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Mars laboratory lands on red ink

Space debris: A growing challenge

A conversation with Graham Love

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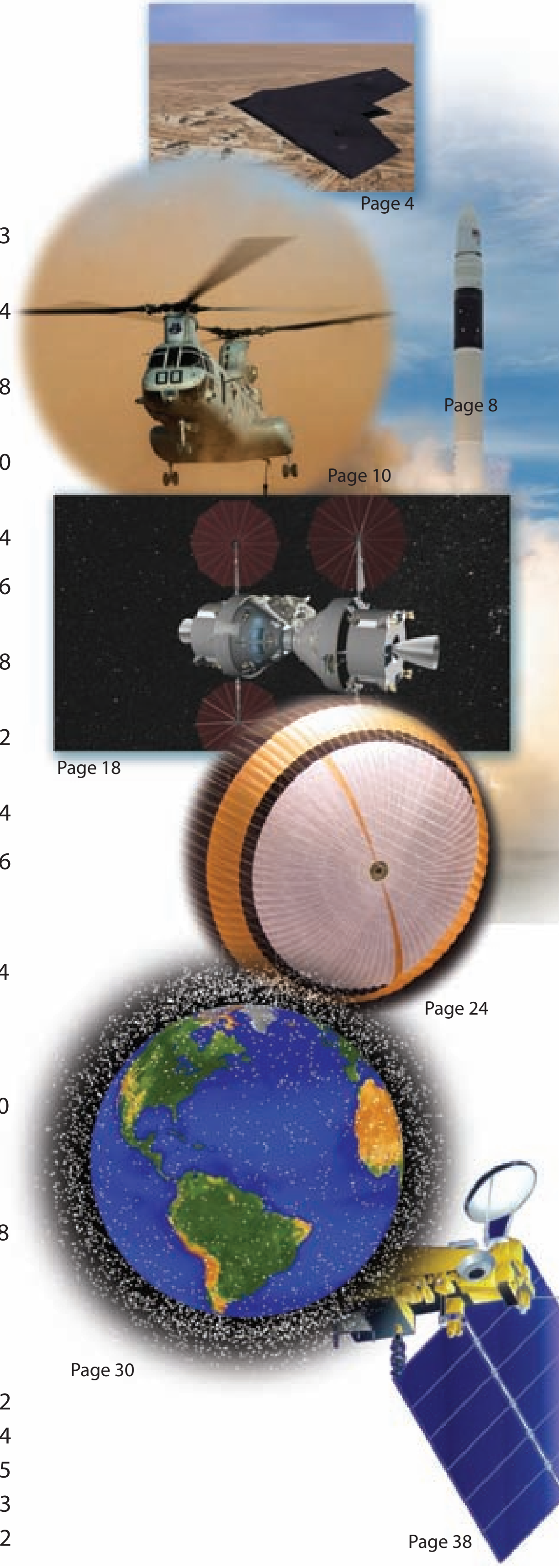
October 2009



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The Mars Science Laboratory is NASA's most complex Mars effort to date. Its large rover will be housed in an aeroshell with a heat shield. For more on this ambitious program, turn to the story beginning on page 24.

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AIAA
American Institute of Aeronautics and Astronautics

Editorial

Our future in space

"The U.S. human spaceflight program appears to be on an unsustainable trajectory. It is perpetuating the perilous practice of pursuing goals that do not match allocated resources."

This is the opening statement of the *Summary Report of the Review of Human Space Flight Committee*, released on September 8. The review was announced on May 7 by the Office of Science and Technology Policy; the committee was led by Norman Augustine, former chairman of the Advisory Committee on the Future of the United States Space Program.

The 12 panel members, all deeply involved in U.S. space efforts, were asked not only to examine NASA's current efforts in human spaceflight, but to explore other potential options for sustaining a U.S. presence in space. The group first looked at current activities—the space shuttle's safety record and its reliability, the future of the international space station, and the Constellation program—then considered the possibilities for the future.

In the course of its deliberations, the committee identified five alternative scenarios for future human space transportation and exploration, positing different destinations and vehicles for reaching them. All of the alternatives had benefits and drawbacks, but all were encumbered by the same problem: None could be realized under the present NASA budget outlook.

Two of the scenarios assumed current spending levels. In both of those cases, the group found that the heavy lift Ares V would not be ready until the late 2020s, with little or no possibility of a lunar landing before the 2030s, if at all. More telling, the committee found that "no plan compatible with the FY 2010 budget profile permits human exploration to continue in any meaningful way." The other three alternatives call for a budget increase of $3 billion annually, an increase the committee believes would enable a viable, sustainable exploration effort.

President Obama's budget for FY10 totals approximately $3.5 trillion. Of that amount, NASA's total FY10 budget of $18.7 billion represents just over 0.5%. There is no question that money is tight, and all U.S. programs are scrambling for funding. But this percentage, which has not changed much over several budget cycles, does not appear to represent a real and sustained commitment to human spaceflight. A $3-billion increase in funding would be less than 0.1% of the U.S. budget, but could mean a 100% improvement in our future in space.

For years the U.S. has maintained its preeminence in space, but not without budget shortfalls and often at the expense of other NASA programs. As exploration activities become increasingly global, even the "first among equals" status would seem to be in peril.

The committee concluded that "Exploration provides an opportunity to demonstrate space leadership while deeply engaging international partners; to inspire the next generation of scientists and engineers; and to shape human perceptions of our place in the universe." Seems to be worth paying for.

Elaine Camhi
Editor-in-Chief

Europe looks for UCAV synergies

Will Europe end up with a single unmanned combat air vehicle program?

At the start of the year such an idea would have seemed unlikely. After all, Europe's largest aerospace industries are pursuing three separate UCAV technology demonstrator/prototype programs, with different capabilities and to different timescales. While continental European countries have more or less agreed to combine their UCAV programs into a single joint venture, the U.K. is developing its own capability, with experience gained from working with U.S. partners. Even if the U.K. wants to cooperate with its European partners, it will be prohibited from sharing much of its UCAV knowledge through technology transfer constraints, agreed with U.S. partners.

Separate paths

The U.K. and France are the two European countries with the greatest investment in UCAV technologies, and they have very different UCAV priorities and road maps. France wants to have the technology matured for its Future Combat Air System (FCAS) program, which could replace the current Dassault Rafale manned fighters in 2030. The country is spearheading the nEUROn program with other European nations to fly a technology demonstrator by 2011 as part of the long-term road map to developing FCAS capabilities.

In contrast, the U.K.'s Ministry of Defence (MOD) is spending £124 million with BAE Systems to develop a UCAV technology demonstrator called Taranis as part of the initial work into the emerging DPOC (deep and persistent offensive capability) requirement, which could see UCAVs flying alongside Eurofighter Typhoons and Lockheed Martin F-35 Joint Strike Fighters as early as 2018. And unlike other European countries, the U.K. is already using UCAVs, having deployed armed General Atomics MQ-9 Reapers in Afghanistan beginning in November 2007. They are flown from Kandahar Air Base in Afghanistan by the RAF's 39 Squadron pilots, based in Creech AFB, Nev., also the home of the USAF Reaper-equipped 42nd Attack Squadron. As well as carrying out intelligence, surveillance, and reconnaissance missions, these Reapers are equipped with Hellfire missiles and Paveway Two bombs.

In strategic requirements for UCAVs, timescales, and industry priorities, therefore, the two countries could not be further apart.

Until now, that is. Economic necessity is driving France and the U.K. to work together on a host of new defense collaborative projects, including UCAV research. The continent simply cannot afford three competing UCAV programs.

Joining forces

In a July 6 announcement following a meeting between U.K. Prime Minister Gordon Brown and French President Nicolas Sarkozy, the two governments agreed to "in the mid- to long-term, assess the scope for collaboration on unmanned air vehicles—ISTAR (intelligence, surveillance, target acquisition) and UCAS (unmanned combat air system)—by undertaking a detailed joint study to map out the key elements of any collaborative programs and establishing concrete discussions between our industries."

But will a major policy change at the government level be followed by a policy change at the industrial level? How easy will cooperation be, given the major dif-

Taranis

nEUROn

Experimental European UCAS programs

Description	Companies involved	Timescales
Taranis A jointly funded U.K. government/private industry technology-demonstrator program, Taranis is a stealthy intercontinental UCAV featuring low observable (LO) technologies. The Taranis platform has a delta-wing shape, tricycle-type landing gear, and is the size of a BAE Systems Hawk trainer. It is powered by a Rolls-Royce Adour engine improved for long-endurance hot and high operations. The control portion covers RF and the infrared spectrum, while LO characteristics include innovative engine intake and nozzle designs. Weapons systems could include high-power microwaves and laser weapons.	BAE Systems, Rolls-Royce, QinetiQ, GE Aviation. BAE Systems and QinetiQ are managing autonomy systems. GE Aviation is responsible for providing the fuel gauging systems and the complete electrical power system. Rolls-Royce provides the engine, and BAE Systems Australia supplies the flight control computing system. The Integrated Systems Technologies (Insyte) division of BAE Systems is providing C4ISTAR support. Insyte is developing mission management, mission planning and control, payload control, and imagery analysis and exploitation. Claverham provides the primary flight control actuation system, and Meggitt Aircraft Braking Systems provides the wheels, brakes, and brake control systems.	First flight 2010. The flight trials of the technology demonstrator will take place at the test ranges at Woomera in South Australia.
nEUROn The technology concept vehicle is understood to measure 9.3 m in length with a 12.5-m wingspan—about three-quarters scale of a production UCAV. Maximum takeoff weight is 5,000-6,500 kg (11,000-14,300 lb), and maximum speed is Mach 0.85 with a 12-hr endurance. Incorporates advanced stealth technologies such as an engine intake that features radar-absorbing material and infrared signature suppression. The air vehicle has four control surfaces and two weapon bays, each sized for a Mk.82 bomb. System software is based on Arinc 653 software design standard. The French government is providing half of the program's €400-million budget with other financing supplied by other member nations.	The program is led by Dassault Aviation, which is responsible for general design and architecture, flight control system, final assembly, and ground tests, as well as the flight tests. Other partners are: Alenia (Italy): internal weapon bay, electrical power and distribution system, air data system, and ground and flight tests; SAAB (Sweden): design of fuselage, avionics, fuel system, and flight testing; Hellenic Aerospace Industry (Greece): rear fuselage, exhaust pipe, test rig; EADS (Spain): wings, ground station, data link integration; RUAG (Switzerland): wind tunnel tests, weapon interface.	Program started in 2004, with flight trials due to start in 2011 at Istres, France, where the vehicle will be assembled. Later flight trials to be carried out in Sweden, for stealth and weapons release validation work. Final flight trials to take place in Italy.
Agile UAV Within Network Centric Environments (Agile-NCE) The program is investigating datalinks and EADS network-enabled technology within a UCAV framework. Two air vehicles are taking part in the program—EADS is building a second UCAV technology demonstrator following the crash of the Barracuda flying test-bed prototype in Goose Bay, Canada, in 2006. The main work comprises evaluating risk-reduction, key technologies, and future operational concepts, carried out through simulations and flight tests.		The study was commissioned by the German Federal Office of Defense Technology and Procurement in 2007. Finland and Switzerland have subsequently joined the project, which is due to run until 2013.

ferences between the nEUROn and Taranis programs?

Problem one—nEUROn is not merely a technical demonstration program, it is a validator of European advanced-technology industrial cooperation, a partnership of six European countries researching how companies in different countries can work together to provide the appropriate technologies at the appropriate price. It is a highly complex partnership with three main goals—maintaining and developing the skills of the participating European aerospace companies' design offices; investigating and validating technologies that will be needed by 2015 to design next-generation combat aircraft; and validating an innovative cooperation process by establishing a European industry team responsible for developing next-generation combat aircraft.

Taranis, on the other hand, is an all-U.K. industry effort to meet a government requirement for the U.K. to develop a sovereign capability in UCAV technology.

Problem two—both programs are already well advanced. "The nEUROn program is now ready to fully enter the development and manufacturing phase,"


Mantis


Talarion

said Philippe Koffi, of the French Delegation Generale pour L'Armement (DGA), at a London UCAV conference in July. "The long-lead time manufacturing has already started. The final design review was held in April 2009, and system global definition is frozen."

There are two other European UAS programs that may have the potential to develop UCAV capabilities. Both BAE Systems' Mantis and EADS' Talarion projects are being designed primarily as ISTAR platforms, but both could be developed to carry weapons, as the Reaper has evolved from the Predator. EADS is reported as saying it has decided not to make major investments in UCAVs, though it is keeping its options on two fronts. One is through continuing involvement by its subsidiary, EADS Spain, in nEUROn—the military air systems company is manufacturing CFC parts and assuming responsibility for the data exchange systems. The other is its ongoing work on the Agile-NCE (network-centric environments) study.

Given a governmental go-ahead for development this year, the maiden flight of Talarion would be in 2013, and with first series deliveries in 2015. Again, the U.K. is seeking a more aggressive development path for its next-generation ISTAR UAS, with the first flight of Mantis planned for later in 2009. Earlier this year the U.K.'s MOD said it was considering deploying Mantis in Afghanistan during 2010.

New road maps

Whether Anglo-French cooperation will result in a joint UCAV by 2030 will depend very much on how their respective defense ministries draw up their UAS road map—with more intensive UCAS collaboration most likely in the post-Taranis, post-nEUROn flight trial era.

The U.K.'s MOD is currently developing a UAS strategy to 2023, and its immediate preoccupation is with integrating its new Watchkeeper ISTAR platforms—based on the Elbit Systems Hermes 450—by 2013. The ministry has identified 16 capability areas where unmanned systems should be used in the future, with these spanning tasks including ISTAR, deep target attack, and theater airspace.

In July the MOD outlined to UAS manufacturers its requirements for a new medium-altitude long-endurance ISTAR UAV, stressing that competitors such as BAE Systems, Thales, EADS, and Selex would have to work together to ensure the next generation of UAVs would be

Experimental European ISTAR programs with potential for carrying weapons

Description	Companies involved	Timescales
Mantis A jointly funded U.K. government/private industry program, Mantis is a long-endurance twin-engine ISTAR platform with autonomous mission system capability. The advanced concept technology demonstrator has a wingspan of over 20 m and features a fly-by-wire, all-electric control system. It is powered by Rolls-Royce RB250B-17 engines. The production aircraft is reported to have a maximum operating altitude of about 55,000 ft. Mantis is being designed for 24-hr endurance operations with a payload capability equivalent of 12 MBDA Brimstone missiles or six Raytheon Paveway bombs.	BAE Systems, GE Aviation, QinetiQ, Meggitt, Rolls-Royce, Selex Galileo.	First flight 2009.
Talarion ISTAR UAS with a 27.9-m wingspan, EADS has proposed a program of six Talarion systems each for France and Germany and three for Spain. One system comprises three Talarion platforms plus ground segment. France, Germany, and Spain have funded a study phase—production decision is awaited.	EADS Defense and Security–government partners from France, Germany, and Spain.	Given a governmental go-ahead for development in 2009, the maiden flight would be in 2013 with first series deliveries in 2015.

able to use common ground stations and support systems. The MOD has also set up a new UAS procurement division within the Defence Equipment and Support organization to smooth differences between air force and army UAS requirements. The Future Systems team within the new division will focus on Mantis and Taranis development.

In its road map, the French DGA is considering 100 potential UCAV capabilities, according to Koffi. These will be prioritized in terms of life cycle costs, mission effectiveness, and fleet sizing. After nEUROn, the DGA will be developing complementary technology and operational concept demonstrations. The French defense ministry is due to begin a more detailed study into UCAV developments beyond nEUROn later this year. Both nEUROn and Tarantis feature the Anglo-French Rolls-Royce/Turbomeca Adour engine.

The prospects for further collaboration between the two countries have also been improved with the in-service date for the U.K.'s DPOC UCAV apparently slipping from 2018 to nearer 2025, coming close to France's FCAS target.

An industrial-level decision to merge the UCAV programs of France and the U.K. would not be feasible at least until 2015—after the flight tests of the Taranis and nEUROn. But the fact that the issue is now under serious consideration by governments, if not yet by industry, is a serious change of course.

Philip Butterworth-Hayes
Brighton, U.K.

Events Calendar

OCT. 1-2
Resolving Uncertainties in Airframe Noise Testing and CAA Code Validation, Bucharest, Romania.
Contact: L. Koop, lars.koop@dlr.de

OCT. 12-16
Sixtieth International Astronautical Congress: Space for Sustainable Peace and Progress, Daejeon, Korea.
Contact: http://iac2009.kr/

OCT. 19-22
Sixteenth AIAA/DLR/DGLR International Space Planes and Hypersonic Systems and Technologies Conference, Bremen, Germany.
Contact: 703/264-7500

OCT. 21-22
International Symposium for Personal and Commercial Spaceflight, Las Cruces, N.M.
Contact: www.ispcs.com

OCT. 25-29
IEEE/AIAA 28th Digital Avionics Systems Conference, Orlando, Fla.
Contact: T. Redling, 903/457-7822; thomas.j.redling@l-3com.com

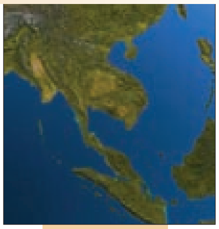
OCT. 26-28
Eighteenth International Meshing Roundtable, Salt Lake City, Utah.
Contact: Jacqueline Hunter, 505/284-6969, jafinle@sandia.gov

OCT. 29-30
Joint Conference on Satellite Communications 2009, Nara, Japan.
Contact: Yoshihisa Takayama, takayama@nict.go.jp

NOV. 3-6
NDIA Aircraft Combat Survivability Symposium, Monterey, Calif.
Contact: Meredith Geary, 703/247-9476; mgeary@ndia.org

NOV. 15-20
Twentieth International Congress of Mechanical Engineering, Gramado, Brazil.
Contact: Joan Luis Azevedo, azevedo@iae.cta.br

Southeast Asia reaches toward space



MUCH ATTENTION HAS FOCUSED ON THE Asian "space race" involving China, Japan, India, and to a lesser extent South Korea—countries that are all intent on sending people and/or machinery into orbit or toward the Moon. But there is no less interesting a range of space-related activity taking place among some of Asia's smaller powers. This centers principally on developing and using space technology for communications, control of resources and—especially—education.

Within this Southeast Asian group, the major nations in terms of geographical size or economic power are the Philippines, Singapore, Malaysia, Thailand, and Indonesia. All five are involved at varying levels in the use of space for broadcasting, communications, meteorology, and mapping, using either their own home-built or other satellites in conjunction with their own ground stations.

In July Malaysia launched its own Earth observation satellite, RazakSat, on a Falcon 1.

The Philippines has a planetarium and an observatory plus a general educational program in astronomy run under the auspices of the Philippine Atmospheric, Geophysical, and Astronomical Services Administration, though there is no formal university course in the subject. A shortage of people qualified for top scientific jobs is something of a self-fulfilling situation, as there are currently few such jobs to be had.

Thailand has science education programs run by the National Science and Technology Development Agency, some involving the development of small satellites, while Singapore is seeking to spread knowledge of and involvement in space research by the not-for-profit Singapore Space and Technology Association and hopes to launch its own microsatellite X-Sat—a technology demonstrator built by Nanyang Technological University—later this year.

Malaysia put itself somewhat ahead of its colleagues by launching its own Earth observation satellite, RazakSat, into LEO on July 14 via commercial launcher Space X's Falcon 1 rocket from Kwajalein in the Pacific. The Malaysian National Space Agency (known by its local name Angkasa) has now achieved two major goals: putting up RazakSat, and sending a Malaysian into space—orthopedic surgeon Sheikh Muszaphar Shukor flew in a Russian Soyuz spacecraft to do a stint at the ISS in October 2007.

Malaysia thus became the first Southeast Asian nation to have an astronaut of its own, though this is somewhat unfair to Indonesia, which had two payload specialists in training and on the flight schedule with NASA until the Challenger shuttle disaster in 1986 forced the cancellation of their missions.

All five countries developed their aerospace industries via engineering work on military aircraft and by maintenance and repair of airliners, with Philippine Aerospace Development and PT Dirgantara Indonesia (formerly IPTN) also performing aircraft assembly work—and, in IPTN's case, designing and building its own or joint-venture models. But still, obviously, the aerospace industry has in general been more "aero" than "space"—except today in Indonesia, a nation that has become heavily involved in the hardware of rocketry.

Indonesian civil activities...

Indonesia's need for air travel across its 3,275-mi. width and 1,373-mi. depth is obvious—the country is roughly three times the size of Texas. Perhaps less obvious behind the tourism-generated stereotypes of balmy weather, clean blue seas, and long white beaches is the need for space-based communications to link its five large and 13,677 smaller islands, about 6,000 of which are inhabited by the country's 240 million people.

Hence the vital nature of the role played by the National Institute of Aeronautics and Space (Lembaga Penerbangan dan Antariksa Nasional, or Lapan by its local acronym). Lapan was set up in 1964 and has as its brief the carrying out of civil and military aeronautical and space-related research, as well as the responsibility for connecting all the populated islands with telecommunications.

Lapan's involvement with satellites includes the whole range of Palapa and Lapsat Indonesian broadcasting and telecommunications spacecraft that began operating in 1976, with their new-generation replacements continuing in service to this day. Lapan also oversees research into the atmosphere, global warming, the environment, remote sensing, communications systems, satellite technology, and weather stations. In addition, it runs well-established rocket motor and propellant laboratories.

That the Palapa satellite series was originally built and launched by U.S. interests is largely irrelevant; through these satellites, Indonesia became only the third country after the U.S. and Canada to have its own domestic broadcasting and telecommunications satellite system. The point was only partly political control—disaster relief and economic development could also proceed at a faster pace than before. Indeed, just as with Canada, Indonesia's name for the satellites was devised for social reasons: Palapa is a mythical fruit that a former ruler is said to have sworn could not be enjoyed until the entire archipelago was united; Canada's satellites were named Anik, an Inuktitut word meaning "little brother," also signifying the desire for unity.

In another important area, education and awareness, Indonesia is well endowed with scientific institutions and facilities built up over many years, with planetariums in the capital, Jakarta, as well as in Surabaya in East Java (a navy facility) and Tenggarong in East Kalimantan on the huge island of Borneo. The country also has two observatories: Bosscha, near Bandung in West Java, for astronomical research, and the Watukosek Solar Observatory at Gunung Perahu Hill in East Java. All these facilities are used to generate a high awareness of space research among students and the public at large and to promote the use of science in everyday life—for instance, training government officials to help fishermen in the use of GPS units to monitor fishing areas.

In October 2007, Sheikh Muszaphar Shukor traveled to the International Space Station.

Five major universities conduct courses up to postgraduate level, with majors in astronomy, aeronautical engineering, remote sensing, and geographical information systems. At the junior level, there are contests to find the best home-made "rocket" powered by pressurized water, as a way of generating interest in rocketry and space-related matters generally.

...and military efforts

But these days, Indonesia's scientists and engineers are intent on joining the big leagues, even though they suffer from budgetary handicaps. Lapan wants to launch its own satellite on its own rocket. Its goals include military needs as well as civil ambitions.

To this end it has been cooperating with Indonesia's military since 1995 to develop more efficient rockets, while at the same time monitoring the strategic Malacca Strait between Indonesia and Malaysia—a well-known area for piracy against commercial shipping—from space, with data from the satellite Lapan-TUBsat's remote-sensing gear, developed in conjunction with Germany's Technical University Berlin. But missiles intended to defend shipping in the strait would necessarily have a relatively short range, and there have been no reports of any guidance or other needed systems being developed.

A pact with China signed in 2005 specifically included acquiring technology for missiles with a range of up to 150 km (94 mi.). Rockets of various sizes have been tested fairly regularly. The smallest is the solid-fueled RX-100, which is 1.9 m long and 110 mm in diameter, weighing 30 kg, and is used to test payload subsystems. A two-stage RX-150-120 with a range of 24 km was launched from a moving armored personnel carrier in March. RX-250s (250 mm in diameter) have been fired regularly since 1987, with range progressively increasing to 53 km in 2007.

If there is a formal program to develop missiles in Indonesia, it is very quiet, possibly because Lapan's budget for 2008 was the same as for 2007 at only 200 billion rupiah ($19.9 million), though in July Lapan was promised an

Bosscha observatory is near Bandung, West Java.

extra $3 million-$5 million to develop the RX-420 and the bigger RX-520. This roughly matches the increase of about 21% granted to Indonesia's military at the same time.

At a test of the RX-420 in July, Indonesian Defense Minister Juwono Sudarsono said his ministry was still calculating the relative costs of developing guided missiles and importing major armaments such as fighter aircraft.

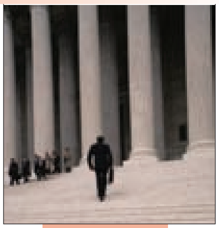
Push toward space

Of more significance is the push to reach space. Last year Indonesia signed an agreement to cooperate with Ukraine in space exploration and data acquisition. Earlier, in 2006, Indonesia and Russia had signed an agreement that would involve Russian Antonov An-124 heavy transport aircraft configured as "air launch systems" operating from Biak Island. Under this agreement, at about 35,000 ft the aircraft would drop a rocket that would, at least in theory, be capable of lofting 3.5 tons of payload into LEO more cheaply than launching from the ground.

The attraction of Biak, or of launching from the ground from much of Indonesia, is that proximity to the equator would give a rocket the benefit of the Earth's rotation to help reach escape velocity. In theory, at least, the first air launch was planned for 2010.

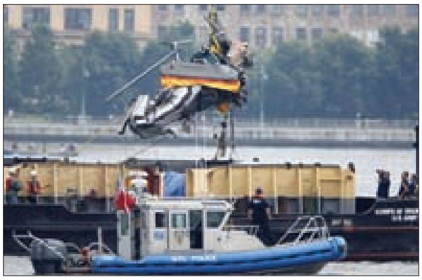
Whatever the likelihood of air launches, Lapan is pressing on with its own rocket research. The scale of the rockets is increasing. Last December the agency ran a ground test with an RX-420 weighing 1,000 kg and designed to reach 50 km altitude. This rocket is de-

(Continued on page 13)



Aviation and spaceflight under scrutiny

ON AUGUST 8, A PIPER PA-32R SARATOGA private plane collided with a Eurocopter AS350B2 sightseeing helicopter at about 1,000 ft over the Hudson River west of New York City. Dramatic video footage showed the Saratoga dropping from the sky with one wing missing while the helicopter, no longer with a main rotor, plummeted like a rock. All nine people in both aircraft perished.



Wreckage from the August 8 crash is pulled from the Hudson River. Photo courtesy Tom Henricks.

The aircraft were in uncontrolled airspace operating under visual flight rules (VFR) in clear weather. It was the worst air crash in the New York region since 2001. It received considerable attention as a local story in and around New York, but almost immediately went viral, with executive and legislative branch leaders in Washington pointing to issues of national significance raised by the collision.

The FAA is responsible for assuring the safety of flight procedures, while the National Transportation Safety Board investigates accidents and determines a "probable cause." To many in Washington, a local New York tragedy highlighted a national concern: NTSB has no enforcement powers, and the FAA can routinely decide not to act on a recommendation from the board.

The tradition of flying in open sky without traffic control, and even without a radio, is as old as aviation itself and is strongly backed by proponents of general aviation. The FAA has long been reluctant to restrict VFR flying, because general aviation enjoys considerable clout on Capitol Hill. Critics say visual navigation of small aircraft is fine in wide open spaces, but not in the crowded sky over the Hudson.

Sen. Frank Lautenberg (D-N.J.) said he would hold hearings into small-aircraft safety. Rep. Jerrold Nadler (D-N.Y.) called the collision "a tragic and powerful reminder of what we have known for some time—that New York's airspace is far too congested to be unregulated by the FAA."

A corridor along the Hudson below 1,100 ft has long been crowded with VFR flyers who are required to visually "see and avoid" to prevent collisions, just as pilots do in uncontrolled airspace all over the country. Among users of the Hudson airspace in 2008 were 409,235 helicopter passengers. Helicopter tourism did about $290 million worth of business last year without a mishap. Along the Hudson, helicopters typically operate at lower altitudes than fixed-wing airplanes.

FAA administrator Randy Babbitt, in what was partly a nod to NTSB investigators, announced that his agency would review safety measures for low-flying aircraft in the New York area. The FAA is also looking into whether a distracted air traffic controller and the temporary absence of the controller's supervisor were factors, although they appear not to have contributed to the collision.

NTSB chair Deborah A.P. Hersman

Rep. Jerrold Nadler

Like Babbitt, NTSB chair Deborah A.P. Hersman spoke of interagency cooperation, but she also said that NTSB has been issuing safety recommendations aimed at preventing midair collisions since the board was founded on April 1, 1967. The board operates independently and, unlike the FAA, is not a part of the Dept. of Transportation.

Hersman says that over the past 22 years the NTSB has issued 50 recommendations focused on enhancing the safety of air tour operations, and that 20 of these remain "open," meaning the FAA has not acted on them.

After a crash in Hawaii back in 1994, the NTSB, then headed by James Hall, issued a special report calling on the FAA to "implement national standards [for helicopter tour operators] by the end of 1995." The agency has never acted on that recommendation but says it has implemented some NTSB recommendations, helping to reduce accidents in the air tour industry from about 13 a year to just eight in 2007.

In a statement, Nadler denounced the FAA's "Wild West approach" to regulating the airspace. In a telephone interview with *Aerospace America*, Nadler said the problem of handling uncontrolled airspace "goes way beyond local concerns in New York" and that the FAA needs to "alter its culture" to be more responsive to VFR safety issues. "It makes no sense that the FAA allows unregulated flights in a crowded sky over a busy metropolitan area," said Nadler, and added that he would support congressional hearings. Nadler believes all aircraft should be required to carry collision-avoidance warning devices.

Shift in space

Retired Marine Maj. Gen. Charles Bolden is now settled in his new job as NASA administrator. However, even from his office on the ninth floor in the northwest corner of the agency's headquarters in Washington, Bolden has only limited leeway to shape U.S. spaceflight policy. Bolden is a former A-6 Intruder attack pilot who flew in combat in Vietnam, and a former astronaut known for a take-charge persona and a readiness to make decisions. But in Washington at the moment, the future of the U.S. space program rests with the White House and its reaction to a report from a committee headed by a retired aerospace executive.

"Our view is that it will be difficult with the current budget [for government] to do anything that's terribly inspiring," said Norman R. Augustine, former CEO of Lockheed Martin and chair of a 10-member panel looking into spaceflight options. The panel, President Obama's Review of the United States Human Spaceflight Plans Committee, had not yet released its findings at press time, but they were dribbling out, and some came from Bolden after he was briefed by the committee.

Norman R. Augustine

A test firing of the Ares I rocket engine had to be rescheduled after a mechanical problem arose.

Augustine and other committee members publicly painted a bleak future for NASA-operated, government-funded journeys by U.S. astronauts. (See 'Is human spaceflight optional?," page 18, for more information.)

The Obama administration had set up the Augustine committee to scrutinize NASA's current plans for retiring the shuttle orbiter, completing the space station, and returning to the Moon, and to examine alternative strategies for moving beyond LEO. Despite its international label, the ISS relies primarily on the U.S. to underwrite its construction and operating costs. Under the current plan, NASA has no funds in its projected downstream budget to operate the orbiting laboratory beyond 2015. Allowing the ISS to deorbit and fall to its destruction—after years have been spent building it—is a potential option now being seriously considered.

While the committee was busy wrapping up its report, Bolden was acting on the policy he inherited. The agency's current long-range plan, developed by the Bush administration in the wake of the 2003 Columbia disaster, is to complete the ISS, retire the shuttle fleet, and develop an Apollo-like crew capsule that will be launched to the station by new Ares I rockets. A larger Ares V rocket would boost the spacecraft, called Orion, on longer reaching missions to the Moon.

If Washington shifts to an emphasis on civilian-operated, privately financed spaceflight, it is not clear what will happen to any of these plans, or even to the Ares I rocket. A test firing of the rocket motor was scrubbed on August 27 after a mechanical failure; it was successfully fired on September 10. Bolden has hinted that because the Augustine committee does not support the existing federally financed human spaceflight program, the test launch of the full vehicle scheduled for October 31 might never happen.

Want not, waste not

As Congress returned from its long August recess, deliberations on the FY10 defense appropriations bill shifted into high gear. In past years, Congress has always added major aircraft procurements to the Pentagon spending bill, even

On August 17, President Obama spoke to the Veterans of Foreign Wars about his opposition to funding what he called "wasteful military projects."

when the administration did not request them. This year, however, with the president and Secretary of Defense Robert Gates determined to curtail unwanted programs, and with a democratic majority in both houses on Capitol Hill, it is unlikely that legislators will be able to tack on the F-22s, C-17s, and C-130Js that they routinely added in earlier years. Experts on both sides of the aisle in Washington now say that further production of the F-22 Raptor superfighter beyond the administration's ceiling of 187 airplanes is a dead issue.

Obama used an August 17 speech to the Veterans of Foreign Wars to reiterate his opposition to funding what he called "wasteful military projects," which to him means the F-22 and a competing turbofan engine for the F-35 Lightning II Joint Strike Fighter.

The president told his audience in Phoenix, Ariz., that it does not make sense to spend $2 billion on more F-22s in the fiscal year that begins on October 1. The Senate Armed Services Committee had proposed an F-22 add-on, but the full Senate later overturned it. The U.S. "can move ahead with a fleet of newer, more affordable aircraft," such as the JSF, Obama said.

Legislators have long held that a program the size of JSF, which could produce 5,000 jet fighters for the U.S. and its allies, needs the insurance provided when two types of engines are available for the same aircraft. The F-16 Fighting Falcon program, begun in the 1970s and still under way for a few overseas customers, always offered buyers a choice between powerplants from the nation's two main engine makers, Pratt & Whitney and General Electric. But other fighters such as the F-15 Eagle and F/A-18E/F Super Hornet have been offered to buyers with only a single engine type available.

Rep. Edolphus Towns

The House Committee on Oversight and Government Reform has charged that the V-22 (rt.) has been underperforming in Iraq, while the CH-46E has a strong record.

At the VFW, Obama decried ongoing attempts by Congress to fund the General Electric/Rolls-Royce F136 engine, the competing powerplant to Pratt & Whitney's F135, for the JSF, saying it is wrong to continue investing in the F136 "when one reliable engine will do just fine." Gates also publicly reaffirmed his desire to ax the F136, downplaying alleged cost and scheduling issues with the F135.

Obama told the veterans: "Waste would be unacceptable at any time, but at a time when we're fighting two wars and facing a serious deficit, it's inexcusable." The reference to two wars is itself a shift in Washington thinking: Leaders in both parties often talk of "the wars in Iraq and Afghanistan"; they rarely use the phrase "global war on terrorism."

The focus on alleged waste came at a time when the V-22 tilt-rotor aircraft was again drawing fire in Washington. A study of the Osprey deployments to Iraq by the Government Accountability Office and June 23 hearings by the House Committee on Oversight and Government Reform produced charges that the Osprey has been seriously underperforming in Iraq, is unsuited for shipboard deployment, and is exceeding estimated operating costs. Rep. Edolphus Towns (D-N.Y.) argued for an end to V-22 production. "It's time to put the Osprey out of its misery," said Towns.

The V-22 has not suffered a serious mishap in Iraq. However, three Marine V-22 squadrons there produced average "mission-capable rates" of 57%, 61%, and 68%, the GAO reported. In contrast, the 50-year-old CH-46E Sea Knight helicopter, which the V-22 was intended to replace, had an 85% mission-capable rate. The GAO reported that just 47 of the 105 Ospreys that the Marine Corps has bought since 1988 are considered "combat deployable" today. The GAO also said that a V-22 requires $11,000 in operating costs per flying hour, or 140% more than the CH-46E.

Towns said the V-22 "has problems in hot weather, it has problems in cold weather, it has problems with sand, it has problems with high altitude, and it has restricted maneuverability...we've gotten half the aircraft for three times the cost." The GAO report and committee hearings did not cover the USAF version of the Osprey: The Air Force has an operational V-22 squadron that has not yet deployed but appears to be functioning without excessive cost or reliability issues.

Robert F. Dorr
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Dorr is coauthor with Thomas D. Jones of Hell Hawks*, the story of an American fighter group in combat.*

A rocket from the Indonesian Aeronautics and Space Agency (LAPAN) was on display at a military exercise at a military camp in Bandung.

clared to use all local materials to avoid problems with embargos when buying items from other countries.

That ground test was followed up in July with the firing of an RX-420 from West Java on a test flight that apparently went perfectly. This was the largest rocket launched in Indonesia to date in the country's quest to loft a satellite into space by 2014. The intention is to set up a four-stage rocket, with the first three stages to be RX-420s and the fourth an RX-320. A two-stage rocket consisting of two RX-420s is planned to be tested next year, with a four-stage assembly to be fired in 2011.

To carry a 50-kg satellite into an orbit 300 km above Earth, the launch vehicle is to consist of three RX-420s in the first stage as boosters, two RX-420s in the second and third stages, and an RX-320 at the top. If problems are found, the stack may be changed to replace one or more RX-420s with the bigger RX-520 rocket—still solid-fueled—as a way of reducing the total structural weight while trying to retain the original payload. Lapan's engineers are trying to cut still more structural weight from the RX-420.

The main areas of concern are the makeup of the fuel itself, exhaust nozzles, and cracking of the rockets' fins. The fuel mixture needs to be adjusted to improve the thrust available, while the exhaust nozzles are to be produced as special steel and aluminum alloy castings instead of milled graphite blocks—this is expected to save 40% of the current 90-kg weight of each nozzle. Cracked fins are thought to be caused by local aerodynamic heating, and adding insulation is expected to cure the problem.

Next year Lapan is to develop booster separation systems and nozzle ignition methods that will work in the atmospheric conditions at 20-km altitude and above, when lower rocket stages are jettisoned and upper stages take over. Also on the menu is a vibration damper that will protect the satellite during its ride to orbit.

Michael Westlake
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Graham Love

You are restructuring your company from a defense research agency to a technology provider. How far has this process to go—how much of your business is still in research and how much is in providing front-line technical solutions? What would be the ideal balance?

QinetiQ is the former research laboratories of the U.K. Ministry of Defence and was privatized in 2006. We have undergone something of a major transformation, from an organization which just a few years ago relied on 100% revenues from the U.K. government to a very much more broad-based business.

Last year our turnover was £1.6 billion, 47% of which came from North America. So that's quite a major shift. We still have most of our business based in the U.K., though we do have a major presence in North America and Australia. We now have 15% of revenues coming from research work and the balance from technology-based services and technologies inserted within platforms—or from products themselves, such as long-endurance unmanned air systems (UAS). But the last few years have been about transforming the business.

What are the key technology areas where you are aiming to have a dominant share of the market?

There are four key capabilities that are central to our strategy moving forward. One of the major areas includes robotics and autonomy—such as the Mantis and Taranis unmanned combat vehicles in the U.K. We are also involved with the Zephyr high-altitude long-endurance UAV. We are working with autonomous systems in the unmanned ground vehicle market and with underwater vehicles as well.

At the same time we are involved in electronic warfare and radar markets.

The training and simulation environment has also been an important business for us, especially in preoperational training. We have developed the JOUST fast-jet pilot simulator, for example, to give pilots the opportunity to improve their performance and tactics in a safe environment. We are working to develop new training for landing jets on carriers. At the center at RAF Waddington, near Lincoln, we train pilots not just in their own aircraft but in how to work alongside other aircraft, before they go to the theatre. This gives us all an ability to learn not just how to use the technology but also how to use it more cost-effectively.

Another major area for us is cyber warfare and cyber security. We are investing heavily on both sides of the Atlantic and working increasingly closely with intelligence agencies.

Tell me more about the training at RAF Waddington.

At RAF Waddington, air force pilots train alongside British Army forward air controllers and artillery personnel prior to deployment to Afghanistan. The contract is worth £26 million over the next four years.

Under the contract sponsored by the RAF, we are working with Boeing to provide around 44 weeks' access to specialist synthetic training facilities each year. The primary users are headquarters-level fire planning cells and fire support teams, who act as the eyes and ears on the front line for artillery batteries, plus the RAF pilots that will be operating alongside them in the region and engaging in ground attack missions. By working together they safely experience the complexities of controlling aircraft, artillery, and other assets before they get to the front line.

There still appear to be problems with the rules on exchanging information between U.S. program managers and partners in Europe and elsewhere—I am thinking in particular of the issue behind the ITAR waiver for the Joint Strike Fighter. Is this impacting your business, and how do you see this issue being resolved?

We are finding this reasonably easy. We have a separate North American team, carefully selected and with a proven track record, with an independent board of directors.

Perhaps our business model makes this less of an issue for us. Although expertise moves both ways across the Atlantic, our business model was initially based on taking products and services from the U.K. market to the U.S.

Again, Zephyr is a good example of this, as it was initially developed in Farnborough, U.K., for the U.K. Ministry of Defence, but we are now under contract to the Dept. of Defense. In the other direction, the TALON family of ground robots were developed in Boston but have been sold to the MOD and the DOD.

So although we have to work within the same regulatory controls as everyone else, we are more about exporting U.K. technology to the U.S. Don't forget we are not a manufacturer, so we tend to export the expertise of our people rather than technology and products themselves.

"We want to change the ratio from five people per unmanned aircraft to five aircraft per person."

Have you noticed any difference in the transatlantic defense/aerospace marketplace since the election of President Obama?

There were the mechanical effects of a change of administration and announcements of potential changes which will have to be voted through by Congress. But most of our work in North America is related to long-term programs, so we have not been particularly impacted by the changes.

Interview by Philip Butterworth-Hayes

In looking at new aerospace research markets, which do you see as the real "game-change" or "step-change" technology areas that will radically alter capabilities? Can you give me some idea of how you are addressing these markets?

We think the autonomy is a very important area—taking operational personnel out of harm's way but still [keeping them] in the loop in making strategic decisions—and we are spending a fair amount of time developing ways of being able to control groups of vehicles at the same time. We want to change the ratio from five people per unmanned aircraft to five aircraft per person.

We are also looking at new power sources, such as solar power and fuel cells. We've developed the Zephyr UAV, which by day flies on solar power generated by amorphous silicon arrays and by night is powered by lithium-sulphur batteries that are recharged during the day using solar power, to the stage where it is now ready for production. And it's been fantastic working with Boeing on the Vulture ultra-long-endurance UAS, sponsored by DARPA. With Vulture we are working toward developing a UAS that can maintain an airborne payload on station for an uninterrupted period of more than five years using a fixed-wing aircraft.

Our customers are interested in ISTAR [intelligence, surveillance, target acquisition, and reconnaissance] platforms, so we are also developing sensors that allow the systems to deliver data and intelligence. Examples are lensless cameras, hyperspectral cameras, and satellite communications.

True autonomy—the ability of a UAS to develop its own missions and react to threats and opportunities—is several leagues more complex than remote control. What are the major technical hurdles to developing true autonomy, what has QinetiQ achieved so far, and what is your view as to when we will see this achieved in the battlefield—if it hasn't been achieved already?

"It is ironic that the more autonomous a system is, the more effort needs to be put into the man-machine interface."

The biggest hurdles are not in achieving an autonomous system but in making it easy to use for human operators and certifying it for operational use. It is ironic that the more autonomous a system is, the more effort needs to be put into the man-machine interface. A key example of our certification work is our effort to enable the routine use of unmanned aircraft in nonsegregated airspace. Such systems could also be used as advisory systems for manned aviation. We think our expertise in autonomy and sense-and-avoid could also be applied as cockpit advisory systems to enable a reduced crew concept while maintaining the required levels of aviation safety.

QinetiQ has been heavily involved in programs like ASTRAEA [autonomous systems technology-related airborne evaluation and assessment] that aim to ensure UAVs can fly safely in civil airspace. Can you describe how close we might be to seeing military UAS platforms regularly accessing civil airspace, and what are the issues still to be resolved?

It's not just military UAVs; we anticipate an increasing market for civilian use. The earliest would be starting in

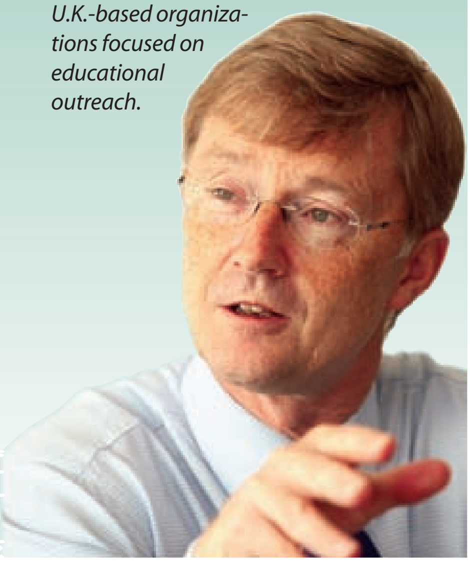
(Continued on page 21)

Graham Love became CEO of QinetiQ in 2005. Previously he was the company's chief financial officer and was also responsible for its North American operations, leading a targeted acquisition program to create a substantial platform in the U.S. defense and security markets.

Love's career has included management roles with Ernst & Young, KPMG, and Shandwick, as well as several years in international consulting. In the late 1980s he was part of the senior management team that made Shandwick the world's number-one public relations group through a major acquisition program involving the purchase of more than 30 PR agencies worldwide.

He was formerly chief executive of Comax Secure Business Services, leading the company through its privatization in 1997 before its sale to Amey in 1999.

Love holds a degree in English from Cambridge University. He is a fellow of the Institute of Chartered Accountants in England and Wales, and a companion of the Chartered Management Institute U.K. He is also a fellow of the Royal Aeronautical Society. Love is a board member of both STEMNET and SEMTA, two U.K.-based organizations focused on educational outreach.



Is human spaceflight "optional"?

PERHAPS THE BEST PRODUCT TO COME from the Review of Human Spaceflight Plans Committee was recognition of the hard truth that our space spending does not match our dreams. The current U.S. space budget is incapable of taking us to the Moon or anywhere beyond LEO.

In its August 12 public deliberations, the panel, led by Norm Augustine, made plain that since the 2004 announcement of the Vision for Space Exploration, continuing cuts to NASA's exploration budget have crippled the agency's plans to return humans to the Moon. With projected funds, NASA will be lucky to build the Orion successor to the space shuttle and extend the life of the ISS beyond 2015. It has no chance, said the committee, of sending astronauts beyond LEO by 2020 or even during the decade after.

The Endeavour crew's STS-127 mission in July delivered the Japanese Kibo laboratory's exposed research facility, bringing the ISS within a few elements of completion. The president's decision on future human spaceflight will determine if the shuttle will retire after its half-dozen remaining missions.

The panel's grim cost assessments were a sobering distillation of the troubles facing not only NASA's Constellation program, but any of the half-dozen other exploration options outlined by the Augustine committee. The panel bluntly declared that NASA's present budget cannot support future exploration plans. Without committing more resources, the U.S. will find its astronauts marooned in LEO for the foreseeable future.

Decisions for the president

The White House chartered the committee to identify and characterize a range of options spanning the reasonable possibilities for continuation of U.S. human spaceflight activities beyond retirement of the space shuttle. The White House further asked the panel to formulate options addressing the following objectives: expediting a new U.S. capability to support utilization of the ISS; supporting missions to the Moon and other destinations beyond LEO; stimulating commercial spaceflight capability; and fitting these options within the current budget projection for NASA exploration activities. As the last requirement seemed too restrictive, Augustine obtained approval to examine options that exceed the projected exploration budget profile.

The committee was to submit its final exploration options and report to the president's Office of Science and Technology Policy by August 31. However, the panel's maturing deliberations at press time made clear that President Obama will face a tough decision in coming weeks: Come up with the added funds to execute NASA's Constellation "program of record," choose one of the committee's options for exploring beyond LEO, or scale back America's ambitions in human spaceflight.

Rocket science vs. economics

Augustine's panel had to deal with three knotty questions: whether to retire the shuttle in 2010; whether to extend the lifetime of the ISS; and what launch system will be most affordable and effective in enabling exploration beyond LEO.

The committee noted that the shuttle could probably be flown safely through 2015 at a rate of one or two flights a year to support the ISS with crew rotation and cargo. It would cost NASA $3 billion-$4 billion a year to cover the shuttle's infrastructure and operations costs, and the agency would also have to conduct an expensive risk assessment to certify the system for continued flight. NASA's projected budget includes none of these costs; in fact, it shows shuttle spending falling by some 90% in FY11, to just over $300 million in program termination costs. The panel therefore recommended that NASA extend the program only if it plans to build a shuttle-derived heavy cargo booster.

NASA, with its partners, has completed 83% of the ISS, but beyond 2015 the facility's future is uncertain: NASA's spending plan assumes that ISS will be decommissioned the following year, with no funds allotted to operations past

2016. Because the panel thought it unlikely that any combination of the remaining partners would be capable of operating or supplying the station, it seemed to favor continued ISS operation by NASA through at least 2020. Panel members noted that the agency would need additional funding to revive its onboard research program and so recoup its investment in the outpost.

Addressing what kind of government launch system would be best suited to support the ISS and beyond-LEO travel, the committee discussed five possible rocket combinations. It first reviewed the "Program of Record," NASA's Constellation program, using the Ares I booster to launch an Orion capsule to the ISS, or, coupled with an Ares V cargo rocket, to the Moon.

The second system, using two Ares V heavy lifters, could reach the Moon or deep space. One of these "light," lower cost versions of the Ares V would carry the Orion crew module; the other would loft the departure stage and Altair lunar lander. The vehicles would then rendezvous and dock in either Earth or lunar orbit for a Moon landing.

The panel next described a shuttle-derived heavy lifter, making maximum use of the shuttle's engines, boosters, and tank. Both side-mount or in-line vehicle designs are feasible; its cargo would rendezvous with an Orion crew launched on a commercial booster. The panel hoped this fostering of commercial space capability would evolve naturally to development of commercial crew services to LEO. Under this vision, routine access to LEO for crew and cargo would shift to commercial providers, while NASA would fly the riskier exploration missions.

The fourth launch system considered was a "super-heavy" version of the expendable Delta IV, again paired in LEO with a commercial crew transport. The panel also discussed a fifth option—to build a new, commercially developed LOX/RP-1 (kerosene) booster. This Saturn V-class heavy lifter should offer NASA long-term savings, but would likely mean abandoning nearly all the Kennedy Space Center facilities that took us to the Moon and still support the shuttle today. The junking of the Vehicle Assembly Building, the crawler-transporters, and Launch Complex 39 would be a drastic and irreversible turn away from our past in hopes of finding a cheaper route to space.

The committee's launch system options include a pair of Ares V heavy cargo vehicles. One would launch an Orion crew exploration vehicle, a second its Earth departure stage and lander/cruise habitat.

The panel expressed an eagerness to enhance these options with a concept that originated in the 1950s with Wernher von Braun—orbital refueling. Propellant would be transferred in LEO from either a companion-launched refueling tanker, or an orbital storage depot. Augustine's committee argued that re-fueling would enable use of smaller launchers for a given payload, or boost the out-of-LEO payload capacity of any upper stage. Developing orbital refueling capability would require a substantial technology investment, and the panel recommended that at least $1 billion be spent annually on such high-payoff exploration technologies.

Deep space options

The panel looked farther into the future to generate options for sending human explorers beyond LEO. Although not bound to recommend a "best" option to the president, the committee will present the pros and cons of each alternative. By mid-August, the panel had largely narrowed the beyond-LEO exploration options to four.

First is the Program of Record, the Constellation plan to use the Ares boosters to establish a lunar outpost for exploration and exploitation of the Moon. Initial sorties would lead to a growing complex of habitats and vehicles capable of expeditions far from the base.

A second alternative would tackle global exploration of the Moon through a sustained series of missions to interesting science targets. The resulting discoveries would eventually point to a preferred location for an outpost, enabling in-depth investigation.

A dash for deep space was the third option, a "flexible path" taking astronauts into lunar orbit, to the Earth-Sun Lagrange points, to near-Earth objects (NEOs), and eventually to a flyby of Mars or a rendezvous with its moons. The panel stated this was the fastest option for getting astronauts out of LEO, bringing a variety of exploration targets within reach while avoiding the budget spike caused by early development of landers and surface systems.

The final and most ambitious option aimed directly at putting human explorers on Mars, skipping intermediate destinations. The Moon would be visited only to test Mars hardware and surface operations, if at all.

Broken budgets

More important to the U.S.'s future in space than the technical details was the panel's mid-August declaration that, under present budgets, the nation could not execute any of these options. Human exploration beyond LEO simply costs more—more than NASA estimated, and surely more than the president's budgeteers had hoped it would. Panelist and former astronaut Sally Ride stated that under the White House's projected spending profile, NASA cannot hope to execute the Constellation program. The budget through 2020 is too small to field the heavy-lift Ares V, NASA's ticket to the Moon, let alone develop a lunar lander or conduct missions to NEOs.

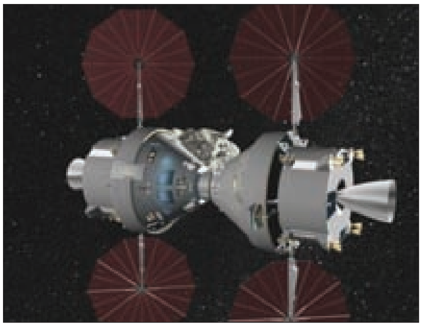
Ride stated that to implement Constellation's lunar return on schedule, NASA would need at least $50 billion in additional funds in the coming decade. If spending were to remain at the lower White House projections, Ares V would not fly until 2028, long after the ISS plunges into the Pacific.

The clear message was that if NASA's budget stays at historic levels, U.S. astronauts have little chance of ever leaving LEO. Even with more generous funding than the White House plans, and skipping a lunar landing, NASA would not be able to launch explorers to NEOs until well after 2025.

What is exploration worth?

The White House got more from the Augustine committee than it bargained for. Instead of a comforting range of affordable options, all within the next decade's planned spending profile, it got a loud wake-up call. The president is now faced with hard choices: either significantly increase NASA spending (perhaps 25% or more), or oversee a major rollback of U.S. human spaceflight plans.

In his July public testimony before the committee, NASA chief astronaut Steve Lindsey gave a common sense assessment of future choices in space. He argued that NASA's next launch system must take us beyond LEO. Building a LEO-only system (such as Orion atop



In August, Lockheed-Martin proposed using two docked Orion spacecraft for expeditions to NEOs, one of the destinations the committee includes in its deep space or flexible path exploration option. Some NEOs require less delta-V to reach than a round trip to the lunar surface, and their low gravity eliminates the need for a lander. (Image courtesy Lockheed Martin.)

Adoption of any of several of the committee's options would send the Ares I booster the way of NASA's X-33 VentureStar, canceled in 2001.

Ares I, or Delta IV, or a new commercial booster) guarantees a dead end: Aimed only at supporting ISS, the human spaceflight program will likely end when the station does.

The committee seemed to find attractive Lindsey's contention that the new rocket system should be powerful enough to reach several deep-space destinations (the Moon, Lagrange points, NEOs), using just a few launches. Because the U.S. is unlikely to design more than one heavy lifter in the next few decades, NASA should build the one that gives it the most flexibility.

As to the cost of exploration, Lindsey urged that NASA be given sufficient budget for adequately supporting presidential and congressional direction. The last five years of Constellation have demonstrated the havoc that ensues when a reasonable plan is chronically underfunded. A stable budget stems from a long-term national commitment to see a program through. Citing the demise over the last 15 years of the X-30 National Aerospace Plane, the X-33 VentureStar, and the X-38 crew return vehicle, Lindsey asked, "How many canceled new human spaceflight programs can NASA survive?"

Whatever new exploration system the White House chooses, NASA's managers argue that the nation must follow through—and build it. With alternative "paper" plans always theoretically better (or faster, or cheaper) than the real one under construction, the U.S. must commit to building the new system or resign itself to watching others explore.

Answering "Why?"

The Augustine committee was chartered to produce viable choices for the White House, for NASA, and for this country's hopes of remaining a leader in human spaceflight. Sometimes lost in the technical details of shuttle retirement, the future of the ISS, new boosters, and future paths for exploration is the overriding question: Why should the U.S. be involved in human spaceflight at all?

Leadership in space for national policy and prestige reasons is one answer; developing cutting-edge technologies to keep our economy competitive is another.

Even more fundamentally, our civilization will not survive unless we develop extensive deep-space experience, sufficient to ward off a future asteroid or comet impact.

Human spaceflight also demands the best talent from our educational and research institutions, and inspires our young people, the next generation of problem-solvers, to choose careers in science and engineering.

Humans are able and flexible explorers, capable of tackling the toughest scientific questions posed by our solar system neighbors. But it will be decades before we see the most important discoveries from our planetary expeditions; human space exploration cannot be justified solely by scientific return.

We should focus our human efforts in space on a more vibrant and immediate goal: building a substantial, expanding commercial presence in space. We must use space resources (energy, water, other volatiles, and structural metals) from the Moon and NEOs to fuel an economic explosion off the planet.

Generating wealth in space, in a variety of locations between the Earth and the Moon, is the surest route to sustaining economic and scientific exploration. Whether it is solar power beamed to Earth, or propellant farms fueled by lunar ice, or industrial facilities fed by asteroidal raw materials, making space a hotbed of entrepreneurial activity will engage the public imagination and ensure necessary taxpayer support. Explorers should be sent where opportunity beckons. Why go to space? To enrich us all.

Four decades after Apollo, will the U.S. again lead the way to space, or will we cede the frontier to those determined to reap its rewards?

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2015, by which time we expect to have understood the route to certification and how to reinterpret manned aircraft regulations. It is likely to be a gradual build-up to establish robust procedures. We are not expecting fully routine access until the following decade.

Is there really a market for solar- and fuel-cell-powered aircraft, given your knowledge gained from Zephyr and others, and if so, how do you see this developing?

Yes, I do think there is a market for this technology, because what it delivers is persistence. Whether for surveillance or communications relay, a solar-powered, persistent unmanned aircraft offers the most effective solution, far more cheaply than a satellite, for example.

Zephyr uses the most efficient batteries and solar cells available today, and we are excited about the potential of this, both in the aviation industry and beyond.

There is increasing pressure on companies such as yours to move badly needed technology from the research labs to the operational theater as quickly as possible. How can we improve the way we convert theoretical research successes into real products?

It is important that we understand what the customers actually want, and that we have the ability to develop the fundamental technology required. We have to develop a strong capability reach and ensure we have a high level of readiness. This is a major enabler, from the customers' point of view.

But also the client has to be prepared to take more off-the-shelf solutions. Sometimes it is better to receive 85% of the requirement in quick time than to wait for 100% of the original requirement.

And I think it is also important that customers are prepared to keep to the original specification—and that suppliers are clear that the systems they develop really remain fit for purpose.

For example, we were asked to help with the RAF Sea King helicopters, which were to be deployed to Afghanistan. These aircraft are now relatively old and underpowered for the height above sea-level at which they have to operate in Afghanistan, and we had to deliver a solution that would rapidly increase their effectiveness. We identified that by using a new type of rotor blade—based on an existing longer version of blades used on the Sikorsky S61 helicopter, comprising advanced aerofoil sections, increased twist, and a swept tip. A significant performance gain could be delivered, so we set about proving this at a fraction of the cost and time it would have taken if we had developed an all-new system.

In this area, success is achieved through a combination of knowing what is going on in the outside world and having the people to identify and manage the right technology.

Your U.S. business is growing rapidly through sales of products such as the Talon mine-clearing robot, and North American business now accounts for almost half of group sales. Are you aiming for the company to become a mainly U.S. business, but with legacy interests in the U.K. and continental Europe? And how will North American business grow—through organic growth or takeovers or both?

The U.K. is still our major source of revenue and will continue to be so. But North America has been a very successful market for us. We have acquired 15 U.S. companies in the last five years, and with 47% of our turnover from this market, we will continue to grow this business—we believe the U.S. budget will continue to grow. We have a particular expertise in autonomy and robotics; Talon robots are manufactured in North America, and there are already over 2,500 Talons in-theater.

We're also seeing growth in systems engineering markets, and we have targeted the U.S. Army aviation segment. We are supporting helicopter operations in Iraq and Afghanistan, for example, where we aim to deliver increased performance for less money. On the Blackhawk, we have developed a maintenance system that will save $50 million over the lifetime of the project, and this is a market that will continue to grow.

We're also developing our mission solutions for the Dept. of Defense and Dept. of Homeland Security, in mission-critical technologies and cyber warfare.

As well as buying companies, our core business in North America has grown organically over the last year by 15%. I wouldn't rule out further acquisitions, but our main focus for growth in North America is continued organic growth.

There is increasing pressure on the U.K. defense budget. For example, there is now considerable debate over whether the U.K. can afford some of the "big-ticket" programs to which it committed—such as a third tranche of Eurofighter Typhoons and two new aircraft carriers. There are growing arguments that the U.K. needs new equipment—smaller, faster—to support troops in the field. Do you have a view on this?

The U.K. government has announced that it will conduct a new strategic defense review to look again at our priorities and, for the moment, they are allocating resources without such a review. But the key, I believe, is to sustain research knowledge in the U.K., so we can support mission capabilities and tie production more closely to the front-line requirements.

You are strong in the U.S., U.K., and Australia—but what about continental Europe? How important is this market to you?

The U.K., North America, and Australia are where we have focused our main efforts. We're not turning our back on continental Europe, but we have found it is smaller and much harder to penetrate than other areas.

However, we are playing an increasingly important role in the technology development for civil aerospace, and are involved in several of the European Commission's seventh framework aerospace research programs. This is especially so in the arena of "clean aircraft technologies"—in airframes, systems, and propulsion.

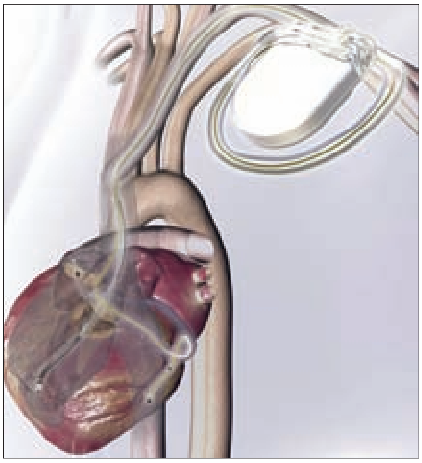
NASA coating helps keep hearts beating

A NASA TECHNOLOGY DEVELOPED FOR AN aerospace high-speed research program is now part of an implantable device for heart failure patients.

NASA Langley in Hampton, Va., created an advanced aerospace resin called Langley Research Center's Soluble Imide, or LaRC-SI. This highly flexible "superplastic" is resistant to chemicals and withstands extreme hot and cold temperatures. It was also determined to be biologically inert, making it suitable for medical use, including implantable devices.

"One of the advantages of this material is that it lends itself to a variety of diverse applications, from mechanical parts and composites to electrical insulation and adhesive bonding," says Rob Bryant, a NASA Langley senior researcher and inventor of the material.

In July 2004, NASA licensed the patented insulation technology to Medtronic, a medical technology company based in Minneapolis, Minn. Medtronic engineers incorporated the material into its Attain Ability left-heart lead, which the Food and Drug Administration recently approved.



A Medtronic Attain Ability left-heart lead is connected to a CRT device to improve the heart's efficiency to increase blood flow to the body. The lead is one of the thinnest available because of NASA's LaRC-SI, an aerospace plastic used as insulation. Image credit Medtronic.

Latest of many medical uses

The use of this material in a medical implant is the latest in a long line of medical applications that have benefited from NASA technology.

"Langley Research Center's Soluble Imide is an excellent example of how taxpayer investment in NASA materials research has resulted in a direct benefit beyond the aerospace sector by extending the quality of life through medical technology," says Bryant.

Heart failure occurs when the heart muscle is unable to pump effectively to meet the body's need for blood and oxygen. It is a chronic and progressive condition that affects more than 5 million Americans and more than 22 million individuals worldwide. Cardiac resynchronization therapy, or CRT, is designed to coordinate the contraction of the heart's two lower chambers and improve the heart's efficiency to increase blood flow to the body.

CRT devices, which are stopwatch-sized, are implanted into the chest and connected to the heart by leads, such as the Attain Ability left-heart lead. A lead is a special wire that delivers energy from a CRT to the heart muscle. Electrical impulses generated by CRTs resynchronize heartbeats and improve blood flow.

The NASA insulation material makes possible the compact and flexible design of Medtronic's CRT lead, one of the thinnest left-heart leads available. Placing a lead in the heart is widely recognized by physicians as the most challenging aspect of implanting CRT devices. The narrow design allows doctors to choose from among different sites on the heart to deliver optimal therapy. The lead is delivered by an inner catheter, a feature that helps physicians place the lead directly in difficult-to-reach areas of the heart. Clinical studies in the U.S. and Canada showed physicians were successful in placing the Attain Ability lead 96.4% of the time.

Role of serendipity

LaRC-SI was discovered by accident. While researching resins and adhesives for advanced composites for high-speed aircraft, Bryant noticed that one of the polymers he was working with did not behave as predicted. After putting the compound through a two-stage controlled chemical reaction, expecting it to precipitate as a powder after the second stage, he was surprised to see that it remained soluble. This novel characteristic ended up making the polymer a very significant find, eventually leading Bryant and his team to win several NASA technology awards, and an "R&D 100" award.

The unique feature of this compound is the way it lends itself to easy processing. Most polyimides (a group of remarkably strong and incredibly heat- and chemical-resistant polymers) require complex curing cycles before they are usable. LaRC-SI remains soluble in its final form and does not require further chemical processing to produce final materials such as thin films and varnishes.

Because the production of LaRC-SI does not require complex manufacturing techniques, it has been processed into useful forms for a variety of applications, including mechanical parts, magnetic components, ceramics, adhesives, composites, flexible circuits, multilayer printed circuits, and coatings on fiber optics, wires, and metals.

When Bryant made his discovery, his team was heavily involved in the aircraft polymer project and could not afford to develop the polymer resin further. Believing it was worth fuller exploration, though, he devised a plan for funding development and submitted it to Langley's chief scientist, who endorsed the effort. Bryant then left the high-speed civil transport project to develop LaRC-SI. The result is an extremely tough, lightweight thermoplastic that not only is solvent-resistant, but also can withstand temperature ranges from cryogenic levels to above 200 C.

With these unique characteristics, the material holds potential for many commercial applications that Bryant believes will ultimately benefit industry and the nation. "LaRC-SI," he explains, "is a product created in a government laboratory, funded with money from the taxpaying public. What we discovered helps further the economic competitiveness of the United States, and it was our goal to initiate the technology transfer process to ensure that our work benefited the widest range of people."

Several NASA centers, including Langley, have explored methods for using LaRC-SI in a broad range of applications—for radiation shielding, as an adhesive, and in replacing conventional rigid circuit boards, for example. In the commercial realm, LaRC-SI can now be found in several commercial products, including a piezoelectric actuator called THUNDER (thin-layer composite unimorph ferroelectric driver and sensor), fabricated by FACE International in Norfolk, Va., another R&D 100 award winner.

Rob Bryant, a senior researcher at Langley, examines a model of a cardiac resynchronization therapy device. Bryant invented the aerospace plastic LaRC-SI that is used as insulation on one of the thinnest left-heart leads available for a CRT. Photo by Sean Smith, NASA Langley.

A collaborative effort

Working with the Innovative Partnerships Program office at Langley, Medtronic licensed the new material. It has been evaluated for space applications, high-performance composites, and harsh environments, but this is the first time it has been used in a medical device.

According to Bryant, "This partnership validates the belief we had that LaRC-SI needed to be introduced in [or by] the private sector: Lives can be saved and enhanced because we were able to develop our laboratory findings and provide public access to the material."

Medtronic is the world leader in medical technology, providing lifelong solutions for people with chronic disease. It offers products, therapies, and services that enhance or extend millions of lives. Each year, 6 million patients benefit from Medtronic's technology, used to treat conditions such as diabetes, heart disease, neurological disorders, and vascular illnesses.

"Our work with NASA Langley was very collaborative," says Lonny Stormo, Medtronic vice president of therapy delivery R&D. "Our scientists discussed Medtronic's material requirements, and NASA shared what it knows about the compound's properties as we continued our testing and evaluations."

In March 2007, working in the U.S. and Canada, Medtronic conducted the first clinical implants of the Medtronic over-the-wire lead (Model 4196), a dual-electrode left ventricular lead for use in heart failure patients with CRT devices.

"Through this partnership, Medtronic was able to deliver a product with enhanced material properties," says Stormo. "In turn this helps our patients, which is the core of Medtronic's mission."

Placing a lead in the left ventricle (LV) is widely recognized by physicians as the most challenging aspect of implanting CRT devices. Anatomic challenges can make it difficult to access and work within the coronary sinus to place a lead in the desired vein of the LV. The lead is specially designed for optimal tracking over a guide wire, which is intended to give physicians greater ability to deliver the left-heart lead in difficult-to-access veins.

Once it is implanted in the LV, two electrodes located at the tip of the lead offer physicians options for tailoring delivery of stimulation to each patient. When approved by the FDA, the lead is expected to be the smallest left ventricular lead on the U.S. market.

Other features and applications

LaRC-SI film is made by casting or spraying a solution consisting of xylene, *N*-methyl-pyrrolidinone, and LaRC-SI powder. At different drying temperatures, various amounts of solvent are removed to the point where it becomes insoluble but retains its melt processability. Characteristics in which LaRC-SI excels include solubility in conventional high-boiling solvents; melt flow and bonding properties; electrical properties (low dissipation factor and high dielectric strength); and resistance to harsh environments such as radiation, cryogenic and elevated temperatures, most fluids, and corrosives; and biological inertness.

LaRC-SI is made from commercially available monomers. A wholly aromatic high-performance thermoplastic polyimide, it is a self-bonding/noncuring resin. In addition to its superior mechanical, electrical, and adhesive properties, it has an extensive range of processing choices that allow it to serve as a dielectric inner layer, a substrate coating, or the substrate.

Other products in which the material offers potential application include matrix resin for composites (carbon fiber and glass); electronic packaging components; optical cladding; dielectric coatings and films; structural and mechanical parts, filled or unfilled; high-temperature adhesives, coatings, and barriers; radiation shielding; flame-retardant foam (structural and flexible); and low-pressure bonding for sandwich panel construction.

For more information about Langley Research Center's Soluble Imide, visit http://technologygateway.nasa.gov/Advanced_Materials.html.

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Mars laboratory lands on red ink

by Frank Sietzen
Contributing writer

In NASA's catalog of planned robotic Mars missions, the largest and most complex is a proposal to land on the Martian surface a mobile spacecraft roughly the size of a school bus. The Mars Science Laboratory (MSL), conceived by NASA engineers and weighing in at over 2,000 lb, is the most ambitious Mars mission ever planned. The lander, weighing 10 times more than previous Mars rovers, will carry to the planet the most advanced collection of scientific equipment ever brought there.

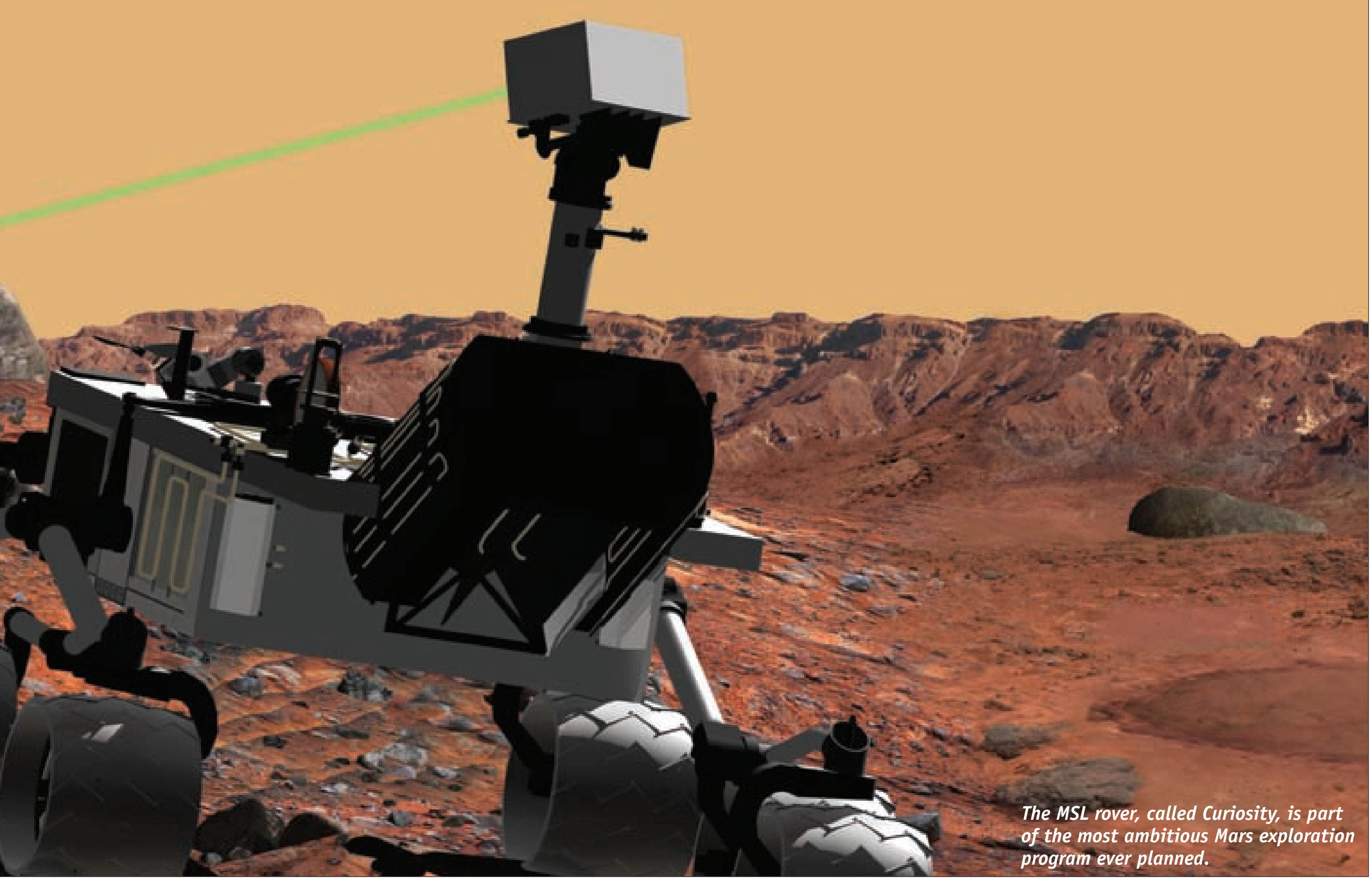
MSL's primary mission is to evaluate the planet's ability, past or present, to sustain life. And unlike the previous robotic Mars missions, this one will steer itself through the Martian atmosphere in a space-shuttle-like descent trajectory, then use a combination of rocket propulsion, parachutes, and crane-like hoists to drop the rover onto a carefully preplanned, narrowly defined landing site.

But in the face of such challenging goals, technical problems and budgetary pressures have led to a flight delay and have even threatened the viability of the project itself. Indeed, MSL has become a test case for placing management constraints and budget boundaries on even a favored project.

Setting the research goals

From the outset, NASA established four goals for all Mars missions: Determine if life ever existed on Mars, define the planet's climate, compile data on its geology, and establish data about Mars that could be used in future human visits.

Eight scientific research goals were also set. Three are biological: Determine the nature and inventory of organic carbon compounds; inventory the chemical building blocks of life (carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulfur); and identify features that may represent the effects of biological processes. Two goals are geological and geochemical: Investigate the chemical, isotopic, and mineralogical composition of the surface and near-surface geological materials; and interpret the processes that formed and modified rocks and soils. Two others are planetary process goals: Assess long-timescale (4-



The MSL rover, called Curiosity, is part of the most ambitious Mars exploration program ever planned.

NASA's MSL, the most ambitious Mars mission yet planned, has faced major challenges, both technical and budgetary. With the current launch window fast closing and important issues still unresolved, the agency has taken decisive action and unusual steps to safeguard the troubled program.

billion-year) atmospheric evolution processes; and determine the present state, distribution, and cycling of water and carbon dioxide. Finally, there is one surface radiation objective: Characterize the broad spectrum of surface radiation, including galactic cosmic radiation, solar proton events, and secondary neutrons.

Four specific scientific objectives for habitability were also established. The first is to assess the biological potential of at least one target environment by determining the nature and inventory of organic carbon compounds, searching for the chemical building blocks of life, and identifying features that may record the actions of biologically relevant processes.

The second objective is to characterize the geology of the landing region at all appropriate spatial scales by investigating the chemical, isotopic, and mineralogical composition of surface and near-surface materials, and by interpreting the processes that have formed rocks and soils.

The third is to investigate planetary processes relevant to past habitability (including the role of water) by assessing the long-timescale atmospheric evolution and determining the present state, distribution, and cycling of water and carbon dioxide.

The fourth objective for habitability involves surface radiation and is the same as the scientific goal described in that category.

All of this was supposed to begin with a launch this year. But as vehicle testing continued, hardware problems increased, and by late 2008 it was clear that the launch to Mars, scheduled in a window that will close late this month, would not be possible.

"We will not lessen our standards for testing the mission's complex flight systems, so we are choosing the more responsible option of changing the launch date," said Doug McCuistion, headquarters director of Mars exploration. Since the launch window for a Mars mission opens only every two years, the agency was now aiming at 2011—and even that would be a challenge. Technical problems had raised budget pressure on the project, to the point where cancellation was not out of the question. This ambitious mission had hit a bumpy trajectory while still in the lab. And

Like two pieces of a giant clam, the aeroshell's backshell (above) and heat shield (below) come together to protect the rover and the propulsion stage that safely delivers it to the surface of Mars.

therein lies a tale of too much mission and not enough time—or money.

Spacecraft details

The MSL rover will be contained inside a trans-Mars coast cruise stage and aeroshell with a heat shield. In a new design approach, the rover will deploy its wheels using a lanyard-hydraulic method much as an airplane drops its landing gear prior to landing.

The spacecraft assembly includes the aeroshell and related components that will hold the rover and shield the spacecraft as it enters the Martian atmosphere and descends. The spacecraft assembly—all hardware above the upper stage of the Atlas V launch vehicle—consists of the cruise stage, an entry descent and landing system of parachutes and crane-like hoist, and the wheeled Mars surface rover.

The encapsulated spacecraft aeroshell is reminiscent of the Viking landers that touched down on Mars in 1976. The rover design is based on Spirit and Opportunity, the rovers that landed on Mars in 2004. The entry and descent system, however, is of an entirely new design. Total launch mass is 7,500 lb.

A complex flight plan

Following launch aboard the Atlas V 541 booster, the cruise phase of the mission will begin after spacecraft separation. During the year-long coast, spacecraft health and system calibrations are to be performed. If the trajectory requires them, small midcourse correction burns by the vehicle's onboard propulsion system will be fired. This will ensure that the spin rotation that began following separation continues in such a way that the spacecraft's antennas remain aimed at Earth and the solar panels at the Sun, because solar energy powers the spacecraft during this period.

As MSL approaches Mars, a number of final preparations are planned, including final trajectory midcourse correction maneuvers. Small attitude pointing updates will be sent to the craft, ensuring antenna alignment for entry communications. Frequent "delta DOR" measurements will be taken to orient the spacecraft position for entry into the atmosphere. On board, the software for the entry will be loaded and activated. The first of several surface sequences and communication windows for the first "sol" (Martian day) will be loaded into the computer. During the approach phase, NASA will use the Deep Space Network increasingly, to determine more accurate trajectory data as the vehicle nears the planet. The DSN's 34-m and 70-m antennas will both be used.

At 78 mi. above the planet, the entry, descent, and landing phase will begin. Using small rockets, the spacecraft will make its final orientation to the atmosphere. The encapsulated descent stage/aeroshell will separate from the cruise stage and will be positioned for entry, the blunt end of the pica-coated heat shield facing the flight path.

The MSL will feature the first soft-landing system used in a robotic Mars mission. After the parachute has significantly slowed the vehicle's descent and the heat shield separates, the descent stage will separate from the backshell. Using four steerable engines, the descent stage will slow down the nested rover even further to eliminate the effects of any horizontal winds. When the vehicle has been slowed to nearly zero velocity, the rover will be released from the descent stage. A bridle and "umbilical cord" will lower the rover to the ground. During the lowering, the rover's

Engineers took the MSL rover for a test drive in the lab. The "Scarecrow" engineering model, so named because it was still missing its computer brain, easily traversed large rocks in JPL's "Mars Yard."

front mobility system will be deployed so that it is essentially ready to rove upon landing.

When the onboard computer senses that touchdown is successful, it will cut the bridle. The descent stage will then pitch away from the rover and power away at full throttle to a crash-landing far from the MSL rover. If the atmospheric trajectory maneuvers are successful, a series of steerable S-turns will have oriented the descending spacecraft toward a narrow, targeted 12-mi. ellipse, much smaller than the 93-mi.x12-mi. ellipses that were the targets of Spirit and Opportunity. This smaller footprint will have been selected before launch, based on orbital photography. The principal means of communication between the rover and Earth will be radio relays between the rover and Mars orbiters.

Three minutes before landing, the spacecraft will deploy a parachute while the descent stage fires a series of retro rockets to slow the descent for the final 1,640 ft. The engines on the stage will slow the descent to a hover, at which point the rover will be dropped from the stage enclosure by a tether for the last several feet before touchdown.

Cameras mounted on a mast above the rover will help guide the spacecraft to specific surface targets. It will use a small nuclear-powered radioisotope power source that will give the mission a full Mars year (687 Earth days) of exploration. The wheeled system will be capable of rolling over obstacles up to 25 in. in size and traveling up to 660 ft each day.

The rover's mission will be to use its advanced suite of on-board instruments to gather rock and soil samples, crush the rocks, and distribute the samples inside the rover to a series of laboratories and test chambers for analysis. The instruments and equipment will be contained inside a rover body similar in design to the earlier rovers, using a rocker-bogie suspension system as before but with larger, six-wheel-drive wheels.

Hardware and software woes

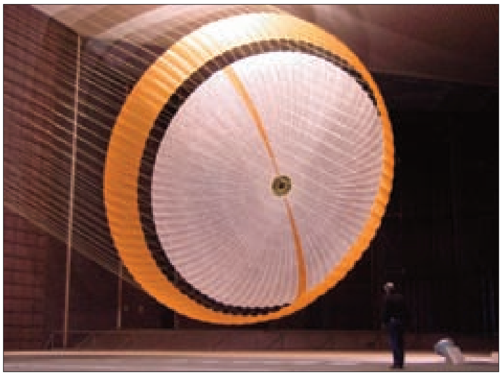
For the tracked wheeled system, NASA at first chose a wet lubricant to coast the gears that drive the wheels. The wet lubricant system was selected because the MSL was designed to operate at much colder latitudes on Mars, notes NASA's McCuistion. "We then switched to a dry system because we didn't have to warm it up," he tells *Aerospace America*. "There were no additional heating require-

Mars Science Laboratory: Components

	Allocated Mass, kg	Cumulative Mass, kg
Rover	850	850
Descent stage (dry)	829	1,679
Descent stage propellant	390	2,069
Heat shield	382	2,451
Cruise stage (wet)	600	3,051
Backshell	349	3,400

Source: NASA JPL.

The team developing the landing system tested the deployment of an early parachute design in mid-October 2007 inside the world's largest wind tunnel, at NASA Ames.



ments," he adds. The design of the gears was shifted from steel gears to titanium because of the desire to reduce weight and mass. "It was much lighter. But the dry film on the titanium [gears] didn't work—the titanium gears were unable to hold the stress," says McCuistion. Dry film would not stay on the gears, or adhere to the metal. NASA then made the decision to change back to a steel gear design—and with it, wet lubricants.

These problems were identified during early development, he pointed out, but also drove up costs and development time. The actuators—which are bearings in the motors' motor encoder-gear box—was where the lubricant issue first emerged. "The bearings in the motors were not able to meet the launch date, and made the motor unstable. The electronics couldn't handle the unstable motors," McCuistion observes.

There also were issues involving the avionics software. Software for a spacecraft, in this case the rover, is constructed in "builds" during different phases of test and development. As different instruments are activated, different software also is activated and comes on line. Software during cruise phase while the spacecraft is enroute to Mars will be fine-tuned. But the final design of the software has yet to be completed, because the hardware itself is still under development.

"We can't finalize all of the software until the hardware is finished," McCuistion says. Several major components are still not finished—and some of what originally was to be validated during cruise flight will now be done on the ground. The motor control avionics are not yet done, and landing radar is not yet finalized. But McCuistion says they were of a "brand new design, better than previous rovers. Better capability."

One area of good design news concerns the pica heat shield, now under final testing. The pica has sufficient heat resisting ability that if the final trajectory is changed to a "hotter" atmospheric entry, the shield as designed has sufficient extra margin to easily accommodate the change. While these design and hardware constructions are under way, science teams are evaluating four potential landing footprints. The teams will meet for a review in late winter 2010, with the possibility of adding a fifth candidate for final analysis. The exact entry and landing targets will be selected in late 2010 or early 2011.

The cost factor

"Cost and schedules are taken very seriously on any science mission," said NASA's Ed Weiler, associate administrator for science, at a news conference discussing the project's delays. "However, when it's all said and done, the passing grade is mission success." Weiler says the decision to slip the launch, while not good news, reflects greater accountability at NASA for the programs it manages. He says that in the late summer of 2008 his directorate first received the cost overrun on the Mars program. Mars program officials were optimistic that a 2009 launch could be met. "I asked the question, [when] will you reach a point where you'll not be able to stay within your budget for that fiscal year?" he recalls. He decided to establish weekly milestones to track the program's progress. "That's unusual for headquarters," he adds.

By late November 2008 it became clear the project was starting to slip. JPL also did a review that confirmed the findings. So a decision was made in early December that the 2009 launch could not be met. "We made the decision not to spend one extra penny and to basically back off two years," Weiler says. He adds that headquarters still has a weekly milestone tracking for MSL in place.

Weiler blames technology and optimistic assumptions for the program's troubles. "Too many technologies having to all fit together… the optimistic assumptions that contractors could build things and make them work the first time at cryogenic temperatures, Mars temperatures. Too many things coming together," he says, adding that MSL's initial budget was "based on a lot of hope…and hope is not a management tool."

With so much of the MSL hardware and software still in assembly, if not design, and the program's budget under constant monitoring because of past cost overruns, the Mars Science Laboratory may yet face the hardest part of its ambitious mission long before the Atlas ever leaves the ground.

SPACE DEBRIS

A growing challenge

Remnants of on-orbit collisions, exploded spacecraft, and defunct satellites now greatly outnumber active space assets. Looming objects have already caused orbiting vehicles, including the ISS, to make evasive maneuvers. Experts are assessing the risks and their implications for future space programs. If steps to mitigate the problem are not taken soon, say some, portions of near-Earth orbit could become unusable for the foreseeable future.

Take a long look into the clear night sky. There is no doubt that the wonder of it all is overpowering. But also take note that you are eyeing Earth's largest junkyard—a dumping ground for dead and dying spacecraft, spent rocket stages, lens caps, paint chips, and, yes, even a lost-to-space tool bag.

The U.S. Space Surveillance Network is tracking more than 19,000 Earth-orbiting man-made objects larger than 10 cm (4 in.) in diameter. Roughly 95% of this number represents some form of debris. But there are also an estimated 300,000 additional objects in Earth orbit measuring 1-10 cm across, along with many millions smaller than 1 cm.

Slipping through space at high speed, even a half-inch-wide piece of debris hitting a spacecraft can have devastating effects.

While all this clutter might be out of sight, it is hardly out of mind. Take for example the February collision between a defunct Russian Cosmos spacecraft and a commercial Iridium satellite. That crash added significantly to the number of bits and pieces already circling the Earth. The accident meant, for instance, that ESA's ERS-2 and Envisat missions were 30% more likely to face a catastrophic impact from space debris.

Two years earlier—again compounding an already terrible situation—was China's destruction of its inactive Fengyun-1C weather satellite. That January 2007 antisatellite target practice by China produced a debris cloud, a messy aftermath described as the most prolific and serious fragmentation in 50 years of space operations. Those leftovers from the test are likely to remain in Earth orbit for centuries, affecting the ability of satellite operators to steer clear of on-orbit collisions. Indeed, in June 2007 NASA reported maneuvering its $1.3-billion Terra satellite to avoid a piece of Fengyun-1C debris.

More recently, ISS crew members took refuge in a docked Soyuz spacecraft to avoid a piece of space flotsam that could have struck the station. The ISS itself has been maneuvered several times to avoid debris.

These and other past incidents constitute a wake-up call.

Domino effect

Answering that call are insurers gauging the risks posed by debris and mulling over premium increases, legal scholars reviewing the many liability issues associated with orbital collisions, and policy specialists studying the need for a new set of decrees to deal with debris and assessing the implications for future space programs.

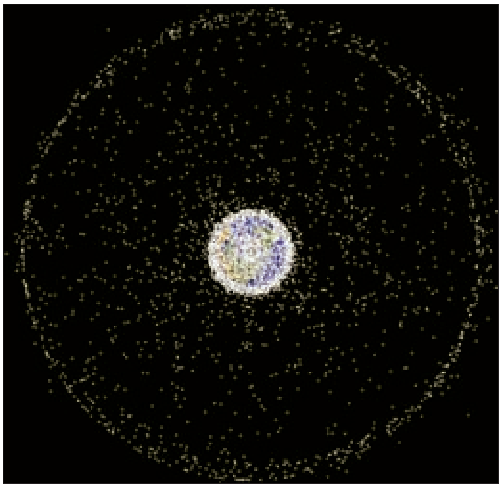
Orbital debris "is the gravest threat to new and existing space systems." That is a view shared by two RAND experts, Caroline Reilly, a research assistant working on defense strategy and planning, and Peter Zimmerman, former chief scientist for the Senate Foreign Relations Committee and a former State Dept. science advisor. They cite the sheer volume of debris and the lack of any mechanism for cleaning it up, factors enhancing the odds that more orbital junk, if left unchecked, may render portions of space temporarily or permanently unusable.

Reilly and Zimmerman have singled out work done decades ago by Donald Kessler and Burton Cour-Palais, NASA space debris experts who concluded that without the means to remove debris, the amount of litter in more densely populated orbits would reach a critical point. Beyond that tipping point, they said, a collision between two objects of sizable mass could spur a space "domino effect"—now known in some circles as "the Kessler syndrome"—that is, each shrapnel cloud would collide with more satellites, creating subsequent impacts and more debris, until that region of space becomes, in effect, a cloud of tightly packed junk.

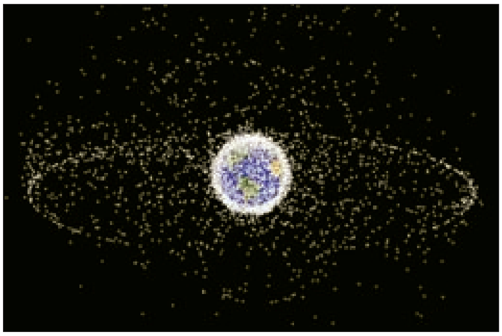
◂ *LEO is the most concentrated area for orbital debris.*

by Leonard David
Contributing writer

NASA's GEO polar images are generated from a vantage point above the north pole, showing the concentrations of objects in LEO and in the geosynchronous region.



This NASA image was generated from a distant oblique vantage point to provide a good view of the object population in the geosynchronous region (around 35,785 km altitude). Note the larger population of objects over the northern hemisphere is due mostly to Russian objects in high-inclination, high-eccentricity orbits.



If a surge of collisions started in the geostationary belt, say Zimmerman and Reilly, "it is possible the entire belt would be closed for business, permanently."

Nicholas Johnson, NASA's chief scientist for orbital debris, testified in April before the House subcommittee on space and aeronautics at a hearing called "Keeping the Space Environment Safe for Civil and Commercial Users." Putting the situation in perspective, he said, "While the adage 'what goes up must come down' still applies in the space age, most satellites take a very long time to fall back to Earth. In many cases, this descent can last hundreds, even thousands, of years. Consequently, after more than 4,600 space missions conducted worldwide since Sputnik 1, a large number of human-made objects have steadily accumulated in Earth orbit."

Johnson pointed out that the numerous operational satellites now circling the globe, as well as the human-occupied ISS, are accompanied by a far greater population of obsolete spacecraft, dilapidated launch vehicle orbital stages, intentionally discarded refuse, and the wreckage of more than 200 satellite explosions and collisions.

"The threat posed by orbital debris to the reliable operation of space systems will continue to grow unless the sources of debris are brought under control. The international aerospace community has already made significant strides in the design and operation of space systems to curtail the creation of new orbital debris, but more can be done," said Johnson.

Space situational awareness

Today, space system operators receive space situational awareness (SSA) data principally from the DOD Commercial and Foreign Entities program, Johnson testified in April. "Enhancements to this program, both to serve a larger number of users and to increase the variety of services available, especially conjunction assessments, offer the greatest near-term and lowest cost improvement to space safety. In the longer term, technical advances in space surveillance, including more capable sensors and higher accuracy data, are likely needed."

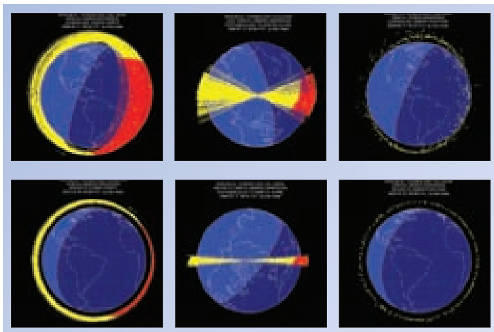
Lt. Gen. Larry James, commander of the U.S. Strategic Command's Joint Functional Component Command for Space, testified at the same hearing. He called space traffic growth both a challenge and a concern.

"In 1980 only 10 countries were operating satellites in space. Today, nine countries operate spaceports, more than 50 countries own or have partial ownership in satellites, and citizens of 39 nations have traveled in space. In 1980 we were tracking approximately 4,700 objects in space; 280 of those objects were active payloads/spacecraft, while another 2,600 were debris. Today we are tracking approximately 19,000 objects, 1,300 active payloads, and 7,500 pieces of debris. In 29 years, space traffic has quadrupled," James noted.

James told lawmakers that based on the past 10 years of launch activity, a conservative estimate projects that the number of active satellites will jump from 1,300 to 1,500 over the next decade. Depending on the effectiveness of future sensors, the overall number of tracked objects could increase from 19,000 to as many as 100,000, he testified.

Ensuring safe operations

James said this year's Iridium/Cosmos collision provided "an excellent example" of the relationship the U.S. military has with commercial users, and of what is being done to ensure safe space operations. This seemed an odd choice of words given his follow-on comment that the Joint Space Operations Center began increased conjunction assessment screening of Iridium assets 4 hr 50 min *after* the conjunction. The center now screens more than 330 objects daily to ensure safe



The Iridium 33/Cosmos 2251 collision in February resulted in a great increase in the debris population. Images generated by Dan Deak.

spaceflight operations for both DOD and commercial space users supporting DOD missions, he added.

"The U.S. space surveillance architecture currently detects and tracks thousands of objects, but critical gaps remain in an ability to fully track and characterize all on-orbit objects, analyze and predict conjunctions," James said. A key program to address this gap, he continued, is the "Space Fence," foreseen as the most accurate dedicated radar in the U.S. Space Surveillance Network, hardware that could provide critical coverage from the southern hemisphere.

The Space Fence would be capable of performing 750,000 observations each day and would track over 100,000 objects, thereby reducing coverage gaps and greatly improving space situational awareness at both LEO and MEO. In addition, James underscored the future fielding of the Space-based Space Surveillance satellite, which will enable an uninterrupted scan of the entire GEO belt every 24 hours—a marked improvement over present-day situational awareness of assets at that altitude.

Also testifying at the hearing was Richard DalBello, vice president for legal and government affairs at Intelsat General, which operates an armada of more than 50 satellites—the largest geostationary commercial fleet assembled to date. He stressed that the U.S. government should play a leadership role on the issue of space traffic control.

At present, satellite operators count on the U.S. government to monitor hardware such as dead satellites and other objects that are drifting in geostationary orbit and could collide with an active satellite. DalBello said, "The safety of commercial space activities can be ensured only if there is a commitment from the U.S. government, and other governments equipped with the same type of radar or optical observation capabilities, to monitor uncontrolled space objects and to alert commercial operators, in real time, of the risks of collision with their operational satellites." Adequate funding for SSA—the ability to monitor and understand the constantly changing space environment—is key, he added.

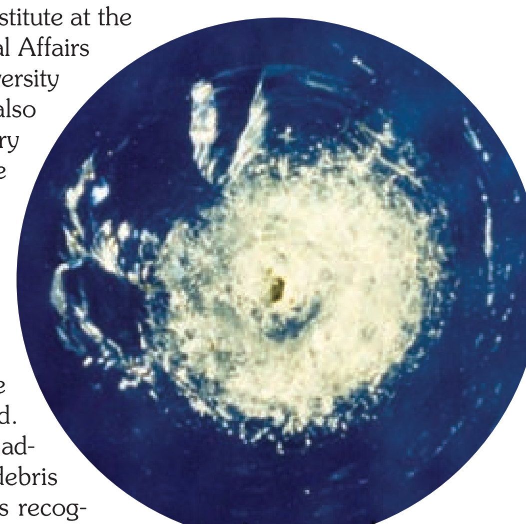
"It would be extremely valuable if satellite operators and governments could find a way to share their collected data in an organized, cooperative fashion. Such a sharing process could result in the creation of a 'Global Data Warehouse' for space information," DalBello observed. He also spotlighted the space debris guidelines developed by the Inter-Agency Space Debris Coordinating Committee, an intergovernmental body created to exchange information on space debris research and mitigation measures.

Other nonbinding guidelines could be developed, he suggested, such as a formalization of existing rules regarding the movement of spacecraft between orbital locations; protocols for informing other operators when one of their spacecraft could potentially cause damage to other space objects; and protocols for managing the loss of control of a satellite.

"Within the next decade, many more countries will gain the ability to exploit space for commercial, scientific, and governmental purposes. It is essential that the world's governments provide leadership on space management issues today in order to protect the space activities of tomorrow," he concluded.

Sharing a similar view is Scott Pace, director of the Space Policy Institute at the Elliott School of International Affairs at George Washington University in Washington, D.C. He also testified in favor of voluntary "rules of the road" for space traffic management.

"Improving space situational awareness and reduction of the hazards posed by man-made orbital debris are both vital to the long-term sustainable use of space for all nations," Pace noted. "Spacefaring nations should adhere to consensus orbital debris mitigation standard practices recognized by the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space. Improving space situational awareness should also be regarded as a promising area of international cooperation."



Space shuttle windows have been dinged by orbital debris on many missions. Credit: NASA.

Taking out the trash

There is no question that the menace of space clutter is real. But that hazard is largely manageable, explains Johnson of NASA's Orbital Debris Program.

Johnson, a 30-year veteran of research on the subject, tells *Aerospace America* that in the past few years, the most significant advance in understanding the orbital debris environment has involved the area near the geosynchronous orbit. "NASA, ESA, and Russian sensors have detected a significant number of [pieces of] debris not yet tracked by the U.S. Space Surveillance Network."

A portion of this small (0.2-1.0-m) debris population exhibits characteristics of high area-to-mass, says Johnson. Near GEO, solar radiation pressure exerts a strong perturbing force on the orbits of such debris. This in turn affects not just the probability that one of these pieces might strike an intact satellite or rocket body, but also the consequences of such a strike.

Although there has been progress in this field, more work is needed in certain areas, notes Johnson. "Clearly, more observational data on debris in both low- and high-altitude orbital regimes is necessary to more precisely characterize the near-Earth space environment and to monitor the growth and evolution of the orbital debris population. To accomplish this, more capable and more numerous sensors—radar and optical—are required."

In terms of public awareness, the debris issue—collisions, clouds of junk zipping through space, and warnings to astronauts about close calls—makes for high media attention. And there is sometimes a degree of hype in such reporting.

Screen shot from an AGI Viewer file shows a Chinese antisatellite scenario from January 2007 (5 min after ASAT test) with the ISS orbit (green line), LEO satellites (green dots), and debris ring (red). Credit: AGI/CelesTrak/CSSI.

"There is a tendency of some, not all, media to exaggerate both the near-term and far-term threats posed by orbital debris," Johnson notes. "While the threats are real, today they are largely manageable. In addition, not enough credit is given to the scientific and operational communities for their efforts to date. The near-Earth space environment would be much worse today without the unheralded efforts of a small segment of the aerospace community during the past three decades."

Clearly, a space edict on "taking out the trash" would reduce future on-orbit collisions. "The problem is there's no cost-effective technology for doing it," says Lawrence Wein, professor of management science at Stanford University's Graduate School of Business. Enforcing existing rules that require space programs to take out their own trash, he believes, could stem the growing threat of expensive orbiting satellites colliding with space litter.

Wein contends that what is occurring in LEO mimics environmental economics here on terra firma. Like resources here on Earth, space is undergoing an early assault from human encroachment.

Wein and Andrew Bradley, a doctoral student at Stanford's Institute for Computational and Mathematical Engineering, argue for compliance with existing NASA rules requiring that objects be removed from orbit within 25 years of being launched. The two call for focusing future policy on achieving full compliance with rules for getting equipment out of orbit, and for making it taboo to blow up orbiting objects intentionally.

Another suggestion by Wein and Bradley is to set fees for every launch and penalize those who ignore their floating trash. Undoubtedly this approach would necessitate heavy political and economic negotiations, "but if we could get high compliance, this problem could stay under control," Wein believes. The fees would be used to compensate for operational spacecraft destroyed in future collisions, and partially fund R&D for space debris mitigation technologies.

A growing predicament

Space law specialist James Dunstan of the law firm Garvey Schubert Barer sees the recent Cosmos/Iridium accident as a case of first importance for space law.

Iridium carried insurance for a collision, Dunstan notes, but only for third-party damage. It is unclear whether Iridium even knew of the probability of the collision. Also, be-

Space traffic management

Reducing the threat to both human spaceflight and satellites from destructive space debris and increasing knowledge about the space environment is more easily said than done. Over the past decade and a half, the world's major space agencies have been developing a set of orbital debris mitigation guidelines aimed at stemming the creation of new space debris and lessening the impact of existing debris on satellites and human spaceflight. These guidelines are one essential part of the long-term sustainability of Earth orbit.

The collision in February between a commercial Iridium satellite and a nonoperational Russian Cosmos spacecraft underscored another essential part of this sustainability—knowledge about objects in orbit and the space environment, also known as space situational awareness.

"Space situational awareness is one of the most important space issues of our time," said Ray Williamson, executive director of the Secure World Foundation, headquartered in Superior, Colo. The group is a strong advocate for a space situational awareness system that embraces several key attributes:

•Combines data from multiple sources, including ground- and space-based sensors, satellite owner-operators, and space weather data.

•Provides a level of data for civil uses by all actors, a function that the U.S. military currently does not have the resources to provide fully.

•Mixes both unilateral solutions with international participation and engagement, potentially saving money through combining data from existing sensors owned by states all over the globe and enhancing overall security.

The optimistic message from Marshall Kaplan, a senior scientist at the Johns Hopkins University Applied Physics Laboratory, is that methods and systems for reducing the debris threat will be developed over the next several years.

The solution, senses Kaplan, will involve several efforts, including added spacecraft shielding, extra satellite onboard propellant for maneuvering, limitations on creating new debris, automated deorbiting of upper stages, mandatory end-of-life risk-reduction maneuvers, and physical removal of debris from high-threat zones.

"Success will require all spacefaring nations to cooperate and work together," Kaplan notes. Still, given these approaches, what comes next?

There must be an ongoing international program to keep debris-collision risks at acceptable levels, Kaplan suggests, a program that could be labeled space traffic management. That effort might operate on a voluntary basis in which spacefaring nations agree to limitations on populating certain orbital slots or zones.

"Each nation would furthermore have to accept the liability associated with the creation of new debris and agree to certain restrictions on orbital usage. Space traffic management would also entail the continued control of debris through an active removal program that maintains the highly used orbital regions safe for operational satellites," Kaplan says. "Ultimately, the space traffic management program may be integrated with the mainstream space program in a way that would permit new spacecraft orbit insertions and debris removal operations with every launch campaign," he concludes.

[Leonard David is a research associate with the Secure World Foundation.]

cause that particular Iridium satellite was well past its useful life, there is a question about whether the operator was hesitant to use any stationkeeping fuel to avoid the collision. Then there is the argument of the Russians, who say that customary international law does not require them to get rid of their derelict satellites. Iridium argues that it is under no obligation to take active steps to avoid the collision, says the space law analyst.

Last March, Iridium issued a postcollision statement explaining that it has been engaged for some time with the U.S. government in an effort to improve assessment and warning, through activities such as the Commercial and Foreign Entities program.

"While these have been useful efforts, Iridium believes this incident has demonstrated the need for even more aggressive action, and the company supports enhanced actions to increase the margin of safety for space operations," says the statement. A specific future activity that Iridium endorses is long-term investment to improve SSA so that the space environment can be better understood and better characterized.

"Iridium believes provision of satellite orbital data by commercial operators would relieve the U.S. Air Force of the necessity to devote resources to tracking the company's satellites, and could provide accuracy greater than would otherwise be commonly available," the statement continues, adding that improved SSA is essential to the well-being of the global space community.

"This event certainly points to the importance of SSA to the success of the commercial space industry, including the commercial and government customers served by Iridium. Iridium is committed to healthy cooperation between government, industry, and the international community to improve the capabilities of SSA and to enhance the security of the space environment for all constituents," the Iridium statement concludes.

Seeking solutions

As the quandary posed by orbital debris worsens, it is stirring some to seek remedies. One clean-up initiative is being fostered by Marshall Kaplan, a senior scientist at the Johns Hopkins University Applied Physics Laboratory in Laurel, Md. This still-embryonic effort could entail working on simulations just to anticipate how bad the situation might become over the next few years, Kaplan tells *Aerospace America*, with the prospect of carrying out ground- and/or space-based experiments on how to actually collect debris. "What we have up there now is sufficiently large, small, and numerous that it's going to propagate and continue to make the problem worse."

Proposed remedies include placing in orbit a huge aerogel-laden fluff ball to snag debris, using terminator tethers, and even using low-power ground-based lasers to churn out pulses of energy directed at chunks of debris. Such energetic zaps would vaporize the surface layer of the debris, causing a thin layer of gas to blow off. This release of gas would kick the debris into a higher altitude but decrease its perigee. The targeted space junk would then reenter and burn up in the atmosphere within a couple of days.

At present, Kaplan says, the approach being taken—trying to mitigate the increase of debris—is the right one. For now, the cost of cleaning up debris in LEO is not economically workable. "It's going to be expensive…it's going to take a long time," he says. We don't have a good solution as yet. But there is coming a time when space debris reduction will become an imperative."

He speculates about one worrisome scenario: "If there were a catastrophic collision between debris and the ISS where lives were lost…I think the end result would be a discontinuation of human spaceflight, at least in low Earth orbit, until the debris problem is fixed. That would give us impetus to do something fairly soon, although you never know what the political landscape might be like."

Decluttering the valuable real estate that is LEO will require international participation, and will take the form of a major new space program, Kaplan suggests. While the time is now to blue-sky space debris reduction options, the task ahead is akin to a superfund clean-up campaign far greater than anything ever undertaken by the Environmental Protection Agency in terms of money and scope.

"This problem has gotten a lot worse," he says. "Space debris is a growth industry, that's for sure."

Cloudy

The National Polar Orbiting Environmental Satellite System has become increasingly important to our ability to predict weather and monitor climate trends. But technical troubles, funding issues, and an unworkable management structure severely threaten this once-promising program. If corrective actions are not taken soon, a serious gap in coverage and a degraded forecasting capability appear inevitable.

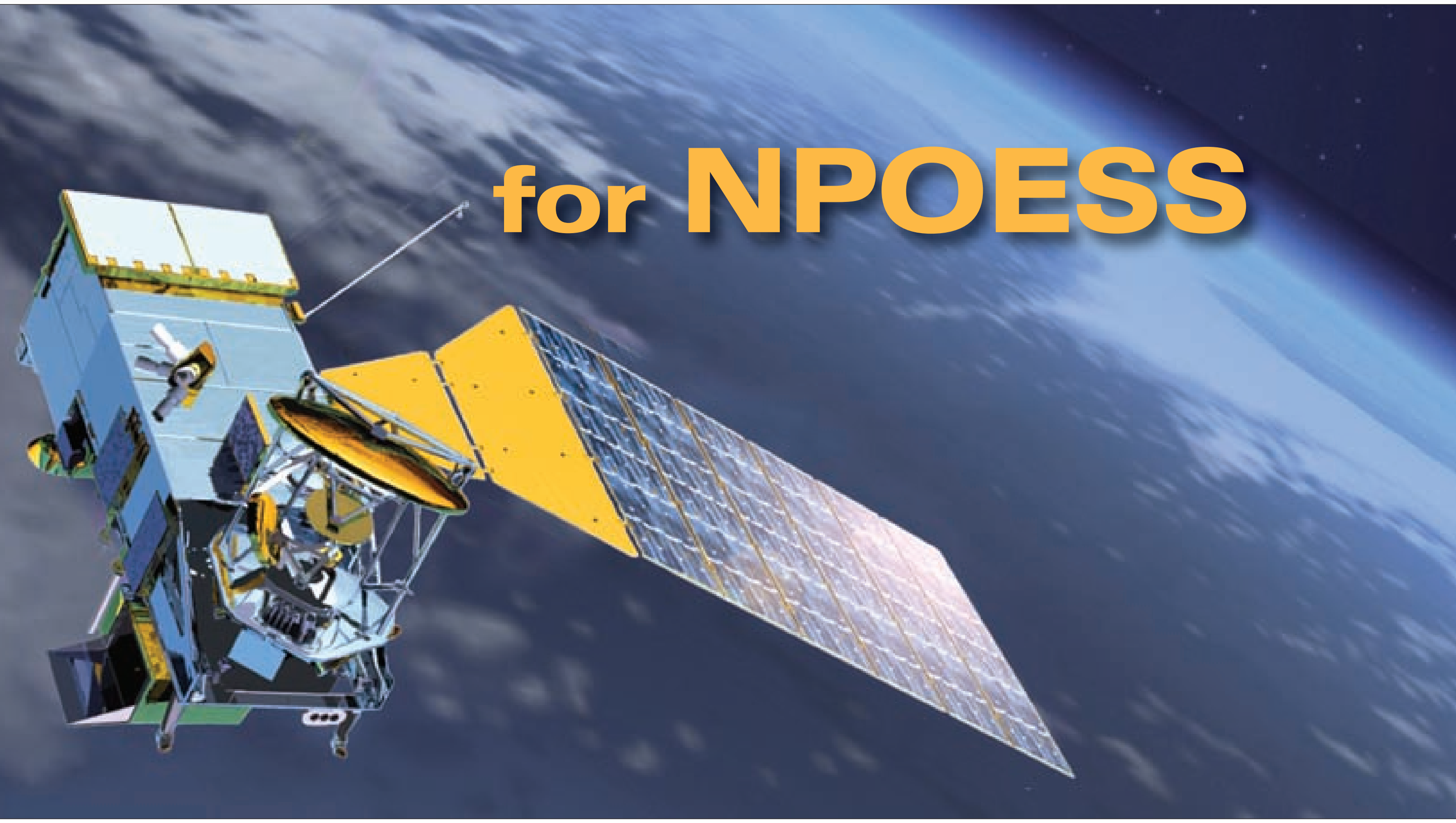
The future looks forbidding for space-based weather forecasting and climate monitoring. Big problems have beset the development of advanced polar orbiting environmental satellites designed to meet both military and civilian needs. The stakes are high for the U.S., and solutions are not in sight.

At issue is the troubled National Polar Orbiting Environmental Satellite System (NPOESS). By all accounts, its timely deployment will be critical to improving and maintaining the continuity of meteorological and climatological data from space. Experts expect it to become ever more important in the years ahead as the U.S. and other nations take measures to control global warming and keep the climate on an even keel.

Early promise dims

NPOESS once showed high promise. The program was created to develop and produce six satellites with highly advanced, state-of-the-art sensors and instruments for measuring and disseminating data on weather and climate. NPOESS was ex-

forecast for NPOESS



pected to generate extraordinarily accurate long-range and short-range weather forecasts. The constellation's high-speed communications links would give meteorologists on the ground the added advantage of almost instant access to weather and climate data from space, experts believed.

NOAA claimed that the NPOESS satellites would collect "a massive amount of very precise Earth-surface, atmospheric, and space environmental measurements from a variety of onboard sensors."

From the outset, one major attraction of NPOESS was its incorporation of Raytheon's advanced visual/infrared imager radiometer suite (VIIRS), designed to see through clouds. Military strategists and tacticians found it enticing. So did hurricane forecasters. But VIIRS ran into technical, weight, and cost problems. It seems to be doing somewhat better now but remains problematic, officials say.

NPOESS began faltering years ago. Its ever-worsening problems sounded alarms in Congress and elsewhere early in this decade, and engendered hearings, investigations, and remedial actions. Because of financial, administrative, and technical difficulties, the program was restructured in 2006, with the planned number of satellites reduced from six to four, and onboard subsystems and sensors cut from 13 to nine. Four of the remaining sensors are said to be less capable than before.

The NPOESS schedule has slipped by at least six years. Cost has doubled to approximately $14 billion, and is expected to grow by at least another $1 billion and counting.

by James W. Canan
Contributing writer

The 2006 restructuring did not do the trick. In its aftermath, "the program is still encountering technical issues, schedule delays, and the likelihood of further cost increases," says a General Accountability Office report. It notes that the schedules for the NPOESS Preparatory Project (NPP) demonstration satellite and the first two NPOESS satellites are expected to be delayed by seven, 14, and five months, respectively. These delays, GAO says, "have endangered our nation's ability to ensure the continuity" of weather and climate data from polar-orbiting satellites.

In July, in an attempt to salvage the satellite, the Obama administration pumped more money into the program, adding $100 million to the $282 million previously budgeted for the coming fiscal year 2010. But the administration was under increasing pressure from Congress to make management changes in the program as well. A Senate Appropriations Committee report on the program declared that "the administration needs to disengage from its autopilot management style" and "start making responsible decisions."

David Powner, GAO's director of informational technology management issues, elaborated on his agency's report in testimony before the House Science and Technology Committee's subcommittee on investigations and oversight in June. "If any planned satellites fail on launch or in orbit," he said, "there would be a gap in satellite data until the next NPOESS satellite is launched and operational—a gap that could last for three to five years."

The worst could well happen. Some officials seem ready to give up on NPOESS in its present form. Such pessimism is reflected in the recent report of the independent review team (IRT) that the NPOESS executive committee appointed to examine the program in the wake of its restructuring.

There is general agreement that much of the problem with NPOESS lies in its unwieldy, three-headed management structure....

A. Thomas Young, a former NASA and Lockheed Martin executive who headed the IRT, told the House subcommittee that NPOESS "has an extraordinarily low probability of success." Young declared that the program is "hardware poor with little protection against a launch failure or an early spacecraft failure," and that the continuity of [meteorological] data from space "is at significant risk."

Even so, the review team recommended retaining the Northrop Grumman/Raytheon contractor team while making other changes mostly pertaining to its management structure and approaches.

Program origins

The NPOESS program had its beginnings in 1994, when then-President Clinton issued a directive combining the acquisition and operation of military and civilian weather satellites in one integrated program office to be staffed by officials from NOAA, NASA, and the DOD and situated within NOAA.

This consolidation marked a major change from the long-established way of doing business, in which the Air Force and the NOAA/NASA partnership each designed, acquired, and operated its particular weather satellite system in low Earth orbits—the Defense Meteorological Support Program (DMSP) and the Polar Orbiting Environmental Satellite (POES), respectively. Big savings—multibillions of dollars—and much smoother, more efficient management and operations were expected of the move.

NPOESS got under way shortly thereafter, with Northrop Grumman under contract as the system integrator and Raytheon as the developer of prime sensors. In 1998, operational responsibility for DMSP satellites was transferred from the Air Force to the triagency Integrated Program Office. Command, control, and communications of both the DMSP and POES systems were combined in NOAA's Satellite Operations Control Center.

POES and DMSP satellites circle the Earth in near-polar, Sun-synchronous low Earth orbits, monitoring the weather almost continuously. NOAA also operates the geostationary operational environmental satellites (GOES), which are developed, acquired, and launched by NASA, and utilizes data from the European Meteorological Operational (MetOp) satellite as well.

Too many cooks?

There is general agreement that much of the problem with NPOESS lies in its unwieldy, three-headed management structure, in which the administrators of NOAA and NASA and the undersecretary of defense for acquisition make up the NPOESS executive committee. All three agencies are represented in the NPOESS integrated program office, which has management responsibility for the system as a whole and for all weather satellite operations.

The Air Force is in charge of NPOESS acquisition. NASA is responsible for facilitat-

ing the development of new technologies and incorporating them into the system. NOAA and DOD share in the overall funding of NPOESS, while NASA funds specific technology projects and studies under the supervision of the executive committee.

At the House hearing, Mary Glackin, NOAA's deputy undersecretary for oceans and atmosphere, played up both the importance and the plight of NPOESS. She called it a "pivotal constellation" and declared that it is now "at risk."

If the delivery of NPOESS satellites were delayed, or if a catastrophic failure occurred during launch or in space, "NOAA's forecasting ability would be severely degraded, because current forecast models rely heavily on [POES] satellites that will be coming to the end of their useful lives," she asserted.

Glackin said a gap in satellite coverage of six months or more would be "unacceptable for weather forecasting, since NOAA would be unable to produce useful four- and five-day hurricane track forecasts," and that the quality of weather forecast models would degrade.

"A gap in satellite coverage of any length would most likely interrupt critical climate measurements that are needed for the nation to determine the cause, magnitude, and direction of future climate change," she noted.

In an attempt to close the threatened coverage gap, the program executive committee decided to press into service the NPP satellite, now in development, that was originally designed to serve solely as a demonstration satellite lacking some operational attributes.

Program officials were expected to propose a new cost and schedule baseline by the end of June, but were forced to acknowledge near the deadline that critical decisions on constraining costs, tightening the schedule, and mitigating technical risks would have to be put off for perhaps another year.

Funding and other problems

The NPOESS management problems were underscored and thrashed out during the House hearings. Rep. Paul Broun of Georgia, the subcommittee's ranking Republican, noted that the "differing priorities and levels of commitment" of the triagency NPOESS management is to be expected, "given their unique missions."

But, declared Broun, "this divergence has ultimately created an untenable partnership. NOAA is pressured by the scientific community to continue operation of research satellites that feed cutting-edge data into weather and climate models, while DOD is content to operate legacy [DMSP] hardware. NOAA doesn't have any extra POES satellites to buffer its transition [to NPOESS] while DOD still has two DMSP satellites on the ground. NPOESS is NOAA's flagship mission, yet [it] barely amounts to a rounding error in the Pentagon's budget."

Broun also noted that another reason for NPOESS problems "is simply that space acquisition isn't easy....We aren't asking these agencies to build cardboard boxes....In the end, we are building one-of-a-kind innovative hardware and launching it at 17,500 mph into the vacuum of space."

NPOESS is an example of "putting all our eggs in one basket," Broun said. "We have sought to limit our costs by putting numerous sensors on fewer spacecraft and launch vehicles," thereby limiting opportunities for sequential upgrades. "We have developed an architecture [in which] it seems that failure is not an option."

Contributing to NPOESS problems, the congressman added, are "issues of requirements creep in satellite sensors, schedule pressure in the face of satellite data disruption, and cost caps" from external factors. "It really isn't surprising that the program isn't run well when the managers can't fine-tune fundamental...parameters like cost, schedule, and performance," he declared.

"A gap in satellite coverage of any length would most likely interrupt critical climate measurements that are needed for the nation to determine the cause, magnitude, and direction of future climate change." *— Mary Glackin, NOAA*

"Every American is impacted by this program whether they know it or not," Broun said. "It is our responsibility to ensure that the farmers, fishermen, warfighters, and everyday commuters continue to receive weather and climate information."

Review team findings

IRT chairman Young told the House subcommittee that implementing the NPOESS program is "extremely difficult" because the program "is not part of a space acquisition organization." His review team recommended putting NOAA wholly in charge of the program, "with NASA acting as NOAA's acquisition organization." The panel "recognized that NOAA has a broader responsibility for

> **"The White House will be required to define the NPOESS program that is in the national interest."**
> *— A. Thomas Young, IRT chairman*

weather and climate requirements than any other organization, and is a natural national advocate for this program," Young said.

The review panel also noted, however, that the Air Force Space and Missile Systems Center would be capable of overseeing NPOESS acquisition.

In the NPOESS program, "the critical issue is that DOD/Air Force and NOAA priorities are not aligned," Young asserted. The IRT found that the Air Force is satisfied with the performance of its existing weather satellites and is unwilling to provide additional funding for the next-generation NPOESS satellites to improve on their performance, he said. NOAA, on the other hand, believes that "accepting legacy [weather satellite] capabilities would be a significant step back."

"This difference in priorities must be resolved," Young added. The panel concluded that the NPOESS executive committee will be unable to resolve it, and that "the White House will be required to define the NPOESS program that is in the national interest."

"Implementation of the IRT recommendations and additional actions is urgently required. Risk and unnecessary cost are being realized at an unacceptable rate," the review panel chairman declared.

The IRT found that the NPOESS managerial agency must have total and absolute acquisition authority, and must be fully responsible for the program's budget and funding, Young told the subcommittee. As things stand, the NPOESS executive committee "is ineffective," he said, because its individual members lack decision-making authority. The triagency NPOESS management considers cost a more important parameter than mission success in making program decisions, and does not focus on top-level issues and timeliness in the process, said Young.

Problems in the development of the VIIRS (shown) and the cross-track infrared sounder continue to drive up costs.

GAO chimes in

The GAO came down just as hard on NPOESS management. The agency reported that even though the program executive committee has made some improvements over the past several years, "it has not effectively fulfilled its responsibilities" and lacks the membership and leadership to oversee and operate the program.

In that vein, Powner testified last June that the undersecretary of defense for acquisition, technology, and logistics, who represents DOD on the NPOESS executive committee, had never attended the executive committee meetings, and had delegated that responsibility to the undersecretary of the Air Force, who lacks the authority to make acquisition decisions for NPOESS.

As a result, "none of the individuals who attend the…meetings for the three agencies has the authority to approve the acquisition program baseline or major changes to the baseline," and as a result, "agreements between committee members have been overturned by the [Air Force] acquisition authority, leading to significant delays," he noted.

Moreover, he continued, the committee "does not aggressively manage risks, and many of the committee's decisions do not achieve desired outcomes." GAO agrees with the NPOESS review panel that unless and until NPOESS management shortcomings are corrected, "important issues involving cost growth, schedule delays, and satellite continuity will likely remain unresolved."

The GAO report on NPOESS recommends that the secretary of defense direct the undersecretary of defense for acquisition, technology, and logistics to attend and participate personally in NPOESS executive committee meetings. It also recommends that the defense and commerce secretaries and the NASA administrator "establish a realistic time frame for revising the program's cost and schedule baselines," develop plans to cut the risk of gaps in the continuity of weather satellites, and closely monitor the program's progress and effectiveness on all fronts.

Reactions and prospects

NASA and NOAA agreed with all GAO findings and recommendations and said they were taking corrective measures, but DOD's reaction was mixed. The department agreed only to "evaluate" the recommendation that its top civilian acquisition official regularly attend NPOESS managerial meetings.

The news for NPOESS is not all bad. GAO reported that the program has made some progress over the past year: Three of the NPP satellite's five instruments were delivered and integrated aboard the spacecraft; the ground-based NPP satellite data processing system was installed and tested; and the NPP command, control, and communications systems passed their acceptance testing.

Even so, problems in the development of two critical sensors—the VIIRS and the cross-track infrared sounder (CrIS)—continue to drive up the program's cost and stretch its schedule, GAO concluded. In addressing these issues, the NPOESS program office halted or delayed activities on other components, including the development of a sensor planned for the first NPOESS satellite, called C1, and redirected its funding to fixing VIIRS and CrIS, GAO said. This caused the costs of those other components to rise, the agency said.

As a result of cost and schedule problems, launch of the NPP satellite has been put off until January 2011, a year later than estimated after the program was restructured in 2006, and seven months later than the July 2010 launch date that was projected a year ago. Moreover, launches of the first and second NPOESS satellites—C1 and C2—are now expected to be delayed at least until March 2014 and May 2016, respectively, GAO reported.

Despite the NPOESS program's many problems, the capabilities it promises are widely regarded as too compelling to dismiss. The administration's big boost of funding for the program last summer is seen as a show of faith that it can be, and that it must be, turned around. Many questions remain as to when the NPOESS satellites will finally fly, which instruments will be aboard, or what they will cost, but there is no doubt about their importance to the national interest or the increasingly urgent need for them, officials agree.

Out of the

25 Years Ago, October 1984

Oct. 5 The space shuttle Challenger is launched on the STS 41G mission and carries the first Canadian astronaut, Marc Garneau. Kathryn Sullivan also performs the first EVA by an American woman. NASA, *Astronautics and Aeronautics, 1979-84*, pp. 509-511, 677.

And During October 1984

—The Association of European Astronauts is formed and includes astronauts selected to train for space missions. One purpose is to enable them to exchange experiences and help plan future European manned spaceflight. NASA, *Astronautics and Aeronautics, 1979-84*, p. 513.

50 Years Ago, October 1959

Oct. 4 The all-solid-fuel Little Joe test launch vehicle makes a 5-min. flight from NASA's Wallops Island, Va., station to test the integrity of a boilerplate model of the Mercury space capsule with a dummy escape system. The spacecraft's aerodynamics are found to be sound. D. Baker, *Spaceflight and Rocketry*, p. 95.

Oct. 4 The Soviet Union's Luna III, also called Lunik III, weighing 614 lb, starts to photograph the Moon during its translunar flight, taking the first pictures of the never-before-seen far side of the Moon. Released on Oct. 26, the pictures create widespread interest around the world. *The Aeroplane*, Oct. 9, 1959, p. 302; *Flight*, Nov. 6, 1959, p. 493.

Oct. 8 Pioneer 4, considered the first successful U.S. space probe, reaches its first aphelion, or farthest point from the Sun. The 107,951,000-mi. distance is a new tracking record for U.S. spacecraft. The probe was launched on March 3. *The Aeroplane*, Oct. 23, 1959, p. 390.

Oct. 10 Pan American World Airways initiates its round-the-world jet service, using Boeing 707 Intercontinental aircraft, with a flight time of a little over two days. On Oct. 27 Qantas Empire Airways of Australia starts the first jet service that goes completely around the world. *Aerospace Year Book, 1960*, p. 456; *FAA Historical Chronology 1926-1996*, p. 64.

Oct. 13 Explorer VIII, the last satellite launched during the International Geophysical Year, is boosted by Juno II, a modified Army Jupiter missile with upper stages. In December, data gathered by the 91.5-lb spin-stabilized craft shows important possible relationships between solar activity and geomagnetic storms. It also reveals more about trapped radiation and cosmic rays near Earth. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 113.

Oct. 13 Bold Orion, a solid-fuel air-launched ballistic missile under development by the Air Force, is successfully test launched from a Boeing B-47 Stratojet near Patrick AFB, Fla. It comes within 4 mi. of the Explorer VI satellite, which is at an altitude of 160 mi. and orbiting at 26,000 mph. *Flight*, Nov. 13, 1959, p. 538.

Oct. 14 At the White Sands Proving Grounds in New Mexico, the solid-fuel Nike-Zeus antimissile is successfully flown for the first time. *Flight*, Nov. 6, 1959, p. 493.

Oct. 17 North American's X-15 rocket-powered research aircraft (X-15 No. 2) achieves its second powered flight. Pilot Scott Crossfield flies the plane, which reaches a speed of 1,419 mph and an altitude of 61,781 ft. D. Jenkins, *X-15—Extending the Frontiers of Flight*, p. 609.

Oct. 21 President Dwight D. Eisenhower announces that the Development Operations Div. of the Army Ballistic Missile Agency, which includes Wernher von Braun's "rocket team," will be transferred to the newly formed NASA, subject to approval by Congress. The move is later approved, and the von Braun team transfers in July 1960. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 114.

Oct. 28 NASA successfully launches a 100-ft-diam inflatable sphere in a suborbital test flight from Wallops Island. This leads to the later use of the inflatable Echo passive communication satellite, to be orbited on Aug. 12, 1960. E. Emme,

Past

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

ed., *Aeronautics and Astronautics 1915-60*, p. 114.

Oct. 31 The first F-106 fighter-interceptor Air Force squadron becomes operational and is based at Fairchild AFB, Spokane, Wash. *The Aeroplane*, Dec. 18, 1959, p. 625.

And During October 1959

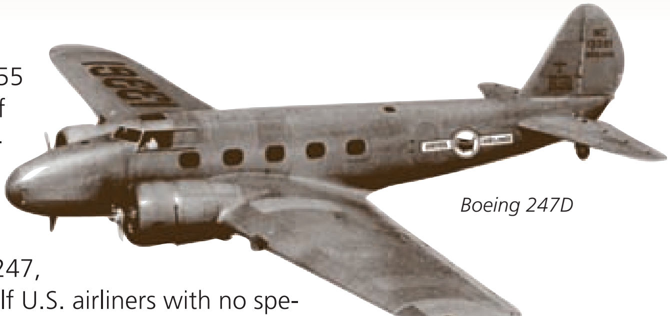
—Dulles International Airport, it is announced, will be the name of the new facility being built at Chantilly, Va., 26 mi. from Washington, D.C. The name is in honor of John Foster Dulles, secretary of state under President Eisenhower. *The Aeroplane*, Oct. 2, 1959, p. 294.

75 Years Ago, October 1934

Oct. 1 Gustave Lemoine, former holder of the world speed record for land planes flying across 1,000 km with a payload of 1,000 kg, and also holder of the world's altitude record, is killed near Amiens, France, when his parachute fails to open after he leaps from a disabled plane. *Aviation*, November 1934.

Oct. 19 Mario Stoppanni and two others break the existing long-distance, nonstop seaplane record in an Italian aircraft with an Isotta-Fraschini engine. The plane leaves Trieste and flies to Massena, Eritrea, in Eastern Africa, a distance of 2,560 mi. The previous record was 2,537 mi., flown between Marseilles and Senegal. *The Aeroplane*, Oct. 31, 1934, p. 511.

Oct. 23 Charles W.A. Scott and Thomas C. Black win one of aviation history's greatest events, the Mac-Robertson race between England and Australia. They win the £10,000 prize and gold trophy when their specially built De Havilland Comet D.H. 88, powered by two 225-hp special Gipsy Six motors, lands at Melbourne after a total flying time of 63 hr 55 min, at an average speed of 176.8 mph. The real significance of the race, however, is that the second and third place winners, a Douglas DC-2 and Boeing 247, respectively, are off-the-shelf U.S. airliners with no special modifications. Their performance dramatizes the superiority of American aircraft and leads to U.S. domination of the airliner industry for years to come. Flown by flamboyant air racer Roscoe Turner, the Boeing 247-D is later displayed in the Smithsonian National Air and Space Museum. *The Aeroplane*, Oct. 24, 1934.



Boeing 247D

Oct. 23 Second Lt. Francesco Agello of the Italian air force beats by more than 15 mph the world speed record that he set a year earlier. Agello's machine is a Macchi-Castoldi MC-72 floatplane powered by a Fiat A.S.6 2,800-hp engine. He averages 440.67 mph in two runs from Lake Garda, Italy. *The Aeroplane*, Oct. 31, 1934, p. 511.

Oct. 25 Hermann Ganswindt, German aviation and space travel pioneer, dies in Berlin at 77. In 1883, he patented a 500-ft-long, 50-ft-diam steam-powered dirigible airship propelled by a 100-hp engine. He offered the idea to Field Marshal Count von Moltke but was turned down. Ganswindt next wrote a book about his aeronautical ideas, which managed to interest the crown prince. But the war minister interceded and Ganswindt was again denied. Undaunted, the inventor took out other patents and also built some of his machines, including a two-man helicopter that flew briefly. His space travel concepts date to 1891, when he lectured at Berlin's Philharmonic Hall. He designed an intermittently exploding dynamite cartridge spacecraft, but the plan was not worked out in detail. In recognition of his visionary ideas, a crater on the far side of the Moon has been named in his honor. *Flight*, Nov. 8, 1934, p. 1171; W. Ley, *Rockets, Missiles and Space Travel* (1958 ed.), pp. 98-101.

100 Years Ago, October 1909

Oct. 16 Delag (Die Deutsche Luftschiffahrt Aktiengesellschaft) is formed by Count Ferdinand von Zeppelin. It is the world's first aviation company organized to carry paying passengers. Between 1910 and 1913 Delag carries 34,000 people on its fleet of six airships without injury throughout Germany. However, because these flights were not scheduled and were for sightseeing purposes only, Delag is not considered the first airline. That honor goes to the St. Petersburg-Tampa Air Boat Line of 1914. R. Davies, *A History of the World's Airlines*.

Oct. 27 Wilbur Wright takes Mrs. Ralph H. van Deman on a flight in his latest flyer, thus making her the first American woman to fly in a heavier-than-air craft. A. van Hoorebeeck, *La Conquete de L'Air*.

Faculty Positions
Mechanical Engineering Department
Vanderbilt University

The Department of Mechanical Engineering at Vanderbilt University invites applications for one or more faculty positions to begin Fall 2010. Applications will be considered for positions at all ranks commensurate with qualifications. Applicants must possess a Ph.D. in Mechanical Engineering or closely related discipline and have expertise and research interests that are synergistic with existing research areas in the department including energy conversion, combustion, microfluidics, bioMEMS, nanotechnology, mechatronics, portable power, and robotics. Successful candidates will be expected to build a strong, externally-funded research program and make a significant contribution to the department's research activities. The candidate should also have a marked interest in and talent for teaching in both the undergraduate (B.E.) and graduate (M.S. and Ph.D.) programs. Vanderbilt University is ranked among the top 20 universities in the nation. The Department of Mechanical Engineering offers B.E., M.E., M.S. and Ph.D. degrees and has a student body of about 265 undergraduates and 40 Ph.D. students. Applications consisting of a cover letter, a complete curriculum vitae, statements of teaching and research interests, and the addresses of four references (include email address) should be sent to Professor Robert W. Pitz, Chair, Search Committee, Department of Mechanical Engineering, Vanderbilt University, Box 1592, Station B, Nashville, TN 37235-1592, or sent electronically to: robert.w.pitz@vanderbilt.edu. Vanderbilt University is an Affirmative Action/Equal Opportunity Employer. Women and minorities are encouraged to apply.

UNIVERSITY OF ARIZONA

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