We've begun to really appreciate what's involved, how difficult it is to work through. We tried to incorporate all of the experience we've gained working with other customers as well as working for NASA in the design.

When I look at it, human rating is an integral part of all of the program activities associated with human spaceflight throughout the life cycle. It includes research on the front end; requirements development; requirements integration, which is probably the most difficult part of the sausage-making; design and development; test verification and validation. And then, finally, certification.

It requires top-level guidance but also inputs from safety and mission assurance, the crew office, engineering, health and medical, program management, and industry. All those different components have to interact.

Human rating does involve procedure documents, requirements, standards and specifications, but you need the knowledge and experience to be able to understand how to integrate them, to apply them in a smart and effective way. But it also requires a strong culture, constantly driven by purpose, experience, and leadership. That sometimes gets overlooked.

And probably the most important part, from my perspective, is it takes a workforce that believes in the processes and methods, understands what's at stake, and has taken personal responsibility to make it all really work. You have to have the ability to work and talk together and understand the real mission. It takes experience, both good and bad—we learn from those things what works and what does not—and a passion to make things work the way they're supposed to.

Also, it takes a lot of money. It doesn't happen on its own. You've got to have the things in place to make it all come together, but, as history has shown us, it's worth it. We always tend to underestimate the cost in blood in terms of making those systems work.

DICKMAN You're in competition for pieces of this and in partnership on others, but sharing your thoughts about what makes sense and what doesn't—is that something that happens?

SHAW Sure. For example, in the shuttle program, five primary companies are responsible for shuttle systems and operations. We work very closely together, but we're not competing with each other. As soon as you insert competition, the conversation closes down a certain amount, and people protect their interest. That is a factor when it comes to how do you work together. You can't ignore competition. We don't ignore it because we're all in business.

CULBERTSON There are lots of cases where we get together, whether it's in an existing program, at conferences, forums, etc.

One of the most valuable parts of the industry is that we all know each other, whether we compete or team at a given time. We know what we're doing, and we know our objective—to safely fly people in space. We see a lot of the problems addressed in these forums in a very open way. It's a bit of a balancing act, but this is a unique community, because we're trying to fly humans and keep them alive. So, yeah, we do share a lot.

SHAW We're terribly interested in this subject, for obvious reasons. From our perspective, there are four major players: the Eastern and Western Test Ranges are responsible for launch vehicle public safety; NASA is responsible for the safety of government astronauts and the protection of government property; the FAA has authority for public safety; and then there's Boeing, which has a very significant brand and reputation to uphold.

There are certain goals we'd like to see achieved in coming to an acceptable solution for how we fly commercially. One is clear RAA—responsibility, authority, and accountability between the Range, NASA, and FAA. That means we need to understand, from a business perspective, who's in charge and who sets what requirements and who establishes what regulations. We need clear, well-documented requirements.

A strict definition of oversight or insight on the part of the government is very important, especially when we're talking about the kind of contracting mechanisms that are being discussed relative to commercial crew. And there has to be a methodology for regulatory changes in this fixed-price environment, because regulatory changes on the government's part can drive cost hugely.

From the Boeing standpoint, we have, over our years of involvement in space and aircraft, established the methodologies we use to design and certify flying machines. We look at all the things that have been mentioned here. And from a mission assurance standpoint we look at failure, tolerances, probabilities, design practices, critical items, failure mode affects and analysis, hazards analysis, parts traceability.

After design requirements you have certifications. And then, of course, it goes into operation, and it's very important to always use the hardware the way it was designed to be used. When you stop doing that you get yourself into trouble. You have to have some methodology for management of waivers, because there are always things that aren't quite the way they ought to be.

But we need a well-defined, stable regulatory and requirements environment. We have to understand the rules of the road, and they have to be reasonably stable, because we're going to have to go outside where we are provided indemnification by the government. We have to be able to buy insurance. And if the insurance industry doesn't have any confidence that the regulatory environment or the risk environment is well understood and is reasonably stable, we won't be able to buy insurance. And without insurance, you can't stand the risk of a bad problem happening.

The risk posture must be measurable and at least acceptably stable. And in a fixed-price environment we need a mechanism to deal with government changing its mind from a regulatory standpoint. There has to be, even on a fixed-price contract, some kind of an opening that allows NASA to come in and say, "No, we want to see this test and that data, and we want you to go off and do this research," or, "We're changing the rules of the road a little bit, and you've got to be able to

deal with that." And in a fixed-price environment, you have to be able to have some way to handle that.

Boeing intends to protect space travelers. Our reputation is at stake. So if we are involved we're going to do it right, and we're going to do it successfully, because we have all the scars and all the experience to help us learn how to do that. But these regulatory environments are all very critical to making a business case.

O'CONNOR As everyone here knows, there's a reason why managers on NASA programs are called risk managers. Our risk management system is set up to allow for the fact that not everything you do is going to be simply complying with some standard black-and-white requirement you either meet or don't. A lot of stuff goes on in the design in the way of trades, in the way of hazards, that are less than controlled but may be acceptable.

We have a yellow area between the red and the green at NASA, and use it quite often. It's an area where you do not have stable requirements to give you the right answer. What you have is judgment, technical authorities weighing in, relative risks, comparisons with other things that may be less risky or more, and is this okay.

And that part of program management is going to be important in human rating. It's assumed in human rating. In fact, one of the most interesting requirements that we have in our human-rating document is the one we call failure tolerance.

The failure tolerance requirement for space shuttle was fail-op/fail-safe for the orbiter avionics and fail-safe for everything else. And there were about 4,000+ waivers to those two requirements. The way the shuttle handled their requirements was they established the requirement, and then they managed the program by disciplined waiver process.

"Waiver" doesn't mean you just blow it off and decide not to comply. What it means is you're not meeting the requirement, but you're going to meet the intent of the requirement or get to a reasonable risk posture by doing something different than the requirement. That was basically how we managed the reliability part from day one. We're hoping we don't have to have a bunch of waiver discussions.

One of the ways that showed up is in the recent version of the human-rating requirements. We said the minimum requirement for failure tolerance is single failure tolerance. In other words, fail-op. You can't use abort for that. Abort is something you do in addition to that. Fail-op is the requirement, and then the fail-safe is applied by a different requirement, abort that can be used all through ascent. So, it's really a fail-op/fail-safe requirement.

But the way it's written is that you start with a minimum of single failure tolerance, that is fail-op, but there then has to be discussion about why you might need more than that. That discussion is part of managing the program, accepting the risk, or doing more to get to a comfortable risk posture. And that's the way we're set up to manage the programs we design and develop. We're having lots of discussions in NASA right now about how you do that if you're stepping back and watching someone else do it, and verifying that their process is robust enough to where you, as the customer, can also accept that same risk.

That's a kind of a challenge in the area of how to manage a program when you have to allow for that kind of discussion to go on, because it tends to look like requirements that aren't quite there yet.

That'll be an interesting area, and we'll be looking for inputs on that in the RFI.

DICKMAN I think I heard you say that, in the response to RFI, you're not restricting the responses to the subjects you ask about.

O'CONNOR We're talking about human rating, and it's more than just a set of requirements. It's about life-cycle management of the risk for humans. We need inputs from all these smart people out there who have the scars and have done this elsewhere.

DICKMAN The model in the airlines is, you do all the things to get your type certification for your airplanes, and then they get passed to somebody else. And the operator takes care of it from then on, unless a change is needed. What I'm hearing is that that's not the model for commercial human spaceflight and, to some lesser extent, for nonhuman spaceflight. The builder, the operator is the same person. Does that change how Boeing looks at the process?

SHAW I think so. Boeing was in the airline business; didn't continue. It built train cars; didn't continue. Sooner or later, you figure out what your core business is and try to do well at it. But here, we are talking about designer/builder/owner/operator models. And that does bring a different set of dynamics and responsibilities.

But, we're all pretty familiar with that because NASA, to a certain degree, has operated in that mode for the entirety of human spaceflight programs. Not necessarily the designer and builder, but certainly a smart buyer and then operator. So we know how to do that as a nation.

I would add one comment. We've talked about the physics of safety. And something that is really important is the human factors of safety, not with regard to the people who are exposed to the risk, but to the leadership of these programs, whether it's a NASA program or a commercially led program, because both of the failures we've had with shuttle were clearly failures of leadership.

And that is something that will ever be a challenge for us, because of the way we operate and the way we think, that we are susceptible to making poor judgment calls. What is lacking, and has been addressed by NASA reasonably well since Columbia, is the check and balance relative to leadership of these programs and the people that are in decision-making positions that are critical from a safety standpoint.

That is something that will always be a challenge for us. We need to continue to pay very close attention to it because, when you get to a point where you stop listening to your systems, listening to your hardware, and responding appropriately, that's when you allow things like Challenger to happen.

DICKMAN I'll read a quote from the same Marshall testimony: "NASA should immediately identify the number of launch successes that COTS partners will need to achieve with the unmanned vehicle in order to demonstrate the required vehicle reliability for a NASA crewed launch." What is that number?

O'CONNOR I don't know. There are various ways to look at these flight tests. But there's the other aspect that asks, how do we actually get comfortable enough to say, "Okay, we're ready to put our people into a mission environment on this?" You could have a different threshold for people flying a test flight vs. carrying passengers to the ISS. You wouldn't necessarily say that once we're ready to do one of those we're ready to do them both.

But there could be a case where you might want to fly a few more flights on a

Human rating for future spaceflight

PANELISTS

***Michael Bloomfield**, vice president, Johnson Space Center Operations, Alliant Techsystems*

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***George C. Nield**, associate administrator for commercial space transportation, FAA*

***Bryan O'Connor**, chief of safety and mission assurance, NASA*

***Ken Reightler**, vice president, NASA programs integration, Lockheed Martin*

***Brewster H. Shaw Jr.**, vice president of business development, Boeing*

***George Sowers**, vice president of business development, United Launch Alliance*

***Robert Dickman**, moderator, AIAA executive director*

system than just what it takes to satisfy the certification that it met the technical requirements.That's what I was trying to get at when I said that with Soyuz we put a lot of value in the fact they had this number of demonstrated flights.

We have a policy at NASA on the ELV payload launches that, depending on how much our oversight and insight is, we may require higher or lower numbers of demonstrated successful flights.

If we've decided that we're going to buy a ride on a vehicle, and decided that we're going to be way backed off—we're not going to have any kind of oversight or insight on it, just maybe a few people watching to see what happens—we've got an example of where you'd have 14 flights in a row before you'd want to have an oversight/insight model like that.

So, there's a relationship between the oversight/insight model and the number of demonstrated successful launches on a vehicle. And we'd like to keep that flexibility in play. If, for example, the agency decides that they want to have a real backed-off oversight/insight model because they want to see some demonstrated flights instead, that should be one of our flexibilities.The more oversight and the more insight, the less chance there is you're going to need to have a question like that, of flying a few more flights to get comfortable.

REIGHTLER With most test programs you have test objectives you want to try to achieve, and you have a pretty good idea about how many flights or missions it takes to be able to accomplish those, but I think that those are always just a good plan to start with. You have to adjust that plan and add or modify flights as you go along to be able to accomplish those. And sometimes you learn things that you didn't expect, so you gain new test objectives you have to put into place to be able to understand a particular anomaly.

It's difficult to come up with exactly the number of flights you're going to need to really feel comfortable certifying a vehicle for an operational flight.

O'CONNOR Yes, certainly from a launcher perspective, having a program that's flying unmanned and manned together allows you to climb up that demonstrator liability curve a lot faster. If we started flying humans in 2014, Atlas V launches will be up in the 60s; Delta IV will be the 40s or 50s. We'll be pretty far along.

DICKMAN Final thoughts?

BLOOMFIELD Bryan mentioned that when we started to look at the Soyuz they had about 60 flights, and then we talked a lot about trust. I think that goes back to, how well do I trust these guys.

And we talked about the risk trades that need to be made instead of being very prescriptive about what the technical solution is, that the folks running the program have to show that ability to make the risk trades and not get suckered into making the poor judgments, which we're all susceptible to.

The last point I'd make is, if you look at Ares, it is built on known components. For example, the first stage has about 220. The technology on the shuttle has 220. So there's a lot of heritage and a lot of understanding there.

O'CONNOR One other thing on the Soyuz is, they're also flying Progress, which is very similar to the Soyuz. They can do development work on Progress while they're bringing new hardware online or new avionics, and test it there and then fly it on the shuttle or Soyuz. That gives them a way to on-ramp changes as well as to monitor the success of their systems on a much larger database.

In terms of how many test flights you need, it's like the oversight/insight question of how prescriptive you really need to be in this situation. It's hard for us to say "it depends" all the time. Makes us sound like a bunch of lawyers. But a lot of times it does depend on what vehicle you're talking about, what its history is, what its purpose is.

And then it depends on who's providing it; what's the culture of the company, what's the quality and competency of the leadership in place. That makes a big difference in how well you trust each other and the design that's coming forward.

I don't think you can make it quite that formulaic. Even though we're trying to achieve certain reliability numbers and probabilities, there are a lot of nonnumerical factors that enter into how many test flights you need and what depth of insight and oversight you need to ensure you're really ready to go do it.

BOWERSOX From the SpaceX perspective, a few things that are important in setting that number are how many unmanned flights you've had before you get there, and then just how much work you've put into your crew escape system.

You want a very robust crew escape system test program before you add people, but I don't think you can do enough to really be comfortable. But all the studies I've seen show you want somewhere between one and three unmanned tests, if you can do that. And it still amazes me that, for the space shuttle, we managed to fly humans on it the very first time.

DICKMAN Is there going to be more than one commercial provider of human launch because of demand?

O'CONNOR The Augustine commission asked that same question, and thought there was a reasonable expectation.

You asked when NASA and the different providers will get a chance to talk. When we put out this RFI we're also going to try to get with folks in person and get their feedback and talk to them before they get into the area where we're doing procurement stuff and have blackouts and all that. We'd like to get in as much talk as we can before all that starts.

There are some restrictions. And we all know about competition and so on, but we're not quite there yet on this. So the more we talk about it, the better.

NIELD One of my favorite management books is *The Seven Habits*, and one of those is, begin with the end in mind. So I'd like to see us as a community think not just about where we are today but where we want to be.

Where I would like to see us in the future is in a situation where there's more than one provider and more than one customer, and we have a healthy industry that is leading the world in terms of its technical capabilities and robustness and its safety and competitiveness.

As a community, what can we do to help facilitate that and to enable that? As government players, as industry players, how can we make that happen? It's hard, but that's what we ought to try to do.

BLOOMFIELD We can fly safely now in airlines because when there was an accident we investigated what went wrong and then tried to fix it.That's where NASA went with the Constellation architecture. It was built out of the CAIB, making crew safety number one, and then planning on an ability to fly in a different vehicle. Components on Ares V can be transferred to Ares I.

I think that's an important way to keep moving forward so that we don't keep repeating history, if you will. You know, what Richard Feynman said in his minority report still sums it up: "For a successful technology, reality must take precedence over public relations, for nature cannot be fooled."

BOWERSOX One of the reasons I joined SpaceX rather than staying with NASA when I decided to retire was I thought that having multiple sources of transportation to LEO was really important for our country. And over the next few years, as the commercial crew development activity gets going, if we don't end up with multiple sources, I think we've missed out on an opportunity.

Even our Russian partners in the ISS program would say that they'd like to have alternatives to Soyuz. So if you find a problem you're not pressed. You don't have to worry about abandoning what you're doing, and you have other ways to get people up to accomplish the useful work you want to do.

CULBERTSON Human spaceflight is very important for this country. It not only is an exciting thing to tell kids that they can do when they grow up, it's an exciting thing to do when you do grow up. It's also a great example of the human spirit in this country and our ability to take risks but keep pushing the frontiers out.

I do believe that there will someday develop a very robust market for multiple providers to go to LEO. I'm not sure when. In the immediate future there is just NASA, but we need to be prepared to take advantage of that if that's the case.

If we continue to safely fly people to LEO, the markets will develop. I can't say how when, but I think continuing to go is one of the most important goals we have to have in this country, by whatever means and procurement strategies turn out to be the best for making that happen.

The life extension of the ISS will be an important next step to continue to give us a reason to fly people in space, but there are other reasons, too, and I hope we don't give up on those.

SOWERS I agree. In the short term, NASA is the market, and NASA's market is really one turnover or six astronauts or six crewmembers every six months. A market like that is probably not enough to sustain competition. It could sustain two providers if NASA is willing to pay extra to have two, kind of EELV all over again.

We had two competitors in the EELV, but not enough market to have independent businesses, so ULA was formed. We kept the two systems, but we couldn't maintain two separate companies in perpetual competition. So we can have two if NASA wants two, but that'll cost more.

In the long run, we want to be able to attract real commercial business, and I think having NASA invest in this capability will do that. It'll lower barriers of entry for commercial business if NASA invests and allows the companies to sell to the commercial guys on the margin.

The EELV model was, the government was going to buy on the margin to this robust commercial market. That model didn't work. If we do it the other way, where NASA needs the capability, is paying for the capability and then allowing the commercial market to develop on the side, I think that can work.

REIGHTLER Human spaceflight is an important aspect of our overall space program, certainly one that we hope continues on. And human rating is an incredibly important part of making that successful, safe.

Lockheed Martin is a commercial space company. We've got a lot of experience in commercial space ventures, some good, some bad, but we've learned a lot and are trying to apply those lessons. Whether we can make a commercial go of this really depends a lot on exactly what it is that is expected and the contractual situation you find yourself in.

SHAW I believe space belongs to everyone. And the more people we can get there, the better. Over half of our company does commercial fixed-price development and sales of high-risk systems. And I very much believe we are capable of working with the others to provide such a service to NASA and other users.

But there has to be a reasonable business case with acceptable risk to Boeing's bottom line and reputation before we can enter into this kind of agreement.

DICKMAN Well, AIAA doesn't have a position on the issues at hand, but I don't think there's anyone at this table who doesn't believe the companies involved can deliver a safe human ability to get to LEO. This can be done. This is something the U.S. can do. The companies involved are good enough, and NASA can bring this together, and FAA can provide an infrastructure that they can make this work. Thank you all for participating.

After a year of refurbishing, Hypervelocity Wind Tunnel Number 9 in White Oak, Md., has emerged from the edge of extinction, serving again as the nation's premier facility for hypersonic testing. It continues a legacy that began, shrouded in mystery, during WW II and lives on today, ensuring that the workforce of the future will be trained in the use of this vital resource and others like it.

Tunnel 9: A national treasure reborn

Hidden in a wooded campus in White Oak, Md., just a few miles north of the Washington, D.C., beltway, the nation's premier high-speed wind tunnel has just emerged from a year-long period of refurbishing and upgrades.

Few even know of its existence. Yet the tunnel, nestled in the middle of the 712-acre former site of the Naval Surface Warfare Center, has been a part of aerospace history for almost 35 years, contributing to nearly every significant U.S. high-speed flight program since the late 1970s.

Hypervelocity Wind Tunnel Number 9, or Tunnel 9 to its operators and customers, is capable of reproducing flight conditions in excess of Mach 14, well into the regime generally identified as hypersonic—more than five times the speed of sound.

Although several other facilities around the world can reach these flow speeds, Tunnel 9 can produce realistic flight conditions for as long as 15 seconds. That may not seem like much, but it is effectively "forever" in the world of hypersonic flow. In contrast, the vast majority of high-speed wind tunnels provide test times on the order of just a few thousandths of a second.

The office corridors of Tunnel 9 are replete with photographs of its many successes, including early tests of the space shuttle, various missile defense concepts, and most recently the USAF/DARPA Hypersonic Test Vehicle (HTV-2) maneuvering reentry craft, which launched on April 22 of this year but unfortunately was lost. This entire complex was almost abandoned, a victim of the Base Realignment and Closure process of the mid-1990s. That it has survived and prospered as a vital national test asset is a tribute to the foresight of its managers and sponsors. It also serves as

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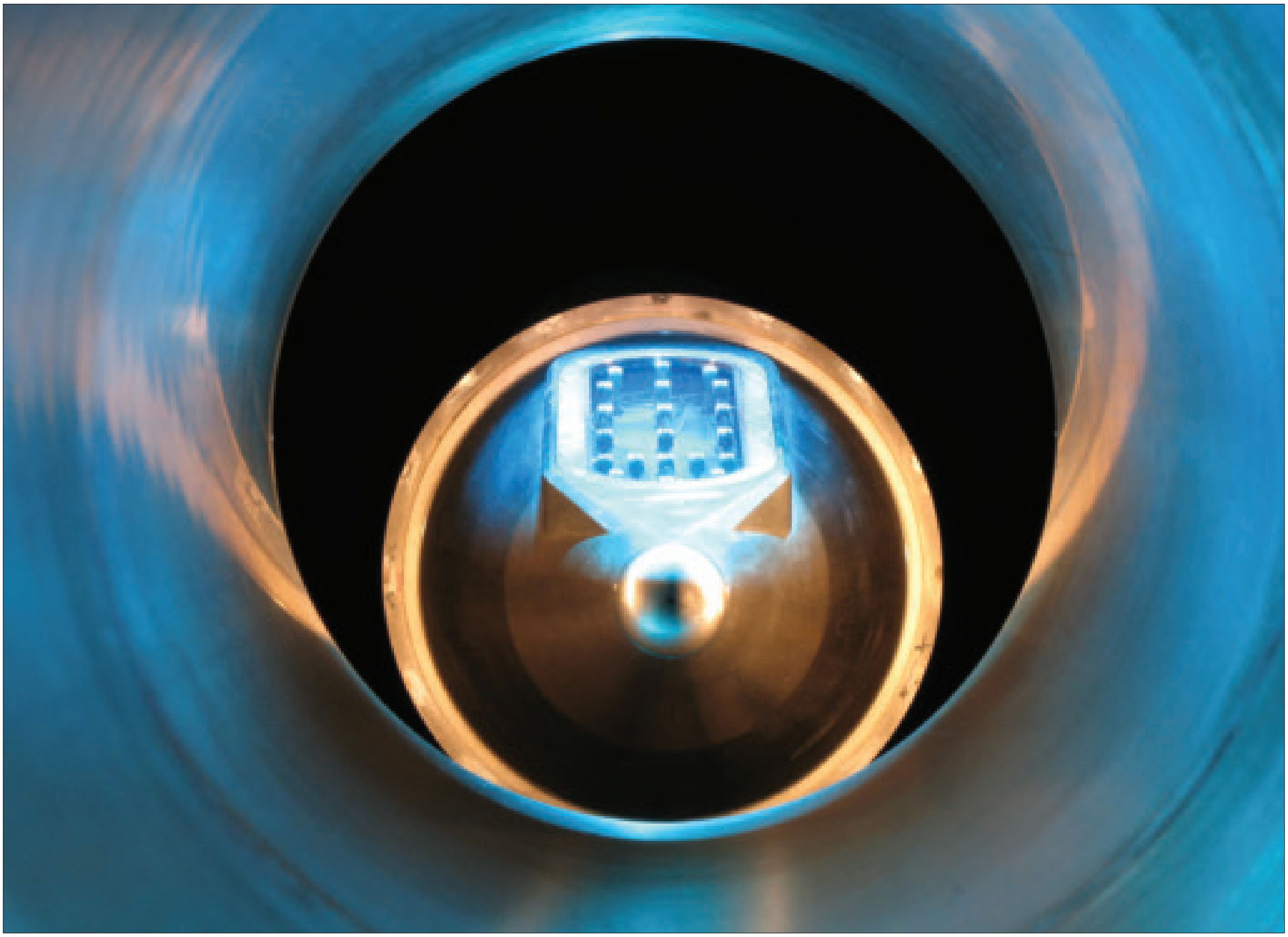


A full-scale flight-quality seeker window was tested for the Missile Defense Agency in the Tunnel 9 Mach 7 thermostructural leg to assess the performance and survivability of optical windows under high heating loads.

continuing proof of the value of high-fidelity ground test facilities.

Learning to fly hypersonically

The evolving role of Tunnel 9 has reflected changes in the way ground test facilities are used in developing flight programs. At a time when some believe that wind tunnels are destined to be replaced entirely by computational simulations, this facility and others of its kind continue to provide significant value, and are key players in the international quest for high-speed flight. (See "Wind tunnels: Don't count them out," April, page 38.)

Indeed, the most recent efforts to bring the tunnel into the 21st century have come during what will be a banner year for hypersonics, culminating in several flight programs that would not have been successful without ground test.

Hypersonic flight is not new; the first man-made hypersonic object flew on February 24, 1949, when a WAC Corporal sounding rocket was lofted atop a captured German V-2 missile at White Sands. Since that time, every spacecraft that has reentered Earth's atmosphere, and every probe penetrating another planet's atmosphere, has flown at hypersonic speeds. All have been decelerating craft, slowing down as a result of drag as they enter the atmosphere. In contrast, some of today's most exciting hypersonic projects are exploring high-speed cruisers and accelerators—craft that can fly through the atmosphere, either as gliders or under their own power, for prolonged periods of time.

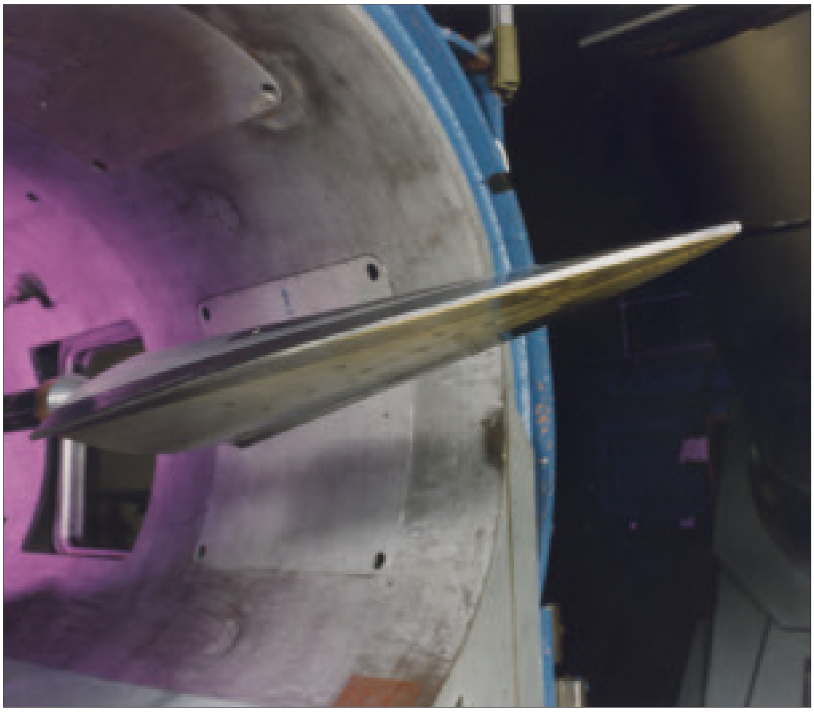
The range of applications for hypersonic craft could profoundly affect military technology, transportation, and civilian access to space. Hypersonic cruise missiles could cover hundreds of miles in a matter of minutes. Hypersonic reconnaissance aircraft could be deployed for rapid sensing in remote areas, possibly filling in for absent space monitoring systems, or providing a closer look at items of interest around the globe. And air-breathing space launchers, using advanced engines to accelerate in the atmosphere on their way to orbit, offer the ultimate promise of airplane-like operations into space.

Despite these promises, efforts to build and fly a hypersonic craft have been mixed at best. Billions of dollars have been spent on failed programs, ranging from the original 1960s AeroSpace Plane to DARPA's recent Blackswift, leading some to question whether hypersonics will ever be practical. Post-mortem analyses usually conclude that the programs have been too ambitious, linking unrealistic goals to insufficient funds. The poster child for this is the X-30 National Aero-Space Plane, a mid-to-late-1980s program that was to provide single-stage-to-orbit airplane-like flight.

Regardless of past failures, this is an exciting time in hypersonics. A wide spectrum of flight programs and research activities that will be filling the gaps in our hypersonics knowledge is currently in progress in the U.S. The USAF X-51 program is leading the way this year in flight testing of a Mach-6-class missile-type cruiser powered by conventional jet fuel. The Navy's HyFly program is similarly developing hypersonic missile capabilities, and although it suffered two flight test failures (unrelated to their hypersonic technologies), hopes are high for eventual success.

Even the fundamental research community is having a banner year, with the joint U.S.-Australia HIFiRE program, aimed at delivering a series of hypersonic flight experiments, and the robust basic research efforts jointly sponsored by the Air Force Office of Scientific Research and NASA.

This waverider was collaboratively developed by the University of Maryland, Boeing, and Tunnel 9. The configuration was the first attempt to test a waverider shape designed for good aerodynamics and good volume and packing, with realistic leading-edge bluntness to survive high heat loads.



Test before flight

With so many flight programs in progress, it is tempting to question the need for hypersonic ground test facilities. Indeed, in the days of the NASP program, engineers were predicting that computational tools would soon replace all ground testing, and hypersonic tunnels could all be mothballed. In fact, the reverse has proven to be true.

Program experience has shown more than ever the importance of testing before flight. Some basic issues, such as unsteady shock phenomena, heating rates associated with boundary-layer transition, and the effects of surface gaps and bumps on the flow, are still poorly understood, and only experimental measurements will be directly revealing. In at least one recent case, ground test has proven essential to determining the thermal protection required for a maneuvering reentry test, revealing details computational simulations had completely missed.

Tunnel 9 is unique in hypersonic ground testing. It uses a "blowdown" design, where flow is literally blown from a high-pressure supply into a vacuum. This approach can provide test times long enough to see unsteady effects and other complicated phenomena that may not be captured in shorter duration facilities. Long test times also allow a model to be moved during the course of a single run, so a wide range of angles of attack can be studied in a single experiment. The tunnel also has two separate test sections that can be rolled in and out, and varying the nozzles enables simulation of flight conditions at Mach 7, 8, and 10, in addition to 14.

Of course, there are always engineering tradeoffs, and the blowdown approach has its challenges compared to shorter duration facilities. Because energy is conserved, as the gas in a blowdown tunnel accelerates through the nozzle, its temperature and pressure drop. By the time it reaches Mach 14, the temperature will have dropped by a factor of 40, and pressure will have decreased by a factor of 400,000. This means the gas must start at extremely high pressures and temperatures or it will condense as it expands in the tunnel. Much of Tunnel 9's technology, therefore, involves the storage of gas at extremely high pressures and temperatures, so that by the time it reaches a model there is still a good match to realistic flight conditions.

This principle depends on having an enormous high-pressure gas reservoir. Buried under the ground at the White Oak campus is a gas supply farm where nitrogen is com-

Building on a legacy

This state-of-the-art tunnel has a history that began with the end of WW II, when Allied forces were evaluating German advances in aeronautics. Theodore von Kármán, one of the top aerodynamicists of the 20th century, led a delegation to postwar Europe to identify critical German researchers and facilities. Working under the instructions of Gen. Henry (Hap) Arnold, head of the Army Air Corps, von Kármán found an aeronautics research and testing complex hidden in a forest on the outskirts of Braunschweig.

As von Kármán later explained, the entire complex had been unknown to the allies during the war. The facility, he said, "was discovered only when the American Army moved into the area. We heard that it was a fantastic place where Germany's ultimate secret weapons were being developed. We went there immediately. There was an airfield which was concealed by means of cover of ash, so it would not present a smooth surface from the air….The whole thing was incredible. Over a thousand people worked there, yet not a whisper of this institute had reached the ears of the Allies."

Fifty-six buildings were identified in the complex, all below tree level and widely spaced so as to be camouflaged. Nearly 3 million documents were recovered, including details on such significant advances as swept wings for high-speed flight. This and other discoveries convinced observers that the U.S. needed its own testing and evaluation centers, especially for the soon-to-be-separate USAF.

A bidding war began among the Allies for captured facilities and equipment and for the scientists who built and ran them. Under Project Paperclip, key individuals in the German military research establishment were brought to the U.S. Among the facilities found were supersonic wind tunnels that Wernher von Braun's team had used in the development of the V-2 missile. The tunnels were crated up for transport to the U.S. They found their way to what was then the newly constructed Naval Ordnance Laboratory at White Oak, Md., but the exact details of how they got there are sketchy. Oral history has it that the tunnels were originally supposed to be sent to the Army, but the Navy wanted them instead. How they wound up in the hands of the Navy is not entirely clear—stories are still told of Navy personnel sneaking into the complex and carrying out crates under cover of darkness. But when the parts arrived at White Oak they were stamped with Army Air Corps labels. Those tunnels became the original "Tunnel 1" and "Tunnel 2," establishing the numbering system that has culminated in "Tunnel 9." About a dozen German engineers also came to White Oak.

Today, parts of the original Tunnel 1 from Peenemünde can be seen on display in the lobby of the complex. Before it was decommissioned, the tunnel was heavily modified, but the test chamber door and an original model of a V-2 derivative rocket still survive as a reminder of Tunnel 9's heritage.

In the two decades following WW II, the laboratory at White Oak added a series of high-speed tunnels, designated 3, 4, 6, 7, 8 (5 was conceived but not built) and finally a modified 8A. They had ever-increasing capabilities, and each played an important role in the development of supersonic flight, both into the atmosphere and beyond. In the early 1960s there was growing recognition that the Navy Submarine-Launched Ballistic Missile Program needed a new facility for the testing of reentry vehicles, and Tunnel 9 was born.

pressed to pressures that are over 1,900 times greater than normal atmospheric pressure; that gas is subsequently heated to temperatures close to 3,500 F on its way through the tunnel and into the test section. Because the heaters cannot survive in oxygen, Tunnel 9 must use only nitrogen, meaning that it cannot simulate combustion conditions.

At the beginning of a test, a 72-ft-diam. vacuum tank is pumped down at one end of the facility, and the high-pressure storage tanks are heated at the other. Initially, a set of metal diaphragms is ruptured by gas pressure and the high-temperature compressed nitrogen races down a 40-ft-long nozzle toward a 5-ft-diam. test cell, then out to the vacuum sphere. The test cell has a unique model mount that can pitch through a range of angles, allowing for wide sweep of data in a single run. The pitching mechanism moves at a rate of 80 deg/sec, carrying heavy models smoothly and precisely. Measurement techniques including advanced flow visualization, pressure sensors, temperature sensors, and newly developed temperature-sensitive paints capture the flow physics.

A fast start…and almost a sudden halt

Authorized by Congress in 1966, first run with cold flow in late 1973, and finally calibrated by mid-1975, Tunnel 9 was fully operational by the nation's bicentennial. Within two years of its opening, the tunnel had completed nearly 300 test runs, in support of all three armed services and NASA, in particular the development of the space shuttle. The start of the Strategic Defense Initiative under President Ronald Reagan in the early 1980s saw a new flurry of activity at the facility, where development of optical windows for high-altitude interceptors was a top priority. At White Oak, part of the renamed Naval Surface Warfare

A new, and vital, mission

Perhaps as important as finding a new home with the Air Force, Tunnel 9 found a new mission as a result of the BRAC process in 1997. Rep. Steny Hoyer (D-Md.), who was instrumental in saving the tunnel, offered an important charge to the facility and its staff: Become more closely connected with engineering education, especially reaching out to the nearby University of Maryland campus. This is a responsibility that the tunnel staff has taken very seriously, with extremely positive results.

Almost immediately after Tunnel 9 became an Air Force facility, its staff began an internship and co-op program with the University of Maryland. Students at both the undergraduate and graduate levels have since been involved in nearly every major project at the tunnel. Today, students work directly on tests, help instrument models, work out new capabilities, and use available tunnel results to provide direct comparison to theory and computational solutions. Among the success stories is one of the first students in this program, Inna Kurits, who graduated with a master's degree working at the tunnel and is now employed there as an engineer. And the Tunnel 9 professionals have plans to expand these student opportunities, with the help of the Air Force Research Laboratory.

In part, the motivation for doing so is nothing less than to preserve the very future of ground testing. There is a genuine concern about training the next generation of tunnel engineers. The average age of the contractor workforce at AEDC is nearly 50, and the average time of service approximately 17 years. At Tunnel 9, all but seven of the total 35 employees have worked there less than 20 years, and most will be eligible for retirement within the next decade. To keep the tunnel operating into the future, and to preserve and develop other ground test facilities, AEDC's leadership recognizes the need for fresh blood.

Upgrading the Tunnel 9 facility has confirmed its relevance to the future of hypersonic flight. Focusing on student involvement, research, and education has ensured that it will have the skilled workforce to use this facility, and others like it, for many years to come.

Center, Tunnel 9 was the centerpiece of a Navy operation that covered the range of hypersonic flight technologies.

Then the 1995 Base Realignment and Closure (BRAC) Commission set its sights on the entire Navy organization at White Oak. Tunnel 9 was almost shut down.

The BRAC process was created to reduce the number of military installations in the post-Vietnam era. Recognizing that each military base would have its own constituents (who could thus fight any closure recommendation), the BRAC Commission was established to recommend installations that might be closed or combined with similar facilities; their recommendations were set to go into effect unless Congress were to specifically disapprove the list by joint resolution. When the commission placed the entire Navy installation at White Oak on its list of recommended closings, Tunnel 9's fate was all but sealed.

But recognizing its unique capabilities and its importance to the entire nation, DOD leadership transferred ownership of Tunnel 9 and its support facilities to the Air Force, under the auspices of the Arnold Engineering Development Center (AEDC) in Tullahoma, Tenn. AEDC already operated a list of other world-class hypersonic facilities, each with a unique set of capabilities, including materials testing and high-speed propulsion applications.

On October 1, 1997, Tunnel 9 officially became a part of the USAF; 40 acres are maintained inside the former Naval Surface Warfare campus for the tunnel and its support. The rest of the site is managed by the General Services Administration for the Food and Drug Administration.

Rebuilt for a new generation

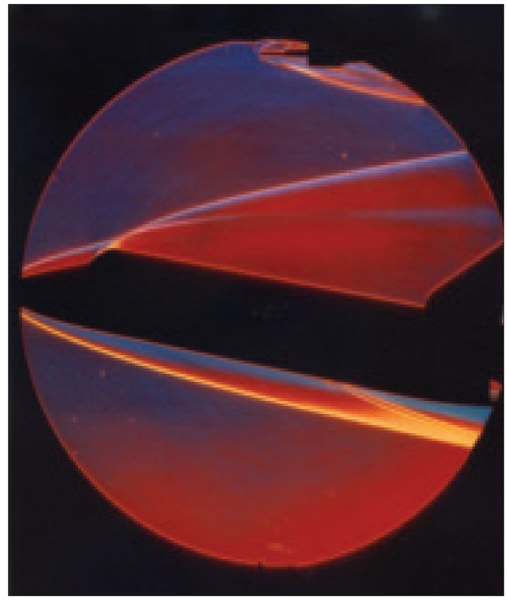
Tunnel 9 received an initial facelift when the Air Force took ownership, but after 10 years it was time for further improvements. Planned FDA construction around the tunnel offered the perfect hiatus for a complete upgrade, including the installation of a state-of-the-art digital control room to replace the old 1970s-era analog system. With a year to plan, engineers readied several experiments and greatly improved instrumentation capabilities in preparation for the tunnel's return to service. March of this year saw the first runs with the new control room and instrumentation, producing significant new results.

In another new approach, the tunnel's technical director, John Lafferty, has successfully coordinated research efforts at Tunnel 9, AFOSR, and universities to perform several experiments simultaneously in the tunnel's vast test section. "By piggy-backing multiple experiments we can maximize the usefulness of the unique conditions provided during each run; this is critical to providing researchers the needed access. Certain challenges in hypersonics cannot make significant advances without access to the salient physics that can be provided by a facility like Tunnel 9," says Lafferty. That approach has already proven extremely successful.

The recent upgrades also reflect a change in the way Tunnel 9 intends to do business in the future. Says Dan Marren, AEDC site director, "Success here will require building partnerships with science and technology activities, inventing test techniques and methods tuned to obtaining important hard-to-measure quantities and providing data in a format that feeds the weaknesses in our computational models." Reflecting the changing nature of ground tests, future tunnel runs will not be isolated data-gathering exercises, conducted only as a precursor to flight. Rather, they will be linked to computation, and some will be done as follow-ups to flight tests.

Marren points out that the first shakedown tests were also an opportunity to include partners in academia, other Air Force organizations, NASA and the Dept. of Energy. That is very much in keeping with the facility's new operating philosophy, integrating more research opportunities into the test and evaluation function of the tunnel.

One researcher who appreciates what Tunnel 9 can do for the research community is Pino Martin, a professor at the University of Maryland and one of the world's foremost authorities on computational simulation of hypersonic flows. As Martin explains, "Tunnel 9 provides the widest range of Mach number and Reynolds number flow conditions in the nation. Using and extending experimental data from Tunnel 9 will allow for the development and validation of new computational tools well beyond the current state of the art."



A series of aerothermal and aerodynamic stability tests of the space shuttle were completed in Tunnel 9 in the late 1970s.

25 Years Ago, July 1985

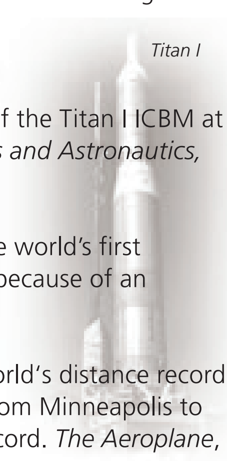
July 19 As part of its Teacher in Space project, NASA selects Concord, N.H., teacher Sharon Christa McAuliffe to become the first private citizen passenger in the history of spaceflight. *Aviation History Facts*, Centennial of Flight Web site.

50 Years Ago, July 1960

July 1 The George C. Marshall Space Flight Center officially opens at Huntsville, Ala., with Wernher von Braun as its director. Von Braun, who was technical director for the development of the V-2 rocket at Peenemünde in Germany before and during WWII, also headed a core group from his V-2 team after the war at Fort Bliss, Texas, and later at the Redstone Arsenal in Huntsville, where the group developed the Redstone and Jupiter missiles. He now brings the same team to Marshall, where they subsequently contribute to the development of the Saturn launch vehicles that take the first men to the Moon under Project Apollo. E. Emme, ed., *Aeronautics and Astronautics, 1915-60*, p. 125.

July 1 An Air Force RB-47H Stratojet is shot down by a Soviet MiG-19 in inter-national airspace over the Barents Sea near the Russian coast. Four of the crew are killed, two are captured by the Soviets but are later released in 1961. *The Aeroplane*, Aug. 5, 1960, p. 151.

July 1 The first complete all-solid-fuel four-stage Scout launch vehicle for boosting light payloads is test fired at NASA's Wallops Island facility. The fourth stage fails to separate, although measurements are taken at 1,007 mi. D. Baker, *Spaceflight and Rocketry: A Chronology*, p. 104.


Titan I

July 1 The attempt to test fire the first operational version of the Titan I ICBM at Cape Canaveral downrange, fails. E. Emme, ed., *Aeronautics and Astronautics, 1915-60*, p. 125.

July 1 After taking 22,952 photos of Earth's cloud cover, the world's first weather satellite, Tiros I, ceases transmitting useful pictures because of an electronics failure. *The Aeroplane*, July 15, 1960, p. 90.

July 4 Max Conrad, flying a Piper Comanche, sets a new world's distance record for this class of light planes in a closed circuit of 6,921 mi. from Minneapolis to Chicago to Des Moines in 60 hr. This doubles the previous record. *The Aeroplane*, July 22, 1960, p. 98; *The 1961 Aerospace Year Book*, p. 444.

July 5 The Boeing 720, which can carry 165 passengers, begins commercial service on United Air Lines' Chicago-to-Denver route. D. Baker, *Flight and Flying*, p. 372.

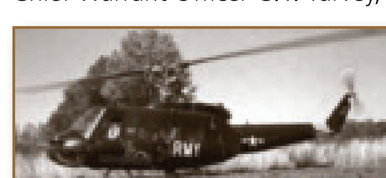
July 6 The largest nonrigid U.S. airship, a 403-ft craft used by the Navy's Early Warning Radar Squadron, is lost at sea off the New Jersey coast. *The Aeroplane*, July 15, 1960, p. 85.

July 8 The second experimental U.S. nuclear rocket reactor in the Project Rover nuclear rocket program, Kiwi-A Prime, is successfully tested at full power at Jackass Flats, Nev. E. Emme, ed., *Aeronautics and Astronautics, 1915-60*, p. 125.

July 11 Hughes Aircraft, the Space Technology Laboratory, North American Aviation, and McDonnell Aircraft contract with NASA to undertake feasibility studies for a manned lunar soft-landing spacecraft. Later this month, at the agency's Industry Conference in Washington, D.C., Project Apollo is announced; NASA's Abe Silverstein suggests the name to continue the use of mythical gods for naming manned space vehicles. E. Emme, ed., *Aeronautics and Astronautics, 1915-60*, p. 125: D. Baker, *Spaceflight and Rocketry: A Chronology*, p. 105.

July 17 British radar pioneer Air Marshal Sir Raymond Hart dies at 61. He was the first RAF officer to work with Robert Watson-Watt, considered the inventor of radar. Hart is also known for a remarkable air victory during WW I, and for pioneering ground control interception stations during WW II. *The Aeroplane*, July 29, 1960, p. 121.

July 19-26 An Army Bell HU-1 Iroquois helicopter beats three Russian-held international rotary-wing records during closed-circuit races. The flights, piloted by Col. Jack Marinelli, with Maj. G.J. Boyle and Chief Warrant Officer C.V. Turvey,



Past

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

include distance and speed records previously held by a Russian Mi-1. *The Aeroplane*, Aug. 12, 1960, p. 176.

July 20 For the first time, a Polaris IRBM is test launched from a sub-marine, the nuclear-powered George Washington. The firing takes place while the submarine is cruising about 30 mi. off the coast of Cape Canaveral, at a depth of about 90 ft. The missile is shot out of the launching tube by compressed air, its motor automatically igniting as it clears the water. It reaches 1,100 mi. downrange, north of Puerto Rico. *The Aeroplane*, July 29, 1960, p. 220.

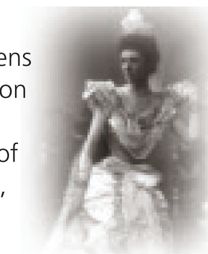
July 22 NASA's Iris solid-fuel sounding rocket is successfully launched for the first time. Although built by Atlantic Research for the Naval Research Laboratory, the Iris became a NASA program when the lab's rocket group was transferred to the agency E. Emme, ed., *Aeronautics and Astronautics, 1915-60*, p. 125.

July 28 A successful test firing of the first stage of the solid-fuel Caleb rocket, following its release from a McDonnell F4D-1 Skyray, takes place off the California coast. The ultimate aim of the effort, known as Project Hi-Hoe, is to place an air-launched satellite in orbit. But only one of the Hi-Hoe flights is successful, when a two-stage Caleb reaches 726 mi. on July 26, 1962. D. Baker, *Spaceflight and Rocketry: A Chronology*, p. 105.

July 29 The two-stage Thor-Agena fails to orbit the Discoverer XII reconnaissance satellite at Vandenberg AFB, Calif. The plan had been to recover the Discoverer capsule ejected on its 17th orbit. *The Aeroplane*, July 8, 1960, p. 31.

75 Years Ago, July 1935

July 11 Laura Ingalls pilots her Pratt & Whitney Wasp-powered Lockheed Orion, the Auto-da-Fe, from Floyd Bennett Field in New York to Burbank, Calif., in 18 hr 19.5 min, becoming the first woman to fly the East-West transcontinental route nonstop. *Aero Digest*, August 1935, p. 68.



July 13 The new Leicester Municipal Airport opens in England. The ceremony concludes with an aerial competition featuring a solo flight by the Duchess of Bedford. With over 200 hr in her log books, she is known as the "grand old lady of aviation." RAF aircraft also fly overhead. *Flight*, July 18, 1935, pp. 72-74.

July 13 The largest mass flight of gliders, 20 in all, sets a U.S. record on the final day of the Sixth Annual National Soaring Contest at Elmira, N.Y. On the same day, new U.S. gliding records for women are set by Allaire C. duPont, who reaches an altitude of 3,600 ft for 5 hr 31 min. *Aero Digest*, August 1935, p. 68.

July 16-17 Mario Stoppani of Italy, with Capt. Casimiro Babbi and Pilot Officer Piaggio-d'Ascanio, break the world's record for a nonstop flight in a seaplane when they fly 3,104 mi. from Monfalcone, Trieste, to Berbera, British Somaliland, in 24 hr 55 min. They fly a Cant Z.501 monoplane with a 750-hp Isotta Fraschini engine. The previous record was 2,658 mi. *The Aeroplane*, July 24, 1935.

July 17 A Martin M-130 flying boat lifts a record 24,000 lb on a flight from Middle River, Md., during Pan American Airways tests. The aircraft carries the load to a height of 18,200 ft. *Aero Digest*, August 1935, p. 68.

July 20-21 The winner of La Coupe Armand Esders, considered the French Aero Club's Grand Prix, is Comte de Chateaubrun, who flies his Percival Mew Gull with a French 180-hp Regnier motor at an average speed of 188 mph over a 520-mi. course between Deauville and Cannes. The race is limited to machines that have a total cylinder capacity of not more than 8 liters. *The Aeroplane*, July 24, 1935, p. 132.

And During July 1935

—Armstrong Siddeley Development Co. and Hawker Aircraft merge to form Hawker Siddeley Aircraft of Great Britain. Pioneer British aircraft designer T.O.M. Sopwith is named chairman of the new company. *Flight*, July 11, 1935, p. 59.

100 Years Ago, July 1910

July 9 Walter Brookins becomes the first person to fly a mile high, reaching an altitude of 6,175 ft in a Wright biplane and winning a prize of $5,000.

Out of the

25 Years Ago, August 1985

Aug. 2 Germany's Messerschmitt-Bolkow-Blohm, Italy's Aeritalia, and British Aerospace agree on joint development of the European Fighter Aircraft, intended to enter service in the mid-1990s. B. Gunston, ed., *Aviation Year by Year*, p. 806.

50 Years Ago, August 1960

Aug. 2 A Naval Research Lab Aerobee sounding rocket is launched from the White Sands Proving Grounds, N.M., and attains a 90-mi. altitude, where its instruments measure the ultraviolet spectrum of the Sun. E. Emme, ed., *Aeronautics and Astronautics, 1915-60*, p. 125.

Aug. 4 The North American X-15 (No. 1) rocket research airplane, flown by NASA test pilot Joseph Walker, sets an unofficial new world's speed record of 2,196 mph, although the aircraft uses its Interim rocket engines, a pair of 8,000-lb thrust XLR-11 rocket engines. The engine designed for the plane, the 59,000-lb-thrust XLR-99, is still under development but will be used in later flights of the X-15. *The Aeroplane,* Aug. 12, 1960, p. 175; D. Baker, *Flight and Flying*, p. 372.

Aug. 5 NASA and DOD announce the settlement of a patent suit initiated in 1951 by the Guggenheim Foundation and the estate of the late U.S. rocket pioneer Robert H. Goddard against the U.S. government for possible prior infringement of his work. Goddard patented many basic improvements in rockets before his death in 1945. The settlement is for $1 million, of which the USAF is to pay $750,000, the Army $125,000, NASA $100,000, and the Navy $10,000. E. Emme, ed., *Aeronautics and Astronautics, 1915-60*, p. 125.

Aug. 10 Discoverer XIII is successfully placed in a polar orbit. The following day, the craft's 85-lb instrumented capsule is recovered from the Pacific Ocean off Hawaii, becoming the first man-made object recovered from space and the first successful U.S. photo reconnaissance satellite. D. Baker, *Flight and Flying*, p. 372.

Aug. 10 The first operational configuration of the Titan ICBM is flown 5,000 mi. downrange from Cape Canaveral, Fla. This is the first completely successful launch of the Mark I version of the missile. *The Aerospace Year Book*, 1961, p. 445.

Ivan Kincheloe

Aug. 12 The transonic X-15 rocket research aircraft (No. 1) sets another new altitude record when pilot Ivan Kincheloe takes it up to 136,500 ft. D. Baker, *Flight and Flying*, p. 372.

Aug. 12 Echo 1, a 100-ft-diam aluminized Mylar-plastic balloon satellite, is launched by a Thor-Delta and becomes the first passive communications satellite. It reflects a radio message from President Eisenhower that is broadcast across the country. Visible to the naked eye, Echo 1 is also the largest satellite launched to date. E. Emme, ed., *Aeronautics and Astronautics, 1915-60*, pp. 125-126.

Aug. 16 Capt. Joseph W. Kittinger Jr., USAF, is safely parachuted from the Excelsior III stratospheric balloon at about 103,000 ft above the New Mexico desert. He falls for 17 mi. before his chute is deployed at 17,500 ft, a new parachute record. This is also the highest manned balloon ascent, the highest ascent in an open gondola, and the longest free fall. Kittinger's total descent time is 13 min 8 sec. E. Emme, ed., *Aeronautics and Astronautics, 1915-60*, p. 125.

Aug. 17 A specially equipped Russian Il-14 aircraft departs from Leningrad for the Arctic coast of the USSR on the Aerometeorological Expedition headed by A.I. Voskredensky, under the support of the Arctic and Antarctic Institute. The six-week expedition is to make weather-gathering data reconnaissance flights to high latitudes for the benefit of ships sailing the northern sea route. *The Aeroplane*, Sept. 9, 1960, p. 339.

Aug. 19 U.S. pilot Francis Gary Powers is sentenced in a Moscow trial to 10 years' imprisonment for espionage conducted while flying over Soviet territory in his U-2. (The plane was shot down by a Soviet surface-to-air SA-2 missile on May 1, but Powers successfully parachuted to a safe landing.) He is released in 1962. *Flight*, Aug. 26, 1960, p. 288.

Past

Aug. 20 The dogs Strelka and Belka are successfully recovered from the 4,600-lb orbiting Sputnik V by the Soviet Union. The satellite was launched on the previous day by a Vostok booster from the Baikonur Cosmodrome up to an apogee of 210 mi. and a perigee of 190 mi. These are the first terrestrial creatures to go into orbit and return alive, paving the way for the first human orbital flight less than eight months later, when Vostok 1 carries Yuri Gagarin. *The Aeroplane,* Sept. 16, 1960, p. 396; D. Baker, *Spacefight and Rocketry*, p. 106.

Aug. 26 Construction on the world's largest radio telescope begins at Arecibo, Puerto Rico. Cornell University is the prime contractor. The huge dish is capable of bouncing signals off Venus, Mars, and Jupiter. E. Emme, ed., *Aeronautics and Astronautics, 1915-60*, p. 125.

Aug. 28 Famed British pilot James Ira "Taffy" Jones dies. Known for downing some 28 enemy aircraft and three balloons during WW I, Jones is also said to have survived 28 crashes during the war. *The Aeroplane*, Sept. 9, 1960, p. 339.

Aug. 29 Distinguished British aviatrix Lady Bailey dies at 70. She learned to fly in 1926 and became the second woman to get an "A" license. She made a name for herself in air racing and in 1927 set a British altitude record of 17,283 ft for light airplanes. She was the first woman to fly across the Irish Sea but is best remembered for her 1928 flight from Croydon, England, to Cape Town, South Africa, a distance of 8,000 mi., and back in a Standard De Havilland Moth. *The Aeroplane*, Sept. 9, 1960, p. 340.

75 Years Ago, August 1935

Aug. 4 Two Soviet balloonists, Boris Romanoff and Andre Babrishkin, claim a world's record for flight duration. They remain aloft for 56 hr and cover 350 mi. Thomas W. Settle and Charles W. Kendall of the U.S. Navy held the previous record of 51 hr. *Aero Digest*, September 1935, p. 62.

Aug. 10 Maurice Arnoux beats his own speed record for a land machine over a course of 62 mi., reaching 296 mph in a Caudron C-460. His previous record was 292 mph. *The Aeroplane*, Aug. 14, 1935, p. 216.

Aug. 12 German aviator Elly Beinhorn makes the first nonstop flight from Germany to Turkey. She flies from Gleiwitz to Constantinople and back to Berlin in 14 hr 29 min in a Taifun-type Messerschmitt Bf. 108. The flying distance from Gleiwitz to Constantinople is 775 mi.; from there to Berlin is another 1,025 mi. *The Aeroplane*, Aug. 21, 1935, p. 227.

Aug. 15 Will Rogers, American humorist and philosopher, is killed while flying as a passenger with Wiley Post in Alaska, on the second stage of their vacation. The first stage covered 1,000 mi. from Seattle to Juneau. Their aircraft is a heavily modified Lockheed Orion with Lockheed Sirius wings. The plane, made dangerously nose-heavy by the addition of floats, crashes from low altitude because of carburetor icing. Post had earned worldwide fame as an aviator, particularly for round-the-world flights made in the Lockheed Vega Winnie Mae in 1931 and 1933. *The Aeroplane*, Aug. 21, 1935, p. 228.

Aug. 25 The American Rocket Society (ARS) begins its third series of static rocket tests on ARS Rocket Test Stand No. 2. The society abandoned its flight rocket program because of high costs and believes that more can be learned from close observations on the static stand. F. Winter, *Prelude to the Space Age: The Rocket Societies, 1924-1940*.

Aug. 31 Maryse Hilsz wins the Coupe Helene Boucher in a race from Paris to Cannes in a supercharged Gnome-Rhone K.14-powered Breguet 27-4. The race is open to women pilots of all nations. Hilsz's speed is 172.3 mph. Second is Claire Roman at 155.8 mph in a modified Maillet. *The Aeroplane*, Sept. 4, 1935, p. 307.

100 Years Ago, August 1910

Aug. 27 For the first time, radio signals are transmitted between the ground and an airplane in flight when James A.D. McCurdy uses an H.M. Horton radio while flying a Curtiss at Sheepshead Bay, N.Y. C. Gibbs-Smith, *Aviation*, p. 158.

THE UNIVERSITY OF IOWA

IIHR—Hydroscience & Engineering, THE UNIVERSITY OF IOWA, has an immediate opening for a Postdoctoral Research Scholar in the area of experimental fluid dynamics. Candidate must have earned a doctorate in Mechanical or Aerospace Engineering or a closely related discipline and have experience and/or interest in experimental methods and procedures for 6DOF radio-controlled models, GPS tracking systems, and PIV and air-water wave elevation local flow measurement systems with applications in ship hydrodynamics in support of IIHR's recently commissioned wave basin. Salary will be commensurate with qualifications and experience.

Applicants should submit a resume with a list of at least three references and copies of selected publications, if appropriate, to Professor Fred Stern, IIHR—Hydroscience & Engineering, The University of Iowa, Iowa City, IA 52242-1585 or by e-mail to frederick-stern@uiowa.edu with the subject header CFD/ship hydro postdoc/RE.

Applications will be screened as they are received and they will be accepted until the position is filled. Information about IIHR is available on the web at: http://www.iihr.uiowa.edu. Information regarding Office of Postdoctoral Scholars can be found at http://postdoc.grad.uiowa.edu.

The University of Iowa prohibits discrimination in employment or in its educational programs and activities on the basis of race, national origin, color, creed, religion, sex, age, disability, veteran status, sexual orientation, gender identity, or associational preference. The University also affirms its commitment to providing equal opportunities and equal access to University facilities. Women and minorities are encouraged to apply for all employment vacancies. For additional information on nondiscrimination policies, contact the Coordinator of Title IX and Section 504, and the ADA in the Office of Equal Opportunity and Diversity, 319-335-0705 (voice) or 319-335-0697 (text), The University of Iowa, 202 Jessup Hall, Iowa City, Iowa, 52242-1316.

Prospective employees may review the University Campus Security Policy and the latest annual crime statistics by contacting the Department of Public Safety at 319-335-5022.

FACULTY POSITION IN THE AREA OF SPACE SYSTEMS

Department of Mechanical & Aerospace Engineering
College of Engineering and Mineral Resources

The Department of Mechanical and Aerospace Engineering (MAE) at West Virginia University (WVU) seeks applications for a tenure-track faculty position at the rank of Assistant or Associate Professor with experience in the general area of Space Systems (Position #5101). This position requires demonstrated expertise in at least one of the following Space Systems specialties:

- Orbital mechanics including Earth orbits, interplanetary missions, orbital decay, trajectory optimization, guidance, navigation, and control,
- Spacecraft and subsystem design including in-space propulsion, attitude determination and control, power, thermal management and protection, command and data handling, space operations, and system design trades,
- Hypersonic planetary entry including Earth reentry vehicles, planetary probes, payload thermal protection, controlled accuracy, and soft landing.

Applicants must hold an earned doctorate in Astronautics, or alternately, Aerospace Engineering, along with strong oral and written communication skills. A proven commitment to innovative engineering education and a strong, demonstrated potential to develop an externally funded interdisciplinary research program are required. The successful candidate will be expected to lead a Departmental effort to develop a Space Systems track in the existing Aerospace Engineering undergraduate curriculum.

WVU is a comprehensive land-grant institution with an enrollment of over 29,000; a Carnegie High Research University at the center of a developing high-technology corridor, providing challenges and opportunities for candidates. The WVU MAE Department is nationally ranked by the National Science Foundation in the top 25 departments of mechanical engineering in research expenditures (NSF, 2008, 2009). It currently employs 29 tenure-track or tenured faculty members and is offering B.S., M.S., and Ph.D. degrees in both Mechanical and Aerospace Engineering to about 450 undergraduate students, 90 M.S., and 80 Ph.D. students. Graduate degree programs in Materials Science and Engineering are also being developed. The department conducts externally sponsored research in a diverse range of specialties, with strong active programs in aerodynamics, flight dynamics, computational fluid dynamics, structures, materials, flight simulations and controls, among others. Additional information may be found on the website of the MAE Department at www.mae.cemr.wvu.edu or by contacting Dr. Jacky Prucz, Interim Chairman, at jacky.prucz@mail.wvu.edu, or regular mail at P.O. Box 6106, Morgantown, West Virginia 26506-6106.

Review of applications will begin on August 16, 2010 and will continue until the position is filled. Electronic applications are required and should be sent to MAEDept@mail.wvu.edu. They should include a cover letter highlighting the applicant's qualifications for the above position, Position #5101, a curriculum vitae, concise descriptions of a research plan and a teaching plan, as well as contact information for three references.

West Virginia University is an Affirmative Action/Equal Opportunity Employer, which encourages applications from women, minorities, and individuals with disabilities, in commitment to building a diverse body of faculty and staff.

Faculty Position In The Area Of Unmanned Aerial Vehicles (UAV)

Department of Mechanical and Aerospace Engineering
College of Engineering and Mineral Resources

The Department of Mechanical and Aerospace Engineering (MAE) at West Virginia University (WVU) seeks applications for a tenure-track faculty position at the rank of Assistant or Associate Professor with teaching and research experience in the general area of Unmanned Aircraft Systems (UAS)/Unmanned Aerial Vehicles (UAV), Position #4101. This position requires demonstrated expertise in at least one of the following UAS/UAV fields of specialty: aerodynamics, propulsion, structures, or design. Applicants must hold an earned doctorate in Aerospace Engineering or a related engineering discipline, along with strong oral and written communication skills. A proven commitment to innovative engineering education and a strong, demonstrated potential to develop an externally funded interdisciplinary research program are required.

WVU is a comprehensive land-grant institution with an enrollment of over 29,000; a Carnegie High Research University at the center of a developing high-technology corridor, providing challenges and opportunities for candidates. The MAE Department is nationally ranked by the National Science Foundation in the top 25 departments of mechanical engineering in research expenditures (NSF, 2008, 2009). It currently employs 29 tenure-track or tenured faculty members and is offering B.S., M.S., and Ph.D. degrees in both Mechanical and Aerospace Engineering to about 450 undergraduate students, 80 M.S., and 75 Ph.D. students. Graduate degree programs in Materials Science and Engineering are also being developed. The department conducts externally sponsored research in a diverse range of specialties, with strong active programs in aerodynamics, flight dynamics, computational fluid dynamics, materials, flight simulations and controls, among others. Additional information may be found on the website of the MAE Department at www.mae.cemr.wvu.edu or by contacting Dr. Jacky Prucz, Interim Chairman, via e-mail at Jacky.Prucz@mail.wvu.edu or by regular mail at P.O. Box 6106, Morgantown, West Virginia 26506-6106.

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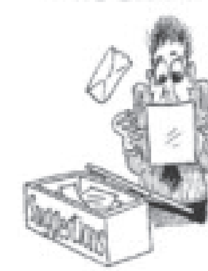
THE AIAA SUGGESTION PROGRAM



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

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

AIAA

FACULTY POSITION IN THE AREA OF ENERGY
Department of Mechanical and Aerospace Engineering
College of Engineering and Mineral Resources

The Department of Mechanical and Aerospace Engineering (MAE) at West Virginia University (WVU) seeks applications for a tenure-track faculty position at the rank of Assistant or Associate Professor with teaching and research experience in the general area of energy, Position #4102. Specific fields of specialty include, but are not limited to, fundamental issues of thermal sciences; energy applications in transportation; computational energy sciences; alternative fuels; and emerging renewable energy resources, such as biomass, biogas, wind, solar, etc. Applicants must hold an earned doctorate in Mechanical Engineering or a related engineering discipline. A proven commitment to innovative engineering education and a strong, demonstrated potential to develop an externally funded interdisciplinary research program are required.

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Review of applications will begin on August 16, 2010 and will continue until the position is filled. Electronic applications are required and should be sent to MAEDept@mail.wvu.edu. They should include a cover letter highlighting the qualifications of the applicant for the above position, the Position #4102, the curriculum vitae, concise descriptions of a research plan and a teaching plan, as well as contact information for three references.

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FACULTY POSITION IN THE AREA
OF SPACE SYSTEMS
Department of Mechanical & Aerospace Engineering
College of Engineering and Mineral Resources

The Department of Mechanical and Aerospace Engineering (MAE) at West Virginia University (WVU) seeks applications for a tenure-track faculty position at the rank of Assistant or Associate Professor with experience in the general area of Space Systems (Position #5101). This position requires demonstrated expertise in at least one of the following Space Systems specialties:

- Orbital mechanics including Earth orbits, interplanetary missions, orbital decay, trajectory optimization, guidance, navigation, and control.
- Spacecraft and subsystem design including in-space propulsion, attitude determination and control, power, thermal management and protection, command and data handling, space operations, and system design trades.
- Hypersonic planetary entry including Earth reentry vehicles, planetary probes, payload thermal protection, controlled accuracy, and soft landing.

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