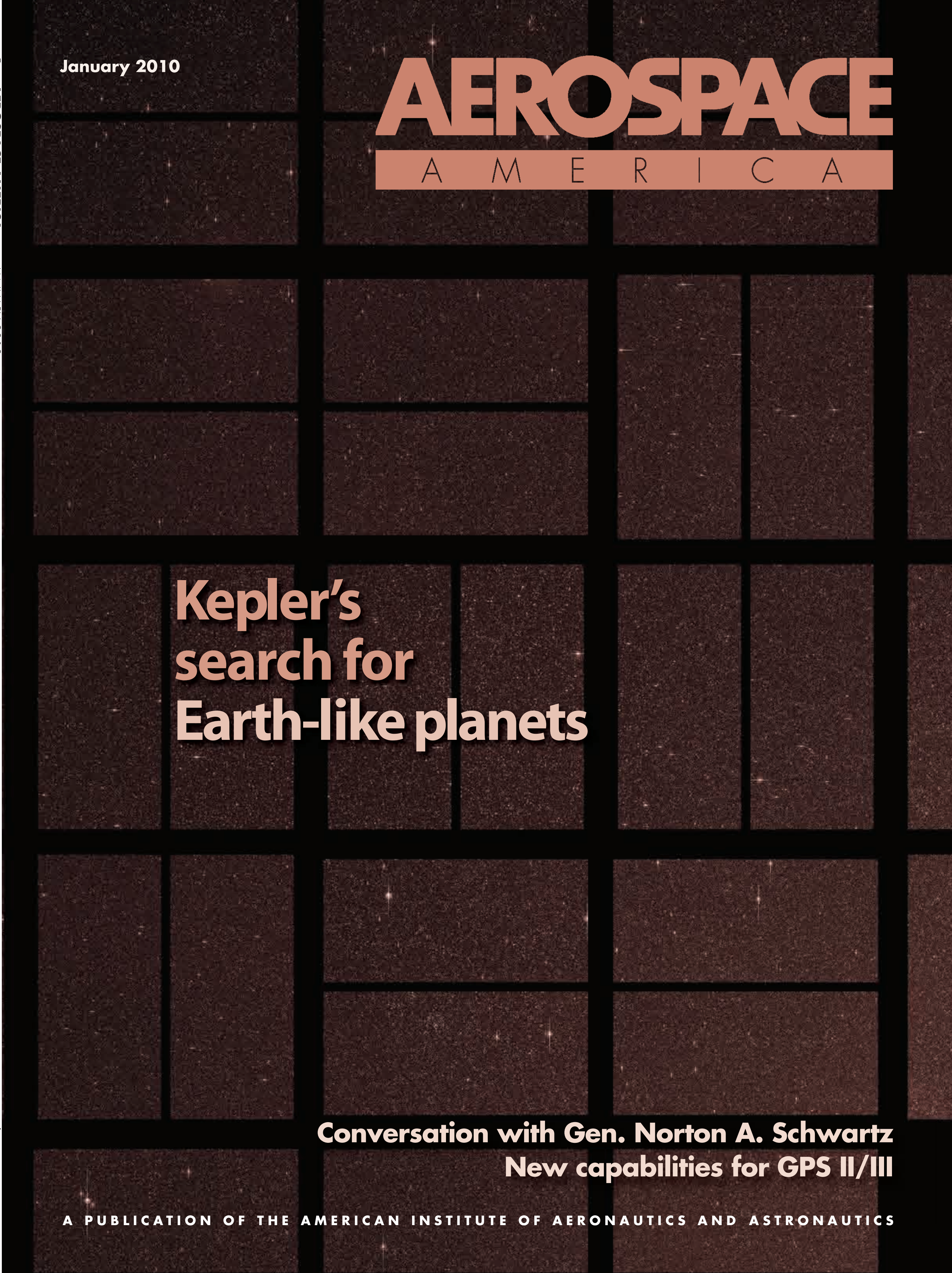
1 AEROSPACE AMERICA JANUARY 2010



January 2010

AEROSPACE AMERICA

Kepler's search for Earth-like planets

Conversation with Gen. Norton A. Schwartz

New capabilities for GPS II/III

A PUBLICATION OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

AEROSPACE AMERICA

January 2010

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COVER
This image from NASA's Kepler mission shows the telescope's full field of view—a star-rich patch of sky in the constellations Cygnus and Lyra. To learn about this effort to find Earth-like planets, turn to page 36

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Editorial

Mitigation and adaptation

For 12 days last December, government representatives from 190 nations came together in Denmark to participate in the United Nations Framework Convention on Climate Change. The convention, according to its official site, "sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. It recognizes that the climate system is a shared resource whose stability can be affected by industrial and other emissions of carbon dioxide and other greenhouse gases."

The end product of the meeting was to be known as the Copenhagen Protocol, supplanting the Kyoto Protocol that has been ratified by 184 parties but is due to expire in 2012. Squabbling arose over targets, and politics often drove the debate, but while no party attending the meetings argued about the need for greenhouse gas mitigation, the final outcome was far from certain.

But that these discussions could be held at all is in no small measure thanks to the data provided by instruments aboard satellites from many nations.

During the convention, representatives from a broad spectrum of space agencies attended a side event, hosted by the European Space Agency, entitled Global Monitoring of our Climate: the Essential Climate Variables. Speakers there highlighted the vital role these satellites play in climate change research. These spacecraft measure not just carbon dioxide emissions levels, but changes in the atmosphere, oceans, and ice caps that collectively describe the state of our planet.

Monitoring the changes in the color of the seas, for example, can tell us about chlorophyll pigment and sediment concentration, which affect the life that thrives within the waters. Instruments aboard a newly launched ESA satellite, SMOS, will be measuring ocean salinity, which contributes to ocean circulation patterns. These data are crucial, because the health of Earth's oceans dictates the health and welfare of its inhabitants.

On a positive note, recent satellite images show the Earth's ozone layer to be healing. According to NASA, "Researchers have no doubt that the increase in ozone is because nations followed the 1987 Montreal Protocol on the Substances that Deplete the Ozone."

At the same time that these efforts at mitigation are being made, steps are also being taken to adapt to the changes that have already taken place. As we search for methods to slow down or halt man-made changes to the global climate, we must also find mechanisms to adapt to those that have already taken place and that are, for the most part, irreversible. Once again, satellites and other Earth-monitoring devices can play a significant role.

As wind patterns evolve, for example, farmers can alter where, and perhaps even what, they plant. As changes in ocean circulation and salinity become clear, fisheries may be relocated; rises in sea levels can be monitored and buildings and roads rethought or relocated; changing herd migrations can be observed and accommodated. Weather changes can be predicted with greater accuracy, allowing people more time to prepare for cataclysmic events.

As the nations of the world strive to mitigate the negative effects of some modern human activity, aerospace advancements enable us to measure them, halt their progress, and adapt to what cannot be undone.

Elaine Camhi
Editor-in-Chief

Europe looks to outsourcing

Over the next few years, Europe's defense departments will increase the amount of non-front-line services they outsource to private companies.

"A combination of budgetary pressures and the fact that the nature of warfare has changed will mean European defense departments will have to look increasingly at outsourcing as a future option," says Peter Howson, director of London-based consultants AMR, specialists in this area. "There are other factors, such as an end to conscription, also involved. In labor-intensive areas such as facilities management, where you need a large workforce involved in cleaning and maintenance of facilities, it makes no sense to tie up troops in these activities, especially at times of turbulence."

Mapping the trend

The degree to which European countries have already outsourced military training, logistics, and facilities management services to private companies is surprisingly extensive.

"We recently mapped the extent to which EU member states have outsourced, and we found that, on average, up to 50% of the total costs of an operation are now sometimes being performed by outside contractors," says Gerard Heckel, assistant capability manager (maneuver) at the Brussels-based European Defence Agency (EDA).

For example, in recent EU crisis management operations (CMO) in Chad, the Congo, and Bosnia and Herzegovina, outsourcing accounted for 50% of all operational costs incurred by EU operational units, with the single largest outsourcing expenditure going to transport (around 30%), followed by food supplies/catering (20%), and communications and information technologies (8%).

European defense departments currently contract out a wide range of aircraft overhaul, facilities management, and training services. The U.K. has generally been at the forefront of outsourcing initiatives, with East European countries more reticent. Continental European military organizations have tended to prefer combining services with their neighbors rather than outsourcing to the private sector.

"Adaptation to requirements for change, even when they clearly reflect the wishes of the taxpayers and the armed forces, is not always as easy as we could imagine."

Learning from failure

But the outsourcing process has not been universally successful. The crash of an RAF Nimrod MR2 aircraft with the loss of 14 military personnel while on intelligence gathering operations in Afghanistan during 2006 occurred because of "a systemic breach of the military covenant brought about by significant failures on the part of the MOD [Ministry of Defence], BAE Systems, and QinetiQ," according to an accident report commissioned by the MOD [http://www.nimrodreview.org.uk/documents.htm]. BAE Systems was responsible for drawing up the "Nimrod Safety Case" between 2001 and 2005 to analyze possible defects in the aircraft, while QinetiQ was employed as an independent advisor on the work.

All sides have since acted on the report's recommendations—but this was not the only case where contractor performance has been criticized; the outsourcing experience in EU's operations in the Congo was unanimously seen as "a complete disaster....it failed to meet the EU demands," according to EDA experts and a report on the operation [http://www.iss.europa.eu/uploads/media/op-72.pdf].

"Furthermore, no standalone outsourcing strategy can exist outside an overall EU-led CMO logistics strategy," say the report's conclusions. They add, "Tactically, outsourcing seems to function poorly for short operations; large-scale single-sourcing strategy should be used cautiously....Because of poor planning, the military sometimes pushes too much responsibility onto the contractor, thus creating unbalanced risk/reward situations for the contractor, which then delivers unsatisfactory services."

But the lessons are being learned from all sides on how government departments and private contractors should best work together. There is now a growing understanding that an excessive focus on price can lead to poor contracting performance.

"A great deal of the knowledge in maintaining ordnance and equipment lies with the original equipment manufacturers [OEMs] anyway," according to Howson. "But the onus is on the defense departments to ensure they agree on the best deal."

Building on success

As European governments seek to control their defense expenditures while increasing their commitment to national and EU operations overseas, outsourcing is likely to become an increasingly integral part of their future operational planning. Not only is the range of activities about to widen, but the way in which contracts are tendered and managed also will change radically over the next few years, as will the mutual understanding between contractors and suppliers.

European defense industry experts point to the success of the Strategic Airlift Interim Solution strategic transport program, which has provided many European countries with access to heavy-lift transporters they would otherwise have been denied. "This has made strategic military transport not just 'nice to have,' but a backbone to future capabilities for many states," says one industry official.

EDA staff are now looking at the possibility of using a private contractor to provide military air-to-air refueling services for a number of states, following the concept laid down by the AirTanker consortium in the U.K. and the U.S. Navy's use of the Omega Aerial Refueling Services commercial operations.

Going online

Another catalyst to further outsourcing by EU member states has been the development of an Internet-based European Third Party Logistic Support portal, hosted by the EDA, to link commercial sector capabilities with military requirements.

"What we have done is to facilitate the outsourcing process," said the EDA's Gerard Heckel. "There is also a need to further optimize this process, which we have found can produce savings of up to 20-30% over legacy services.

"The first objective was to increase the visibility of commercial services and to consolidate the offer and the requirement. We also wanted to offer assistance to member states throughout the entire contractual process. In multinational operations there is often a lack of visibility, with each state working with its own database of contractors. With this portal we can introduce more competition and more transparency in the cross-border market. It's not always about savings—it's about paying the right price for the job."

The EDA has been working alongside other institutions such as NATO and its Maintenance and Supply Agency, as well as the U.N. World Food Program and Dept. for Field Support, to share best practices and lessons learned and avoid any unnecessary duplication. "The initial focus is on crisis management," says Heckel, "but the portal can support any type of activity, and registered companies offer IT and training services, as well as logistics." The portal is open to any commercial organization established in an EU country.

The ultimate decision about what to outsource and what to retain in-house remains with member states, which have differing views on what is a "core" or "noncore" military capability. But there is a widespread view among Europe's military that there are now clearly defined areas where outsourcing has been shown to have worked, despite initial reservations.

"Adaptation to requirements for change, even when they clearly reflect the wishes of the taxpayers and the armed forces, is not always as easy as we could imagine," said Åke Svensson, chief executive of Saab AB, at a 2008 EDA conference on outsourcing. "However, in several countries, best practices

Military aviation outsourcing among EU member states

Aircraft maintenance, repair, and overhaul

EADS Military Aircraft carries out depot inspections on the EIF-18 Hornets flown by the Spanish air force. The maintenance program covers the engines, fuel systems, installation of new equipment, and repair work.

QinetiQ has been awarded a U.K. MOD contract by the Harrier integrated project team for through-life support to the Harrier aircraft to 2018.

EADS Military Aircraft provides system support for the German navy's eight P-3C Orion long-range maritime patrol and antisubmarine warfare aircraft.

Fokker Services maintains, modifies, and repairs a wide range of military aircraft, from jet fighters to fixed-wing patrol and transport platforms to helicopters, including F-16 midlife upgrade work for NATO air forces.

Saab has a 550-million-SEK order from the Swedish Defense Material Administration, FMV, to support the Saab Gripen´s operative capacity. The order includes program management, product maintenance, support, flight testing, pilot equipment, and simulators.

Air traffic control

The U.K. MOD has signed a contract with National Air Traffic Services (En Route) to provide an en route ATC facility to the MOD until 2021. Military personnel manage en route traffic in a joint and integrated operation alongside NATS (En Route) staff.

Pilot training

The French ministry of defense has a contract with EADS´ Military Air Systems and Socata for the supply of new training aircraft, the procurement of line and base aircraft maintenance, and ground-based training devices such as flight simulators, and integrated logistics support, with supply chain management plus infrastructure handling. EADS has set up a subsidiary in Cognac, the EADS Cognac Aviation Training Services, to fulfill the contract.

Ascent, a consortium formed by Lockheed Martin and VT Group, has a $12.7-billion contract with the MOD to supply all aircrew training for the U.K.'s armed force.

Alenia provided the Italian air force with simulator training for Eurofighter pilots at its Turin facility between 2003 and 2007. Alenia is building simulators for the Italian and Romanian air forces, as well as teaming with L-3 to build a simulator for U.S. pilots, to be operational this year or next.

Information technology

Project Hercules is a 2006 $10.6-billion 10-year program in which a consortium of private companies, notably Siemens and IBM, upgrade and support nonmilitary IT and communications systems for the German defense department. The work is undertaken by BWI Informationstechnik GmbH (BWI IT), 49.9% owned by the German government, with the remaining 50.1% split equally between IBM and SBS.

Military airlift

Several European NATO member countries and partners have pooled their resources to charter six heavy-lift Antonov An-124-100 transport aircraft under the Strategic Airlift Interim Solution operation. The consortium includes 16 NATO nations (Belgium, Canada, the Czech Republic, Denmark, France, Germany, Greece, Hungary, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, and the U.K.) and two partner nations (Finland and Sweden).

Air to air refueling

AirTanker is a U.K. company created to provide the Future Strategic Tanker Aircraft (FSTA) service to the U.K. MOD under a 27-year private finance initiative contract. The FSTA program will replace the RAF's current fleet of VC-10s and TriStars with 14 Airbus A330-200 aircraft, the first of which will be delivered in 2011. These new aircraft will be owned, supported, and operated by AirTanker, who will also provide all support services, including construction of a two-bay hangar, training, maintenance, flight operations, fleet management, and ground services.

at [a] national level exist today that lead to 'win-win' solutions."

Teaming for security

Another impetus for increased outsourcing will be the growth in combined EU security operations overseas. These tend to be led by the larger EU states, which are often farther down the outsourcing road than small countries—and the use of a single logistics supplier to a number of different national military units can make clear economic sense.

"Using commercial support services can help to release military personnel that are badly needed for operations in the field," said EDA Secretary General Javier Solana at a February 2008 EDA conference. "Second, there is the argument of cost-effectiveness. Outsourcing can save money while enhancing overall logistics performance. Crucially, cost savings will increase when logistic support is organized on a multinational basis....Finally, third-party logistics can sometimes compensate for the absence of support assets of the member states. The lack of such assets has increased in the past decade as many armed forces had to transform from static to more mobile structures. This required new investment, which often led to shortfalls, in particular in logistic and technical support."

New EU security initiatives—such as combined maritime surveillance operations and support to security operations in Somalia—offer new opportunities for logistics outsourcing. One key requirement is for more helicopters and more helicopter support services, a need that will not be easily met even by combining national assets.

"This is a problem for NATO and the European Union alike," said Solana in March 2009. "Inventories are high in numbers, but the problem is that they are not deployable outside Europe in sufficient numbers. Third-state partners assist in our ESDP operations. We are grateful to them for their contributions, but we must not be dependent on them for key capabilities such as helicopters....For the medium term, the EDA is looking at options for upgrading existing assets, in particular the Mi-type helicopters, hundreds of which are in the inventories of Central and East-European countries. European helicopter industries will have to be closely involved to provide upgrade packages at reasonable cost."

Growing demand for MRO

The demand for new maintenance, repair, and overhaul (MRO) services to European military aircraft operators, which currently account for the bulk of military aerospace outsourcing, is also large. The global estimated military aircraft MRO market in 2009 was $61.1 billion, according to a recent Aerostrategy report, which has highlighted the European platforms of the NH-90 and the Eurocopter Tiger as particularly significant.

Europe's largest military spenders have already outsourced many of their military MRO requirements, mainly to the national OEMs. Eurocopter, Dassault, and Snecma have extensive military MRO contracts in France, according to Aerostrategy. Eurocopter's business interests include a €319-million contract for Eurocopter to support over 600 platforms, and a 22-year contract to provide E120 training.

The U.K. has restructured its entire approach to aircraft support through the creation of the Defence Equipment and Support Agency and the sale of DARA Fleetlands (a helicopter support center) to Vector Aerospace. Prime contractors are now providing "through-life" support packages, with BAE Systems providing MRO services to all fast jets and to most AgustaWestland helicopters.

In Germany a number of public/private MRO contracts have been signed, for example, with MTU on engine support for the RB199 and EJ200 power plants. Helicopter Flight Training services, a consortium of CAE, Eurocopter, Rheinmetall Defense Electronics, and Thales, has a €488-million 14-year contract with the defense department to provide NH90 training. In Italy, military MRO work is undertaken by AgustaWestland, Alenia, Avio, and Aeronavali.

There is a limited amount of outsourcing to OEMs of different states. In Sweden, for example, AgustaWestland performs support work on the military's AgustaWestland A109s (known as the Hkp 15 in Sweden), while Saab supports the Saab 105 trainer and the coast guard's Bombardier Dash 8s.

"Attitudes of other countries vary, but in most cases there's a mix of organic capability and outsourcing," says Aerostrategy's David Stewart. "Is outsourcing becoming more commonplace? I believe so, yes. However, the change of practice mostly occurs at the point of fleet replacement or new acquisitions, so the change is happening slowly."

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In general terms there is agreement within Europe that using private companies to perform front-line security tasks would be a step too far. But with platforms, weapons, and communications becoming increasingly complex and European nations now involved in a growing number of overseas operations at a time of immense budgetary pressure, the benefits of outsourcing have never looked more attractive.

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Correspondence

Our future in space (October 2009, page 3) and **Is Human Space Flight Optional** (October 2009, page 18) deserve comment. Both start with the premise that the U.S. should venture into space with a premature and irresponsible plan using existing, inefficient technology. No other plans were considered. The complaint against the space shuttle program is that it is too expensive. The current plans will create another system which is too expensive to operate because it is based on inefficient rocket engines. "…the committee identified five alternative scenarios for…human space transportation….None could be realized under the present NASA budget…." The only thing the Advisory Committee on the Future of the United States Space Program could recommend was to spend more money to implement premature and irresponsible plans.

A new plan that stays within budget would seem to be in order, but the committee did not even consider such a plan.

A plan that develops advanced performance rocket engines (APREs) before we return to the Moon or venture to Mars is such a plan. APREs would be more efficient because they would use less fuel. Hence the fuel tanks would be smaller and would therefore have less aerodynamic drag. A vehicle with APREs would put a greater payload in orbit at lesser cost. APREs on the shuttle would mean a $7-million saving in fuel costs each flight, a 15% reduction in the cost of an external tank, and a 24% reduction in aerodynamic drag of the external tank. The shuttle would become a less expensive vehicle to operate.

Also, development of APREs would make it possible to develop a single-stage-to-orbit vehicle such as the X-33, Venture Star, which failed because of its inability to build tanks large enough to carry the fuel. APREs could be developed within the current budget. NASA is doing that now with the J-2 rocket engine; a redevelopment effort costing $1.5 billion over seven years. We should be able to develop an APRE for $2 billion in five years. Such a program will maintain the U.S. leadership in space.

Dale L. Jensen
Jentec

Editor's Note Both authors take issue with the writer's opening premise.

I just read **Nuclear propulsion—the affordable alternative** (November2009, page 3). Some of authors' points are valid, especially those relating to safety of nuclear propulsion. However, they neglected or misrepresented some salient points, and I am troubled by several erroneous assertions.

First, nuclear propulsion, at least in the NERVA format and probably in any form, cannot be used for an Earth-to-orbit launcher. Too much radiation, bad mass fractions. With today's knowledge, chemical propulsion is the only feasible way of safely getting heavy payloads out of the Earth's gravity well. Therefore, for human Mars exploration programs, for the foreseeable future, we will need the large chemical rockets, which tend to cost-optimize in the 90-120-tonne to orbit size. But we can do a lot of good planetary work, perhaps even human exploration, without a generation of new launchers, using the existing fleet.

Nuclear propulsion, once activated, is extremely radioactive, and cannot be safely returned to Earth. But in nuclear-safe orbits and for planetary injection and transit, it is fine. This is where nuclear propulsion comes into its own, and I am an advocate for using it.

To claim that billions of dollars could be saved by using nuclear propulsion may be true in an extended Mars program, but in the early phases, would add billions of dollars of development costs to an already too-thin NASA budget.

In an ideal world, a six or seven year development may actually be possible, but it is not hard to envision the practicalities, including the environmental work, doubling or tripling that time.

Hum Mandell
Former manager, NASA SEP

Hum Mandell's letter alleges neglect or misrepresentation of several salient points and erroneous assertions. These criticisms have missed their mark.

First, in our commentary there is no advocacy of nuclear propulsion for LEO transports. On the other hand, the benefits of nuclear rockets in upper stages are well established, even for lunar flights and use. The many ferry flights of propellant stores to LEO demanded by chemical propulsion to Mars are greatly diminished by using the much higher performing nuclear rockets for Mars transport propulsion. This reduction in ferry flights (a factor of around four) can enable utilization of lower cost shuttle-derived transports from LEO. Shuttle-C derivatives offer over 90 mT cargo to orbit using a proven flight system and existing launch base facilities, requiring no massive new transporter (Ares V) that are costing billions to develop and later about $1 billion+ a launch. Yes indeed, implementation of the nuclear rocket saves many billions vs. chemical rockets, even at the inaugural mission.

The last 50 years are a testament that large-scale, man-rated space exploration will *not* occur with chemical propulsion. While we can send flyweight robots to Mars, Jupiter, and Saturn, nuclear propulsion must be recaptured for the ultimate manned mission to Mars. The reliance on large chemical rockets for Mars has already been demonstrated to be a self-defeating, bottomless cost pit, and a change of propulsion technology must be followed up.

As to radioactivity post flight, it is well known that reactor "cooldown" occurs with exponential rapidity after core shutdown, and a number of days in parking orbit enables straightforward, safe operations with a postfired nuclear rocket.

The Rover/NERVA program was shut off in 1972 after an investment of $1.5 billion. A total of 21 cores and rocket engines were fired, with thrust up to 210,000 lb. A flight engine capable of 10 hr and many restarts was the next iteration in the program when it was terminated. Much of that legacy is still in hand, and a fast-track seven-year project to get the flight engine is realistic.

Stanley V. Gunn
Ernest Y. Robinson

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Money woes take center stage

THE NATION'S FUTURE POLICY ON HUMAN spaceflight, as well as the future path for NASA, are waiting to be defined as debates on the economy, health care, and troop levels in Afghanistan continue.

NASA fits and starts

A plea by 81 members of the House of Representatives for more money for human spaceflight drew little press outside the insular realm of those who focus on space developments. A successful shuttle mission, one of the last unless current plans change, was scarcely noticed by Congress, the media, or the public. Also making little news were the first flight of a rocket booster for the next-generation human spacecraft and the discovery of water on the Moon.

The 81 representatives wrote President Barack Obama, urging the White House to increase NASA funding by up to $3 billion annually so that the agency can accelerate a plan Obama inherited to send astronauts beyond LEO.

Rep. Suzanne Kosmas (D-Fla.) organized the appeal and attracted cosigners from Florida, Texas, and California—all with important NASA installations.

"We believe an increased level of funding is essential to ensure NASA has the resources needed to meet the mission challenges of human space flight," wrote the lawmakers. They pointed to the importance of the space station, the future of which is closely interwoven with that of a next-generation human spaceflight vehicle.

"The International Space Station should remain operational as long as it can be productive without being constrained by an arbitrary, budget-driven termination date," the representatives wrote. "The [NASA] Authorization Act of 2005 designated the ISS as a U.S. National Laboratory to conduct research for other federal agencies and the commercial sector. Extending the ISS, at least through 2020, is necessary in order to maintain and improve important in-

Rep. Suzanne Kosmas

ternational partnerships, maximize the return on our nation's investment, and spur discoveries that will enable exploration of our universe and improve life here on Earth."

A next-generation human spaceflight vehicle is essential to support the space station. But critics who question its scientific value argue that the station exists merely as a reason to justify a next-generation vehicle. As of now, the shuttle is still slated for retirement this year, a new vehicle is still under development (without additional funding), and NASA says it will be able to resume putting American astronauts into low Earth orbit in 2016 or 2017. In the interim, Americans will journey into space and service the station using Russian spacecraft.

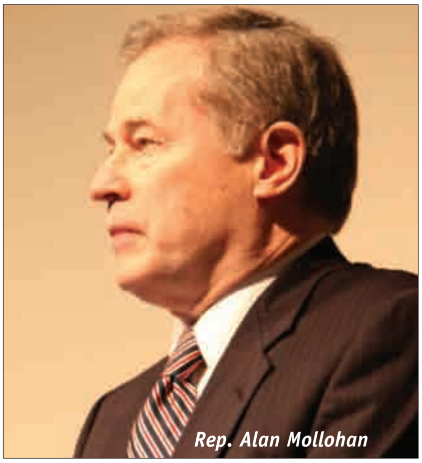
The appeal to Obama for spaceflight funding could not have come at a worse time in the larger national context. Although the government will show a $1.4-trillion deficit for FY09, which ended on September 30—by far the largest in history—the administration is operating several programs aimed at controlling, and not increasing, government-wide funding of programs.

Critics of human spaceflight spending pointed out that Rep. Alan Mollohan (D-W.Va.) did not sign the letter. Mollohan is chair of the House subcommittee that oversees NASA funding. Also not participating in the appeal was Rep. Bart Gordon (D-Tenn.), chair of the House Science and Technology Committee and usually a highly visible figure during space deliberations.

The much-anticipated October 28 launch of NASA's Ares I-X flight test vehicle was seen by some as a milestone on the way to a next-generation human spaceflight program. Others wondered if it was the last gasp in a program that could be fundamentally altered or canceled. After routine delays, the rocket apparently performed flawlessly on its 2-min flight.

Although it was an important scientific find that might have seemed dramatic in some other era, few in the capital took much notice of what NASA Administrator Charles Bolden called a "bright moment" when scientists found nearly 25 gallons of water on the Moon in the aftermath of an October experiment in which they slammed a spacecraft into the lunar surface. The crash was part of NASA's Lunar Crater Observation and Sensing Satellite mission.

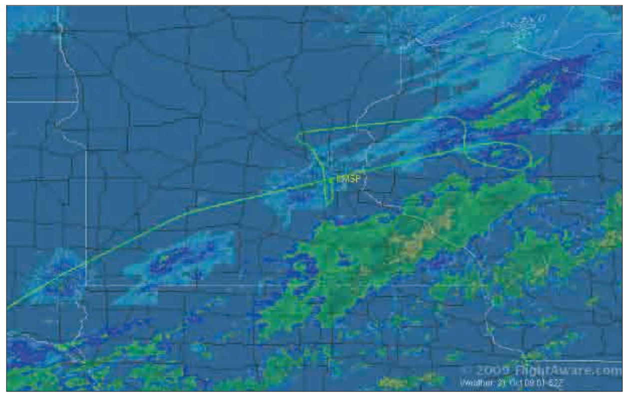
If water can be harvested on the lunar surface, astronauts might be able to establish a colony or a jumping-off base for flights farther out into the solar sys-



Rep. Alan Mollohan

tem. Water is also a key ingredient for rocket fuel. The bloggers who pooh-poohed the discovery pointed out that, in any event, the nation is nowhere near sending astronauts to the Moon.

On November 27 the shuttle Atlantis and its seven-person crew commanded by Marine Corps Col. Charles Hobaugh touched down after undocking from the ISS and heading home from 11 days in space. When launched on November 16, the STS-129 mission established a record for the fewest problems reported in any NASA launch sequence in the history of the program.



Northwest Airlines Flight 188 overflew its destination by 150 miles.

The FAA and an air emergency

The government's reaction when an out-of-communication airliner flew past its destination October 21 was hindered by poor communication and a failure to notify the military for more than an hour, say officials in Washington.

The two pilots of Northwest Airlines Flight 188 from San Diego to Minneapolis, an Airbus A320-200 with 144 passengers and three flight attendants, were out of contact with air traffic controllers for 78 min. This condition is known as NORDO (no radio communication) and is considered an emergency. At 37,000 ft in busy airspace, the Airbus overflew its destination, Minneapolis-St. Paul Wold-Chamberlain International Airport, by 150 miles.

Initially suspected of drifting asleep while at the controls, Capt. Timothy Cheney and First Officer Richard Cole later said they were distracted in the cockpit while using laptop computers. The use of laptops on the flight deck is prohibited by Northwest company policy and the ban is likely, now, to become a federal regulation. Northwest is owned by Delta Airlines. The FAA revoked the pilots' licenses; they have appealed.

Air Force Gen. Victor E. Renuart Jr., who heads both the North American Aerospace Defense Command and U.S. Northern Command, said he learned the airliner was out of touch only minutes before the FAA belatedly restored communication with the pilots. In several interviews, the general's displeasure was palpable.

Had the incident been a hijacking, he would have been responsible for scrambling jet interceptors. If a hijacked airliner were being aimed like a missile toward a U.S. city, the general would be expected to pass a presidential order to fighter pilots to shoot the airliner down, killing innocents on board in order to save a larger number of lives on the ground. But all plans for using interceptors to halt a repeat of the events of September 11, 2001, rely on prompt notification, and in the first "real world" test of the arrangement, nothing happened promptly.

"No secret. We could have done better," said FAA Administrator Randy Babbitt, referring to communication between his agency and the military. He characterized the lapse as an internal communication problem and said the FAA would retrain employees to follow the rules for missing-airplane incidents. Babbitt also said that the Northwest Airlines overflight was part of a larger problem—eroding professionalism among commercial airline pilots.


Gen. Victor E. Renuart Jr.

Lawmakers on the Hill expressed concern over both the failure to notify the military and the evidence of pilot ineptitude. Referring to the Northwest incident and to a recent Continental Airlines crash in Buffalo that was blamed on a lack of focus by pilots, Sen. Byron Dorgan (D-N.D.) said, "We need to know a lot more about what's happening in cockpits." He and Sen. Amy Klobuchar (D-Minn.) introduced a bill to prohibit pilots from using personal electronic devices while in flight.


FAA Administrator Randy Babbitt

"Passengers should not have to worry about whether the pilots are flying the plane or checking their laptops," said Klobuchar, in whose state the aircraft was supposed to land. "This legislation will allow the FAA to make sure distractions are removed from the cockpit and increase the safety of our air carriers." Observers in Washington did not expect the legislation to reach the Sen-

AIAA FORMS NEW EARTH OBSERVATION TASK FORCE

AIAA has created a new task force to assist in the formulation of a national road map for the U.S. to address investments in the Earth-observing industry to adequately inform future climate change debates and decisions. Composed of leading experts on policy and climate-monitoring technology from within **AIAA** and in collaboration with other organizations, the task force is developing a stategy to come up with recommendations to help reach this goal.

For more information, contact **Craig Day** at **703.264.3849** or **craigd@aiaa.org**.

AIAA
The World's Forum for Aerospace Leadership

ate floor, because Babbitt's staff was likely to preempt it by establishing a ban in the form of a federal regulation.

Fighter falls behind

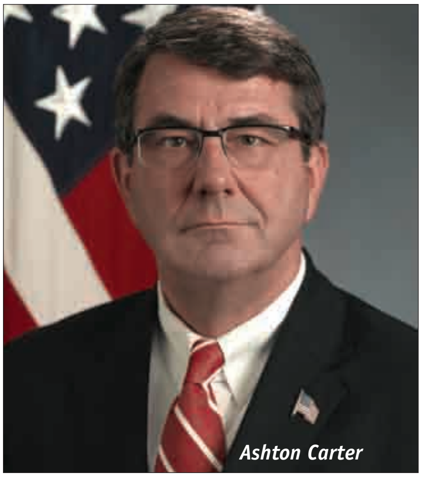
Ashton Carter, who became the Pentagon's acquisitions boss last April, ended 2009 under pressure to reshape the F-35 Lightning II Joint Strike Fighter program. Carter is a longtime defense professional and physicist who handled the Pentagon's international affairs office in the early Clinton years.

The aircraft is running above cost and behind schedule, and could become a burden on the administration as it prepares its FY11 defense budget proposal. Carter called a weekend meeting in November to address JSF cost issues. He was reacting to a report from the Defense Contract Management Agency disclosing significant delays on deliveries of test airplanes and components for future production aircraft.

JSF is important because by early 2013 it could become the only manned warplane being manufactured in the U.S. Under current plans, the Air Force's F-22 Raptor and the Navy's F/A-18E/F Super Hornet will be out of production then. Small numbers of F-15 Eagles and F-16 Fighting Falcons are being assembled for overseas purchasers but not for U.S. forces. Defense Secretary Robert Gates has postponed development of a new manned bomber.

Never before has the nation staked its air warfare future on a single aircraft type, let alone one that is still at an early stage in its flight-testing program and far from becoming operational. Yet the Pentagon is committed to buying 2,456 JSFs in three versions, with other nations purchasing perhaps 2,000 more.

The F-35 BF-2 aircraft made its initial flight on February 25, 2009.



Ashton Carter

Lockheed Martin is prime contractor for the F-35, but the contract management report was also critical of other participants in the program. Lockheed's senior JSF official, Dan Crowley, acknowledges that the report is largely accurate but says the worst delays have been overcome and good progress is now being made.

The first conventional, runway-based F-35A version of JSF for the Air Force made its maiden flight December 15, 2006. After 43 subsequent flights, technical problems prevented F-35A tests from staying on schedule. The first short takeoff vertical landing F-35B version for the Marine Corps, known as BF-1, made its initial flight on June 11, 2008, followed by BF-2 on February 25, 2009. A second F-35A, paradoxically called AF-1 rather than AF-2, made its first flight on November 12, 2009. The carrier-based F-35C version for the Navy has yet to fly, in part because of a conscious Navy plan to conduct this part of the program at a deliberate pace.

Thus, only four examples of the aircraft—representing two of the three versions—have taken to the air. The critical report noted that just seven of 13 test aircraft have been completed, even though all 13 were to have been completed and delivered for testing by October 2009. Nevertheless, production is under way: Any design changes made as a result of flight testing would have to be incorporated into the initial production aircraft after they are built, increasing costs.

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Gen. Norton A. Schwartz

As chief of staff, you seem to have put a premium on jointness, on making sure that the Air Force performs in harmony with the other services. Tell us about it.

We, as an institution, have to play our part on the joint team. All of us—all of the services—have to operate collectively in order to succeed for our country. Secretary [of the Air Force Michael] Donley and I and the rest of the Air Force leadership believe it is very important that the Air Force prepares itself and positions itself in ways that enable us to be the best possible partner on the joint team. That is our ethic.

The Air Force has been portrayed in some circles as having been marginalized in comparison to the ground services in Iraq and Afghanistan. How do you respond to that?

There will be times when the Air Force is ascendant in whatever missions might be assigned. At the moment, that is not the case. The missions in Iraq and Afghanistan are largely ground-force-intensive. That does not threaten us, does not threaten the Air Force. Nor should it. We must field a body of airmen with the equipment and the know-how to do our work with precision and reliability, and to engender trust, not only among our immediate teammates but among the folks who rely on us—the broader American public. This is why the nuclear incidents of 2008 were so difficult, because they undermined that fundamental trust in this wonderful institution, the United States Air Force.

The previous chief of staff and secretary of the Air Force were asked to resign as a result of those incidents, which involved the Air Force unwittingly flying nuclear warheads over the continental United States and mistakenly shipping ICBM components to Taiwan. So the Air Force was under a cloud at the time of your appointment to chief of staff. Tell us about that.

People worried legitimately whether we had our act together, whether our nuclear enterprise was locked up tight. Our goal—mine and Secretary Donley's—was to settle things down and reestablish the level of trust, which is essential for a national security institution to succeed and remain viable. So we went back to basics—as in football, the fundamentals like blocking and tackling—emphasizing the things that are really important, including precision and reliability in our nuclear operations and management.

What happened?

We stood up Global Strike Command last August, to combine our ICBMs and our nuclear-capable bombers under a single authority. This was not a case of going back to SAC [Strategic Air Command], but there are aspects of the SAC culture that are worth emulating.

One of those is the focus on professionalism, on precision, on compliance. There are some disciplines that require higher levels of compliance than others. There are some that allow for more innovation, but the nuclear business is not among them. In the nuclear business, we have procedures that stand until officially amended. Sure, in a crisis, people have to make judgments. But what we experienced in our nuclear incidents was an insufficient level of focus, and in some cases a lack of compliance. So we have emphasized correcting that, making sure that it never happens again.

How has your approach affected the Air Force as a whole?

The beauty of this, I think, is that the discipline that characterizes Global Strike Command will migrate out into the larger Air Force organization, and that is healthy. I'm not saying that we don't value innovation or that we do not want our people to think about how to improvise. We're not stifling imagination. But there are some disciplines where there is absolutely no room for error, and the nuclear discipline is one.

Back to the Air Force role in Iraq and Afghanistan. How do you assess the performance and the importance of your UAVs, and what does that have to do with the evolution of the Air Force and your goals for it?

I think the short answer is that the best shooters in the world won't go around a corner or through a door or a window without the situational awareness that the Air Force provides with our persistent, 24/7 surveillance. I think the reality is that we have enabled our teammates to be successful at less risk to themselves, and to exercise greater precision themselves with respect to positively identifying the enemy and neutralizing or detaining the enemy—whatever the requirement might be.

And your UAVs have played a big part in making this possible?

Yes, and by the way, "unmanned" is not an accurate description. They are piloted and heavily manned—about 140 airmen per orbit. Remotely piloted vehicles is probably a better description.

They were called RPVs in the beginning, weren't they?

Yes, way back when. These platforms in a relatively benign environment allow us to maintain a level of surveillance that was unthinkable even 10 years ago. And the surveillance and targeting that they provide enable other aircraft and other systems to maximize their capabilities as well. A UAV may tip

"My view is that yes, the unmanned systems are a powerful capability, and one that's growing in prominence and value, but that does not suggest that the manned systems are declining in value."

Interview by James W. Canan

a gunship, or tell a rescue helicopter crew where their pickup needs to occur. These are the kinds of things that are happening all the time.

Are we heading for an all-UAV Air Force?

I do not think that we will get to that point, at least not in the near future. This may be hyperbole, but would you put your wife or your grandchildren on a passenger-carrying aircraft without a pilot aboard? Maybe someday our aircraft will be totally unmanned, but we're not there yet. The reality is, at least in my mind, that there will be a continuing need for tactical aviation—some of the tactical aircraft will be manned and some unmanned.

What is the trend in Air Force procurement of manned and unmanned aircraft?

In the current year, our aircraft procurement is about one-third unmanned and two-thirds manned. The percentage of unmanned will probably increase over time.

To one-half perhaps?

I would say so. But I think it will be some time before it goes beyond one-half. This is a period of change in the Air Force and it does make some people nervous about their future. My view is that yes, the unmanned systems are a powerful capability, and one that's growing in prominence and value, but that does not suggest that the manned systems are declining in value.

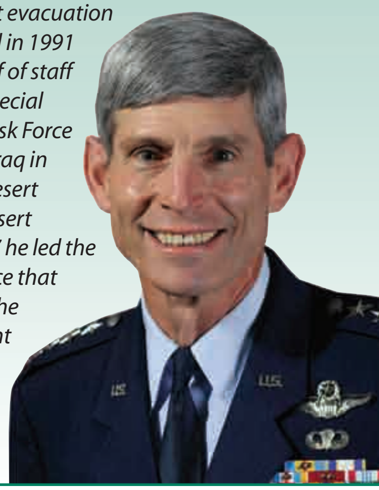
Again, back to the action in Iraq and Afghanistan. The Air Force has taken a lot of criticism for civilian collateral damage from both manned and unmanned air strikes, for killing noncombatants as well as combatants. How do you respond to that?

Do I apologize for civilian casualties? Of course I do. We want to minimize them, and we strive diligently to do so. If you talk to the commanders in Iraq and Afghanistan, they will confirm that. At the same time, we want to be sure that when the chips are down, our airmen deliver. We want them to be what they need to be in tough spots. That is true for the ground forces, too. We also want them to exercise judgment. So we need mature and sophisticated and talented people in order to do this—people who can think while they are flying airplanes.

Gen. Norton A. Schwartz is chief of staff of the Air Force, responsible for the organization, training, and equipping of nearly 700,000 active-duty, guard, reserve, and civilian forces serving in the U.S. and overseas. As members of the Joint Chiefs of Staff, the general and other service chiefs function as military advisors to the secretary of defense, the National Security Council, and the president.

A 1973 graduate of the U.S. Air Force Academy, Gen. Schwartz is also an alumnus of the National War College, a member of the Council on Foreign Relations, and a 1994 Fellow of MIT's Seminar XXI. He has served as commander of the Special Operations Command-Pacific, the Alaskan Command, Alaskan North American Aerospace Defense Command Region, and the 11th Air Force, Elmendorf AFB. Before assuming his current position, he was commander, U.S. Transportation Command, and served as the single manager for global air, land, and sea transportation for the Dept. of Defense.

Gen. Schwartz is a command pilot with more than 4,400 flying hours in a variety of aircraft. He participated as a crewmember in the 1975 airlift evacuation of Saigon, and in 1991 served as chief of staff of the Joint Special Operations Task Force for Northern Iraq in Operations Desert Shield and Desert Storm. In 1997 he led the Joint Task Force that prepared for the noncombatant evacuation of U.S. citizens in Cambodia.



Do you have them, or enough of them?

Yes. And if they are trained well and have decent equipment, and if we provide them the insights they need to make good decisions in real time, then they will deliver.

Your aircrews don't have to do it all by themselves, do they?

No. Unlike even 10 years ago, when our people in the cockpits were operating alone much more, there is connectivity today. There is data passing from command and control nodes that allows those flying the aircraft to make more informed decisions. Our people are very good at interacting with the joint terminal attack controller on the ground, for example, who has eyes on the target, at weaponeering their targets—choosing from among a mix of weapons—and at taking advantage of the precision that our weapons give us. Our choice and delivery of weapons is done in such a way as to generate just the desired effect and no more.

But the civilian casualties still happen.

Are civilian casualties an inherent part of our business? I would argue that that they are the exception. We are far from perfect; I wouldn't argue that. Avoiding civilian casualties means in some cases that our airmen don't shoot, and that's true for ground forces as well.

You mentioned the increasing importance of persistent ISR [intelligence, surveillance, and reconnaissance] and the role that UAVs play in that. Are unmanned systems supplanting space systems to some extent in ISR, and is space becoming less important in the

"There is going to be a lot more of 'not bad' than there will be of 'wow' in our space acquisition

Air Force scheme of things?

No. I don't think that's the case at all. But we are becoming more sophisticated in attaining some of the benefits of near-space platforms and coverage that communications satellites or surveillance satellites provide from geosynchronous or even low-Earth orbits.

Transatmospheric platforms?

Even lower in altitude than the transatmosphere. We could have a communications relay package on a Global Hawk at 65,000 ft that essentially serves the same function as a communications satellite. The footprint would be somewhat less—maybe not half the globe, but theater-size—and that is a promising prospect.

So where are you headed with all of that?

I think we are headed for a mix. We will have some satellite-like capability from air-breathing platforms, and it is conceivable that some of those could be lighter than air. Talk about going back to the future, we could have dirigibles or blimps or other lighter-than-air platforms that could remain at 65,000 ft for weeks at a time.

But would you say that space platforms are indispensable, by and large?

There are very powerful reasons to have eyeballs in space, including breadth of coverage and relative invulnerability. But there are other concepts that are beginning to jell that suggest that not everything has to be a billion-and-a-half-dollar satellite.

As to that, would it be fair to say that you are intent on the Air Force going back to basics in space acquisitions?

Yes. I have said in the past that we have had a temptation to design and build the most exquisite systems, and we have proven that we can do that. But we went too far in trying to build too many things on the same platform. So there is going to be a lot more of "not bad" than there will be of "wow" in our space acquisition programs—and in all of our programs.

You referred to the relative invulnerability of space systems. Taking into account the real-world demonstration of China's antisatellite capability, does the notion that U.S. space systems are increasingly vulnerable play more heavily in your plans for space?

It does, and this is why space situational awareness is so important to us. In the past, we basically assumed the invulnerability of our space platforms. Now that basic assumption has been called into question. What is increasingly required is the ability to ascertain whether a particular satellite is threatened in some way, and if it is, to attribute the threat. Easier said than done, but that is our need. And so, because of developments, space situational awareness will increase in prominence.

Are you accentuating acquisition programs that are aimed at space situational awareness?

Absolutely.

Let's talk about fighters now—the F-22 and the F-35. You and Secretary Donley took some heat in Air Force circles and elsewhere for agreeing with Defense Secretary [Robert] Gates in curtailing F-22 production at 187 aircraft. Tell us about that.

The F-22 was not an easy call, but we came to the conclusion that, given all of the demands on our Air Force, we had invested enough capital in F-22 and it was time to move on to the F-35.

"The F-35 is vitally important; there is a lot of pressure on the program to deliver."

The key thing here is that the F-35 is not only our path to sustaining our tactical air capability, it is that for the Navy and the Marine Corps as well and, importantly, for at least eight international partners in the program. The F-35 is vitally important; there is a lot of pressure on the program to deliver. It is important to the Air Force because it will transition us to a fifth-generation fighter force. It will allow us to deal with the aging aircraft issue we have in the remainder of our fighter fleet—provided we have F-35 production rates of at least 80 aircraft a year, and hopefully higher than that.

When is F-35 production supposed to start?

Deliveries of the first trainer aircraft are scheduled for 2013. The F-35 IOC [initial operational capability] should be in the neighborhood of 2014. We expect to take deliveries of 250-300 F-35s by 2016 or 2017, if the program produces as intended.

We have been hearing more about the following fighter, your sixth-generation fighter. Where does the Air Force stand on that?

We are a junior partner with the Navy on the Navy UCAS—the Unmanned Combat Aircraft System. It is an unmanned, low-observable design. As this program proceeds, we will see how well we can get [unmanned] tactical aircraft to operate autonomously and in close proximity with others, and to do other things. That's the purpose of the test program.

How will it be possible to have an unmanned air combat fighter? It was once considered unthinkable in terms of command and control.

Again, this is a question of combining sensors and communications. We think it can be done. An unmanned fighter is attractive in some respects. The typical operational flight duration of a fighter might be two to six hours with refueling and so on. But an unmanned fighter could conceivably fly much longer than that. It might be able to pull 10 *g*s, something a manned fighter could not do, because of the physical limitations of the man or woman in the cockpit.

And your acquisition costs would be less for an unmanned fighter because it would not have the life-support systems required of a manned fighter?

Somewhat less. We think a larger

programs—and in all of our programs.”

aircraft—an unmanned bomber—would be only about 5% less costly than a manned one. The delta—the difference in cost—would be somewhat greater for an unmanned fighter. But in any case, I think the key thing here is that there is much promise in this unmanned business. That does not suggest that our tactical aviation will be unmanned before 2020, at the earliest, and probably not before 2030.

Back to acquisition and the future shape of the force. Tell us about that.

Let’s talk about long-range strike. As you know, the secretary of defense terminated our former next-generation bomber program, because he was not convinced that we had all the parameters just right—manned or unmanned, subsonic or supersonic, low observable or very low observable, range, payload. We must convince him that the U.S. needs the capability to perform long-range strike and to penetrate denied areas in order to do so. There are those who advocate standoff weapons or ballistic missiles instead of a penetrating bomber. But my sense is that the nation needs a more versatile portfolio than something that I would describe—perhaps an oversimplification—as “fire and forget.”

Should it be a manned bomber?

That depends. Will it be a nuclear-capable bomber? We don’t know yet. If it is going to be a nuclear-capable platform, like the B-2, my sense is that it has to be manned. Would you be comfortable with an unmanned nuclear bomber?

Much depends on how everything comes out in the nuclear posture review and in strategic arms control negotiations. There is still much to be resolved.

Talk about tanker acquisition. The previous competition for the KCX turned sour, and the Air Force was criticized and temporarily relieved of responsibility for the next round of bidding. Are you confident that the program will work out this time?

I’m pleased and honored that the secretary of defense chose to allow the Air Force to run this program. I do think that it reflects renewed confidence in our institution. Of course, that brings with it special obligations. We’re going to conduct this acquisition process as scrupulously as we possibly can, and with lots of help from whoever wants to offer it. There is no territoriality about this. We want to do this so scrupulously that the offerers—the contractors—will not have an incentive to protest the contract award. The key thing here is that there is more on the line than just the Air Force’s reputation. This is really a question of the efficacy of defense acquisition, and whether the industry can perform its role in a responsible way.

When all is said and done, will you have enough long-range and tactical combat aircraft—and the right mix?

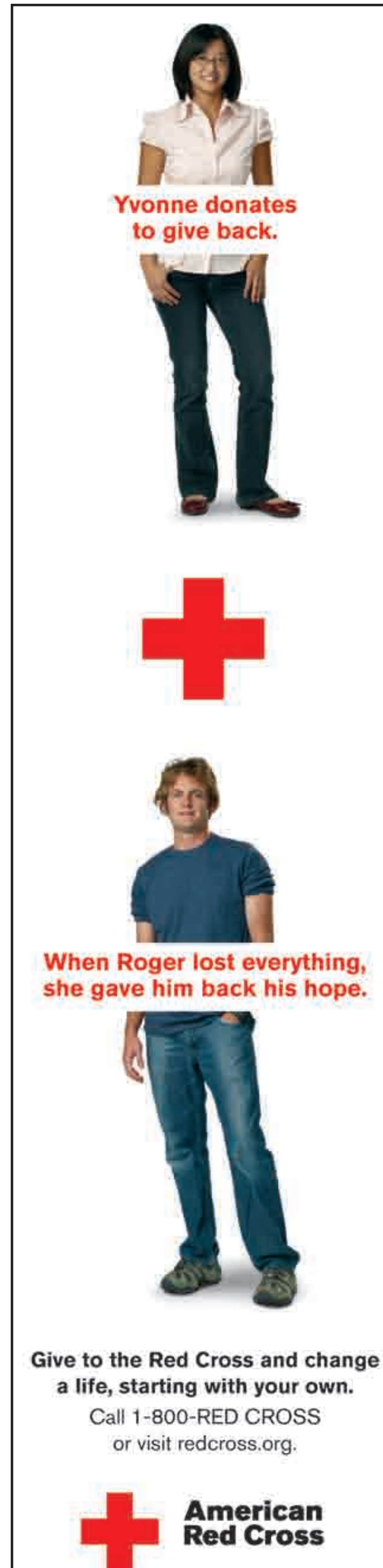
We are going to be a somewhat smaller force. We’re not going to have 150 bombers after the present fleet phases out. And we’ll probably have fewer fighters than the 2,200 we would have preferred, after the F-16s age out. So this means that we will have to compensate for that through better training and high-quality maintenance and crews.

So force multiplication will be increasingly important as you go along?

Force multiplication is the secret weapon. Precision, simulation, and pervasive ISR are the keys to that. Some areas are growing, and ISR is clearly one of them. Some areas are shrinking a little bit, and the fighter force structure is one. But we still have and will always have mandates for the capabilities that only America’s Air Force can provide, so we have to be ingenious and innovative and imaginative about how we go about providing those capabilities.

Sum up your priorities.

Our priorities for the Air Force simply are to sustain our nuclear enterprise; to function in ways that make us an absolutely trusted partner on the joint team and in today’s fight; to take care of our people and, importantly, our families; to be successful in our key modernization programs, including the KCX and F-35, and to improve our acquisition process.



A safer path to orbit

ITS ANNIVERSARY WENT ALMOST UNNOTICED, but 40 years have now passed since Apollo 12 achieved humanity's second lunar landing. Astronauts Pete Conrad, Dick Gordon, and Al Bean launched into a Cape Canaveral downpour on November 14, 1969, atop their 363-ft Saturn V booster. Thirty-six seconds after liftoff, the rocket's ionized exhaust plume triggered a pair of spectacular lightning strikes that jolted the vehicle, knocking the spacecraft fuel cells off line and lighting up Yankee Clipper's instrument panel like a Christmas tree. Mission commander Conrad's left hand hovered near the abort handle as the crew and Mission Control scrambled to understand and react to the emergency.

At an Astronaut Scholarship Foundation commemoration featuring Bean and Gordon last November, backup command module pilot Al Worden remembered how the crisis caused momentary confusion both on the ground and aloft. Conrad, recalled the Air Force's Worden, could have aborted, blasting the command module free of the Saturn V and dumping several hundred million dollars of Moon rocket into the Atlantic. But "Pete did exactly what Navy pilots typically do in an emergency—nothing."

It was Conrad cool—and the right decision. The Saturn V, its guidance system unaffected by the strike, rumbled confidently upward. John Aaron of Mission Control had Bean cut in a backup power source to the command module's signal conditioning equipment, restoring telemetry and instrument readings. Minutes later, Apollo 12 was safely in orbit. Gordon piloted Yankee Clipper around the Moon while Mission Control Central guided Conrad and Bean to a pinpoint landing next to the Surveyor 3 probe in the Ocean of Storms.

A lightning strike on the Apollo 12 Saturn V 36 sec after liftoff nearly caused a launch abort. Future launchers should be designed for much better safety performance, including both high reliability and a robust launch escape system.

Deciding the future

Four decades later, the U.S. government is rethinking the 2004 decision to send its astronauts in the footsteps of the Apollo 12 crew. President Obama's administration has not as yet announced its policy for human spaceflight, but the president's space priorities will no doubt be reflected in his proposed FY11 budget, to be released in February. A worrisome portent was last fall's White House request that NASA identify a plan to reduce its overall budget by 10%.

Coupled with the Augustine committee's finding that the current NASA budget is inadequate to do more than replace the space shuttle and operate the ISS, the proposed reduction would mean a deliberate shelving of U.S. plans to send humans beyond LEO. Such a decision, if formalized and endorsed by Congress, will reverse the Bush administration's 2004 policy direction. The Moon will be off limits to U.S. explorers for the foreseeable future.

These disturbing rumblings undercut the string of technical successes notched by NASA in the final months of 2009. On October 9, the LCROSS probe dove through the plume of debris thrown up by the impact of its Centaur carrier stage into the Cabeus crater near the Moon's south pole. Analysis of LCROSS spectral measurements released on November 12 confirmed the presence of significant amounts of water ice in the ejecta. If tapped, an ice reservoir could supply water for life support and even propellant, cutting the long-term costs of supporting deep space exploration.

NASA launched the Ares I-X vehicle successfully on October 28, 2009. Future tests of the Ares I series, designed to launch the Orion spacecraft, will depend on the White House's policy and budget priorities for NASA.

On October 28, NASA's Constellation program launched its Ares I-X test rocket on a brief but spectacular suborbital flight. The first stage, an ATK-built shuttle solid rocket motor, powered the dummy upper stage and Orion boilerplate capsule to 130,000 ft and Mach 4.7 before burnout. The vehicle's flight avionics and roll control thrusters performed well. There were problems: Motor exhaust battered launch pad 39B, the unpowered second stage tumbled unexpectedly after booster separation, and a failed main parachute caused the spent booster casing to buckle upon water impact. Still, the test proved NASA could design, build, test, and fly a new rocket for astronauts.

Finally, Atlantis lifted off for the ISS on November 16, marking the shift of ISS logistics to the post-shuttle era. STS-129's crew—Randy Bresnik, Mike Foreman, Charlie Hobaugh, Melvin Leland, Bobby Satcher, and Butch Wilmore—installed two 13,000-spare-parts platforms on the ISS truss, each storing components too large to be easily delivered by other vehicles once the shuttle retires. This was Atlantis' penultimate flight; just five shuttle missions remain before the orbiter fleet stands down late this year.

Despite these successes, NASA's future seems beyond its control, dependent on how high the Obama administration ranks the agency amid a constellation of competing priorities. NASA Administrator Charles F. Bolden Jr. acknowledged in mid-November that he hoped to brief the White House on new human spaceflight options by Thanksgiving, but at press time a presidential direction for NASA was still pending.

Last September the Orion launch abort system underwent ground vibration tests at Orbital Sciences' facility in Dulles, Va. The 53-ft-long assembly was an inert test article; a live pad-abort test of the system will be conducted this spring at White Sands.

Ares I in Eclipse?

Even before the Ares I-X flight took place, the Augustine committee had displayed little enthusiasm for the Constellation "program of record," particularly the proposed crew launch vehicle. Although acknowledging that Ares I was a reasonable solution in 2005, the committee found that its development would likely stretch into 2017, too late to provide much crew or logistical support to ISS. Instead, the panel recommended that NASA pursue commercial options for LEO crew transport. As a hedge against failure, NASA could launch Orion on a human-rated version of the heavy-lift Ares V.

Ares I critics have focused on purported technical problems such as thrust oscillation, flight stability, and potential collision with its launch tower. None of these "show-stoppers" has withstood the application of concentrated problem-solving by NASA and contractor engineers. More difficult to address has been Ares I's launch performance for the lunar mission: Its LEO payload capacity of 55,600 lb may limit Orion's propulsion capability and system redundancy. Although rigorously controlling Orion's mass growth might enable Ares I to support a lunar landing mission, achieving the full suite of lunar destinations and follow-on missions to near-Earth objects would require squeezing better performance out of the vehicle.

The inadequate Constellation budget has been the biggest source of Ares I troubles. It may fly too late to fulfill one of its original purposes—a safe and efficient shuttle successor for LEO crew transport. And cost is a concern: With only two launches per year to the ISS, and lunar voyages well down the road, Ares I will never realize economies of scale. Its residual value today may be to serve as a transitional vehicle, like the 1960s Saturn IB: Ares I could flight-test components slated for Ares V, such as five-segment solid rocket boosters and the J-2X engine. Ares I would also help retain Kennedy's skilled launch workforce while NASA develops the massive Ares V, the key to beyond-LEO exploration.

In the committee's view, the solution to performance and workforce problems alike was to have NASA bypass Ares I, move to commercially provided (vs. government-operated) LEO transport, and accelerate the Ares V. If commercial services failed, the panel argued, Ares V could get crews to ISS. The group was confident that military launchers like the Delta IV, as well as new commercial designs, could with NASA oversight meet human-rating safety standards, just as the Atlas and Titan ICBMs had safely launched Mercury and Gemini.

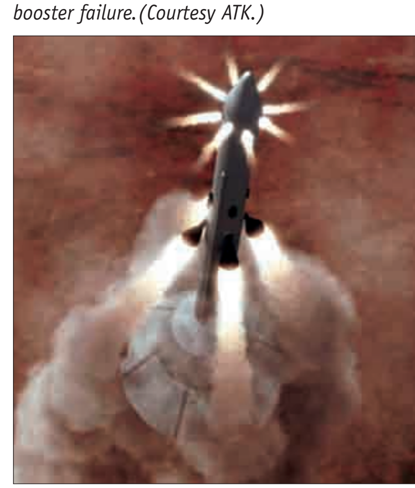
Is there a safety gap?

Commercial space firms were delighted at the Augustine committee's broad endorsement. SpaceX believes its Dragon cargo capsule can be upgraded quickly to handle crew services (given several hundred million dollars in NASA funding), and plans to launch its inaugural Falcon 9 booster this year. Orbital Sciences hopes to demonstrate its Taurus II-launched Cygnus capsule in early 2011. NASA hopes that once cargo delivery flights to ISS begin in 2011, commercial providers will gain the orbital experience needed to handle future crew transport. Traditional industry firms like United Launch Alliance also argue that their existing boosters can help shorten the pending LEO-access gap.

Constellation managers argue that Ares I is well into development and will be fielded before any commercial system—whether a human-rated EELV or a new launcher—can reach maturity. Designed from the ground up with astronauts in mind, Ares I meets NASA human-rating standards. Should it fail on ascent, the Orion crew would be blasted clear by its launch abort system. The Ares I-Orion design goal is to decrease the shuttle-era probability of "loss of crew," the euphemism for a fatal accident, by at least a factor of 10.

The commercial space sector has argued that it can match that reliability. Brett Alexander, president of the Commercial Spaceflight Federation, argued in September that the safety of EELV or new commercial launchers is "a non-issue." He explained, for example, that operators of an Atlas V carrying a billion-dollar Mars probe would be foolish to take shortcuts that might reduce launch safety and reliability. Alexander

The Orion launch abort motor will provide 500,000 lb of thrust for 5 sec to pull Orion clear of a booster failure. (Courtesy ATK.)



contends that commercial vehicles can incorporate fault-detection and abort systems at reasonable cost, equaling the safety performance of Ares I while delivering astronauts to ISS more cheaply.

But experienced military space managers I've talked to say the Air Force's current stable of satellite launchers were simply not designed with astronauts in mind. For satellite cargo, a success rate of 99% is perfectly acceptable—gratifying, in fact. The shuttle's demonstrated reliability is just over 98%, and NASA would like its successor to be at least an order of magnitude more reliable. Thus, for commercial crew transport, the vehicle had better be significantly more reliable, or its escape system will need to be bullet-proof.

The safe course

Whether or not the White House directs NASA to embrace commercial crew transport, it is worthwhile to recall where our human spaceflight program was after the Columbia accident, just seven years ago. The agency had again fatally underestimated the potential for a catastrophe, and looked hard at how it might improve the odds for future shuttle crews.

After Challenger, NASA added only a minimal escape/bailout capability to the orbiters, anticipating they would retire by the mid-1990s. In case of a launch or entry emergency, my colleagues and I trained for a manual bailout through the orbiter's side hatch, an escape option that assumed the orbiter could achieve stable, autopilot-guided gliding flight.

We had no illusions about how unlikely that scenario was. In a major inflight emergency, we thought at best that a few of us might make it out. A more capable escape capsule was never seriously considered, as its weight and cost would be prohibitive given the few remaining years before shuttle replacement.

Columbia was a terrible reminder of the consequences of extending the shuttle era well into the 21st century. But ISS required the shuttle's payload, EVA, and robotics capability. After the accident, the Columbia Accident Investigation Board recommended that the shuttle be retired as soon as practicable, that its successor separate crew from heavy cargo, and that it incorporate a robust escape system. Nevertheless, shuttle would soldier on for a few years without additional escape capability. NASA again decided that expensive safety modifications made little programmatic sense during the few years needed for station completion.

Acknowledging the very real cost and schedule pressures it faces today, NASA should disregard the CAIB recommendations with only the greatest reluctance. It may be possible to human-rate the Ares V, just as the Saturn V safely carried the Apollo 12 astronauts 40 years ago. But building a launch abort system capable of pulling an Orion crew free from a failing Ares V will be a significant challenge—not impossible, but not trivial, either.

A commercial crew launcher, using either Orion or a commercial capsule, would emulate Ares I in separating crew from cargo (something Ares V or a shuttle-derived heavy lifter would not do). But how will commercial providers keep their costs low while fielding a highly reliable booster and capable launch escape system? Because bulk ISS cargo services demand neither high reliability nor an escape system, mandating an early shift to commercial crew services would put astronauts aboard without a demonstrated safety record. A more prudent path would be to first demonstrate system safety with a five-year program of testing via operational cargo flights.

Safety imperatives

As NASA's Astronaut Office put it to the Augustine committee in July, the agency has had 50 years of experience getting astronauts to and from orbit. NASA today should thus be capable of building systems that significantly reduce the risk of ascent and entry. Said the astronauts: "Although flying in space will always involve some measure of risk, it is our consensus that an order-of-magnitude reduction in the risk of loss of human life during ascent, compared to the space shuttle, is both achievable with current technology and consistent with NASA's focus on steadily improving rocket reliability, and should therefore represent a minimum safety benchmark for future systems."

The office argued that achieving such safety performance depends on designing and building new vehicles according to NASA human rating requirements. In engineering terms, that means a structural factor of safety of 1.4, crew situational awareness, manual control, robustness, redundancy, and so on. I could not agree more with their recommendation that these requirements "not be waived or rationalized away," in the name of cost-cutting, for example.

The Cygnus advanced maneuvering spacecraft is Orbital Sciences' cargo delivery vehicle. Cygnus will perform ISS resupply flights under NASA's commercial resupply service contract.

I'm one space flier who is certainly rooting for the commercial sector to develop affordable—and, more important, reliable—transportation to LEO. The engineering state of the art can deliver significantly better safety levels than the shuttle, and we should design to that standard. Let the commercial firms prove their system reliability by flying cargo to the station, returning hardware from ISS, and even flying private passengers. When their record is proven and their economic advantage is clear, NASA should move rapidly to purchase crew transport services to LEO, devoting the saved dollars to exploration at the Moon, near-Earth objects, and beyond. Decisions made now by the White House and NASA will later have life-or-death consequences for my colleagues. We must do this right.

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Aircraft industry rides out the recession…so far

THE GLOBAL ECONOMY TOOK A SERIES OF devastating shocks in 2008-2009, the first year without economic growth since WW II. With the exception of China and India, every major economic power saw its economy shrink, with high unemployment and mounting deficits. All civil aviation market indicators suffered unprecedented drops, particularly for air cargo traffic and business jet utilization.

However, with a few exceptions, the world's aircraft industries have so far avoided the pain associated with this downturn. In fact, new aircraft deliveries continued their upward rise, a trend almost uninterrupted since 2003. But there is a very strong chance that this year will be an inflection point, if not a year of reckoning for the industry.

The large jetliner question

Large commercial jetliners represent about half of the total 2009 market for aircraft deliveries—$61.3 billion out of a total aircraft market worth $121.8 billion (in new deliveries alone). This is an 11.5% rise over 2008, but that number is highly distorted by the impact of Boeing's 52-day machinist strike in late 2008, which artificially reduced deliveries that year by over 100 jets.

In reality, jetliner production rates are treading water. Unfortunately, however, there are no air travel market health indicators that justify this record level of production. Passenger traffic is stabilizing after over a year of precipitous drops, but it remains 6% under the peak level seen in January 2008. There are 2,490 jets parked in the desert, up from 1,681 in December 2007. At least 900 of these parked aircraft are competitive enough to return to service when demand warrants. Lease rates and asset values have fallen, even for newer equipment. The International Air Transport Association anticipates $11 billion in industry losses for 2009, following nearly $17 billion the previous year.

Nonetheless, production rates remain at record high levels. A key enabler of these high production rates has been U.S. and European government export credit financing, which now assists with a record level of transactions. This might be sustainable, but it clearly speaks to some fundamental weaknesses in the market, in terms of both demand and finance availability. Most of the 2009 deliveries financed by private banks and lessors were arranged before the credit crunch transpired. While this crunch is easing, many key jetliner financiers remain under heavy pressure, particularly AIG's ILFC unit, CIT, and the Royal Bank of Scotland.

Production cuts will begin in earnest in the second half of this year and will primarily affect narrowbodies.

In short, large jets are a lagging economic indicator. That market will avoid a downturn commensurate with the horrors that befell the world's economies in 2008-2009, but there is no hope that the jetliner industry will avoid some kind of painful aftershock. The most likely scenario is that production cuts will begin in earnest in the second half of this year. These cuts will primarily afflict narrowbodies—Airbus's A320 and Boeing's 737 families. Together, these families comprise over 55% of 2008-2009 deliveries by value, the highest level in decades. Narrowbodies have seen the worst drops in asset values and lease rates, yet are most dependent on low-margin domestic traffic. Teal Group's forecast calls for narrowbody production to fall by one-third in 2011-2012.

Both of the big jetliner primes face challenges through the downturn. If Boeing finally succeeds in flying its 787 Dreamliner and beginning deliveries in 2011, that will provide some level of insulation from the drop in narrowbody revenue. However, there are still major challenges and uncertainties associated with bringing this new product to market. As for Airbus, there is no hope of additional revenue from an A380 ramp-up. That product is marginally relevant in good times, and almost completely unwanted in a downturn. The major challenge for the company will be to keep funding development of the far more important A350XWB.

One part of the air transport business has already begun shrinking. The regional jet market, which spent the great 2003-2008 boom going exactly nowhere, began contracting in 2009. Given ongoing capacity cuts in the key North American market, there is a near certainty of further cuts in 2010, at least for the two big legacy producers, Bombardier and Embraer. Next year should see first deliveries of Sukhoi's SuperJet, to be followed by China's ARJ21.

Business jets suffer first

While regional jets have suffered from a softened market, business jets have felt the full up-front impact of the downturn. While they usually are also a lagging economic indicator—deliveries lag corporate profit changes by about 18 months—this time the bottom half of the business jet market has fallen directly in line with the broader economy.

Even excluding the VLJ (very light jet) segment, which has seen a precipitous drop since Eclipse went bankrupt and ceased production in late 2008, business aircraft deliveries fell 22.5% by value in the first half of 2009 relative to the first half of 2008, with a similar number forecast for the complete year. Yet when business aircraft delivery numbers are broken down by model, an unusual pattern emerges. Deliveries in the bottom half of the market have declined by a remarkable 46.6% (also excluding VLJs). Deliveries in the top half have actually stayed almost constant. Dassault, the one business jet company that plays exclusively in the top half of the market, actually plans on being the only manufacturer to increase jet output in 2009 relative to 2008.

Curiously, this bottom-half market downturn does not appear to have affected turboprop models. Turboprop production has declined by only 19% in the first half, a gentler drop than the broader business aircraft market decline of 22.5%. The major turboprop producers are also keeping their production plans generally steady. This is purely a light and medium jet market collapse.

Civil helicopters have also begun to feel up-front pain. Corporate demand has softened, and budget cuts in some state and local governments have threatened to decrease law enforcement demand. However, civil helicopters have been boosted by surprisingly buoyant prices for raw materials, particularly oil. This should limit the market's downturn to -13.3% in 2009. Given the market's record growth rates of 2003-2008, this does not look like a major setback, although anything that threatens government and homeland security budgets in the coming years could make the situation worse.

Defense holding up, for now

The important military market—30% of 2009 aircraft deliveries by value, but a much higher share of profits—is largely immune from economic cycles, but there are few doubts that military spending in the key U.S. market has peaked. Political sentiment is turning toward deficit reduction and social costs, particularly health care. On the foreign policy front, interest in fighting two very expensive wars, in Iraq and Afghanistan, is clearly waning. This virtually guarantees that the FY10 base budget is the highest we will see for years, at least in real terms.

The FY10 base budget request hit a new post-Cold War peak of $550 billion (including funds for nuclear arms and other non-DOD functions). However, supplemental spending packages, requested by the administration or added by Congress for warfighting purposes, are expected to shrink. In fact, with supplemental funds, FY09's total defense budget of $676 billion was down from FY08's $696 billion.

It is also important to note that the Obama administration has carried on the Bush administration's refusal to use defense spending as a form of economic stimulus. As a result, the F-22 and VH-71 programs will die with the FY10 budget. Without congressional intervention, the C-17 program would have died as well, terminating the last jet built in California.

Military helicopters are an ongoing bright spot in the defense budget. Most of the U.S. fleet has been badly worn out by combat operations in Iraq and Afghanistan, and many allied military helicopter fleets are feeling a similar strain. In the U.K., an inadequate helicopter force has become a major factor in the public debate over committing troops to Afghanistan.

This makes mature production helicopter programs big winners. FY10 is notable as the first U.S. defense budget in years that did not rely on supplemental spending to provide necessary helicopters. In previous budgets, the Army would request about 60 UH-60 Black Hawks, and count on Congress to add about 20 more in the supplemental process. In FY10, the Army's budget requests 79 UH-60s, the highest number in over 15 years.

The UH-60 Black Hawk is a big winner in the defense budget.

As a result of this strong demand, the military helicopter market grew 30.1% by revenue in 2009, with further growth into this year. High levels of use guarantee strong profits for U.S. rotorcraft primes and their supplier base.

The only aviation market that has performed almost on par with military helicopters over the past year is aircraft. However, this is due to a surge in Eurofighter Tranche Two deliveries, after the last few Tranche One planes were delivered in 2008. Thus it is not a sustainable trend. On the other hand, given strong backing for F-35 funding and the ongoing political popularity of Boeing's F/A-18E/F, there is little risk of any significant market dip over the next five years, at least.

The promise of exports

With the U.S. defense budget trending downward, U.S. primes will increasingly look to international markets for growth, or at least sustainment. They will be in good company. U.S. commercial companies have already reached record levels of export reliance. The 238 companies of the S&P 500 are expected to report that about 50% of their revenues

AIRCRAFT MARKET

Type	CAGR* '03-'08	'08-'09
Jetliners	6.8%	11.5%
Business AC	17.1%	-22.0%
Regionals	2.0%	-20.0%
Civil Rotorcraft	14.0%	-13.3%
Military Rotorcraft	11.5%	30.1%
Fighters	6.6%	24.5%
Military Transports	4.3%	7.6%
Total	**7.9%**	**4.6%.**

Compound annual growth rate.

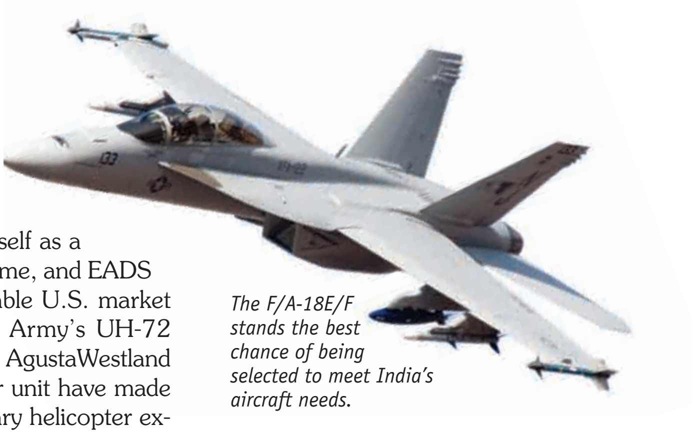
in 2009 came from export markets, up from 43.6% in 2006. Boeing currently relies on exports for about 90% of its jetliner revenue. U.S. business jet manufacturers, typically reliant on the U.S. for about 65% of their sales by revenue, now export the majority of their production by value.

Defense company reliance on export runs counter to home market budgets. With a robust U.S. defense budget, fighter aircraft exports made up just 26% of deliveries by value in 2009. But in the late 1990s, when U.S. and European defense budgets were quite weak, export deliveries comprised about 70% of the market by value.

U.S. companies looking to expand their sales abroad will also find themselves mirroring European companies that have long been forced to seek export markets, particularly in the U.S., because of low levels of home market defense spending.

BAE Systems has succeeded in reinventing itself as a transatlantic defense prime, and EADS has scored several notable U.S. market victories, including the Army's UH-72 Light Utility Helicopter. AgustaWestland and EADS's Eurocopter unit have made strides in securing military helicopter export orders at the expense of U.S. incumbents, most notably in Australia, South Korea, and Turkey.

Finally, U.S. defense primes will find some welcome opportunities abroad. The biggest export fighter competition of all time, India's 126 aircraft requirement, will likely be decided in the next year or two, and Boeing's F/A-18E/F has the best chance of all six contenders. Significant opportunities also exist in South Korea and the Middle East, where Saudi Arabia is reportedly considering a 72-aircraft F-15 buy.



The F/A-18E/F stands the best chance of being selected to meet India's aircraft needs.

The world aerospace industry saw some very good numbers in 2009, despite the economic downturn. Defense work at home and abroad will provide some insulation from troubling commercial numbers, but there is no doubt that 2010 and 2011 will see a decline in sales, unless the economy makes an unusually strong recovery.

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Out of This World: The New Field of Space Architecture

A. S. Howe
Brent Sherwood
Syd Mead
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Out of This World: The New Field of Space Architecture

This collaborative book compiles thirty chapters on the theory and practice of designing and building inhabited environments in outer space. Given the highly visual nature of architecture, the book is rich in graphics including diagrams, design drawings, digital renderings, and photographs of models and of executed and operational designs.

Written by the global network of practicing space architects, the book introduces a wealth of ideas and images explaining how humans live in space now, and how they may do so in the near and distant future. It describes the governing constraints of the hostile space environment, outlines key issues involved in designing orbital and planet-surface architecture, surveys the most advanced space architecture of today, and proposes far-ranging designs for an inspiring future. It also addresses earth-based space architecture: space analogue and mission support facilities, and terrestrial uses of space technology.

In addition to surveying the range of space architecture design, from sleeping quarters to live-in rovers to Moon bases and space cities, the book provides a valuable archival reference for professionals. Space enthusiasts, architects, aerospace engineers, and students will find it a fascinating read.

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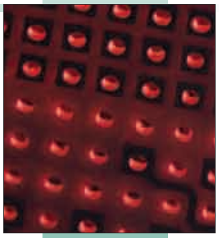


Future tactical communications: Getting the JTRS

Modern warfare as fought by the U.S. and its major allies is dependent upon C4ISR (command, control, communications, computers, intelligence, surveillance, and reconnaissance). An ever-increasing amount of bandwidth-intensive data and video must be moved to, from, and across the battlefield. Yet U.S. legacy tactical communications links (radios) lack the capacity and flexibility to "achieve and maintain this level of information superiority," according to the GAO and most services.

For the past decade, the planned solution to this deficiency has been the joint tactical radio system (JTRS). This DOD family of common software-defined programmable radios will form the foundation of future radio frequency information transmission. Designed to interoperate with existing radio systems, JTRS radios have additional capabilities, including accessing maps and other visual data, communicating via voice and video, and obtaining information directly from battlefield sensors. JTRS will provide an Internet protocol-based capability and is planned to replace all existing tactical radios with interoperable line-of-sight and beyond-line-of-sight radios.

JTRS is built around an open software communications architecture (SCA), allowing common software waveform applications to be used across the family of radios to provide joint-service, allied, and coalition interoperability (including signed agreements with Japan, the U.K., and Sweden).

To satisfy these demands, JTRS has improved networking, increased bandwidth, and emulation/interaction with many different legacy radios that today cannot intercommunicate. The system will also function as a router for tactical networks.

A comparison of the most important legacy and next-generation tactical radio waveforms shows significant differences. SINCGARS (single channel ground and airborne radio system)—today's primary means of command and control for Army combat and support units, and the most important tactical radio in the world—has an extremely limited data transfer capability, not useful for transferring maps, images, or video. The Army's current battlefield digital data communications system, EPLRS (enhanced position location reporting system), has a data transfer rate more than 50 times greater, up to 1 Mbps—still incredibly slow by commercial standards.

TADIL-J/Link 16, the waveform utilized by the increasingly ubiquitous airborne MIDS (multifunctional information distribution system) data link, has a similar, and still slow, data rate. Future JTRS ground vehicle radios, using a wideband networking waveform, will provide up to 5 Mbps, and the joint airborne network-tactical edge will provide a still-unspecified but much greater capacity for airborne communications and data transfer.

JTRS radios will use these new waveforms, and will be able to operate on multiple channels simultaneously. For example, a four-channel JTRS radio on a ground vehicle could be programmed to have channels dedicated to SINCGARS, EPLRS, the wideband networking waveform, and the joint airborne network-tactical edge waveform. With a gateway device, data can be transferred from one channel to another, providing a vital router and networking function encompassing legacy and next-generation radios and ISR systems.

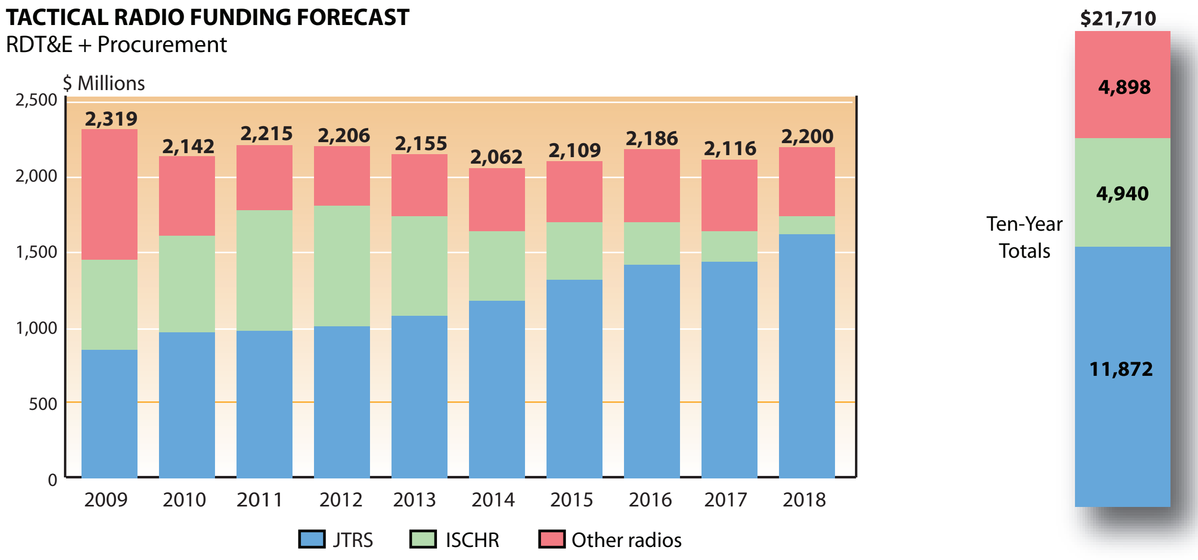
Airborne programs

Today's most important legacy aircraft radio is the Rockwell Collins AN/ARC-210(V) multimode integrated communications system, an airborne transceiver for secure and nonsecure voice and data communications. A joint service system, it links all branches of U.S. and NATO forces, the civil air traffic control system, and land-mobile and maritime users. It is the standard multimode radio for the majority of U.S. combat aircraft, replacing 19 different existing radios in the Navy alone. With JTRS not yet ready,

TACTICAL RADIO WAVEFORMS

Waveform	Frequency, MHz	Bandwidth,[1] kHz	Data rate, kbps	Voice data rate, kbps
SINCGARS	30-88	25	.075-16	16
EPLRS	420-450	3,000	<1,000	
High frequency	2.0-30	3, 6, 12	.075-9.6	.075-9.6
Have Quick	225-400	25	.075-16	16
TADIL-J[2]	960-1,215	3,000	28.8-1,137	2.4/16
UHF SATCOM DAMA[3]	225-400	5, 25	.075-56/64	.075-56/64
Wideband networking[4]	2-2,000	25-30,000	<5,000	
Soldier radio[5]	2-2,000	13,000	<1,000	
Joint airborne network-tactical edge	2-2,000	TBD	TBD	TBD

Based on GAO-08-877, August 2008.
[1]Nominal channel bandwidth.
[2]Tactical data information link-joint.
[3]Ultra-high-frequency satellite communications demand assigned multiple access.
[4]Four different waveforms in family; intended for ground vehicles.
[5]Three different waveforms in family.



the U.S. services have continued to procure the ARC-210.

In 2008, the Navy was funding ARC-210 upgrades to add capabilities not included in the first JTRS increment, such as the ability to host the JPALS (joint precision approach and landing system) waveform. The service is also modernizing the radio to address NSA requirements for cryptographic obsolescence in legacy radios. According to Navy officials, the Navy plans to spend about $50 million in RDT&E for ARC-210 modernization.

While the ARC-210 is primarily a radio, and the aforementioned MIDS includes a secure voice channel, MIDS is more important for the common navigational grid it automatically creates for its subscribers, providing situational awareness and command and control capabilities. MIDS was developed by an international consortium, MIDSCO, led by the U.S. and including France, Germany, Italy, and Spain. In 1994, DOD awarded a $342-million EMD contract for the MIDS-LVT (low volume terminal), today serving aboard the F-15, F-16, F/A-18, Rafale, Eurofighter, and many other platforms. Production began around the beginning of the decade and continues.

MIDS-JTRS, with $140 million in RDT&E contracts awarded to Data Link Solutions and ViaSat in 2004, is designed to be plug-and-play interchangeable for Navy and Air Force platforms that use MIDS-LVT, while accommodating future JTRS technologies and capabilities. The objective is to transform the current MIDS-LVT into a four-channel, SCA-compliant JTRS, adding enhanced throughput, link 16 frequency remapping and programmable crypto, while maintaining current link 16 and tactical air navigation system functionality.

By December 2007, two Navy F/A-18s had been equipped with preproduction versions of MIDS-JTRS, and the Navy planned to buy at least 441 systems for all F/A-18E/Fs and EA-18Gs. Other planned platforms are Navy E-2D Advanced Hawkeyes and Air Force B-1 bombers and F-15E fighters.

But another system is planned as the comprehensive next-generation airborne solution—the airborne/maritime/fixed-station JTRS program. In FY06 presystem development and demonstration contracts were awarded to Boeing and Lockheed Martin, which won the $766-million development contract in April 2008. These radio/data links will eventually be integrated onto UAVs, aircraft, ships, submarines, and ground stations.

War intervenes

Ten years ago, DOD plans foresaw almost total dominance by JTRS, with the services not even permitted to buy non-JTRS radios without a special waiver. But the wars of the past decade have drastically changed these plans. Over the past several years, DOD funding for tactical radios has shifted dramatically, as JTRS development faced delays and

JTRS PLANNED PROCUREMENT HISTORY (Current Procurement by Service)

JTRS Radios	Initial Approved Procurement	Restructured Procurement (2006)	Current Procurement (2008)	Army	USAF	Navy	USMC
Ground mobile	108,086	138,913	86,512	86,209	93	0	210
Handheld, manpack, small form fit	328,514	164,137	95,551	74,512	10,680	1,477	8,882
Airborne, maritime, fixed station	N/A	17,007	11,040	5,845	4,725	470	0
Total	**436,600**	**320,057**	**193,103**	**166,566**	**15,498**	**1,947**	**9,092**

as active wars required immediate replacement of older tactical radios (including some Vietnam-era radios still in the Army National Guard and Reserves). Changes in tactics and the U.S. concept of operations also brought many more radios to ground forces. These increases in the total number of radios were filled by shifting and increasing funds to buy hundreds of thousands of legacy radios (led by SINCGARS), and by decreasing JTRS funding.

From FY03 to FY07, DOD spent an estimated $12 billion on tactical radios, more than it spent on Virginia-class submarines ($10.8 billion) and the Future Combat System ($10.4 billion) in the same period and a dramatic increase over the $3.2 billion planned in 2002. JTRS funding decreased from just under $3 billion to $2.5 billion, with no systems produced aside from an enhanced legacy handheld radio. Legacy radio funding increased from only $235 million planned (after a 1998 virtual ban on new procurements of legacy radios) to $5.7 billion for the Army ($4.1 billion) and the Marines ($1.6 billion). War supplemental funding bought most of these radios.

Availability and transfer of information are vital in modern warfare, and access to tactical communications has widened to lower and lower levels, with current soldier radios equivalent to the squad radios of a few years ago. A typical rifle company of around 180 Marines had about nine tactical radios before the war in Iraq; it now has about 225, with most for intrasquad communications. Also, nearly every vehicle used in combat operations has a radio, a necessity now that U.S. support vehicles are nowhere safe in occupied countries.

Current plans and forecasts

With war supplemental funding expected to disappear after this fiscal year, the U.S. no longer has a comprehensive investment strategy for future tactical communications. Increased JTRS costs and the presence of hundreds of thousands of new legacy radios (expected to have a useful life of 10-15 years) mean the services have been scaling back their planned purchases. The Marine Corps has essentially dropped JTRS ground mobile radio procurement plans, preferring to continue buying legacy radios until JTRS is proven. The Navy and Marines have also dropped most of their airborne JTRS requirements, instead continuing procurement of ARC-210s, which are much cheaper and provide a voice channel that initial AMF JTRS radios will not. But legacy radio procurements will also fall as needs are met.

JTRS was originally intended to replace most or all legacy tactical radios, but with the total number of radios in service now greatly increased, it will presumably take over higher end networking applications, with newer legacy radios continuing to serve at other levels for a decade or more. Planned procurement numbers show that the low-end handheld JTRS has already dropped from 328,514 units to only 95,551.

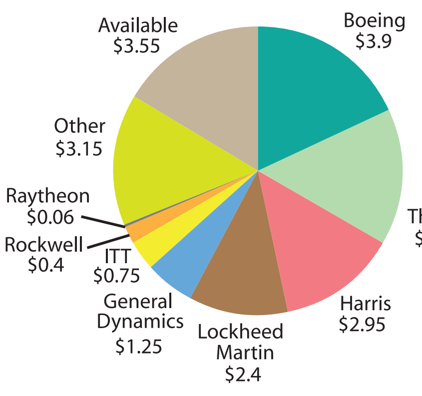
Since the need for improved C4ISR will undoubtedly continue to grow, as ISR and other needs require exponentially increasing bandwidths and networking capabilities, we see today's already-reduced 10-year JTRS procurement numbers holding or increasing as production ramps up (especially if unit costs drop significantly).

Thus, Teal Group forecasts a continuation of substantial JTRS funding, with further increases as production begins in volume over the next decade. In the meantime—for the next five years or so—transitional radios such as Harris and Thales' interim single-channel, handheld radios (ISCHR) will continue to receive massive funding. ISCHR does not provide the networking capabilities intended for JTRS, but it is capable of running multiple legacy waveforms, and it meets NSA security modernization requirements. The big change will be a drastic reduction in the wartime-funded legacy radios, which has already begun. The JTRS/legacy funding ratio may never return to the DOD plans of 2002 (92.7%/7.3%), but the ratio will change back to favor JTRS.

JTRS will have combined annual growth rates of 6.7% (FY09-FY14) and 7.4% (FY09-FY18); ISCHR will have −5.2% and −16.4% (with an interim production surge between now and FY14); and all other radios taken together will have −13.4% and −6.8% (because of still-substantial pre-JTRS SINCGARS, ARC-210, and other legacy funding today).

Our forecasts are necessarily somewhat speculative, as the FY10 budget provides no funding requests beyond FY10 and, as the GAO pointed out, DOD does not itself have definite plans for total radio requirements. Our forecasts are based to a significant degree on

TACTICAL RADIO MARKET SHARE
FY09-FY18 Value, FY09 $Billions



the current contracts, many of which are long term and give an idea of production at least for the next five years.

Beyond our forecast period, what will happen when the 2003-2007 Iraq/Afghanistan supplemental radio surge ages is very much in question. Will JTRS finally be cheap enough to replace tactical radios across the spectrum of applications? Possibly, but not with current or currently planned radios. We suspect new technology and miniaturization may make a new generation of small, cheap radios possible. But costs will have to be no more (and possibly less) than unit costs during the massive 2003-2007 recapitalization. Today's radios may soldier on for decades.

Competitors

In terms of competitor market shares, we see a near-equal share of funding over the next decade, spread among at least four top manufacturers. Teal Group sees the tactical communications market remaining more competitive than many other defense electronics markets, especially as high-volume products such as radios often offer cost-based contracting that is recompeted or reassigned every year (as ISCHR is planned).

Of the top four firms, Boeing and Lockheed Martin will rely largely on JTRS for their positions (Boeing also builds the legacy combat handheld aircrew survival radio), while Thales and Harris are the top non-SINCGARS legacy radio producers, and the co-primes for ISCHR.

Below these four, General Dynamics is prime for the JTRS HMS, and the now-legacy digital modular radio. ITT, the SINCGARS prime and one of the most important radio manufacturers of the past several decades, will struggle in a post-SINCGARS future, with its market share dwindling to almost nothing as JTRS ramps up, unless it can secure another major production program. On a smaller scale, Rockwell produces the ARC-210, and Raytheon builds the AN/PSC-5D TACSAT satellite radio.

Finally, note that some fairly important players lurk in our 'Other' funding forecast, including Motorola. Also, in addition to contracts for major efforts, some companies may earn considerable additional funding from smaller radio programs, as well as RDT&E funding. Thus, all the funding forecasts for Boeing through Raytheon are low-end estimates, and all these companies will likely earn more funding from other programs.

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Seeking other Earths

NASA's Kepler spacecraft will search for worlds that could host life. It is the first mission with the ability to find planets similar to Earth—rocky planets that orbit Sun-like stars in a warm zone where liquid water could be maintained on the surface. Liquid water is believed to be essential for the formation of life.

"Kepler is a critical component in NASA's broader efforts to ultimately find and study planets where Earth-like conditions may be present," says Jon Morse, the Astrophysics Division director at NASA Headquarters in Washington, D.C. "The planetary census Kepler takes will be very important for understanding the frequency of Earth-size planets in our galaxy and planning future missions that directly detect and characterize such worlds around nearby stars."

Kepler was launched from Cape Canaveral AFS, Fla., aboard a Delta II rocket on March 6, 2009. The mission will spend three-and-a-half years surveying more than 100,000 Sun-like stars in the Cygnus-Lyra region of our Milky Way galaxy. It is expected to find hundreds of planets the size of Earth or larger at various distances from their stars. If Earth-size planets are common in the habitable zone, Kepler could find dozens. If they are rare, it might find none.

In the end, the mission will be our first step toward answering a question: Are there other worlds like ours, or are we alone?

"Finding that most stars have Earths implies that the conditions that support the development of life could be common throughout our galaxy," says William Borucki, Kepler's science principal investigator at NASA Ames. "Finding few or no Earths indicates that we might be alone."

Designed for detection

The Kepler telescope is specially designed to detect the periodic dimming of stars, caused by planets as they pass by. Some star systems are oriented in such a way that their planets cross in front of their stars, from our earthly point of view. As the planets pass, their stars' light appears to dim slightly, or wink.

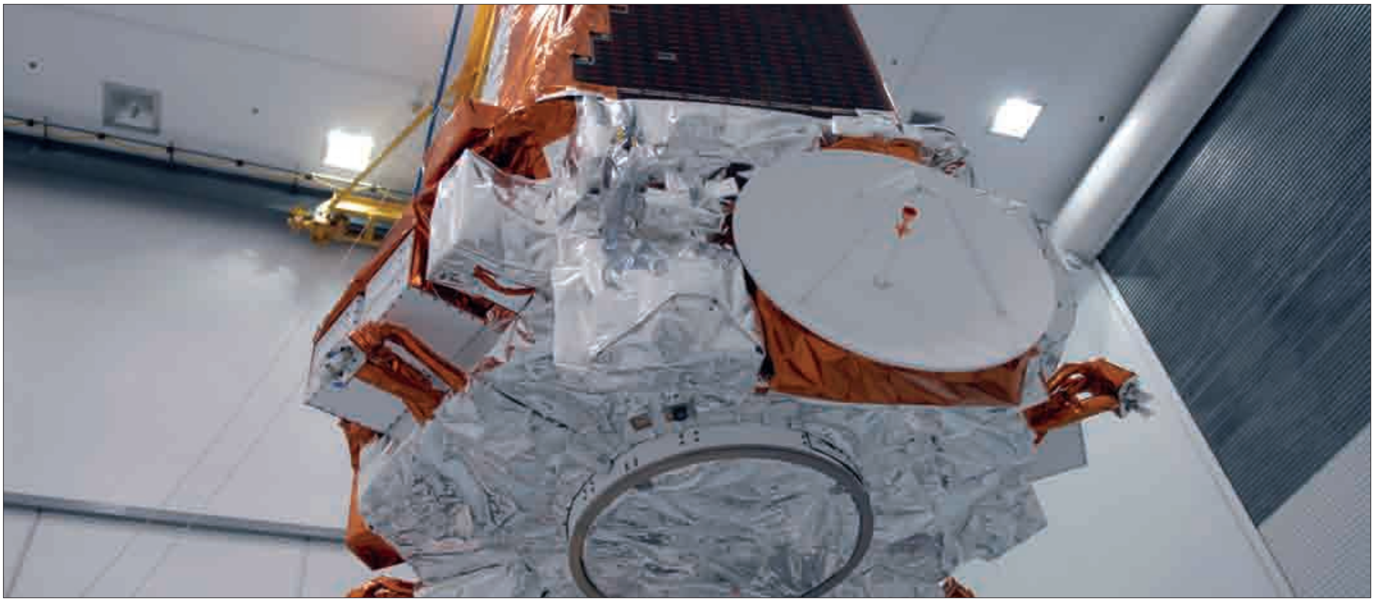
The telescope can detect even the faintest of these winks, registering changes in brightness of only 20 parts per million. To achieve this resolution, Kepler will use the largest camera ever launched into space, a 95-megapixel array of charge coupled devices.

"If Kepler were to look down at a small town on Earth at night from space, it would be able to detect the dimming of a porch light as somebody passed in front," says James Fanson, Kepler project manager at JPL in Pasadena, Calif.

By staring at one large patch of sky for the duration of its lifetime, Kepler will be able to watch planets periodically transit their stars, over multiple cycles. This will allow astronomers to confirm the presence of planets. Earth-size planets in habitable zones would theoretically take about a year to complete one orbit.

To confirm the presence or absence of such planets, Kepler will monitor those stars for at least three years. Ground-based telescopes and NASA's Hubble and Spitzer space telescopes will

The Kepler spacecraft, shown during its preparation for launch, is now searching for planets. Credit: NASA and Ball Aerospace.



perform follow-up studies on the larger planets.

"Kepler is a critical cornerstone in understanding what types of planets are formed around other stars," says exoplanet hunter Debra Fischer of San Francisco State University. "The discoveries that emerge will be used immediately to study the atmospheres of large gas exoplanets with Spitzer. And the statistics that are compiled will help us chart a course toward one day imaging a pale blue dot like our planet, orbiting another star in our galaxy."

Early payoff

In August 2009, a few months after its launch, the Kepler space telescope detected the atmosphere of a known giant gas planet, demonstrating the telescope's extraordinary scientific capabilities. The discovery was published in the journal *Science*.

The find is based on a relatively short 10 days of test data collected before the official start of science operations. The observation demonstrates the extremely high precision of the measurements made by the telescope, even before its calibration and data analysis software were finished.

"As NASA's first exoplanets mission, Kepler has made a dramatic entrance on the planet-hunting scene," says Morse. "Detecting this planet's atmosphere in just the first 10 days of data is only a taste of things to come. The planet hunt is on!"

Kepler team members say these new data indicate the mission is indeed capable of finding Earth-like planets, if they exist.

"When the light curves from tens of thousands of stars were shown to the Kepler science team, everyone was awed. No one had ever seen such exquisitely detailed measurements of the light variations of so many different types of stars," says Borucki, the paper's lead author.

The observations were collected from a planet called HAT-P-7, known to transit a star located about 1,000 light-years from Earth. The planet orbits the star in just 2.2 days and is 26 times closer to it than Earth is to the Sun. Its orbit, combined with a mass somewhat larger than that of the planet Jupiter, classifies this planet as a "hot Jupiter." It is so close to its star that the planet is as hot as the glowing red heating element on a stove.

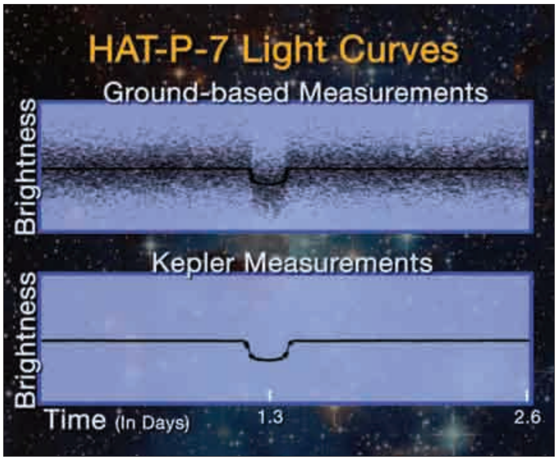


Chart compares the ground- and space-based light curves for exoplanet HAT-P-7b. The small drop in light called an occultation occurs when the planet passes behind its star. Image credit: NASA.

The Kepler measurements show the transit from the previously detected HAT-P-7. However, these new measurements are so precise that they also show a smooth rise and fall of the light between transits caused by the changing phases of the planet, similar to those of our Moon. This is a combination of the light emitted from and reflected off the planet. The smooth rise and fall of light is also punctuated by a small drop in light, called an occultation, exactly halfway through each transit. An occultation happens when a planet passes behind a star.

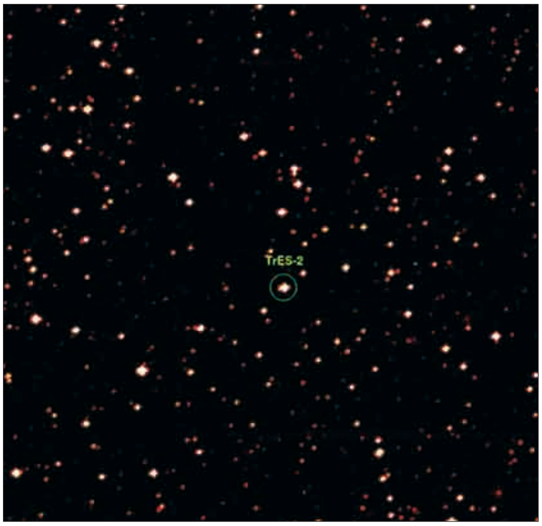
The new Kepler data can be used to study this hot Jupiter in unprecedented detail. The depth of the occultation and the shape and amplitude of the light curve show the planet has an atmosphere with a day-side temperature of about 4,310 F.

Little of this heat is carried to the cool night side. The occultation time compared to the main transit time shows the planet has a circular orbit. The discovery of light from this planet confirms the predictions by researchers and theoretical models that the emission would be detectable by Kepler.

This new discovery also demonstrates that Kepler has the precision to find Earth-size planets. The observed brightness variation is just one-and-a-half times what is expected for a transit caused by an Earth-sized planet. Although this is already the highest precision ever obtained for an observation of this star, Kepler will be even more precise after analysis software being developed for the mission is completed.

"This early result shows the Kepler detection system is performing right on the mark," says David Koch, deputy principal investigator at NASA Ames. "It bodes well for Kepler's prospects to be able to detect Earth-size planets."

Kepler is a NASA Discovery mission. Ames is the home organization of the science principal investigator, and is re-



As you zoom into a small portion of Kepler's full field of view, at the center is a star with a known hot Jupiter planet, TrES-2, zipping closely around it every 2.5 days. The area is one-thousandth of Kepler's full field of view, and shows hundreds of stars at the very edge of the constellation Cygnus. The image is color-coded so that brighter stars appear white, fainter stars, red. Image credit: NASA/Ames/JPL-Caltech.

sponsible for the ground system development, mission operations, and science data analysis. JPL manages the Kepler mission development. Ball Aerospace & Technologies in Boulder, Colo., is responsible for developing the Kepler flight system and also for supporting mission operations.

For more information about the Kepler mission, visit: http://www.nasa.gov/kepler

The bigger picture

Providing additional perspective on the search for living planets, Alan Boss, affiliated with the Carnegie Institution for Science, Washington, D.C., says that we entered a new era of human understanding of our universe following a major advance that occurred in 1995: the discovery of planetary systems around stars other than the Sun.

Speaking at the February 2009 meeting of the American Association for the Advancement of Science in Chicago, he pointed out that roughly 300 planets have been found outside our solar system to date, ranging from the fairly familiar to the weirdly unexpected. Nearly all the planets discovered so far appear to be gas giants similar to our Jupiter and Saturn.

The star COROT-7 is located at a distance of about 500 light-years. Slightly smaller and cooler than our Sun, CoRoT-7 (in the center of the image) is also thought to be younger, with an age of about 1.5 billion years. It is now known to have two planets, one of them (COROT-7b) being the first to be found with a density similar to that of Earth. (Copyright: ESO/Digitized Sky Survey.)

However, Boss adds that the past few years have witnessed the discovery of over a dozen planets with much lower masses, in the range of 5-20 times that of the Earth—masses comparable to those of our ice giant planets, Uranus and Neptune. It is not yet clear if these smaller mass planets are ice giants or perhaps rocky planets similar in composition to the Earth, but with much more mass—that is, super-Earths. The latter possibility would be tantalizing evidence that Earths are common.

European space agencies and NASA have launched and planned an array of space-based telescopes that will carry out this search in the next several decades.

COROT's results

The French-led COROT Mission and NASA's Kepler are searching for evidence of Earth-mass planets by relying on the transit technique, whereby the presence of a planet is inferred from the tiny dimming of starlight it causes as it passes in front of its star. COROT and Kepler are likely to provide our first firm estimates of the frequency with which habitable Earth-like planets are distributed in our neighborhood of the galaxy.

Once that frequency is known, Boss adds, scientists can design specialized space telescopes that can image these new worlds and tell us whether their atmospheres show evidence of the molecules necessary for life (such as water and oxygen), and possibly even evidence of those created by life (methane).

He points out that we will then know if any of the nearby stars harbor planets that are habitable and perhaps even inhabited. We will know just how crowded the universe really is.

Some early results of the COROT space mission are remarkable. The COROT (convection, rotation, and planetary transits) satellite is a 30-cm space telescope launched on December 27, 2006, from Baikonur, Russia. Since then it has been orbiting at about 900 km from the Earth, monitoring the changes in brightness of a huge number of stars with unprecedented accuracy. This aims at both detecting exoplanets by the transit method and studying the seismology of a wide variety of stars.

In October 2009 *Astronomy & Astrophysics* published a special issue dedicated to the early results from COROT. The mission was developed and is operated by the French space agency CNES, with the participation of ESA's RSSD and science programs, Austria, Belgium, Brazil, Germany, and Spain.

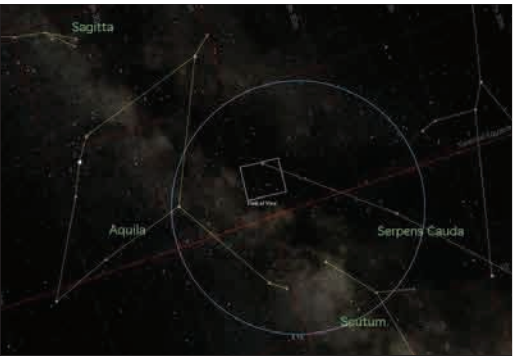
So far, seven exoplanets have been discovered in the COROT data and confirmed by ground-based follow-up campaigns. The difficulty with this exoplanet hunting is that it requires a long process of deciphering the candidates and finally characterizing a few stars hosting planets among tens of thousands.

The most exciting, and now famous, planet-hosting star is named COROT-7. The discovery of COROT-7b, the smallest exoplanet ever found, was announced in February 2009 during the first COROT international symposium. Scientists measured the mass of the planet—five Earth masses—using additional ground-based measurements. They calculated its density (about 5.6 g/cm^3), showing that COROT-7b, like Earth, is rocky. This is the first rocky exoplanet confirmed to date. Scientists also discovered a second planet in the COROT-7 system. Now known as COROT-7c, it is another super-Earth exoplanet of about 8 Earth masses.

Detection of the secondary transit of COROT-1b provides an example of the accuracy of COROT's data when the planet passes behind its star. This is a real challenge, because the amplitude of such an event is about 100 parts per million. Comparing the depths of both transits provides information on the albedo of the planet, hence on the nature of its atmosphere.

Seismology of stars

COROT's primary goal is not only to hunt exoplanets, but also to study the seismology of stars. This part of the mission is also a major step forward. Several scientists are working to detect and measure solar-like oscillations in distant stars. COROT shows that the oscillations are generally more complicated than those of the Sun, which poses new problems of interpretation. Such oscillations have also been detected and quantified for the first time in many red giants, us-



The field of view is seen at the frontier between Aquila and Serpens Cauda. Alya is an appropriate seamark to precisely locate the sky surveyed by COROT.

ing data from the exoplanet search program. The physical processes responsible for these complex oscillations are now understood.

COROT's observations of hot stars also gave astonishing results. The satellite observed a Be star during an outburst phase and measured the change in the oscillation spectrum during this rare event. A Be star is a B-type star that shows hydrogen emission lines. The B spectral type includes luminous, white-blue stars, with surface temperatures of 10,000-30,000 C. Typical Be stars are rapidly rotating, variable bodies. Achernar (a Eridani), the ninth brightest star in the sky, is a famous Be star. These observations gave insight into the nature of the explosion. It will help in solving a question that has been pending for years: Are oscillations the cause of the outburst?

Stellar physics

Although primarily devoted to asteroseismology and exoplanet search, COROT also addresses many important topics in stellar physics. Several scientists who deal with stellar activity have detected spots in the stars' photospheres, giving access to their rotation rate. In some cases, it is even possible to detect the latitude dependence of the rotation rate. Significant progress in the modeling of fast-rotating stars will help in understanding the new data.

The COROT satellite has been orbiting the Earth for nearly three years and will be operated until 2013. Already it has been a pioneering mission that has led to major insights in both exoplanetary and asteroseismic domains.

An even more ambitious mission, the ESA project PLATO, is still under assessment as part of the ESA Cosmic Vision program for 2015-2025. PLATO will be able to combine the detailed study of the stellar interior and of the planetary environment of tens of thousands of bright stars.

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Small Explorers with big benefits

Although the public's attention usually focuses on larger spacecraft with high-profile missions, it is often NASA's small satellites that make the most surprising and useful discoveries. Fast-track schedules, low launch costs, and mission flexibility are among the key benefits of these innovative Small Explorer spacecraft.

NASA's purpose is to push the frontiers of exploration and knowledge in aviation and space. Public attention, however, focuses mainly on the agency's big, expensive space efforts—manned lunar missions, robotic explorations of the planets, moons, asteroids, and comets in our solar system, and specialized telescopes seeking other Earth-like planets in our galaxy or previously undiscovered galaxies in the universe.

However, some of the most useful—and surprising—discoveries in NASA's five-decade history have come from small satellites, often sent aloft via small, inexpensive launchers or tacked onto large rockets when space was available. While such missions have been part of the NASA portfolio from the beginning, since 1992 they have been formalized in four categories of Explorers programs:

•Medium-class Explorers (MIDEX): Their missions do not exceed $180 million (in FY02 dollars) and are under the direction of a principal investigator (PI).

•Small Explorers (SMEX): Their PI-led missions do not exceed $105 million (in FY08 dollars).

•Missions of Opportunity (MoOs): These are non-NASA space missions of any size, having a NASA cost of less than $70 million (in FY08 dollars). MoOs are conducted on a no-exchange-of-funds basis with the organization sponsoring the mission. Proposals are solicited in each announcement of opportunity issued for both SMEX and MIDEX investigations.

•University-class Explorers (UNEX): The least expensive of the lot, these are

by J.R. Wilson
Contributing writer

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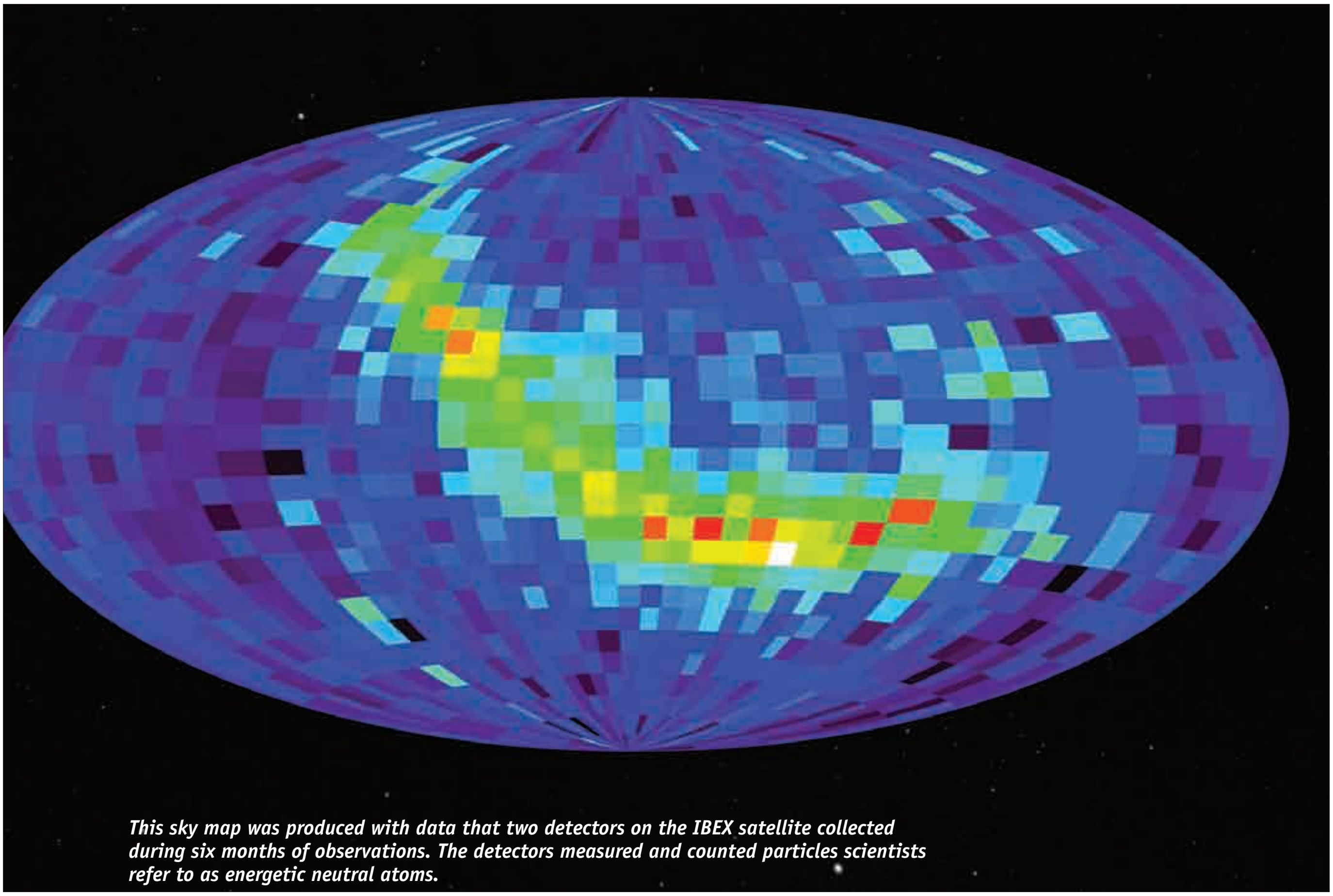


This sky map was produced with data that two detectors on the IBEX satellite collected during six months of observations. The detectors measured and counted particles scientists refer to as energetic neutral atoms.

launched by a variety of low-cost methods. NASA currently has suspended UNEX missions for lack of inexpensive launch opportunities.

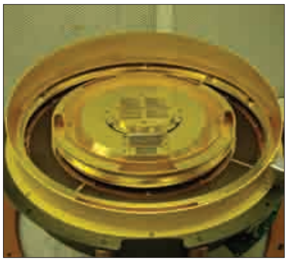
Breaking new ground

The first SMEX mission was the Solar Anomalous and Magnetospheric Particle Explorer (SAMPEX), launched on July 3, 1992, by a Scout rocket. SAMPEX quickly entered the history books with the discovery of a new belt of trapped interstellar heavy nuclei circling the Earth within the inner Van Allen radiation belt—itself discovered by NASA's Explorer I satellite in 1958.

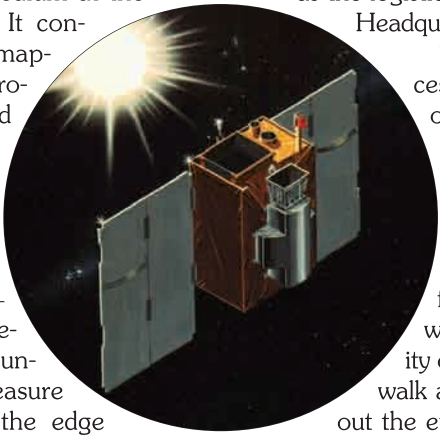
SMEX satellites have relied on the least expensive launch vehicles available, primarily the Orbital Sciences Pegasus rocket, which is first carried aloft with its payload by a Lockheed L-1011 converted for that purpose. The Pegasus is dropped from the aircraft, then ignites its own rocket to lift its payload into LEO.

IBEX, the Interstellar Boundary Explorer, launched on October 19, 2008, featured an innovation that broke new ground for future SMEX missions: A separate solid rocket motor (SRM) was attached to the satellite, enabling it to move from LEO to the near-lunar orbit required for its mission.

"Pegasus can fly about 1,000 lb to LEO; we used about 70% of that for the extra rocket and put a 300-lb IBEX satellite on top of that, basically using Pegasus as a first stage," IBEX PI Dave McComas tells *Aerospace Amer-*



IBEX has two sensors, IBEX Hi (seen here) and IBEX Lo. Each time an energetic neutral atom comes into one of the sensors, it is recorded; at the end of six months of that data scientists will have a picture of the entire 360° longitude celestial sphere. (Photo courtesy Southwest Research Institute.)



SAMPEX, launched by a Scout rocket, was the first SMEX mission.

ica. "So now there is a proven launch capability other small science missions can use. We were only about 10 lb away from leaving Earth orbit, so the same launch technique could be used to get to L-1 or the Moon, or even other planets. That's a really cool sideline of this, developing a new launch capability for NASA as part of our Small Explorers program.

"It took a lot of effort. We bought two SRMs, testing one and flying the second, and had to figure out a lot of rocketry rarely done by science teams—maybe never done by a science team before. Orbital was the lead on that work, although we also worked on it and brought in other experts as well. We were the prime, they were our subcontractor, so we retained overarching responsibility."

Mapping the heliosphere

IBEX's science objective was to discover the nature of the interactions between the solar wind and the interstellar medium at the edge of our solar system. It conducted the first complete mapping of the heliosphere, a protective boundary of solar wind traveling at 1 million mph and preventing about 90% of galactic radiation from entering the solar system. IBEX used two energetic neutral atom (ENA) sensors—one on each side of the spacecraft, perpendicular to its Sun-pointed spin axis—to measure particles coming in from the edge of the solar system, roughly 100 times farther out than the Earth is from the Sun.

As the spacecraft spun at four rpm, the ENA measurements were converted to pixels, building a crescent-shaped piece of the map. As it tracked the Sun, the sensors' circular swaths moved across the sky, gradually creating a complete image of the heliosphere and its interaction with interstellar radiation.

Without the heliosphere, radiation levels would make manned spaceflight, even to Earth's Moon, extremely dangerous, if not impossible, according to McComas, who is assistant vice president of the Space Science and Engineering Division of the Southwest Research Institute in San Antonio, Texas.

McComas compares the IBEX map to an artisan weaving a colorful pattern on a loom, one thread at a time.

"For the first time, we're sticking our heads out of the Sun's atmosphere and beginning to really understand our place in the galaxy,"said McComas following the October 2009 release of the sky map image. "The IBEX results are truly remarkable, with a narrow ribbon of bright details or emissions not resembling any of the current theoretical models of this region."

Managing for success

Although McComas' team went further than most, having full responsibility for every aspect of a SMEX mission is part of the job description for a PI.

"The PI formulates and manages the mission. We'll provide support to the PI in any way we can, such as providing expertise he may not have and backing him up with that resource, but the PI is really the architect of the mission, from the science to implementation," says Joe Dezio, Explorers deputy program manager at NASA Goddard. "One of our functions is to pass the budget on to him as the logistics interface with the [NASA] Headquarters line item budget.

"Our job is to make him successful. Period. But there is one caveat—while it is the PI's mission and team, as long as taxpayer money is involved, we have to be accountable for the success and application of that funding, so we still have what we call technical authority on the mission. We can't just walk away from the PI. Throughout the effort, we support all the reviews and have our own standing review teams mixed in with the PI's. So it is a bit of a strange mix—the PI's team and architecture, but we still have technical authority and must follow developments closely enough to assure everyone it will be successful on orbit."

Speed is key to a SMEX mission, which typically seeks to use the best available technology to learn something new before another generation of technology passes it by. As a result, the ideal SMEX concept takes about 36 months from initial proposal to launch, compared to an average of seven years for a standard NASA satellite program.

"We like to see about 2.5 years' development time, although sometimes it takes a bit longer," says Richard Fisher, director of the Heliophysics Division of NASA's Science Mission Directorate, which is responsible for approving Explorer missions. "The launch vehicles are at the 200-kg level for total payload, which usually means a single instrument or set of sensors, such as particle sensors, and a simplified data stream with one instrument or instrument suite.

"The payloads that have been selected have been pretty much equally divided between astrophysics and heliophysics or space science. SMEX is operated out of the Heliophysics Division, but for the benefit of both groups. However, the program is not shared in that the missions go from one to the other."

Outside the box

Unlike larger NASA missions, which are chosen on the basis of how well they fit into the national goals and priorities identified about every 10 years by the National Academy of Sciences, the Explorers program is designed to allow outside scientists to propose the science to be investigated. More often than not, that involves rapidly following up on a new discovery or theory and, often, finding something no one had expected or thought to explore.

"IBEX, for example, is a unique mission attempting to image the protective bubble that shields us from cosmic radiation and particles from the galaxy. My view is this relatively small, rapidly done experiment will change textbooks forever. That's an example of a good SMEX mission—and something not part of a national goal identified by the decadal survey," says Fisher.

But not being part of the formal NASA research program also has its drawbacks.

"We have gone through a bit of a dry spell for access to space to be in the right price range for Explorer missions," Dezio notes. "We got used to Scout and Delta vehicles, which were modestly priced, from $50 million to $70 million in the 1990s, which was a reasonable price for access to space. Back then, we scheduled about one every 12-18 months.

"In the past few years, the Pegasus vehicle has become one of the workhorses for the smaller missions. And there is competition coming into play with the Falcon [privately developed by SpaceX], which is adding to the access to space. And, of course, the [Orbital Sciences] Taurus is developing, taking the smaller end of the [retiring] Delta II market, and Minotaur [ICBMs converted for civilian launches by Orbital], which may be a little more capable than the Taurus. There may be more coming down the road, but Falcon and Pegasus are the only viable ones we have now."

Because of their comparatively low cost, SMEX missions are given more leeway on risk than larger satellites requiring more expensive launchers. They also tend to have shorter active life spans—typically only one or two years, although McComas believes IBEX may have enough reserve fuel to continue mapping operations for a full decade.

Birth of a mission

A Small Explorer begins with a NASA announcement of opportunity, usually including several missions in the SMEX or MIDEX range. Scientists then submit proposals for peer review, both within NASA and by non-NASA experts in the related fields.

"They make a judgment about cutting-edge science that is technically feasible. Once that determination is made, the associate administrator for science will look at the distilled evidence and make a selection," Fisher explains. "We like to offer a range of sizes of flight opportunity, from suborbital with high-altitude balloons and sounding rockets up to MoOs and SMEX and MIDEX.

"It is not uncommon for scientific knowledge to change from one mission to the next, and the scientific community is extremely good at evaluating and imaginative in using whatever opportunities there are. So people will propose the best science, which shows up in various places. You also get a lot of cross-fertilization, where an investigator may submit a proposal that is rejected, for whatever reason, then improve it until it is highly honed and focused."

For the last competition, 49 proposals were deemed compliant with all stated requirements—17 MoOs and 32 SMEXs. A second competition reduced that to six chosen for a concept development, SMEX study along with about a half-dozen MoOs.

"At that point, you have about 20% of the SMEX proposals still in play. Now we will have to make a decision about downselecting to one to three of those," Fisher says. "That will depend on a number of things, including future obligations of the program, which is basically an economic problem. You also don't want to stretch things out, because the science may become obsolete the longer you wait, so there is a balance between the time for development, funding rate, and science."

(Continued on page 41)

The early Explorer missions were launched on less expensive rockets like the Scout.

Today, Pegasus and Falcon 1 are two options for launching SMEX satellites.

NASA's Kepler spacecraft, which is seeking Earth-like planets orbiting stars in the Milky Way, began as an unlikely candidate for success. But unusual persistence by the project's principal investigator has paid off, and the spacecraft has already proven its capability with its first successful detection of such a planet.

Kepler's search for Earth-like planets

by Leonard David
Contributing writer

Now far from Earth in a heliocentric orbit is NASA's Kepler spacecraft. This sharp-eyed probe is designed to spot Earth-size planets in or near the habitable zone of their parent stars. A planet residing in that not-too-cold, not-too-hot precinct is a world on which liquid water could exist. And where there is water, so too might there be life.

As NASA's first mission capable of finding such planets, the census-taking Kepler rocketed into space atop a Delta 2 booster on March 6 from Cape Canaveral AFS, Fla.

But Kepler is not just a success story. It is also a tale of cost overruns, near-cancellation, squabbles over its technological readiness, and a heavy dose of sheer persistence. Call it the little spacecraft that could…and is.

Staring contest

It is no easy assignment taking on the centuries-old aspiration to discern other worlds similar to our own. Thanks to ground- and space-based observations, hundreds of planets orbiting other stars have already been discovered. At present there is clear evidence for three types of exoplanets: gas giants, hot super-Earths in short-period orbits, and ice giants. But Kepler's task is to detect terrestrial planets ranging from one-half to twice the size of Earth. The spacecraft will gaze at a patch of space for indications of Earth-size planets moving around stars similar to our Sun. The search space contains some 100,000 such stars. Kepler is specifically designed to survey our region of the Milky Way galaxy.

"If Kepler got into a staring contest, it would win," says James Fanson, Kepler project manager at NASA's JPL in Pasadena, Calif. "The spacecraft is ready to stare intently at the same stars for several years so that it can precisely measure the slightest changes in their brightness caused by planets."

Making use of a 0.95-m-diam. telescope and an array of 42 charge-coupled devices, Kepler serves as a very fancy light meter, or photometer. From its orbit, the craft can measure brightness changes in a parent star as a planet transits across its face. From that light fluctuation in starlight—and time between transits—scientists can deduce the size of the planet, even the size of its orbit, and make a ballpark estimate of the planet's temperature.

Kepler is in a sense a finder-scope, locating candidate planets that can then become the target for Earth-based observations to rule out false-positive detections.

Building Kepler has meant tackling a suite of key requirements: pointing accuracy, a very large field of view, and low-noise electronics to maximize the ability to read data from the sensitive detection system.

Ball Aerospace & Technologies developed the Kepler flight system and supports mission operations. And while Kepler almost did not have its day in the Sun, the spacecraft has already displayed its brilliance.

First find

In an August 6 NASA science briefing, Kepler officials joyously announced that the exoplanet-hunting spacecraft had detected the atmosphere of a known giant gas planet, demonstrating the telescope's skill in meeting its scientific objectives.

Kepler's observations were collected from a planet called HAT-P-7, known to transit a star located about 1,000 light-years from Earth. The planet orbits the star in just 2.2 days and is 26 times closer to it than Earth is to our Sun. Because of this proximity, and be-

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cause its mass is slightly greater than the largest planet in Earth's solar system, HAT-P-7 is classified as a "hot Jupiter," with temperatures as high as the glowing red heating element on a stove.

"We are seeing a new discovery…the first time anyone has ever seen light from this planet. And we can use that light to understand the physics of its atmosphere," notes William Borucki, Kepler science principal investigator at NASA Ames. For 17 years he has worked to prove that Kepler is a workable proposition.

Borucki says Kepler's quest to determine the distribution of Earth-size planets is just a step, with more strides to follow, "in our exploration of the galaxy, to find out if there is other life out there."

Sara Seager, professor of planetary science and physics at MIT, was equally delighted. "This data today is just the tip of the iceberg…where discoveries will come much more rapidly than they have in the last 10 years," she said, also noting that exoplanet detection over that period has already been fast paced.

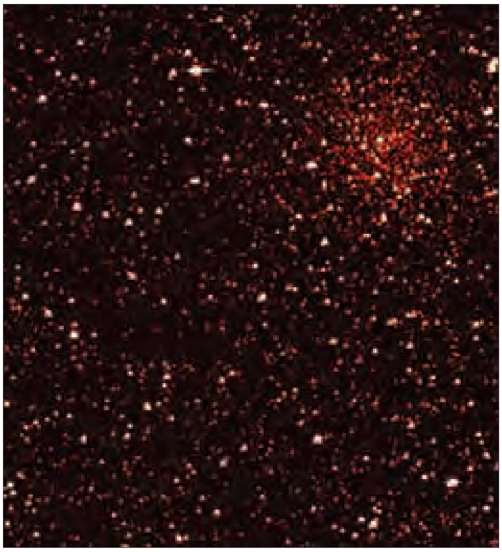
Taking part in the NASA science press conference, Alan Boss, an astrophysicist in the Dept. of Terrestrial Magnetism at the Carnegie Institution in Washington, D.C., gave kudos to Kepler. "We know now that Kepler can do it," Boss reported. "The question that remains is how many Earths are actually out there for Kepler to find? But the bottom line, the real headline for this whole press conference, is that Kepler works," he stated.

"The discovery of the optical light from HAT-P-7 proves that Kepler can find the transit of Earth-like planets. Now we have to wait for Kepler to do its job," Boss said.

Light curves over time

Kepler is a NASA Discovery mission costing $590 million. Overall, the spacecraft and its built-in photometer are about 2.7 m in diameter, and the craft measures some 4.5 m high—about as big as some shuttle buses. Its primary

The center of Kepler's photometer features a focal plane array of 42 CCDs. See a NASA animation of the optical path for the photometer at http://www.aerospaceamerica.org



This image zooms into a small portion of Kepler's full field of view—an expansive patch of sky in our Milky Way galaxy. An eight-billion-year-old cluster of stars 13,000 light-years from Earth can be seen in the image.

mirror is 1.4 m in diameter, and the spacecraft tips the scale at roughly 2,320 lb.

Kepler's Scientific Operations Center and project management (operations) are located at NASA Ames. Project management (development) is handled at JPL. The spacecraft's Mission Operations Center is in Boulder, in the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado.

A Data Management Center for Kepler is situated at the Space Telescope Science Institute in Baltimore, with NASA's Deep Space Network maintaining spacecraft telemetry. Flight segment design and fabrication were carried out at Ball Aerospace & Technologies.

"Kepler is being nice and boring right now," according to John Troeltzsch, Kepler mission program manager at Ball Aerospace. "We're up there taking the data, storing it…doing our mission. The whole vehicle is very healthy. We have good signal margin," he told *Aerospace America* in an August interview.

Over its 3.5-year mission, Kepler will seek planets 30-600 times less massive than Jupiter. Given that Earth-size worlds do indeed exist around stars like our Sun, Kepler is expected to be the first to find them, and the first to quantify their distribution. Mission lifetime can be extended to at least six years.

While there are no Hubble Space Telescope-like images flooding out of Kepler, its very large field of view—105 deg^2—allows it to be perfectly optimized for gleaning light curves over time, Troeltzsch says.

The spacecraft rolls every 30 days to align a fixed high-gain antenna to download that month's gathering of readings to the Deep Space Network. Kepler also carries out a 90-deg roll every 90 days to keep its solar panels always pointed at the Sun. It is the first operational Ka-band mission to pipe its science data down to Earth once a month. X-band is used for uplink and downlink communications. X-band contact is twice a week, for commanding and also for checking out the health and status of the probe.

"Talking to and from the vehicle is working very well right now," Troeltzsch notes. "Our solid-state recorder is healthy. All the capacity is there, and our compression ratio, which is something that we couldn't fully test before launch, looks good. As for our solar panels…again, our margins are excellent."

The spacecraft provides the power, pointing, and telemetry for the photometer. Pointing at a single group of stars for the entire mission greatly increases the photometric stability and simplifies the spacecraft design. Other than Kepler's small reaction wheels, used to maintain the pointing, and a now-ejected dust cover on the telescope's front end, along with three focus mechanisms for the primary mirror, there are no other moving or deployable parts. The only liquid is a small amount for the thrusters, kept from sloshing by a pressurized membrane. This design enhances the pointing stability and the overall reliability of the spacecraft.

Safing events and science creep

Kepler's photometer, its sole instrument, has a field of view 33,000 times greater than that

Noise in the system

Kepler engineers have encountered one glitch that has slowed the process of spotting Earth-size worlds.

Data from three of Kepler's array of 42 light-sensing detectors is subject to systematic noise. That noise is large enough to swamp out the ability of those detectors to identify tiny changes in light—central to spotting the minute Earth-size planet signal that they are looking for, says John Troeltzsch, Kepler mission program manager at Ball Aerospace.

The problem is not unique to Kepler. Every instrument that NASA has ever flown has its own unique characteristics. However, be it image artifacts or noise, calibration software on the ground can be rejiggered and refined to special process those effects.

Troeltzsch emphasizes that "Kepler is producing great data. It has demonstrated its capability to find Earth-size planets." Scientists at NASA Ames are developing new algorithms or adjusting existing algorithms to exploit Kepler's stream of planet-searching data, he says.

"The final release of software for the science pipeline is going to be in 2011," Troeltzsch tells Aerospace America. *"It's a little later based on what we've learned on-orbit …than what we predicted prelaunch."*

Those ground fixes will be in place in plenty of time to process Kepler data to confirm detection, if they are there to be spotted, of Earth-size worlds. Meanwhile, the spacecraft continues to churn out a mother-lode of exoplanet information, Troeltzsch suggests.

A wealth of information regarding larger-than Earth-size planets that Kepler has found is to be released this month at the annual meeting of the American Astronomical Society in Washington, D.C.

Troeltzsch reemphasizes that "Kepler is doing fine. We have software that we have to update for the ground to handle things that we have learned on orbit." The bottom line, he concludes: "Kepler is an amazing facility for finding exoplanets."

of the Hubble telescope. At its center the photometer features a focal plane array of 42 CCDs with more than 95 million pixels, the largest camera NASA has ever flown in space.

To detect an Earth-size planet, the photometer must be able to sense a drop in brightness of only 1/100 of a percent—analogous to sensing the drop in intensity of an automobile headlight when a fruit fly flutters in front of it.

"The one area where we had the most risk was in the camera, and it's working well. The CCDs are stable, the electronic temperatures are stable," says Troeltzsch. "Our overall noise number, which is really our sensitivity to finding planets, is coming in really nicely. We had our requirements. We had our goals. And we're inside of those. Not every CCD behaves exactly the same. There are a couple of them that are outside the specification, but that was to be expected. The distribution is nice."

But Kepler's commissioning has not all been smooth sailing. There have been hiccups. Spacecraft operators are looking into two safing events, apparently prompted by resets of the RAD750 main processor. The team is working to isolate the root cause of the events, "looking at observables, looking at the facts, and looking at our assumptions," says Troeltzsch. This process has led them to use a cause-and-effect tool, a fishbone analysis.

All flight programs have issues that operators have to live with, Troeltzsch stresses. "If you can deal with something that's a problem by just living with it, that's a perfectly acceptable way to run the mission."

Overall, Kepler's commissioning process took 67 days, a week longer than anticipated. That extra time adds up to a bit of "science creep"—with scientists asking for an even tighter pointing of the spacecraft, beyond specifications. "What they are doing is exploiting the capabilities of the machine," Troeltzsch adds, "so we're helping them achieve better than what was required performance. We did and it worked out well."

Call it the greedy scientist philosophy, something Troeltzsch realizes up front. "This is what they do for a living. They are going to come up with all kinds of powerful ways to get better science out of the machine. The goal is to build a machine that meets requirements, has some flexibility and margin so that when you get it on orbit you can exploit it, resulting in even better data."

Lesson learned: Persistence

Kepler has taken a long and winding road to its destination in space. At one point, it was facing the ax at NASA.

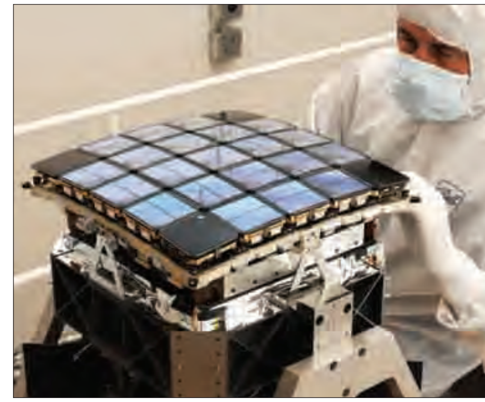
It was Borucki, Kepler's science principal investigator, who first suggested the transit technique for detecting Earth-size planets, in 1984. The lesson learned, he says after all those years, is "Be persistent. Get the data and show the data to make your case."

Kepler gained flight approval as a NASA Discovery mission in late 2001. But the price tag rose several times following its selection, with the total cost rising above $550 million. In the spring of 2007 the team asked for an extra $42 million, a request not well received by then-NASA science chief Alan Stern, who bluntly told the Kepler team to look within to keep costs down—or face termination.

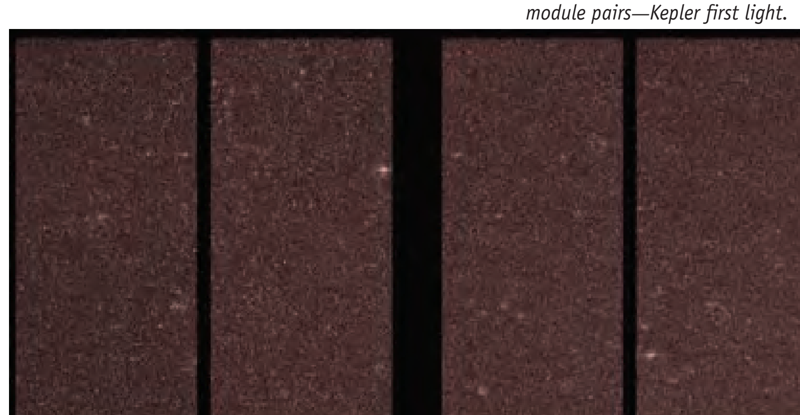
At Ball Aerospace, there was a lot of pressure, Troeltzsch remembers vividly. That Stern warning and call for replanning had a catalyzing effect, he says, and sparked a flurry of activity, including elucidation of management, accountability, roles, and lines of authority inside the company as well as with NASA's partners on the project. "Trust and accountability are two things that are just critical to success," he says, and the Kepler team had challenges in both those areas.

In the end, the team demonstrated that it could deliver, and it did.

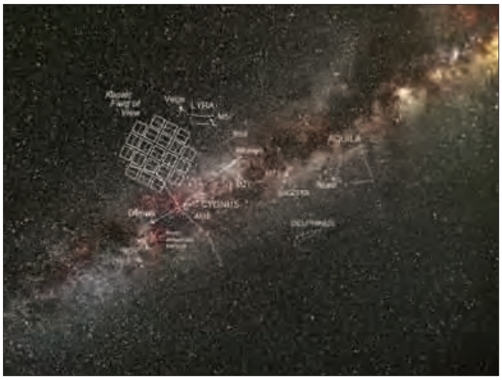
"Kepler went from the poster child for what could go wrong in a development program to the poster child for how to turn a project around and deliver a fully working scientific mission, on cost and schedule," says Stern, now associate vice president of the Southwest Research Institute's Space Science and Engineering Division in Boulder. "From what's been released so far in flight, Kepler has all the makings of a smashing success. The mission team deserves congratulations."



Focal plane assembly was conducted at Ball Aerospace.



Images were gathered from two CCD module pairs—Kepler first light.



Each rectangle indicates the specific region of the sky covered by each CCD element of the Kepler photometer. There are a total of 42 CCD elements in pairs, each pair comprising a square. Image by Carter Roberts.

Planetary payoff

Indeed, Kepler and tenacity go together, according to astronomer Jill Tarter, director of the SETI Institute's Center for SETI Research, in Mountain View, Calif. "If it were easy, somebody else would have done it by now," she points out.

Years ago, in workshops on detecting planets, precision requirements such as microarcseconds and millimagnitudes seemed unbelievably unattainable. However, "there were dreamers in the crowd who grew older but never stopped working on their dreams," recalls Tarter.

Early critics were justified in being skeptical about the feasibility of detecting transits of Earth-size planets—it's an extremely challenging measurement. "But perseverance, guided by a vision, can pay off," says Fanson.

Kepler was the dark horse in the race, with NASA's Space Interferometry Mission (SIM) and then the Terrestrial Planet Finder (TPF) being the odds-on favorites to be launched first, notes astrophysicist Boss.

"In the end, Kepler won the race by so many lengths that SIM and the TPFs still haven't even made it to the starting gate, much less to the finish line. The lesson is that it is not a bad idea to bet on missions with long odds. They just might win in spite of the poor odds," Boss says.

In his recent book, *The Crowded Universe: The Search for Living Planets*, Boss says that "a new space race" has begun—an international and lively competition to discover how numerous Earth-like planets are in our neighborhood of the Milky Way galaxy. That contest is being spurred by the blossoming quest to detect planets with life around other stars. The bottom line for the astrophysicist is that life is not only possible elsewhere out there…it is common.

Joining Boss in saluting Kepler and its early shakeout is James Kasting, a professor of geosciences at Pennsylvania State University: "I, like others in the exoplanet community, am absolutely thrilled by the data that we expect to get out of Kepler. So far, they've shown us enough to indicate that the telescope is working very well. The really interesting data on Earth-like planets will take awhile, perhaps two to three years, but I think it could have a big impact on getting momentum built up for more ambitious planet-finding missions like SIM and TPF."

Borucki's insistence that Kepler was doable met with repeated rejection for a decade, Kasting notes. "It is a tribute to his perseverance that he eventually pulled it off and now has the hottest thing going in all of exoplanet science," says Kasting.

Putting on his forecasting hat, Troeltzsch of Ball Aerospace looks to the year ahead:

"The only star that we've really studied intensely from this photometry point of view is our Sun—we have a sample of one. And now we've got 120,000 stars under the microscope out there. And I tell you…the Sun is not generic. I think there are going to be two really cool things that come out from Kepler. One is going to be an understanding of stars in our galaxy. The other, I think, is that we're going to find a bunch of planets." 𝔸

Kepler-certified students

Kepler's on-orbit operation is conducted at the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado in Boulder, under a $5-million contract to Ball Aerospace. The Kepler mission control activity melds the talents of professionals and students at the university and specialists from Ball Aerospace.

"Overall, it's actually working better than we expected. It has been really smooth," says Bill Possel, director of Mission Operations and Data Systems at LASP.

Working with the long-distance Kepler spacecraft, in concert with NASA Ames and the Deep Space Network, is a first for LASP. Along with Kepler, Possel explains, the LASP control center is presently flying four Earth-orbiting satellites: the Aeronomy of Ice in the Mesosphere, the Solar Radiation and Climate Experiment, ICEsat, as well as QuikSCAT. All of them need different degrees of care and maintenance, he says.

In terms of intensity, however, Kepler rates the highest. Still, spacecraft operations make use of LASP-developed software akin to that used for the other university-run satellites.

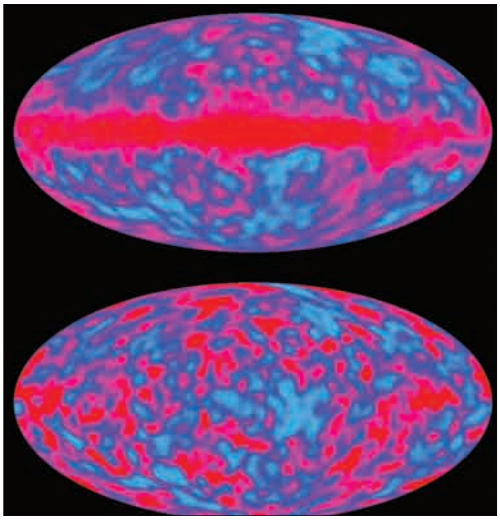
Some 27 student operators are trained on Kepler, each taking 4-hr shifts. Not only is engaging LASP a cost-reduction step in Kepler mission operations, but the hands-on learning is also a priceless, career-enhancing opportunity for students, Possel says.

"It's a win-win," says Troeltzsch of Ball Aerospace. "It gives the university a chance to participate in these big programs and a chance to have an educational experience with their students. On our side, it's a way to efficiently run a satellite for a good cost for the taxpayers."

There is an eventful future ahead for LASP. On the books is the NASA Mars Atmosphere and Volatile Evolution (MAVEN) mission, set to launch in 2013. LASP will provide science operations and data packaging. Lockheed Martin Space Systems, based in nearby Littleton, Colo., will provide the MAVEN spacecraft, as well as mission operations; JPL will navigate it. LASP is also on tap to carry out science operations duties in 2014 for a NASA Goddard project, the Magnetospheric MultiScale mission, consisting of four spacecraft flying in formation to gauge magnetospheric and solar wind interaction.

"That's 11 instruments each on four spacecraft—that's 44 instruments we'll be operating from here. So it's going to be pretty busy," Possel concludes. "LASP has been growing for the last few years, and I think we're still looking at growing more."

Small Explorers
(Continued from page 35)



These famous maps of the cosmic microwave background anisotropy were formed from data taken by the COBE spacecraft, a SMEX mission.

Future prospects

Nick Chrissotimos, Explorers program manager at Goddard, says they are still looking at a rate of 12-18 months between missions.

"And we like to mix those up a bit, so we're proposing to [NASA] Headquarters that we fly perhaps two SMEXs, then a MIDEX, then two SMEXs, another MIDEX, etc.," he says. "We can modify the rate depending on what we can afford. Headquarters gives us a guideline as to what kind of money they are thinking about, then we model what kind of missions that money will support—three SMEXs, two SMEXs and a MIDEX, etc.

"Up to now, I don't think the SMEXs have had as much breakthrough science as the MIDEXs. COBE [the Cosmic Background Explorer, winner of the Nobel Prize for physics in 2006], which mapped the background, was a MIDEX launched in 1989. SWIFT, launched about three years ago, also was a MIDEX and is doing really great science in gamma-ray burst activity, looking for black holes and leading to pretty astounding information on how black holes work, how stars collapse, and what's happening in the middle of quasars."

Even so, Chrissotimos adds, as newer and more advanced tools become available—especially smaller electronics—he expects SMEXs to contribute even more to the advancement of science.

"The SMEXs contribute a lot, and I think they will start coming more into their own as the scientists get newer and better tools for observations that they can put on smaller spacecraft. Given the last decade of efficient chips, there is more capability built into smaller buses than we had before. So scientists can put a lot of potential into SMEX missions that eventually will lead to more science breakthroughs," he says.

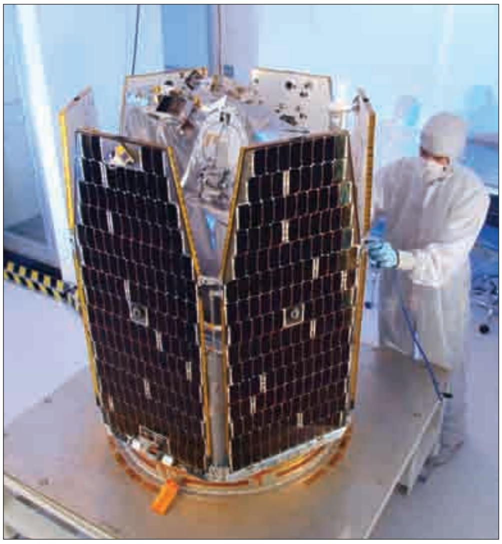
In addition to IBEX, Chrissotimos pointed to the 2008 launch of AIM (Aeronomy of Ice in the Mesosphere), which is looking at extremely high altitude—and rarely observed—clouds floating over the poles, as an example of that growth.

"Those observations will change our thinking about how vapor gets up that high, what are [these clouds] composed of, how do they work," he says. "So there is a lot of good science being done by the SMEX missions, and I expect that not only to continue but to improve as the technology allows smaller and more efficient systems to be built."

Although NASA was in a state of uncertainty during the four months it took President Obama to find a new administrator, Fisher is moving forward on the assumption the Explorers budget line will remain intact.

"Our plan continues the Explorers program out beyond 2020," Chrissotimos concludes. "We never know what will come over the transom, in terms of science. The chief scientist at NASA says the Explorers program is an example of rampant scientific capitalism—winner takes all, the best science at the lowest price. And, while I'm an advocate, I'd say that is true.

"The biggest change I anticipate—and I'm excited about that—is a slow change in launchers. In the next few years we will see other options for SMEX and MIDEX as new launchers come out of the commercial world. I believe that will have considerable impact on the program, because it will alter prospects for payloads, perhaps to L-2 or L-5. So I would anticipate growth in that area, and increasing complexity."



The AIM spacecraft, seen with its solar arrays in stowed configuration, will look at extremely high-altitude clouds floating over the poles. (Image credit: NASA/Orbital Sciences.)

Out of the

25 Years Ago, January 1985

Jan. 24 Space Shuttle Discovery is launched and carries the first DOD mission and crew, who deploy a signal intelligence satellite. NASA, *Astronautics and Aeronautics 1985*, p. 7.

50 Years Ago, January 1960

Jan. 7 The all-solid-fuel Polaris fleet ballistic IRBM achieves its first fully guided flight from the Atlantic Missile Range. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 118.

Jan. 8 It is announced that Pan American Airways has activated, at Shannon, Ireland, the first unit of a planned global radio transmission system using the "forward scatter" technique. This is the first very-high-frequency ground station to be used by an airline. *FAA Historical Chronology*, 1998, p. 65.

Jan. 11 The Air Force announces the development of the solid-fuel Skybolt air-launched ballistic missile, revealing that prototypes have been successfully launched from aircraft at both subsonic and supersonic speeds. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 118.

Jan. 11-15 The First International Space Science Symposium takes place in Nice, France. The Earth's radiation belts, as recently discovered by several satellites, are the favorite topic. This is the first international forum for discussing these radiation belts, the Earth's magnetic field, and lunar photography. The event, organized by the International Committee on Space Research, attracts 90 scientists. *The Aeroplane*, Jan. 29, 1960, p. 140; D. Baker, *Spaceflight and Rocketry: A Chronology*, p. 98.

Jan. 12 Aviation pioneer and popular novelist Nevil Shute, best known for his book *On the Beach,* dies. Born Nevil Shute Norway in England in 1899, he served during WW I in the British Army and in 1922 joined de Havilland Aircraft as a stress engineer. In 1924 he took a position with Vickers, where he later headed a team that designed the Vickers R.100, a prototype for passenger airships. Shute became Vickers' deputy chief engineer in 1928. In 1931 he founded Airspeed, the company that would produce the Envoy aircraft. By the start of WW II he was a successful novelist and was also involved in secret weapons development projects. *The Aeroplane*, Jan. 15, 1960, p. 58; Nevil Shute file, NASM.

Jan. 21 The fourth Little Joe test vehicle, carrying a Project Mercury space capsule with a rhesus monkey named Miss Sam aboard, is launched and successfully tests the spacecraft's emergency escape system. The monkey is recovered after a 20-*g* acceleration and a 9-mi.-altitude flight. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 118.

Jan. 26 A 173-ft-diam. Navy sounding balloon is launched from the deck of the USS Valley Forge, not far from Puerto Rico. The balloon carries a 1,630-lb scientific payload to record cosmic rays and other particles in the upper atmosphere. The next day, film packs taken of the rays are recovered successfully by the destroyer Hyman. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 118.

Jan. 29 An Honest John artillery rocket is successfully destroyed by a Hawk surface-to-air missile flying at a low altitude, in a test at White Sands Missile Range, New Mexico. *The Aeroplane*, Feb. 19, 1960, p. 214.

And During January 1960

—It is announced that an IBM 650 RAMAC computer at the Indianapolis Air Route Traffic Control Center is now linked with other computers at Washington, D.C., Cleveland, and Pittsburgh. This is part of the FAA's plan to establish computers at 30 air traffic control centers throughout the U.S. by 1965. *The Aeroplane*, Jan. 15, 1960, p. 60.

75 Years Ago, January 1935

Jan. 1 A regular program of stratospheric studies by radio balloons is begun in Moscow by the Aerological Dept. of the Central Institute of Experimental Hydrology and Meteorology. One of the balloons, designed by Pavel Molchanov, ascends to a record height of 55,777 ft. The radio signals are received for 30 min. *Flight*, Feb. 14, 1935.

Past

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

Jan. 2 The overseas model of the British-designed Airspeed Envoy commercial airplane is demonstrated for the first time to the public at Portsmouth Airport, England. Powered by two 240-hp Siddeley Lynx IV.C engines, it is considered possibly the fastest British commercial airplane, with a top speed of 174 mph and a cruising speed of 153 mph. The low-wing, streamlined machine seats six to eight passengers. The overseas model will be used for Europe and India. *The Aeroplane*, Jan. 9, 1935, pp. 40-42.

Jan. 5 Lt. Cmdr. J.R. Poppen, USN, becomes the first flight surgeon assigned to the Naval Aircraft Factory. He will observe pilots, conduct physical examinations, and work on the hygienic and physiological aspects of Navy R&D projects. E. Emme, ed., *Aeronautics and Astronautics, 1915-60*, p. 32.

Jan. 12 Amelia Earhart completes the first solo flight between Hawaii and California when she lands her Lockheed Vega, equipped with a supercharged Pratt & Whitney SID1 Wasp, at Oakland Airport. She flies the 2,400-mi. distance from Wheeler Field, Honolulu, in 18 hr 17 min at an average speed of 140 mph. This is the first westward crossing made on this route. Earhart navigated by dead reckoning, supplemented by position fixes from ship and shore radio stations. She flew at an average altitude of 8,000 ft, encountering many rain squalls, cloud banks, and fogs, but no severe storms. *Aviation*, February 1935, pp. 64, 66.

Jan. 15 In an unusual delivery flight starting from Pembroke Dock, England, four Short Brothers Singapore III flying boats take off for Singapore to replace the older Southampton flying boats on station there since 1927. The aircraft are assigned to No. 205 (F.B.) Squadron in the British colony. The pilots then return to England by steamer. *Flight*, Jan. 17, 1935, pp. 62-64.

Jan. 16 The new Latecoere 37-ton Transatlantic Flying Boat, powered by six 860-hp Hispano engines, begins its trials at the Biscarosse seaplane base in France. On its initial flight, the duralumin and stainless steel flying boat flies at 600 ft around the lake at Biscarosse, gradually increasing its loads until it reaches the loaded weight of 37 tons. *Flight*, Jan. 24, 1935.

Jan. 22 The Federal Aviation Commission, appointed by President Franklin D. Roosevelt the previous year, submits its first report and sets forth a broad policy on all phases of aviation in the U.S. It recommends strengthening commercial and civil aviation, expanding airport facilities, and establishing more realistic procurement practices by industry. E. Emme, ed., *Aeronautics and Astronautics, 1915-60*, p. 32.

Jan. 24 Richard Light, with Richard Wilson, completes a leisurely 29,000-mi. flight around the world in a Bellanca seaplane. The pair set off from New Haven, Conn., on August 20, 1934. They visited Labrador, Greenland, Iceland, Holland, Scandinavia, Germany, Italy, Greece, Cypress, Iraq, Persia, India, Siam, Malaya, Java, Borneo, and the Philippines. They then took their aircraft on a steamship to Vancouver and from there flew to Mexico and Cuba, then up to New York. *Flight*, Feb. 21, 1935.

Jan. 29 A new women's altitude record is set by Madeleine Charneaux of France, flying a Farman powered by a single Renault Bengali engine up to 19,790 ft, near Paris. Accompanying her is Edith Clark. *Flight*, Feb. 7, 1935, p. 145.

And During January 1935

—Polish Lot airlines orders two Douglas DC-2s from the Fokker Works. They are to be used on the Berlin-Warsaw route that is run in conjunction with Deutsche Luft Hansa. More than 65 DC-2s have been delivered so far. European companies using the U.S. plane, which is built under license by Fokker, include KLM, the Austrian airline OLA, and Swissair. *Flight*, Jan. 31, 1935, p. 133.

100 Years Ago, January 1910

Jan. 7 Hubert Lathan becomes the first to pilot an aircraft to an altitude of 1,000 m, flying an Antoinette monoplane from Chalons, France. A. van Hoorebeeck, *La Conquete de L'Air*, p. 82.

Jan. 10 The Aero Club of California sponsors the first air meet in the U.S. when competitors from around the country gather at Dominguez Field in Los Angeles. A. van Hoorebeeck, *La Conquete de L'Air*, p. 82.

LSU

LOUISIANA STATE UNIVERSITY

DEPARTMENT CHAIR AND RICHARD J. AND KATHERINE J. JUNEAU DISTINGUISHED PROFESSORSHIP (Tenured position)

Department of Mechanical Engineering

The Department of Mechanical Engineering at Louisiana State University (LSU) invites applications/nominations for the position of Department Chair. The position will be tenured and will also carry the title of Richard J. and Katherine J. Juneau Distinguished Professorship. The department is ABET accredited and has 25 faculty members. Student enrollment in the department is approximately 450 undergraduates and 100 M.S. and Ph.D. students. LSU is the Flagship University of the State, has Carnegie Research-I status, and a current enrollment of nearly 30,000 students.

The Department covers the traditional disciplines of Thermo-Fluids, Mechanical Systems, and Materials Science and Engineering, with several interdisciplinary groups and strong collaborations with other departments and colleges. Departmental research is supported by several centralized resource centers, including the Center for Advanced Microstructures and Devices (CAMD) which houses the only electron synchrotron facility in the southeast, the Materials Characterization Center (MCC), the Center for BioModular Multi-scale Systems (CBM2), the Center for Rotating Machinery (CeROM), and the Center for Turbine Innovation and Energy Research (TIER). Externally funded research programs average in excess of $3 million annually, and cover the full spectrum of research areas of mechanical engineering (for details see: **http://me.lsu.edu**). The Department of Mechanical Engineering is one of LSU's designated "Foundation of Excellence" departments.

Required Qualifications: Ph.D. or equivalent degree in mechanical engineering or related discipline; a record of achievement in externally funded scholarly research; a commitment to excellence in teaching and service to the profession. The Chair must qualify for the rank of tenured full professor within the Department of Mechanical Engineering.

An offer of employment is contingent on a satisfactory pre-employment background check. Application deadline is February 26, 2010 or until a candidate is selected. We welcome the nominations of potential candidates. For details and nominations of candidates contact: **Prof. Kalliat T Valsaraj, Chair; ME Dept Chair Search Committee; Cain Department of Chemical Engineering; Louisiana State University; Baton Rouge, LA 70803; e-mail: valsaraj@lsu.edu.**

Apply online at: www.lsusystemcareers.lsu.edu. Position #000640.

LSU SYSTEM IS AN EQUAL OPPORTUNITY/EQUAL ACCESS EMPLOYER

FACULTY POSITION
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AFB, DAYTON OH

The Department of Aeronautics and Astronautics seeks applicants for a tenure-track (preferably at the assistant/associate professor level) Aerospace Engineering position.

Candidates should have a strong background in one or more of the following areas: space operations, spacecraft design, spacecraft systems, spacecraft attitude dynamics and control, astronautical engineering, rocket propulsion.

In addition to an earned Ph.D. in Aeronautical Engineering, Astronautical Engineering, Space Systems Engineering, Systems Engineering, Mechanical Engineering or a related field, the candidate should have a demonstrated or a potential ability in teaching at the graduate level and in conducting independent research for the Air Force and other government agencies. Good communication skills, both oral and written, are essential. U.S. citizenship is required.

The Department offers the M.S. in Space Systems and offers both the M.S. and Ph.D. degrees in Aeronautical Engineering, Astronautical Engineering, and Materials Science. The Department has several state-of-the-art computer and experimental laboratories. Interested candidates should send a resume and the names of three references to:

Dr. Brad S. Liebst
Professor and Head
Department of Aeronautics and Astronautics
Air Force Institute of Technology
AFIT/ENY
2950 Hobson Way
Wright-Patterson AFB, OH 45433-7765
Phone: (937) 255-3069
e-mail: Bradley.Liebst@afit.edu

The Air Force Institute of Technology is an Equal Opportunity/Affirmative Action employer.

VirginiaTech
Invent the Future

FACULTY POSITION IN AEROSPACE PROPULSION

Aerospace and Ocean Engineering
Virginia Polytechnic Institute and State University

The Department of Aerospace and Ocean Engineering at Virginia Tech requests applications and nominations for a tenure-track faculty position in Aerospace Propulsion. One or more positions will be filled. Candidates are sought with expertise and a record of achievement in the area of aerospace propulsion. The successful candidate will have the opportunity to participate in a large, multi-disciplinary interaction with Rolls Royce spanning several departments at Virginia Tech. Exceptional candidates with a high level of accomplishment may be considered for an Endowed Professorship.

Applicants must hold an earned doctorate in Aerospace Engineering or a closely related field, and will be expected to develop a significant externally funded research program. Responsibilities will include teaching at both undergraduate and graduate levels, directing graduate students, and establishing a research program.

Virginia Tech, the land-grant university of the Commonwealth, is located in Blacksburg, adjacent to the scenic Blue Ridge Mountains. The University has a total student enrollment of 26,000, with approximately 7,500 students in the College of Engineering. Additional information about the department can be found at http://www.aoe.vt.edu. Additional information about Blacksburg, Virginia can be found at http://www.bev.net. Information on resources for prospective faculty can be found at http://www.provost.vt.edu.

Review of applications will begin on February 1st, 2010 and will continue until the position is filled. Interested persons should apply on the Internet at http://jobs.vt.edu (posting number 090586) along with a cover letter, current curriculum vita and the names and addresses of three references. All inquiries can be sent to: Prof. Joseph Schetz (ptiger@vt.edu), Chair, AOE Aerospace Propulsion Faculty Search Committee, Aerospace and Ocean Engineering, Virginia Tech, 215 Randolph Hall 0203, Blacksburg, VA 24061.

Virginia is the recipient of a National Science Foundation ADVANCE Institutional Transformation Award to increase the participation of women in academic science and engineering careers.

Virginia Tech has a strong commitment to the principle of diversity and, in that spirit, seeks a broad spectrum of candidates including women, minorities, and people with disabilities. Individuals with disabilities desiring accommodations in the application process should notify Mrs. Wanda Foushee at (540) 231-9057.

FACULTY POSITION IN SPACECRAFT DYNAMICS AND CONTROL

Aerospace and Ocean Engineering
Virginia Polytechnic Institute and State University

The Department of Aerospace and Ocean Engineering requests applications for a tenure-track faculty position in areas related to spacecraft dynamics and control including, but not limited to, astrodynamics, attitude dynamics and control, and space systems engineering. AOE faculty members are active in a number of interdisciplinary research centers and groups, including the Center for Space Science & Engineering Research (www.space.vt.edu) and the Virginia Center for Autonomous Systems (www.unmanned.vt.edu). Faculty in Virginia Tech's AOE department have access to Virginia Tech's extensive computational resources, including System X, and world-class experimental facilities to support combined attitude and orbital motion simulation and control, vacuum chamber testing, high-speed flow measurements, advanced materials characterization, and other activities related to spacecraft systems.

Applicants must hold an earned doctorate in aerospace engineering or a closely related field, and will be expected to develop a significant, externally funded research program. While it is expected that this position will be filled at the assistant professor rank, persons nationally recognized for their work in the field may be considered for a more senior position. Responsibilities will include teaching at both the undergraduate and graduate levels, directing graduate students, and establishing a successful research program.

Virginia Tech, the land-grant University of the Commonwealth, is located in Blacksburg, adjacent to the scenic Blue Ridge Mountains. The University has a total student enrollment of 26,000, with approximately 7,500 students in the College of Engineering. Additional information about the department can be found at www.aoe.vt.edu. Additional information about Blacksburg, Virginia can be found at www.bev.net. A link to more information on resources for prospective faculty can be found at www.provost.vt.edu.

Review of applications will begin on January 18, 2010 and will continue until the position is filled. Interested persons should apply on the Internet at http://jobs.vt.edu (posting number 090616). Applications must include a cover letter, current curriculum vita, and the names and addresses of three references. Inquiries can be sent to:
Prof. Craig Woolsey (cwoolsey@vt.edu), AOE Spacecraft D&C Faculty Search Committee Chair, Aerospace and Ocean Engineering, 215 Randolph Hall (Mail Code 0203), Virginia Tech, Blacksburg VA 24061.

Virginia Tech is the recipient of a National Science Foundation ADVANCE Institutional Transformation Award to increase the participation of women in academic science and engineering careers.

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University of Toronto Institute for Aerospace Studies
Faculty Position in Aerospace Engineering

The University of Toronto Institute for Aerospace Studies (UTIAS) is seeking applications for a tenure-track position at the level of Assistant Professor or Associate Professor in aerospace engineering. The successful applicant will be nominated for a Tier II Canada Research Chair (www.chairs.gc.ca). The appointment will begin on or after July 1, 2010.

We seek applicants whose primary area of research is related to high-fidelity multi-disciplinary optimization, as applied to aircraft design. However, consideration will be given to applicants with expertise in any area related to aerospace science and engineering. Preference will be given to applicants who will contribute to the UTIAS strategic focus on reducing the environmental impact of aircraft. Experience with large-scale computing is also an asset; the University of Toronto's supercomputer ranked 16th in the June 2009 Top 500 ranking. Applicants must have a doctoral degree, typically from an aerospace or mechanical engineering department, and a strong commitment to both teaching and research. The successful candidate is expected to establish and lead a dynamic research program, supervise graduate students, and teach undergraduate and postgraduate courses. The selection will be based primarily on the applicant's potential for excellence in research and teaching. Salary is commensurate with qualifications and experience. For information about UTIAS, please see our web site (www.utias.utoronto.ca).

Applications should include: (i) a detailed curriculum vitae, (ii) a concise statement (3 pages maximum) of teaching and research interests, objectives and accomplishments, and (iii) examples of publications and material relevant to teaching experience. Applicants are also asked to provide the names and contact information (mailing address, telephone, fax, and email) of five referees who are able to comment on the applicant's experience and ability in teaching and research. Address your application to Professor D.W. Zingg, Director, University of Toronto Institute for Aerospace Studies, 4925 Dufferin Street, Toronto, Ontario, Canada M3H and submit it electronically to Joan DaCosta at dacosta@utias.utoronto.ca. Review of applications will begin on January 31, 2010, and applications will be accepted until the position is filled.

The University of Toronto is located in Toronto, a large multicultural city offering many cultural, professional, and research opportunities. The student body at the University reflects the diversity of the city. The breadth of the University provides numerous opportunities for interdisciplinary collaborative research. The University of Toronto is strongly committed to diversity within its community. The University especially welcomes applications from visible minority group members, women, Aboriginal persons, persons with disabilities, members of sexual minority groups, and others who may contribute to further diversification of ideas. The University is also responsive to the needs of dual career couples. All qualified applicants are encouraged to apply; however, Canadians and permanent residents will be given priority.

CLARKSON UNIVERSITY
Wallace H. Coulter School of Engineering
Michael E. Jesanis Endowed Chair in Sustainable Energy Systems

Wallace H. Coulter School of Engineering (CSoE) at Clarkson University invites applications for the Michael E. Jesanis Endowed Chair in sustainable Energy Systems in the Department of Mechanical and Aeronautical Engineering (MAE) (anticipated starting date: August 2010). Strong record of scholarly accomplishment and a Ph.D. in Mechanical Engineering, Aeronautical Engineering, or energy related area is required. Applications are encouraged from individuals whose research programs can contribute to areas of renewable and sustainable energy including energy efficiency, solar, wind, biofuel and nuclear energy conversions and resources.

Clarkson University has established interdisciplinary focus areas of research in advanced materials (including biomaterials), environment and energy (including sustainable energy systems), bio-rehabilitation engineering, and innovation and entrepreneurship. The Coulter School of Engineering offers B.S. degrees (mechanical, aeronautical, civil, environmental, chemical, electrical, computer and software) engineering, and M.E., M.S. and Ph.D. degrees in mechanical engineering, civil engineering, electrical and computer engineering, chemical engineering, environmental science and engineering, and engineering science. In addition, the school offers a minor in sustainable energy systems engineering for under graduates.

The successful Michael E. Jesanis Chair will be expected to develop strong funded research programs in emerging areas of sustainable energy, lead and mentor junior faculty members, and develop and teach graduate and undergraduate courses and curricula in energy related areas in mechanical/aeronautical engineering. Applicants need to articulate a clear and substantiated vision of their plan for their sustained accomplishments.

Clarkson University is committed to providing an educational experience in which students develop an appreciation for diversity in both working and living environments. Candidates are encouraged to outline teaching, research, service and/or outreach activities that support this commitment.

Applications will be reviewed starting February 2010 and will continue until the position is filled. Direct inquires to Dr. Goodarz Ahmadi, Dean of Wallace H. Coulter School of Engineering, Clarkson University, Potsdam, New York 13699-5700, (315-268-6446). Please send your electronic application including the CV and the names of at least three professional references to Rhonda Sharpe at sharper@clarkson.edu. Additional information about the Coulter School of Engineering and the MAE Department can be found at www.clarkson.edu. Clarkson University has one of the highest percentages of women engineering faculty in the nation (ASEE 2005 profiles of Engineering Colleges). We are building upon this foundation to create a diverse faculty and strongly encourage applications from female and minority candidates. Clarkson University is an AA/EOE. Job Postings #41-09.

NANYANG TECHNOLOGICAL UNIVERSITY

College of Engineering – Faculty Appointments

Being one of the largest engineering colleges in the world, NANYANG ENGINEERING is recognized for its strength in both education and research, and boasts a confluence of multi-national faculty and diverse talent that are distinguished in many emerging fields of engineering. More information can be accessed via **www.coe.ntu.edu.sg**. NANYANG ENGINEERING actively promotes complementary synergy and trans-disciplinary activities among its six engineering schools, to continually evolve its research landscape to be a leader in science and engineering research.

As part of its on-going drive to excel, NANYANG ENGINEERING invites motivated persons who can flourish in the prevailing, unparalleled, research-oriented environment in this university and in Singapore, to apply for faculty positions. Many positions of all ranks are available in various engineering schools. The aspiring candidate should possess a PhD from a well-recognized university and must have a strong passion and commitment to excel in both research and teaching. In addition, candidates for senior appointments must have a demonstrated leadership position in their field of expertise.

Applications and enquiries are invited in emerging fields, which include but not limited to the following broad areas:

Engineering and Medicine
- Bio-informatics
- Pharmaceutical and Biomolecular Engineering
- Synthetic Biology and Bio-physiology
- Medical Devices
- Remote Healthcare

Energy
- Electrical Power and Energy
- Hybrid Power Systems
- Materials and Devices for Energy Harvesting and Storage

Sustainable Living
- Environmental Chemistry
- Green Building Systems and Materials
- Risk Analysis and Management
- Protective and Resilient Systems
- Urban Infrastructure

Intelligent Media, Systems and Computing
- Artificial or Computational Intelligence
- Digital Media Processing
- High Performance Computing
- Machine Learning and Intelligent Agents
- Systems Engineering applied to transportation and Healthcare
- Bio-mimicry
- Information Security

For information on the submission guidelines, please refer to **http://www.ntu.edu.sg/ohr/career/submitApplications/pages/faculty.aspx**
Electronic submission of application should be forwarded to **Dean, College of Engineering** at **d-coe@ntu.edu.sg**.

Positions are open until filled but review of applications will begin immediately.

www.ntu.edu.sg