May 2011

AEROSPACE AMERICA

Lows and highs for SBIRS

In search of cleaner skies

Strong UAS market attracts intense competition

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In a clean room at Northrop Grumman, a SBIRS highly elliptical orbit payload is prepared for delivery to Lockheed Martin. Turn to page 26 to learn about the Space-Based Infrared System.

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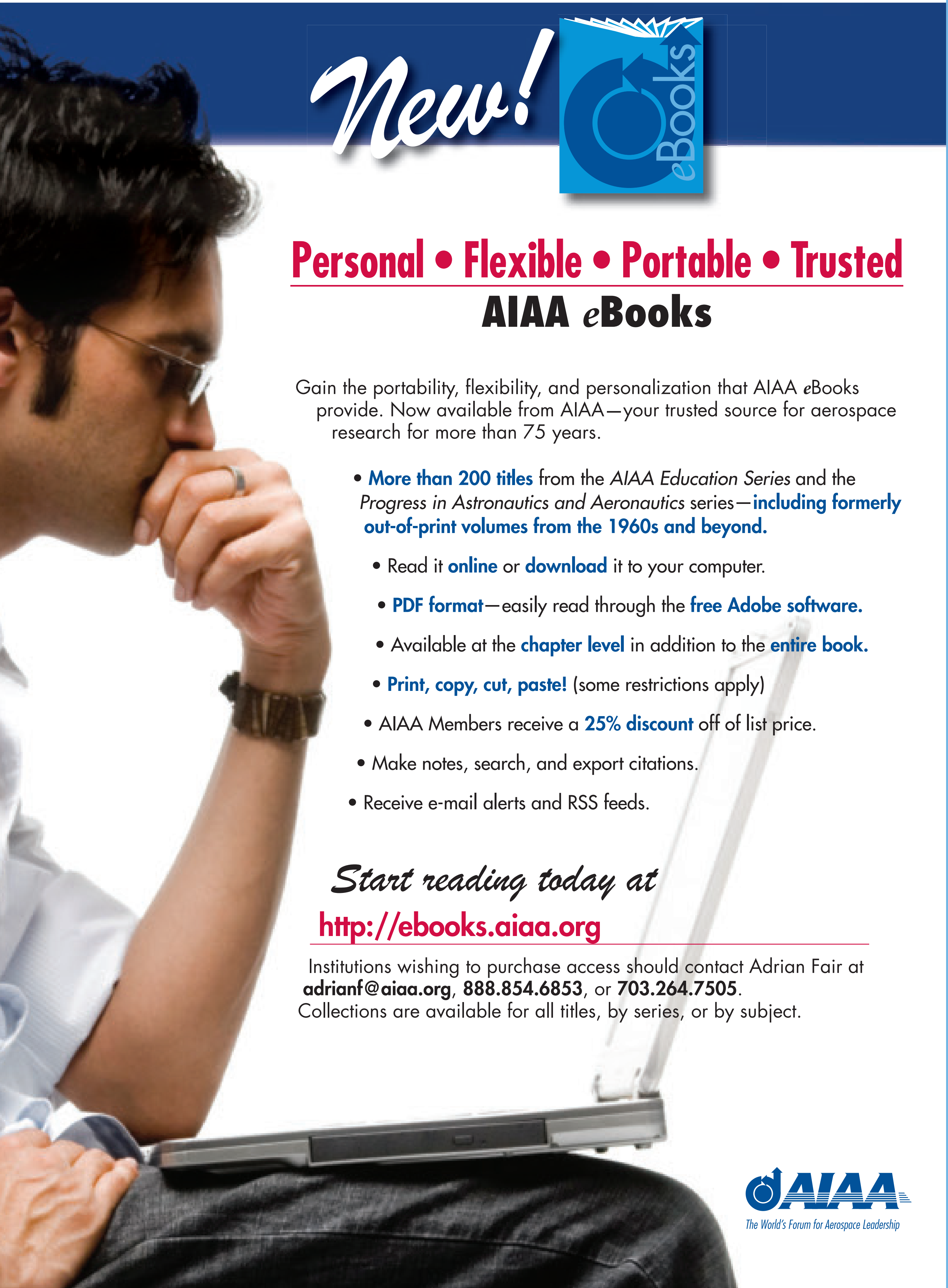
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AIAA
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Editorial

Can the past be prologue?

On May 25, 1961, President John F. Kennedy made an impassioned speech in a special address before Congress. It followed the startling wake-up call from the Soviet Union in the form of the orbital flight of Yuri Gagarin, the first person in space, on April 12. Just over three weeks later, that call was answered by Alan Shepard's May 5 suborbital flight—the first American in space.

In that speech, with soaring rhetoric, Kennedy issued a challenge to the citizenry: "First, I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish."

To emphasize that last point, Kennedy called on the Congress to supply the financial resources necessary to make that challenge a reality—which it did. And just nine short years later, Neil Armstrong stepped down onto the surface of the Moon, taking that "one giant leap for mankind."

Now, 50 years later, the U.S. stands at another watershed moment. The era of the space shuttle is drawing to an end, and the decisions needed to create its replacement or its successor are mired in the slough of partisan politics. The looming menace of the Cold War between the U.S. and the Soviet Union is no more—in fact, the two nations are partners in many space efforts. The U.S. role in the current 'space race' is now driven by economics, not by a need for world leadership. Is this why the passion for the human exploration of space seems to be gone?

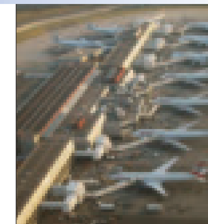
Some legislators are calling for NASA's development of a new heavy-lift rocket and crew vehicle, as a replacement for the space shuttle, but are less ready to acknowledge the ongoing financial commitment such developments would require. Others, including President Obama, are looking to commercial enterprises to provide the way forward. But nowhere can be found the awe and excitement that accompanied the early days of the race to the Moon, the rallying call that will inspire a nation.

There is no question that the U.S. is facing serious economic issues, and demands on the country's purse strings come from all directions. But the heart of what we are as a people still remains: a commitment to discovery and growth, perhaps best exemplified by our achievements in space.

Humankind throughout its history has been a curious species. The desire for exploration has been a driving force since we first emerged from the cave. As Americans we have a history of always striving to be the best. And while this drive has often been fueled by global competitiveness, it is truly in our collective DNA.

As we reflect this month on the golden anniversary of the flights of those two brave men and all the many men and women who followed them, we should also remember some other words in Kennedy's speech that day, a message as true now as it was 50 years ago: "For while we cannot guarantee that we shall one day be first, we can guarantee that any failure to make this effort will make us last."

Elaine Camhi
Editor-in-Chief



Air traffic growth in 2010 defies forecasts

THE RELEASE OF 2010 TRAFFIC FIGURES will make forecasters at Airbus and Boeing rethink their long-term predictions. It seems the speed of airline growth in Asia has been seriously underestimated while the speed at which Europe is emerging from recession has been seriously overestimated.

In 2010 air traffic grew much faster than most forecasters expected. According to figures from ICAO (International Civil Aviation Organization), the world's airlines carried approximately 2.5 billion passengers last year, up 6.3% over 2009. Airports Council International, the global airport association, also reported a 6.3% rise in passengers, along with a 15.2% increase in cargo but just a 1% increase in air transport movements in 2010 over 2009. The world scheduled airline industry body, the International Air Transport Association (IATA), reported an 8.2% increase in passengers and a 20.6% increase in freight.

Airlines and manufacturers have widely underestimated the speed and strength of recovery. IATA airlines recorded net profits of $16 billion in 2010; in September 2009 the association was predicting a loss of $3.8 billion for 2010, with a possible return to profit in 2011. In September 2009 Airbus was also predicting the 'best case' scenario of a 4.6% rise in passenger numbers for 2010. The strength of the global economic crisis that hit North America and Europe particularly hard in 2009 suggested the recovery would take longer to emerge than it actually did. But the degree to which traffic surged in the Far East, Latin America, and the Middle East also took many forecasters by surprise.

Teasing out trends

The aerospace industry works in long economic cycles, and the recent dramatic short-term fluctuations in supply and demand have been dealt with by Airbus and Boeing through careful management of the supply chain, and through increasing production levels only moderately during the demand peak. In the high-level view, the return to strong growth has merely confirmed that, on average, since the end of WW II passenger traffic is increasing at around 4.9%.

But beneath the macro figures there are some new trends emerging that will have wide repercussions for the manufacturing sector.

A rapid rise

The first is the speed and strength of aviation growth in the Far East, especially in China and India, which continue to defy all expectations.

"You could say that 2009 was a turning point marking, on one hand, the rise of emerging market airlines and, on the other, the growing ambitions of these countries' aircraft manufacturers in a market hitherto dominated by Airbus and Boeing," explains Karine Berger, chief economist at the credit insurers Euler Hermes.

According to the Centre for Asia Pacific Aviation, Air China, which has a market capitalization of $18.9 billion, now is valued more on the stock exchange than U.S. carriers United-Continental, US Airways, JetBlue, Hawaiian Air, AirTran, American Airlines, Republic Airways, and SkyWest combined.

In its 2009 forecast, Airbus predicted that by 2028, 14 of the top 20 large aircraft airports will be in Asia-Pacific, with Hong Kong handling the biggest number and London Heathrow in second place. But at current growth rates, Hong Kong will overtake Heathrow in just five

According to ICAO, by 2030 there will be a severe shortfall in training capacity for sorely needed airport personnel such as air traffic controllers.

years, and Beijing has already overtaken London in terms of international travellers.

How long will these growth rates continue, and what will be the implications for manufacturers?

With the Chinese economy in danger of overheating, the government is trying to redress the economic situation by enlarging the domestic consumer market within the overall economy. So, for example, south China city planners have agreed to merge the nine cities around the Pearl River Delta into a 'mega city' of 42 million people across an astonishing 16,000-mi.^{2} urban area.

The development of mega cities is one of the prime market drivers in the very large aircraft (VLA) market, a sector in which Boeing with its new 747-8 Intercontinental and Airbus with the A380 are competing head to head.

The one area of major disagreement between the two manufacturers involves the shape and size of the future market. Airbus believes that 1,700 VLAs will be required over the next 20 years; Boeing believes only about half that number will be needed. Over the past few years sales of VLAs have been slow: Airbus sold 32 A380s in 2010 to Emirates, with possibly four more to Japan's Skymark—an order confirmed in February of this year—while Boeing sold just a single B747-8 in 2010, though Air China ordered five in March of this year. The announcement of the new Pearl River mega city will therefore be music to Airbus's ears.

Beijing has already surpassed London in numbers of international travellers.

In March, Airbus's Chris Emerson, senior vice president for product strategy and market forecast, predicted that Asia-Pacific operators will acquire some 3,360 new widebody aircraft over the next two decades, with the deployment of larger planes expected to help reduce flight delays and ease air traffic congestion, especially between huge urban clusters. Airbus forecasts that more than 50% of the world's VLAs will be operated by airlines in the Asia-Pacific region.

So far, in terms of assessing the VLA market, the more conservative Boeing predictions have been closer to the mark. But as airlines in China and India contemplate over the next 18 months how they can better link their burgeoning economies to the outside world, it will become clearer which of the two has made the better forecasts.

There are signs now that there might be a limit to Chinese aviation growth. To rebalance the economy, Prime Minister Wen Jiabao has set a target of economic growth of 7% per year for 2011-2015, against a figure of 11% for the past five years. While this is still very high, it shows the government has started to consider ways of controlling growth—reducing the flow of credit to consumers and increasing taxes on consumer goods, for example. China also recently embarked on a 2-trillion yuan ($292.9-billion) investment program to increase its high-speed rail network by 16,000 km by 2020, which will strongly affect domestic airline growth.

However, these measures are unlikely to have an impact on aviation growth in China over the next five years.

The real shock to forecasters has been the performance of India. Aviation growth rates there are currently touching 50% per year increases, a rise driven mainly by low-fare airline growth. This is far higher than any forecasters had imagined. Most of this growth has come from domestic services, and it is likely this will be followed by a new wave of aircraft acquisitions from Indian airlines for intercontinental services.

AIRPORT TRAFFIC GROWTH IN 2010

Regions	Passengers	Percent change	Cargo, tonnes	Percent change	Movements	Percent change
Africa	126,950,421	8.8	1,107,764	9.4	1,998,532	3.7
Asia Pacific	1,171,232,331	11.5	30,568,352	18.6	1,048,632	5.0
Europe	1,409,464,291	4.3	17,337,248	17.0	17,596,411	(0.4)
Latin America and the Caribbean	360,994,685	12.1	4,335,375	14.1	5,631,185	6.2
Middle East and Africa	125,775,339	11.5	4,500,502	11.8	1,144,824	6.1
North America	1,457,930,721	2.4	25,021,564	11.2	27,999,158	(1.2)
Total	**4,652,347,788**	**6.3**	**82,870,805**	**15.2**	**64,418,742**	**0.8**

Source: ACI.

FORECAST DEMAND FOR PILOTS, CONTROLLERS, AND MRO PERSONNEL

Personnel category	Current population (2010)	Population needed (2030)	Training needs*	Training capacity*	Shortage*
Pilots	463,386	980,799	52,506	44,360	8,146
Maintenance	580,926	1,164,969	70,331	52,260	18,071
Controllers	67,024	139,796	8,718	6,740	1,978

*Estimated on an average annual basis. Source: ICAO.

The personnel shortfall

It is not just the demand for aircraft itself from China and India that is fueling business for Western builders. Unlike the aircraft replacement market, which dominates sales in Europe and North America, the market for new aircraft brings with it the need for training and for maintenance, repair, and overhaul facilities. Boeing predicts that the Asia-Pacific region alone will require 180,600 pilots and 220,000 maintenance technicians over the next 20 years, with China needing 70,600 pilots and 96,400 engineers.

According to an ICAO study produced in March, at current aircraft delivery forecasts, by 2030 there will be a shortfall of training capacity equivalent to 160,000 pilots, 360,000 maintenance personnel, and 40,000 air traffic controllers, driven in the main by demand for air travel within Asia.

"If no action to increase training capacity is initiated early, shortages in qualified aviation personnel are likely," says Raymond Benjamin, ICAO secretary general.

Adding new training capacity to Asia will be relatively easy, but the consequences will be to speed further the relative importance of China and India as aviation and aerospace business hubs. According to Airbus, North America and Europe—which together made up around 59% of global revenue passenger kilometers in 2008—will see their share of the global market decline to 46% by 2028, with Asia becoming the leading region, accounting for a third of the world's traffic.

The need for trained MRO personnel and facilities in the Asia-Pacific region will continue to grow.

A faster fall

But the current trends point to an even faster shift in the market. What most forecasters have not envisaged, in terms of aviation activity relative to the global market, is the rapid fall of Europe. Another unforeseen element in the 2010 traffic figures has been the speed with which Europe's share of the overall aircraft market also appears to be in free fall.

In terms of traffic growth, the world is now operating on two different tracks: the slow lane—Europe and North America, where aircraft movements actually fell in 2010—and the fast lane, everywhere else.

According to Angela Gittens, ACI World director general, "2010 also pronounced the shift and divergence in growth across the regions. While North America and Europe have struggled to reach precrisis passenger volumes, Asia-Pacific, Latin America-Caribbean, and Middle East sustained a strong momentum and gained market share through double-digit growth."

In Europe, airports registered 4.3% growth in 2010, but actual flight numbers were up just 0.8%. Yet the airport figures do not tell the whole story. According to ICAO, aircraft movements—which included overflights—increased the most in Latin America-Caribbean (up 6.2%), the Middle East (up 6.1%), and Asia-Pacific (up 5%) but continued to decline in Europe (down 0.4%) and North America (down 1.2%).

According to the Brussels-based air traffic management agency Eurocontrol, the total number of flights in Europe in 2010 was 9.49 million, an increase of just 0.8% over 2009.

"Flight growth was concentrated in a few states: Turkey, Italy, Ukraine, and Germany were the states adding most traffic to the European network. The economic crisis and a series of general strikes reduced traffic in Greece overall; and the U.K. and Ireland both ended the year with fewer flights than the already reduced levels of 2009. Russia was a clear source of growth this year, and indeed for one month during the summer passed the U.S. as the main external partner for Europe."

Exceptional factors

In 2010, Europe was also hit by a number of extraordinary events, most of which are unlikely to be repeated often—ash-clouds, snow, and strikes. But even taking these issues into account, the U.K., traditionally one of the key market drivers within Europe, is in serious aviation decline. Statistics from its national regulator, the Civil Aviation Authority (CAA), suggest U.K. airports handled 3.4% fewer passengers in 2010 than in 2009 and that passenger numbers have now fallen consecutively for three years, to a level lower than that in 2004.

According to Iain Osborne, CAA's director of regulatory policy: "The U.K.'s fragile recovery is not yet driving increases in passenger numbers. Although the decline in business travel levelled out last year, leisure travel continued to fall in 2010. Without the year's exceptional events, with snow, strikes, and volcanic ash all affecting aviation, passenger numbers overall would likely have been level with 2009.

"Overall, the outlook for aviation is still uncertain. A return to robust economic growth should see increased passenger numbers, but this will be affected by other costs that bear on the sector, such as high oil prices and taxation, and by the availability of capacity. Congestion in the southeast could also see more customers flying from regional airports, or via other European hubs to travel to or from the U.K."

Airport capacity lagging

Europe is now starting to suffer from a severe lack of airport capacity. According to Eurocontrol, an estimated 175,000 scheduled flights were canceled during 2010, and this summer is likely to feature further delays and disruption in Europe. The lack of runway capacity at major hubs exacerbates the situation, as there is very little additional capacity to cope with disruptions to flight schedules.

Eurocontrol is now predicting air traffic growth will rise between 1.6% and 3.9% in Europe between 2011 and 2030, with growth limited by airport capacity. According to the agency's forecasts from January of this year, "Between 0.7 [million] and 5 million flights will be unaccommodated in 2030, representing from 5% to 19% of the demand. In addition to unaccommodated demand, airport capacity constraints have an effect on the flow of operations in the network. The decline in traffic in 2008 and 2009 has eased the pressure on airport capacity, but in the longer term the demand will grow, and airports will not always be able to fully respond."

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It is highly probable that, despite the current steep price of fuel, this year will see airline growth return again more vigorously to Europe and the U.K. But aviation businesses looking for new opportunities in manufacturing, maintenance, and training will look at these global trends and draw their own conclusions.

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Events Calendar

MAY 2-5
Reinventing Space 2011, Los Angeles, California.
Contact: James R. Wertz, jwertz@smad.com

MAY 9-12
IAA Planetary Defense Conference, Bucharest, Romania.
Contact: William Ailor, 310/336-1135, william.h.ailor@aero.org

MAY 10-12
IEEE/AESS/AIAA Integrated Communications, Navigation and Surveillance Conference, Washington, D.C.
Contact: Col. John C. Gonda III, jgonda@mitre.org, www.i-cns.org

MAY 11
Inside Aerospace, Washington, D.C.
Contact: Steve Howell, steveh@aiaa.org

MAY 18-20
Sixth Argentine Congress on Space Technology, San Luis, Argentina.
Contact: Pablo de Leon, 701/777-2369 (U.S.); www.aate.org

MAY 23-26
Twenty-first AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar, Dublin, Ireland.
Contact: 703/264-7500

MAY 27-29
European Air Surveillance Expo 2011, Bitburg Airport, Germany.
Contact: Richard Ayling, richard@avbuyer.com

MAY 30-JUNE 1
Eighteenth St. Petersburg International Conference on Integrated Navigation Systems, St. Petersburg, Russia.
Contact: Prof. V. Peshekhonov, +7 812 238 8210; elprib@online.ru

MAY 30-JUNE 1
Second International IAA Symposium on Private Human Access to Space, Arachon, France.
Contact: Christine Bonnal, www.avantage-aquitaine.com

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

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

JUNE 6-8
The Space Shuttle: An Engineering Milestone, Atlanta, Georgia.
Contact: dlpeinfo@dipe.gatech.edu

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

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

Resolutions, but few solutions

In Washington, March 20, the first day of spring, was the day a U.S.-led coalition began air and missile strikes on Libya, U.S. aircraft and space assets were being used to assist a disaster-torn Japan, and U.S. federal agencies were still without an FY11 budget. It now appears that the government will continue to operate on a series of continuing resolutions (CRs) until the end of this fiscal year. The administration has produced a proposed budget for FY12, which begins October 1, but it is unclear when, whether, or how Congress will act on the proposal.

Sen. Olympia Snowe

At press time, the government was operating on the sixth, short-term CR of the year. The resolution cut discretionary spending by $6 billion and was slated to last until April 8. The result of a split Congress being unable to agree on a full spending plan, it was expected to be followed by a seventh CR. Sen. Olympia Snowe (R-Me.) blamed "a complete budget breakdown in the Senate" and an "absence of presidential leadership," saying "the government is running on an unsustainable patchwork budget by which no business in America would ever dream of operating." Rep. Nancy Pelosi (D-Calif.) said, "This is not any way to run a government or a business." Added Pelosi, "It certainly is not a way, as the military generals, leadership, have told us, to protect the national security of our country, on a week-to-week basis."

As legislators spar over the annual deficit and the overall national debt, the debate revolves around small portions of the 14% of government spending that is considered discretionary. No one on Capitol Hill is demanding any cut in the so-called entitlements—Social Security and Medicare—and not many are suggesting serious cuts in defense.

Libya campaign

Through it all, the Pentagon is continuing operations. Just before the U.N. ordered a no-fly zone in Libya, hoping to prevent Muammar Gaddafi's forces from crushing a fledgling rebellion in the country's east, USAF Chief of Staff Gen. Norton Schwartz surprised many by predicting that establishing a no-fly zone would not change the outcome of Libya's internal conflict. Schwartz said "enormous resources" would be required and that the U.S. F-22 Raptor superfighter—which has not participated in the Iraq and Afghanistan wars—might be needed. Schwartz has said privately that the U.S. military is stretched too thin and that any prolonged campaign over Libya would be a challenge.

A CV-22 Osprey was part of the rescue operation after an F-15 Eagle crashed in no-fly zone in Libya. Photo by Lance Cpl. Santiago G. Colon Jr.

From the start, many in Washington questioned the need for the U.S. to take the lead role in the no-fly campaign aimed at neutralizing Gaddafi's air defenses and air force.

The first aircraft lost in what was quickly named Operation Odyssey Dawn was an F-15E Strike Eagle of the 48th Fighter Wing, based at RAF Lakenheath, England. The pilot and the weapons systems officer bailed out and were rescued—the pilot in the first-ever combat rescue performed by a V-22 Osprey tilt-rotor. It was the second time the 48th Wing had hammered Gaddafi's homeland. Equipped in an earlier era with F-111F Aardvarks, the wing led the mission known as Operation Eldorado Canyon, the April 15, 1986, attack on Libya in retaliation for its support of the Abu Nidal terrorist organization.

Both in 1986 and in 2011, U.S. officials denied that the purpose of air raids was to kill Gaddafi. Retired Air Force Col. Arnold Franklin, leader of the 1986 mission, told this author that no one had ever said to aircrews that Gaddafi was their target—but that one of Gaddafi's residences, also used as a military headquarters, was. President Barack Obama says the U.S. position in 2011 is that "Gaddafi has to go" but insists that the Libyan leader is not being targeted for death from the air.

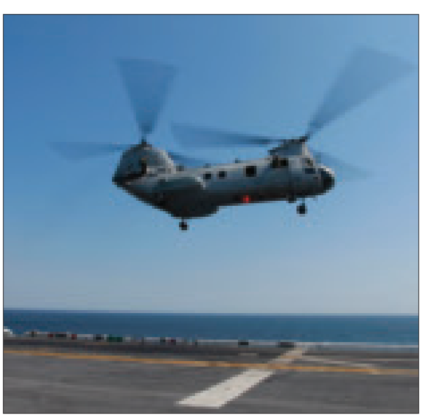
Supporters of the strikes say they were long overdue in protecting the wave of protesters sweeping the Arab world. Critics, including many in both parties on the Hill, say the aerial campaign lacks a clearly defined mission. Said Adm. Michael Mullen, chairman of the Joint Chiefs of Staff, "There have been lots of options which have been discussed, but I think it's very uncertain how this ends."

In late March, NATO agreed to take over command of the Libyan mission, including the air strikes on Libyan ground units, and on March 27, NATO planes began patrolling the no-fly zone. In a speech on March 28, President Obama described a narrower role for U.S. troops in this NATO-led effort.

A friend in need

In Japan, ravaged by the worst earthquake ever to strike that country (on March 11), by the resulting tsunamis, and by nuclear power concerns, the U.S. launched Operation Tomodachi (Japanese for friend). USAF Special Operations command used a combat tactic intended to gain access to an adversary's airfield—sending in an MC-130H Combat Talon II aircraft to land on the battered runway at Japan's Sendai Airport and unloading specially equipped troops who reopened the facility.

An MC-130H Combat Talon II makes a successful landing at Sendai Airport, Japan, bringing specially equipped troops to help open the facility. Photo by Staff Sgt. Samuel Morse.



Sea Knights delivered humanitarian cargo.

Air Force transport planes then joined Japanese aircraft and airlifters from other nations to haul relief supplies and emergency equipment into Sendai, which is at the epicenter of the tsunami that inflicted widespread devastation. U.S. Marines used aging CH-46E Sea Knight helicopters to haul more than 100,000 lb of humanitarian cargo to devastated areas far from the airport. The Air Force has deployed WC-135 Constant Phoenix aircraft to collect atmospheric samples to help monitor radiation levels around the damaged Fukushima nuclear plant.

Leaders in Washington, while debating the Libya operations, expressed bipartisan support for efforts to assist Japan.

Drowsy at the FAA

FAA boss Randy Babbitt says it will not happen again:

Just after midnight on March 23, two jet airliners were forced to land at Ronald Reagan Washington National Airport without help from the control tower after their calls for instructions went unanswered. American Airlines flight 1012, a Boeing 737-800 flying from Miami with 97 on board, and United Airlines flight 628T, an Airbus A320 carrying 68 people—a total of 165 crew and passengers—touched down safely after pilots took matters into their own hands, communicating with a different facility and making what amounted to visual landings.

In Washington's follow-up to the incident, it became known that only one air traffic controller had been scheduled for duty at Washington National, also known as DCA, during the time in question. The airport is constantly used by members of Congress and cabinet officials and is in a sensitive location just a few miles from the White House, the Capitol, and the Pentagon. According to press reports, the controller, who was rated as a supervisor, initially blamed his silence on a 'stuck mike.' Even though he was working alone, the postmidnight work slot in the control tower is reserved for a supervisor.

Officials later confirmed that the controller had fallen asleep. Babbitt said the controller was drug-tested by federal authorities (apparently a routine procedure) and was suspended from his job. Babbitt's boss, Transportation Secretary Ray LaHood, immediately directed that two people be on duty in the early morning hours. "It is not acceptable to have just one controller in the tower managing air traffic in this critical airspace," LaHood said in a statement. He then tasked Babbitt to study staffing levels at other airports around the country.

Many question the size of tower staffing and wonder whether hard-pressed controllers are sometimes too drowsy to perform their jobs. At least 25 other 'controlled' U.S. airports currently have just one air traffic controller on duty between midnight and 6 a.m. The issue of tower staffing arose back on August 26, 2006, when Comair Flight 191, a Canadair CRJ-100-ER preparing to take off, turned onto the wrong runway at Blue Grass Airport in Lexington, Kentucky. The craft crashed when it ran out of runway before it could take off, killing all 47 passengers and two of the three crew, with the first officer the only survivor. Investigators concluded that there was only one air traffic controller in the tower. On that occasion, having a solo controller was a violation of the airport's own policy.

The abilities of controllers came into question again on December 24, 2007: A supervisor controller at Washington National left his swipe-card pass key behind when he stepped outside the tower's secure door and was unable to get back in.

The incident involving the sleeping air traffic control supervisor at DCA triggered calls for congressional hearings.

The latest incident is expected to prompt congressional hearings. Rep. John Mica (R-Fla.), chair of the House Transportation and Infrastructure Committee, said in a statement that this and other recent aviation performance failures are a "serious concern." Mica said his committee will investigate the incident. Rep. Nick Rahall (D-W. Va.), ranking Democrat on the committee, called the event "troubling." Said Rahall, "We must deal with the immediate safety and security concerns of this critical airspace, so I welcome Secretary LaHood's decision to increase personnel at the airport and examine staffing levels at airports around the country."

Built on landfill in the Potomac River in an area of high air traffic congestion and population density, DCA has severe limitations with its runway length of just 6,869 ft. Although it handles about 18 million travelers a year, some skeptics say the airport would not exist if it were not so handy to the lawmakers who hold airport funding purse strings. Two larger airports also serve the area but are more distant from the capital and more difficult for traveling lawmakers to reach. DCA operates with severe restrictions on the number of flights it can accommodate and the distance they can travel. No one is seriously proposing further restrictions, let alone closing this prominent airport, but its operations are likely to face greater scrutiny in the coming months.

STOVL fighter endangered

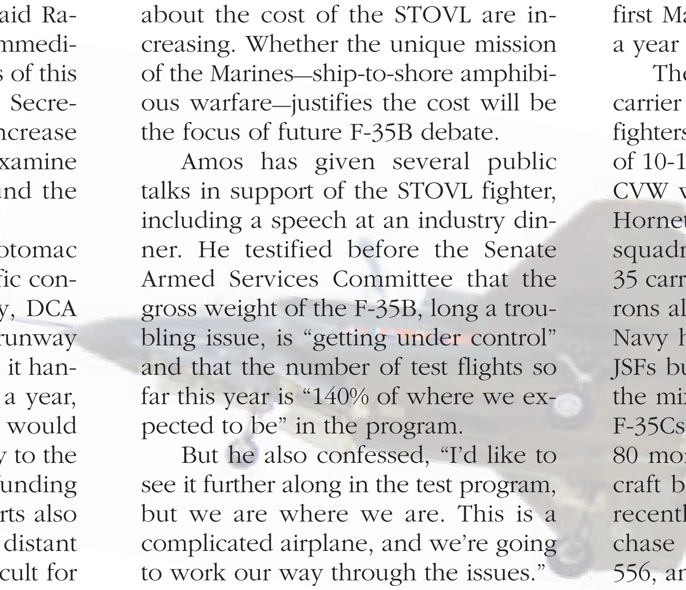
The viability of the short takeoff and vertical landing (STOVL) version of the Joint Strike Fighter, known as the F-35B Lightning II, is being questioned now that plans have been disclosed for the 'mix' of F-35B and carrier-based F-35C versions that the Marine Corps will operate.

Gen. James F. Amos, Marine Corps commandant, defends the F-35B but acknowledges the STOVL plane will have to prove itself affordable to retain its place in the U.S. inventory. Doubts arose about the viability of the F-35B when the British canceled their plans for the STOVL version. The U.K. is shifting to the F-35C model as part of a dramatic downsizing of its forces.

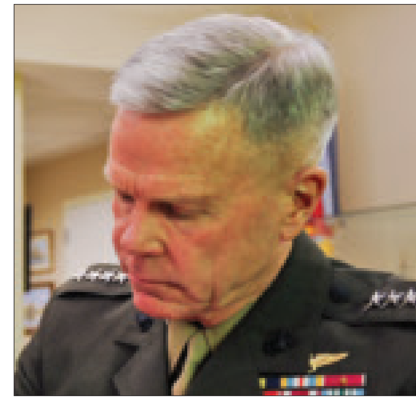
The only other STOVL user, Italy, wants 22 F-35Bs for its navy for the carrier Cavour and 40 more for its air force. Observers in both Washington and Rome, however, are doubtful the 40 air force aircraft will be built. If not, overall purchases of the F-35B would be cut in half at a time when questions about the cost of the STOVL are increasing. Whether the unique mission of the Marines—ship-to-shore amphibious warfare—justifies the cost will be the focus of future F-35B debate.

Amos has given several public talks in support of the STOVL fighter, including a speech at an industry dinner. He testified before the Senate Armed Services Committee that the gross weight of the F-35B, long a troubling issue, is "getting under control" and that the number of test flights so far this year is "140% of where we expected to be" in the program.

But he also confessed, "I'd like to see it further along in the test program, but we are where we are. This is a complicated airplane, and we're going to work our way through the issues."



The viability of the STOVL version of the F-35 is once more being called into question.



Gen. James F. Amos

For the past few years the Marine Corps focus—and its top priority—has been STOVL operations from land and from assault ship decks. Originally, the corps planned to acquire only the F-35B model, to continue the long tradition begun with early versions of the AV-8B Harrier II. Until recently, Marines were not expected to operate the carrier-based F-35C at all.

Now, under an interservice agreement signed by the Navy and Marines, the 'program of record' calls for the Marine Corps to acquire 80 F-35Cs. Marine pilots serving aboard carriers will fly the same C version as their Navy compatriots. Following several restructurings of the program, the first Navy F-35C carrier squadron is set to stand up in December 2015, with the first Marine F-35C squadron to follow a year later.

The Navy has 11 carriers and 10 carrier air wings (CVWs) with 44 strike fighters in each, broken into squadrons of 10-12 aircraft each. Eventually, each CVW will have two F/A-18E/F Super Hornet squadrons and two F-35C squadrons. The Navy will then have 35 carrier-capable strike fighter squadrons along with the Marines' five. The Navy has long said it would buy 680 JSFs but had not previously disclosed the mix; now the service will use 260 F-35Cs, while the Marines will operate 80 more, with the remaining 340 aircraft being STOVL F-35Bs. The Navy recently increased its planned purchase of Super Hornets from 471 to 556, and has 418 in inventory today.

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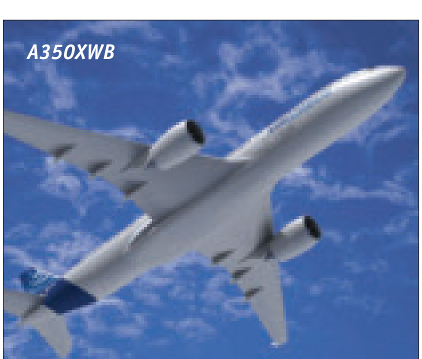
A bigger and wider jetliner decade?

THE JETLINER INDUSTRY STANDS ALONE as the only major world manufacturing segment that actually saw output grow during the great recession of 2008/2009. Although there was a program-related output reduction in 2010, aggregate jetliner output rose by a 5.3% CAGR (compound annual growth rate) between 2008 and 2010. Considering that this was the worst year for the world economy since WW II, that indicates a very healthy level of jetliner demand.

There are solid reasons for the jetliner market's impressive performance. But not content with this success, Airbus and Boeing are planning a remarkable production upturn, starting from a very high base. This phase of growth will see a focus on twin-aisle jets, but there are valid reasons to doubt that the market, and supply factors, will be able to support all of these new production goals.

Ambitious goals

Airbus and Boeing have announced ambitious plans to increase twin-aisle production rates greatly over the next three years. Last year, just 191 twin-aisle jets were delivered. In 2014, the manufacturers plan to deliver more than 450, a record level of twin-aisle production. Using aircraft value multipliers, this equates to a 137% production output increase relative to 2010 deliveries.


A350XWB


777

The first source of growth will be new-generation jets. After a very damaging series of delays, Boeing's 787 is now expected to enter service later this year, with a very aggressive ramp-up plan to 10 aircraft per month. Also, the new 747-8 will reach an anticipated two-per-month rate within the next two years.

At Airbus, current plans call for A380 rates to ramp up to at least three per month. The new A350XWB, slated to enter service in 2013, is scheduled to ramp up to 10 deliveries per month within a few years of the aircraft's anticipated in-service date.

Yet while these new products ramp up, the two companies are also planning considerable legacy product output increases. In December 2010 Boeing announced that it was increasing monthly production of the 777 family from the current goal of 7 per month to 8.3 per month starting in the first quarter of 2013. The current minimal rate of 767 output is also expected to rise, possibly doubling to two per month. And at Airbus, in February the company announced that A330 production would increase from 8 to 10 per month by early 2013.

These plans are not taking up the slack from any kind of single-aisle rate reduction. In fact, both manufacturers are planning further single-aisle rate increases. Airbus's current plan is to increase A320 series production from 36 to 40 per month by 2012, and it is currently surveying the supplier base to investigate the feasibility of further rate increases. Boeing increased 737 series production rates to 31.5 per month last year, a new record. Later in 2010 it announced plans to reach a 35-per-month rate starting January 2012, and a rate of 38 per month in the second quarter of 2013.

In addition, Bombardier is scheduled to enter the main-line twin-aisle jetliner market in 2013 with its new CSeries family.

Adding all single- and twin-aisle output plans produces market growth numbers equating to a record "super cycle." The plans imply a CAGR of 9% in 2003-2014, a remarkably long-lived upturn. Even more remarkable, the plans imply a market CAGR of 13.3% in 2010-2014. In other words, the jetliner market grew during economic numbers that should have precipitated a cyclical downturn, and is now planning for the kind of growth numbers typically associated with a strong recovery from a severe downturn.

Positive signs

The most encouraging reason to believe these manufacturer delivery goals is that twin-aisle jetliners have been considerably underrepresented by the present market upturn. During the last decade, single-aisle output grew by 50.3% by value (compared with the previous decade, 1991-2000), while twin-aisle output actually fell by 6% by value.

However, passenger growth implies a mismatch here. Between the two decades, domestic market passenger count increased by 30%. Yet inter-


787

national passenger count—traffic much more likely to be flown on twin-aisle jets—increased by 75%.

Program delays, as we mentioned, provide much of the reason for this divergence. Both Airbus and Boeing intended to have produced far more A380s, 787s, and 747-8s at this point. According to the original plans, well over 200 of these new-generation jets should have entered service by now. Instead, the market has only received 40 A380s—and 2010 was the first year since 1969 to see zero 747s delivered.

Meanwhile, Boeing, acknowledging that slumping air cargo numbers in 2008/2009 were impacting demand for cargo aircraft, decided to reduce 777F production rates. This was the only legacy jetliner program, 747 excepted, to actually see a deliveries reduction in 2010. The cargo market's remarkable 2009/2010 recovery clearly supports increased 777F output.

Another reason the new goals might actually happen is that market fundamentals are quite strong. Both airline traffic and profits have come back very strongly in 2010, which implies additional demand for aircraft. But a key factor behind the recovery in airline profits has been capacity discipline. Airlines avoided losses, and then went on to earn respectable profits, largely because most of them have avoided adding too much capacity. Many successfully cut fleet sizes.

Another reason that these ambitious plans might succeed concerns finance. For many investors, jetliners have come to embody an ideal combination of safety and profit. As hard assets, they are a solid hedge against inflation. Over one-third of orders in 2010 came from financial entities. This has tracked a broader economic trend termed "excessive demand" for safe assets, although financiers' demand for jetliners arguably has not risen to excessive levels.

Most financial-company demand for jets over the past few years has focused on just two single-aisle aircraft families, Airbus's A320 and Boeing's 737. As twin-aisle output and demand increase (hopefully), it is possible that the financial players will shift their interest to twin-aisle jets.

Finally, it does not look as though fuel prices will return to low, or even moderate, levels any time soon. This implies a continued market preference for new equipment and a willingness to dispose of older jets, even at premature aircraft ages. The single-aisle market has come to depend on this dynamic, and as new technology comes on line the twin-aisle market could well follow suit.

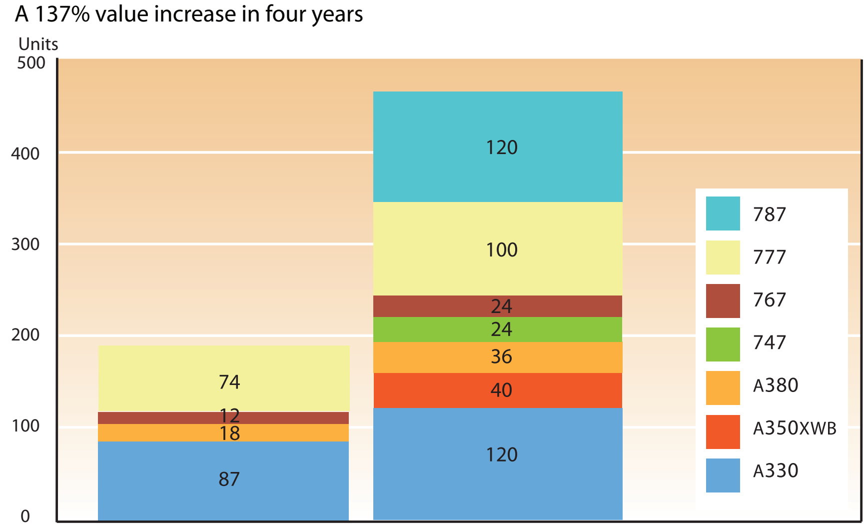
Market and production risks

The biggest risk to the manufacturers' objectives, of course, is that economic growth could be derailed, causing a traffic drop and a demand drop. While the past few years have seen deliveries conform to economic growth trend lines, there are no global growth forecasts that would justify a 13.3% CAGR in 2010-2014. Indeed, given the fragility of the economic recovery, there are no guarantees of any kind of additional deliveries growth at all.

In similar fashion, anything that impacts commercial or government finance for the new jets could keep production plans in check. The new Aircraft Sector Understanding agreement, signed in February 2011, clearly implies that government-backed export finance will come at more expensive rates. Government export finance has risen in importance, supporting over

BIG TWIN-AISLE PLANS, FOR NEW AND LEGACY PRODUCTS

A 137% value increase in four years



one-third of jetliner transactions in 2010, but given its higher costs under the new ASU its appeal will likely diminish. We do not know what impact it will have on the market, or whether private capital will ramp up as government finance ramps down.

A strong economy and finance outlook are necessary for more than just deliveries. The manufacturers will need to book additional orders for several products that are key to their production plans. Counting all current firm and option orders, existing A330 and 777 backlogs sustain planned output into 2013. But all orders and options cover just about 60% of planned output for both planes in 2014, just after both aircraft reach their current anticipated maximum rates.

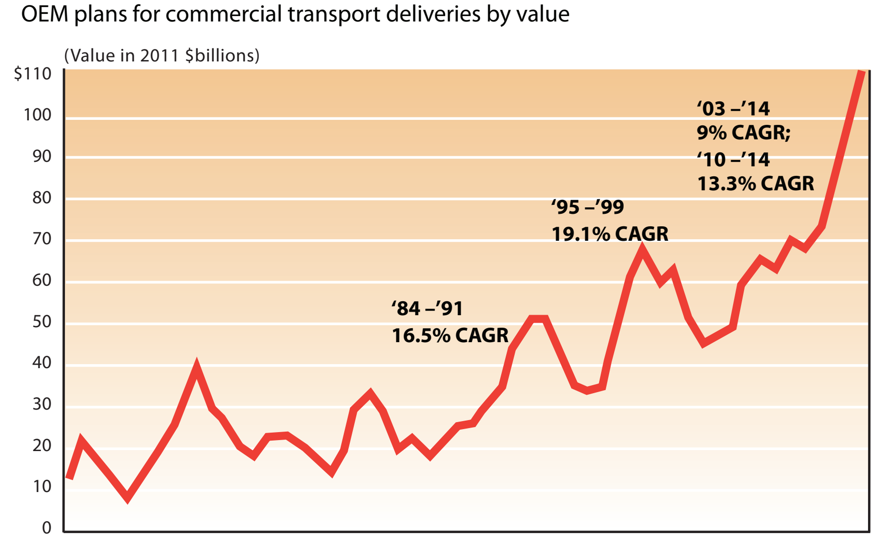
Also, even though there was a mismatch over the last decade between higher international market growth and lower twin-aisle jetliner production, it is quite possible that current twin-aisle jet backlogs reflect a certain irrational exuberance by the airlines. A large number of carriers have centered their plans for future growth around international traffic, particularly premium passenger traffic. There might not be enough of this traffic to justify everyone's fleet growth ambitions.

Similarly, a considerable segment of the twin-aisle backlog is for Mideast carriers competing with global legacy airlines. A remarkable 32% of Airbus's twin-aisle backlog, and 46% of its A380 backlog, is for carriers in this region. Almost all of these numbers are for just three carriers, Emirates, Etihad, and Qatar. The three carriers are basing their ambitious growth plans on traffic between two other places, rather than origin and destination traffic to or from the Mideast. This inevitably raises concerns about backlog overlap. There's only so much traffic to go around, and a jet delivered to a Mideast carrier often means a jet not delivered to a European or Asian carrier pursuing the same global traffic.

A380

DO YOU BELIEVE IN SUPER CYCLES?

OEM plans for commercial transport deliveries by value



The next risk is the supply chain. A production ramp-up of this magnitude and duration always carries risks, but high materials prices make the situation more challenging. Will subcontractors and prime contractors successfully pass higher costs to the airlines without affecting demand? As in the broader economy, there is a risk of a stagflationary crunch, where demand softens yet input prices stay high. Given strong demand in emerging economies such as India and China, it is quite possible that materials and oil prices will go higher still.

Also, the new jets that are a key part of the ramp-up—Boeing's 787 and Airbus's A350XWB—both require extensive use of new composite materials and a much greater use of titanium and other expensive metals. There is always a cost and manufacturing process adaptation risk in moving to new materials. The latter factor has already played a key role in delaying the 787 program.

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Our forecast, balancing all of these ambitions and risks, is optimistic. We anticipate continued robust growth in the jetliner industry, with deliveries growing from a 2011 peak of $68.8 billion to an impressive $100 billion by the end of the decade. But this impressive achievement implies slower growth than the two big manufacturers currently have in mind.

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John Logsdon

Fifty years ago, President Kennedy announced his decision to send U.S. astronauts to the Moon. You have observed the U.S. space program for most of those 50 years and have written extensively about it. Take us back to that presidency.

Kennedy came into office Jan. 20, 1961, not knowing much about the space program. Nobody could have predicted that, only four months later, he would make the historic decision to mobilize really immense national resources in an effort to send Americans to the Moon.

What was the situation as JFK entered the White House in regard to U.S. space plans?

In the late 1950s, NASA, the military, and some elements of the technical community had ideas for ambitious future space programs. NASA had already chosen a lunar landing as its long-term goal, and these plans were briefed to President Eisenhower, who was unenthusiastic about human spaceflight. Eisenhower said, no way am I going to send people to the Moon. Then Kennedy's [presidential transition] task force on space downgraded the importance of human spaceflight, and the biomedical people in his scientific advisory group could not assure him that humans could survive in space. So the future of human spaceflight was very much in doubt as Kennedy took office.

So what happened to influence his decision?

At first, Kennedy said he didn't know what kind of a post-Mercury human spaceflight program he wanted, and needed time to make up his mind. He also said, in his inaugural address, that his first preference was to cooperate with the Soviet Union in space. Then came the historic launch of [Soviet cosmonaut] Yuri Gagarin into orbit in April 1961. The worldwide reaction to it was very positive. What Kennedy concluded in the immediate aftermath of the Gagarin flight was that the United States could not stand by and let the Soviet Union do all the dramatic "firsts" in space. The Cold War was on, and U.S.-Soviet competition was fierce on all fronts.

"[The recommendation] said men, not machines, capture the imagination of the world."

Did U.S. embarrassment at Cuba's Bay of Pigs in that same month influence Kennedy's decision to go to the Moon?

To some extent, it did. But I believe that the basic decision to compete in space was made before the Cuban fiasco. After the Gagarin launch and the Bay of Pigs, Kennedy wrote a classic memo asking his advisors to find him "a space program that promised dramatic results with which we could win." His set of requirements was clear: space, dramatic, win. He made the fundamental decision in the immediate aftermath of the Gagarin flight that the U.S. had to get into the leading position in space.

It is important to realize that Kennedy brought to the presidency the concept of "American exceptionalism"—that the U.S. rightly was and should be the leading nation in the world. He was willing to expend national resources and to demand national sacrifice to make sure that the United States was the leading nation.

"Human involvement in spaceflight is still an essential element of using the space program as an element of U.S. 'soft power.'"

NASA's Mercury program was under way at the time. How did it figure in Kennedy's outlook on Apollo?

A condition necessary to Apollo happening was the success of the suborbital [Mercury] flight of Alan Shepard May 5, 1961, just as the president's advisors were preparing to give him their recommendations on accelerating the space program. If the Shepard flight had been a failure—and there was great concern about the risks involved—it is doubtful that Kennedy could have gone to Congress three weeks later and said we are going to send people to the Moon even though we just killed an astronaut.

When was the Moon landing adventure recommended to Kennedy?

The recommendations from his advisors were prepared over the weekend of May 6 and 7, 1961, and embodied in a May 8 memorandum that first went to [Vice President] Lyndon Johnson, which Johnson endorsed. It went to JFK the same day. It was a remarkable document, mainly for the language that was used to justify setting a lunar landing as the central goal. It said men, not machines, capture the imagination of the world, and that, basically, the national prestige that comes from large-scale space achievements, even though it may not have military or economic value, is "part of the battle along the fluid front of the Cold War."

How does that set of circumstances relate to the current debate over the priorities of today's space program?

One of the problems today is that there is no question of high political significance, the answer to which is go

Interview by James Canan

to Mars or even go back to the Moon. Kennedy concluded that space leadership was essential to U.S. leadership. And how could the United States become the space leader? Kennedy's answer was: send people to the Moon. It worked, and now in 2011, 50 years later, the United States remains the space leader, although potentially in danger of losing that position.

Can you draw a parallel with the contemporary space issues?

I happen to think that today there is a similar answer to the question of how to assure U.S. leadership in space: Send humans somewhere out there and explore, but this time as the leading partner in a cooperative undertaking. Human involvement is subject to reasonable debate, but my conclusion is that the line in the recommendation to Kennedy—that men, not machines, capture the imagination of the world—still has validity. Machines also capture our imagination now—Mars Rovers and the Hubble telescope, for example—but I think human involvement in spaceflight is still an essential element of using the space program as an element of U.S. 'soft power.'

Many American astronauts have gone into orbit since the Apollo program, on Skylab, the shuttle, the international space station. Does that count for something?

Over 500 people have gone into space, but relatively few of their missions have captured the public imagination to anywhere near the extent of Apollo. Repetitive missions to Earth orbit really aren't all that exciting.

Do we have to be in competition with a rival nation in order to do the kind of things we did in Kennedy's time?

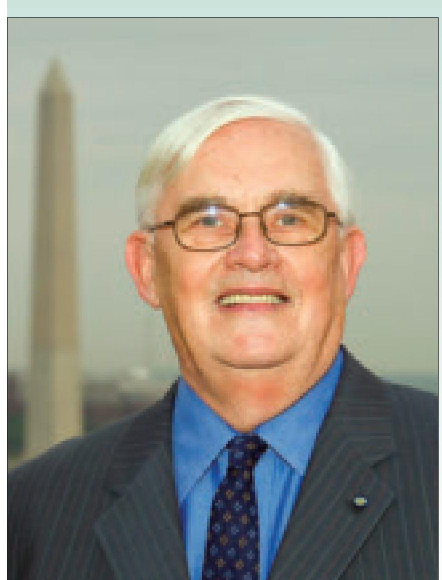
I think our bitter competition with the Soviet Union made it possible to conduct the peaceful but warlike mobilization of resources to win the race to the Moon. People tend to forget what was involved in that mobilization. After Kennedy's decision, NASA's budget went up 89%, and the next year, it went up 101%. This was the largest peacetime mobilization of human and financial resources in U.S. history. Even the Panama Canal and the Manhattan Project cost considerably less.

I now think that the set of circumstances that made the Apollo program possible—a new, young president at the beginning of his time in the White

John M. Logsdon is professor emeritus of political science and international affairs at George Washington University's Elliott School of International Affairs. Prior to leaving active faculty status in 2008, he was on the GW faculty for 38 years. Before that, he taught at the Catholic University of America for four years.

Logsdon was the founder and long-time director of GW's Space Policy Institute. From 1983 to 2001, he was also director of the Center for International Science and Technology Policy. He is also on the faculty of the International Space University.

During 2008-2009, Logsdon held the Charles A. Lindbergh Chair in Aerospace History at the National Air and Space Museum. He was the first holder of the museum's chair in space history and has served on its Research Advisory Committee.



His book John F. Kennedy and the Race to the Moon *was published in January 2011. He is also the author of* The Decision to Go to the Moon: Project Apollo and the National Interest, *and is general editor of the eight-volume series* Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program.

Logsdon was a member of the NASA Advisory Council from 2005 to 2009 and remains a member of the council's Exploration Committee. In 2003, he served as a member of the Columbia Accident Investigation Board.

He is a recipient of the Exceptional Public Service, Distinguished Public Service, and Public Service medals from NASA, the 2005 John F. Kennedy Astronautics Award from the American Astronomical Society, and the 2006 Barry Goldwater Space Educator Award from AIAA. He is a fellow of AIAA and AAAS and a member of the International Academy of Astronautics and numerous other space-related institutions.

Logsdon is on the editorial board of the international journal Space Policy *and was its North American editor from 1985 to 2000. He is also on the editorial board of the journal* Astropolitics. *He holds a B.S. in physics from Xavier University and a Ph.D. in political science from NYU.*

House, a powerful rival, no big national debt or budget deficit, no technological breakthrough required, just lots of good engineering—were unique and will not be repeated.

Tell us more about Kennedy's decision in the context of the Cold War and what it means for U.S. space decisions today.

It is hard to recreate the sense of dire U.S.-Soviet competition, of real fear, of bomb shelters and civil defense. The possibility of nuclear war with the Soviet Union was very real, and there was the perception that the U.S. was in danger of losing its position as the world's leading nation.

What about China? Its successful ASAT test and its space programs and ambitions in general are said to be cause for concern.

The parallel between U.S.-Soviet competition in the Cold War and U.S.-Chinese competition for global leadership in the 21st century has some validity, but I don't think it's totally valid. Since the U.S. has made space central to its warfighting capability—maybe excessively so—it is entirely logical from the Chinese point of view to develop the capability to counter that.

But I don't think that necessarily means that China is intent on using its military power directly counter to U.S. interests, in the way that the Soviet Union during the Cold War developed military power to counter U.S. interests in Europe and in other locations. I don't agree with the notion that space is or will be an area of U.S.-Chinese competition in the same way that it was with the Soviet Union during the Cold War.

As I recall, we were worried about the clear Soviet advantage in heavy-lift launch vehicles. How did that play into Kennedy's decision to prepare to go to the Moon?

After careful study of what led to Kennedy's decision, I came to believe that his number one concern was having a more powerful rocket than the Soviet Union, because that would allow the U.S. to do anything it wanted to do in space. There was a great disparity in rocket lifting power between the U.S. and the Soviet Union. The Soviet rocket, the R-7, which had already been built as the first Soviet ICBM, turned out to be a terrible ICBM but was a very good, very powerful space launch vehicle, now called Soyuz and still in use in much-improved form. It gave the Soviets a great weight-lifting advantage.

How did Kennedy and his advisors assess the importance of the R-7?

Their calculation was that the Soviet Union, using that launch vehicle, could be first in doing almost everything dramatic in space, including possibly sending one cosmonaut around the Moon.

So it was obvious at the time that the U.S. needed to build a much more powerful space launch rocket?

That's right. Saturn V. In simplistic terms, the Saturn V rocket was a very scaled-up V2 rocket. Wernher von Braun started the V2 in Germany and the V2 led to Saturn V. But von Braun didn't originate the F1 engine for Saturn V. The USAF did.

Back to the Apollo decision. What happened after Kennedy made it?

What made Kennedy's involvement with Apollo so remarkable was that not only did he set the goals and allocate the resources, but that he stayed with it. When faced in 1962 and especially in 1963 with criticism and concerns about the burgeoning cost of the program, he had his staff look very carefully at the pros and cons of backing off or going ahead, and his decision was to go ahead. So it was not only his original decision but also a series of reinforcing decisions that made Apollo possible and ultimately successful.

Compare then to now.

The setting is much different. In 1961, the U.S. decision on what to do in space was tied to the U.S. position in the world. That's not true any more, for better or for worse. We are not spending anywhere near the same level of national resources on space, either. The NASA budget in the last years of the Kennedy administration was about 3.5% of the federal budget. Now it's 0.6%. So we are not asking for the same level of support out of the political system that Kennedy asked for.

You noted that Kennedy, in his inaugural address, called for cooperation with the Soviet Union in space. Tell us more about that. What happened along the way?

Kennedy kept returning to the idea that cooperation was better than competition. He proposed space cooperation again in his first State of the Union message 10 days after his inaugural. But all of that was trumped by the Gagarin flight and Kennedy's decision that the United States really needed to take the leading position in space. Even so, very shortly after the May 25, 1961, announcement of his decision to go to the Moon, he met with [Soviet Premier Nikita] Khrushchev in Vienna—on June 3 and 4—and proposed going to the Moon together. Basically, Khrushchev said no.

"What made Kennedy's involvement with Apollo so remarkable was that not only did he set the goals and allocate the resources, but that he stayed with it."

Was that the end of it?

No, it wasn't. I find it remarkable that very few people in the space community know or remember that Kennedy went to the United Nations September 20, 1963, just two months before his assassination, and asked, why shouldn't the United States and the Soviet Union—and indeed all other countries—pool their efforts in this great adventure. It is fascinating to speculate what might have happened if Khrushchev had accepted Kennedy's proposal—as it seems he was willing by 1963 to do—and if Kennedy had lived.

The Apollo budget eventually came into question, though, didn't it?

It did. For the first couple of years after Kennedy announced his decision to go to the Moon, Congress was supportive. But in 1963, there was increasing skepticism of the value of the lunar landing program. That year, the Congress cut NASA's budget by 15%. But after Kennedy was assassinated, Apollo became a monument to him, and that momentum carried the program through the Apollo 1 accident and on to its successful completion. President Johnson did nothing to delay Apollo, but he was not committed to a space exploration program beyond Apollo. In fact, it was Johnson who made the initial decision to shut down the Saturn V production line. Skylab was the last Saturn-fired launch.

So would you say that there was a negative aspect to Apollo's success?

One of the problems with Kennedy's rationale for going to the Moon was that it wasn't sustainable. It was cast as a race, and once we won the race, with Apollo 11, the race was over. There was enough residual momentum for six more missions to the Moon, five of them successful, but three additional missions were cancelled. Kennedy's decision to go the Moon was something really great in American history, but it wasn't good for the space program after Apollo.

Go ahead and elaborate on that.

Apollo created a large organization in NASA, lots of great new capabilities, lots of jobs for people, and, thus, lots of political interest in particular congressional districts. In my mind, the main sustainment of the space program in the 40-plus years since Apollo has been the relatively parochial political interests in maintaining jobs, maintaining contracts, and maintaining the economic impact of the space program at certain facilities around the country, not fully committed presidential leadership.

Will we see anything like Apollo ever again?

It seems to me that the circumstances and context that made Apollo possible cannot be repeated, and will not be repeated. And so, in thinking through what is required for a sustainable space exploration program, we have to develop a rationale that does not depend on geopolitical competition or public entertainment or excitement. The problem is that all attempts to do that since Apollo have come up relatively empty. In my opinion, we need to develop a single, clearly articulated, widely supported rationale for human exploration of space, and we need to understand that expanding our experience, doing things we have not done before, is part of our responsibility as a leading society, and is part of our being human.

"The question is whether there is the political will among our country's leadership to allocate sufficient resources—in a very difficult, resources-constrained environment—for leadership in space."

Do you think it will happen?

I think ultimately there is going to be human travel beyond Earth orbit that will be lasting, not just for decades but for centuries. We just have to find something of economic value out there, and be able to live off the land once we get there. We can't continue to send everything from home. At the moment, the question is whether there is the political will among our country's leadership to allocate sufficient resources—in a very difficult, resources-constrained environment—for leadership in space.

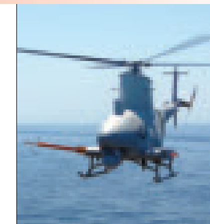
If the U.S. doesn't lead, will another nation fill the gap?

I think even back in the early 1960s Kennedy saw that in the long run, human space exploration and deep-space development should be a cooperative enterprise transcending national military and geopolitical rivalries. That imperative hasn't changed. The space program today is global. It is a very, very different world from the one in which only the two global superpowers had space capabilities, as was the case back then. Now there are nine countries—and counting—that have space launch capability, 50-some countries with space agencies, and high-quality technical space capabilities in a number of nations.

Whether the Obama administration and Congress can put the United States in position to be a reliable partner in a global program of space exploration is the key space policy issue of the next few years, I believe, and is still to be determined.

What is the salient connection between Apollo and the formulation of U.S. space policy today?

Apollo turned out to be an example of how not to do a sustainable space program. Apollo is constantly referred to as the golden age of the U.S. space program, and in some ways, it was. We did exciting, grand things in Apollo. But it was not a model for a sustainable 21st century program. And I think that's what the Obama strategy proposed last year is all about—let's get off the Apollo paradigm and create a space program that is appropriate for the 21st century. The debate since then has certainly been confusing, and unfortunately, the way forward is still not clear.



Strong UAS market attracts intense competition

Competition in the unmanned aerial systems (UAS) market, already one of the hottest sectors in the U.S. aerospace industry, promises to intensify even more in the coming years.

Not only is the field crowded, but new players also continue working to enter the market both in the U.S. and internationally. Companies spend freely on R&D and acquisitions to bolster their positions in the market. New technologies could reshape UAS leadership in the future.

One reason for this intense interest is that the UAS market offers a refuge from anticipated pressures on defense budgets overall, both in the U.S. and abroad. In the U.S., the Army released its most recent UAS Roadmap last year. It predicted that over the next 25 years, Army aviation would shift from using mainly manned to mainly unmanned aircraft, including optionally piloted types.

FY12 funding request

The FY12 budget request unveiled in February also gives UAS companies good reason for optimism. The base budget UAS procurement is $4.8 billion, with Global Hawk, Reaper, and Fire Scout all receiving strong funding requests. For Predator and Reaper systems the figure rose from $1.6 billion in FY10 to $2.5 billion in FY12. Global


Global Observer

Hawk is funded at about $1.7 billion, the same level as 2010.

The Navy has long been less enthusiastic than the other services about UAS, having voiced skepticism about the safety of operating these systems off carriers. In the FY12 budget, however, it gives them strong support, for the first time requesting $121 million in research funding for the UCLASS (unmanned carrier-launched airborne surveillance and strike) aircraft. The goal is to have at least some UCLASS systems operating off carriers by 2018. In the budget request, funding for the Navy unmanned combat aircraft system demonstrator was set at $198 million, down from $266 million in FY11.

The Defense Dept. selected the MQ-8 Fire Scout as the medium-term Special Operations Forces intelligence, surveillance, and reconnaissance (ISR) solution, leading the Navy to add 32 extended range and payload airframes and $721 million in R&D and procurement funds to the Future Year Defense Plan through FY16 to support this joint mission. In the FY12 request, 12 Fire Scouts are requested, compared to three in the original FY12 plan and three in the FY11 budget.


Fire Scout

The MQ-4C BAMS (broad area maritime surveillance) derivative of the RQ-4 Global Hawk sees an increase in R&D funding to $548 million in the FY12 request, up from $529 million the previous year. Procurement remains at 15 throughout the multiyear plan, with the first three to be purchased in FY13. The Navy's small tactical UAS also holds as planned in the request, with 20 procured throughout the multiyear defense plan, including eight systems in the FY12 request.

The longer view

Teal Group's 2012 UAS forecast, released in February, sees strong U.S. and worldwide UAV funding continuing throughout the next decade. The 2011 market study estimates that UAV spending will almost double over the next decade, from current worldwide annual UAS expenditures of $5.9 billion to $11.3 billion, totaling just over $94 billion in the next 10 years.

Medium-altitude long-endurance (MALE) UAVs such as the Predator and Reaper, which have proved their value in Afghanistan and Iraq, are projected to represent a particularly large portion of the market, approximately 35%, or $22.8 billion. High-altitude long-endurance (HALE) UAVs such as Global Hawk are predicted to represent 23% of the market, or $15.2 billion.

Of course, these are two market segments that are currently dominated by one manufacturer. MALE is dominated by General Atomics with the Predator family, which the Air Force and the Army are purchasing. HALE is dominated by Northrop Grumman's Global Hawk, which is being purchased by the Air Force and the Navy.

Other segments represent smaller dollars, but opportunities in emerging fields may be great. Naval UAS is a particularly dynamic area. This segment is projected to grow from $60 million annually in 2011 to $588 million by 2020, according to Teal Group. Over the same period, worldwide naval UAS sales are projected to reach $3.5 billion, or 5.3% of the market.

Another potential growth area is that of unmanned combat air vehicles (UCAVs). The uncertainty of long-term support for such programs makes it a highly speculative sector, but the Teal Group estimates it could reach $8.6 billion, or 13.1% of the market, over the course of the decade.

Other areas of the market where the military already has established UAS inventories appear more likely to face pressure in coming years. Tactical UAS, a sector dominated by the Shadow in the U.S., faces a projected decline over the 2011-2020 timeframe.

Competition promises to increase, because the market remains wide open when it comes to new missions such as maritime and cargo UAS. DARPA even issued a request for proposals in October for a $47-million persistent close-air support project. This could include a demonstration that would involve modifying an A-10C into an optionally piloted vehicle.

Companies are also hopeful that DOD's drive to increase competition will translate into increased opportunities to displace incumbents in UAS.


Shadow

New approaches

Another factor that keeps competition intense is the potential for technological breakthroughs that upset the existing market structure. For example, AeroVironment was flying its Global Observer in a joint concept technology demonstration led by Special Operations Command. The goal was to demonstrate the ability to fly for seven days with a 400-lb payload at up to 65,000 ft. If successful, it would mean substantially fewer UAS would be required to maintain continual coverage of an area, dramatically lowering the cost of coverage. Unfortunately, the craft crashed about 18 hr into its ninth flight; the cause is under investigation.

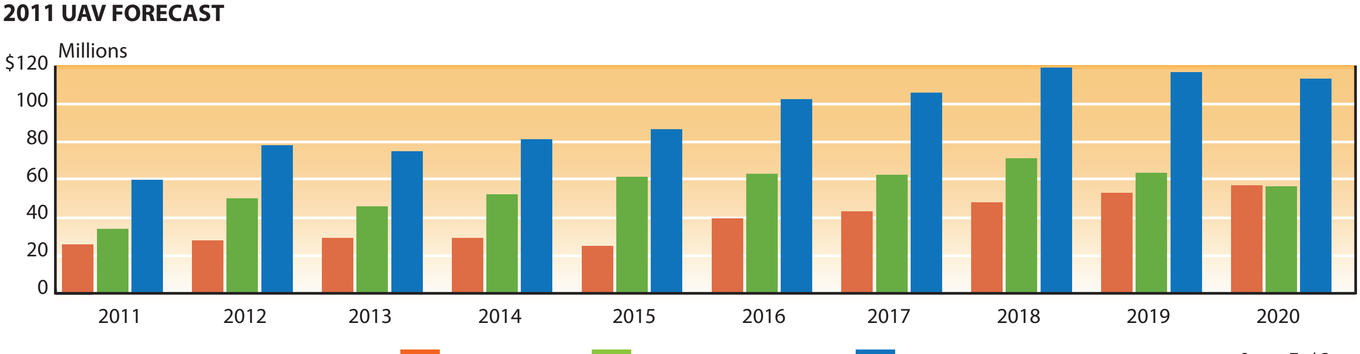
Other companies are working to develop their own approaches to a longer endurance UAS. Boeing and EADS, for example, are working on hydrogen-powered UAVs.

DARPA has an even more ambitious project to develop a five-year endurance UAS. Under an $89-million contract awarded in September, a team consisting of Boeing and Qinetiq will create a solar- and electric-powered prototype for DARPA. By 2014, the team seeks to prove that it can achieve 30 days of flight.

Optional piloting is emerging as another area of tremendous technological interest. Sikorsky is investing heavily in developing an unmanned version of the Army Blackhawk helicopter, while L-3 Communications has the Mobius. Smaller companies such as Aurora Flight Systems and Israel's Aeronautics are developing their own optionally piloted versions of the Diamond Aircraft 42.

The prospect of new approaches and new technologies also levels the playing field for smaller companies. Aurora Flight Systems beat Lockheed Martin to win the Air Force Research Laboratory's MAGIC (medium-altitude global ISR and communications) joint

2011 UAV FORECAST



Source: Teal Group

capability technology demonstration competition.

Investments, acquisitions rise

As companies seek to establish themselves in these segments of the UAS market, they are spending freely. At the May 2010 unveiling of the Phantom Ray, Boeing officials noted that this technology demonstrator, which was fully financed by the company, is a symbol of Boeing's commitment to becoming a major player in UAS.

"Phantom Ray represents a series of significant changes that we're making within Boeing Defense, Space & Security," explained Darryl Davis, president of Phantom Works, at the unveiling ceremony. "For the first time in a long time, we are spending our own money on designing, building, and flying near-operational prototypes. We're spending that money to leverage the decades of experience we have in unmanned systems that span the gamut from sea to space."

Boeing, now the third largest U.S. company in UAS, has built up its position by making such investments and acquiring two key UAS companies—Frontier Systems in 2004 and Insitu in July 2008. Insitu, manufacturer of the ScanEagle and Integrator, is particularly important because of its rapid growth in the market. It reported approximately $375 million in sales last year, compared to only several million dollars in 2003 and $50 million by 2006. Insitu was put in charge of Boeing's tactical UAS operations.

Northrop Grumman, the worldwide leader in UAS, has achieved its own position through a combination of heavy investment in R&D and crucial acquisitions, including Ryan Aeronautical, developer of the Global Hawk. Most recently, Northrop Grumman purchased Swift Engineering's KillerBee UAS family. It is also working with Bell in a jointly funded effort to develop the Fire-X, a UAS based on the commercial Bell 407.

Lockheed Martin also has been investing heavily in efforts to build up its position in UAS. This has included the use of company funds to develop and build the $27-million P-175 Polecat UAV demonstrator. The company has a relatively low-visibility position, partly because it has lost some key programs, and partly because its most important effort, the Air Force RQ-170—a stealthy MALE UAS that has been deployed to Afghanistan—remains highly classified.

L-3 Communications has been a leader in making acquisitions of UAS businesses, purchasing three different operations in recent years, including Geneva Aerospace in 2007 and BAI in 2004. In addition, in August 2010 it paid $18 million for Airborne Technologies, a small UAS manufacturer that developed the Cutlass UAS. This is a small, foldable UAS that can be aircraft launched.

Challenging the leaders

With so much investment in new technologies and acquisitions, it is uncertain which companies will be the industry leaders in the future. General Atomics Aeronautical Systems, the second largest company, is benefitting from soaring sales of the Predator/Reaper. In coming years, the ramp-up in U.S. funding for the aircraft promises to yield revenues for the company, enabling it to challenge Northrop Grumman, the long-established UAS revenue leader.

Northrop Grumman owes its leadership largely to the Global Hawk and research funding for its BAMS variant. But there have been problems with the Global Hawk program, which accounts for about half of the company's annual $1.9 billion in UAS revenues. Senior Dept. of Defense officials have criticized the cost of the program, saying it threatens to become unaffordable. Northrop Grumman is making changes to ensure the program's continued viability.

Still, they have tremendous breadth that goes beyond Global Hawk. Fire Scout procurement is ramping up. The BAT, a family of tactical UAVs now in development, will be used to challenge tactical systems such as the Scan Eagle, the Integrator, and the Shadow. Northrop Grumman is also the market leader in synthetic aperture radar payloads for UAVs.

Other companies are working to challenge the leading players, and not just with breakthrough technologies involving hydrogen- and solar-powered UAVs.

MALE programs are attracting intense interest from major companies eager to break into the next decade's largest UAS segment. The Navy's UCLASS program is expected to attract interest from Northrop Grumman, Boeing, Lockheed Martin, and General Atomics. The Air Force's next-generation MQX effort to build a stealthy, jet-powered MALE UAV that can survive in contested airspace is expected to bring bids from Raytheon, Northrop Grumman, Boeing, Lockheed Martin, General Atomics, and Israel Aerospace Industries (IAI).

In the international markets, IAI's Heron and Heron TP are already mounting a successful challenge to General Atomics, winning fee-for-service contracts in Canada, Australia, and Germany. Elbit Systems is planning its own challenge with its new Hermes 900, which has just been purchased by the Israeli Air Force.

In coming years, the leaders of today's industry may find that the strength and fluidity of the UAV market will make it a difficult one in which to maintain continued leadership.

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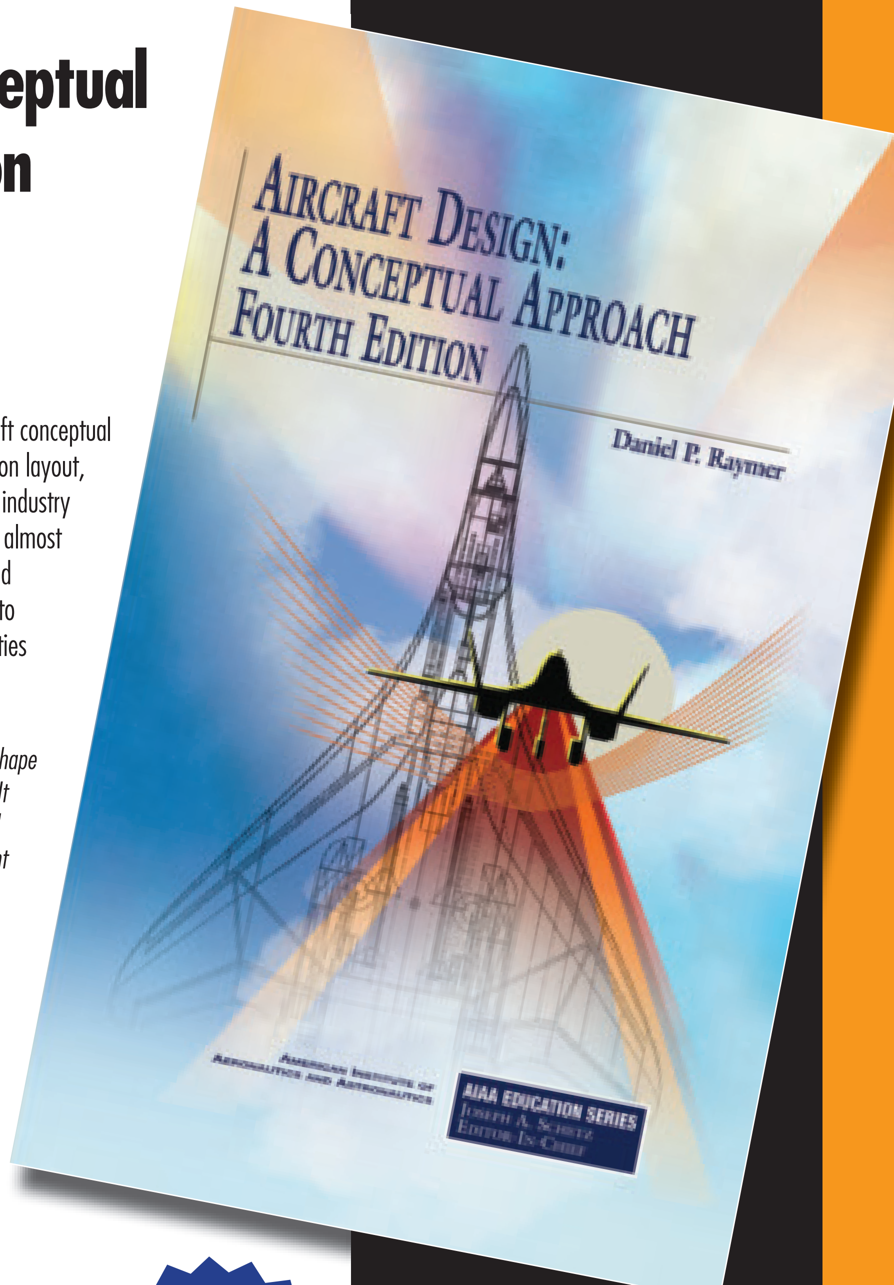

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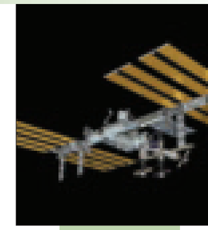
A green space station



THROUGHOUT THE U.S. COMMERCIAL and residential construction community, environmentally friendly 'green buildings' are all the rage. Inside the five-bedroom-equivalent public housing unit known as the international space station, NASA has staked its claim for green building leadership by devoting significant resources to an ambitious engineering project called ECLSS, the integrated regenerative environmental control and life support system.

ECLSS includes an oxygen generation system delivered in July 2006 by the space shuttle Discovery. Through a process called electrolysis, this system uses electricity from the ISS solar panels to generate breathable oxygen for crewmembers by breaking down water into hydrogen and oxygen. The ECLSS also uses a water recovery system (WRS) that recycles potable water, water for technical uses from humidity, used wash water, and crewmembers' sweat and urine. The WRS employs an extensive distillation and purification process to produce about six gallons every six hours. The system was delivered in November 2008 by the Endeavour shuttle.

Augmenting the ECLSS is Hamilton Sundstrand's Sabatier reactor system, delivered to the ISS in April 2010 by the shuttle Discovery. Sabatier takes carbon dioxide that is removed by the station's carbon dioxide removal assembly and combines it with hydrogen produced by the ECLSS water electrolysis systems. This combination produces both water, which is fed into the station's wastewater recycling system, and methane, which is vented into space. NASA has yet to figure out a way to use the waste methane, but notes that future experimentation on board the ISS may be useful in determining if the methane can be recovered for use as rocket fuel for deep space exploration.

ECLSS also features two devices for monitoring and ensuring atmosphere quality. One is the major constituent analyzer, a mass spectrometer that samples air quality. The other is a system of filters called a trace contaminant control subassembly, which removes over 200 atmospheric chemical compounds generated by equipment off-gassing and human functions. To monitor and ensure water purity, the WRS uses conductivity sensors and a device called the total organic carbon analyzer, which measures the amount of organic and inorganic carbon in station water samples, as well as their pH and conductivity.

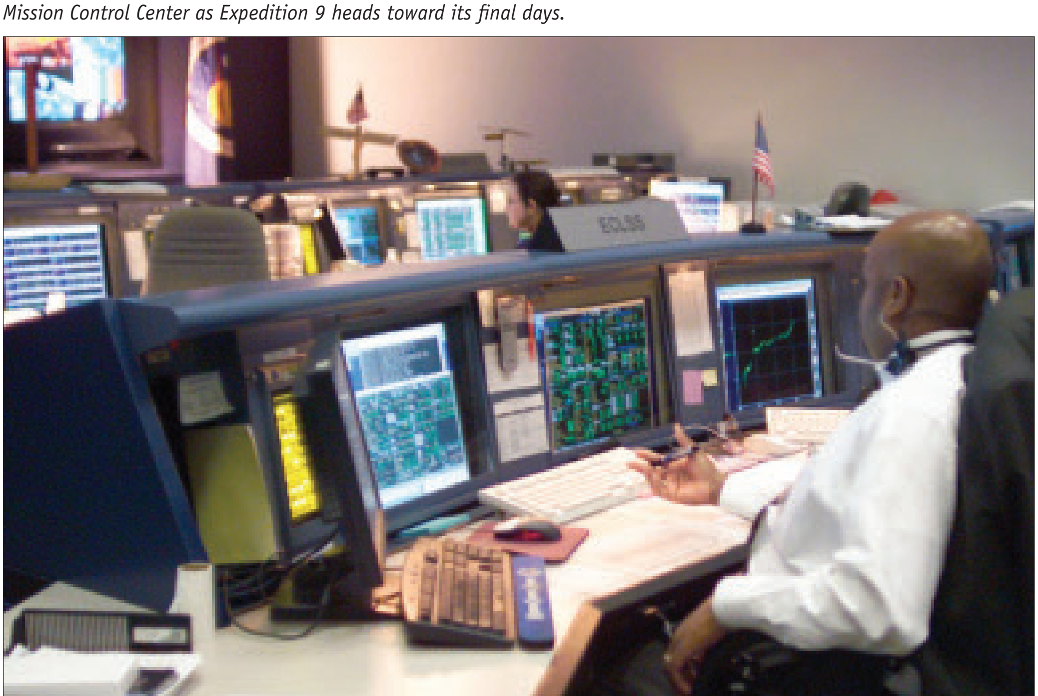
A philosophical shift

NASA's ECLSS venture is important for several reasons. First, from a practical standpoint, it relieves the ISS partners of requirements for costly water and consumables resupply missions, reducing annually the need for about 6.8 tons of upmass to the ISS. Second, it simply would not have been possible to double the station's crew size from three to six without the 2008 mission that delivered the WRS.

ECLSS also represents a major shift in design philosophy from open-loop life-support systems, favored in the first half-century of human spaceflight, toward a more functional closed-loop system.

With the older, open-loop systems, nearly all consumables were brought by spacecraft flown in Earth orbit or to the Moon. With the closed-loop approach, dependence on ground sys-

Kwatsi L. Alibaruho, ECLSS officer, monitors data at his console in the station flight control room in NASA Johnson's Mission Control Center as Expedition 9 heads toward its final days.



tems for consumables is increasingly limited, a vital criterion for future human missions to the Moon, near-Earth asteroids, or Mars.

Ron Ticker, manager for space station development at NASA Headquarters, refers to the ISS as a self-contained, life-sustaining ecosystem, or 'biodome.' By that he means that the station "is largely dependent on recycling. We do have resupply ships coming up there, but the more that we can do on board, [the more] it cuts our logistics requirements, and cuts our costs up there. So when I say it's a biodome, it is for the most part self-contained, or tries to be self-contained. That was the genesis, for example, of going to a more regenerative ECLSS to try to close those loops even more."

With ECLSS, "We're learning a lot about life support," says William Gerstenmaier, NASA's associate administrator for space operations. "We are close to an 85% level of regeneration with recycling urine into potable water, and we're learning a great deal about how to maintain systems in a microgravity environment."

"Sometimes the systems are tough to operate," adds Gerstenmaier. "With the oxygen generation system, for example, small particles clog up filters much more easily in microgravity. So we're learning to make the filter holes larger to avoid this problem."

Surprises in microgravity

NASA engineers responsible for the design and management of the ECLSS say that while it works well in space, the agency has had to deal with unexpected surprises simply because Earthbound tests of the refrigerator-sized oxygen and water regeneration equipment could not duplicate the station's microgravity environment.

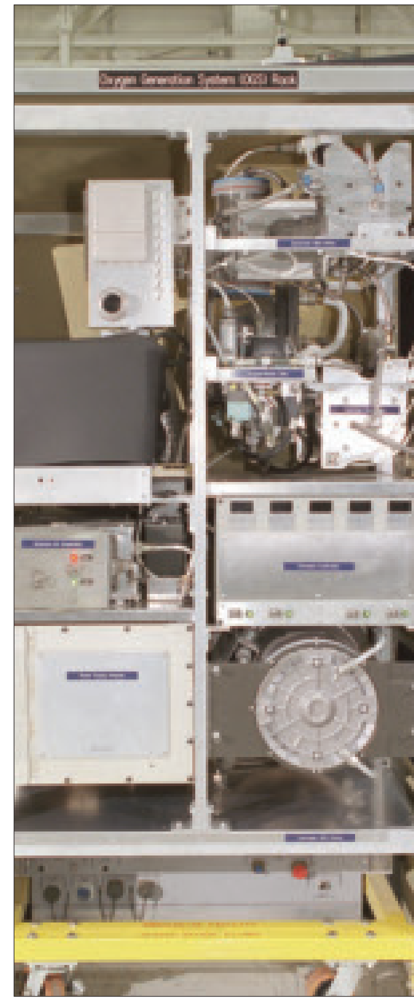
One example occurred in the recycling of urine into potable water, an effort never before attempted in space (since Mir, and on the ISS, the Russians have worked strictly on recycling humidity into drinkable water, though they have used recycled urine for regeneration of oxygen). The task is easier to accomplish on the ground than in microgravity conditions, explains Monsi Roman, project manager for life support and habitation systems at NASA. While it has been known for years that astronauts shed calcium in their urine, the mineral's high concentration added a layer of impurity to the recycling process, and it proved more difficult to filter out in space than in on-the-ground testing. "That's giving us a challenge we did not expect," Roman explains.

"With the rest of the process [for distilling humidity and waste water into drinkable water]," she adds, "you can recycle 100% of what you put in. But the urine you can't. That precipitant of water that you lose in the brine—contaminants from urine left over after water is boiled off in a large tank—is your net loss of how much you're actually recycling.

"Originally we thought we could recycle 93% of everything we put in [from the urine], but because of this high concentration of solids, we are not at this level….So it's a challenge, it's something that we needed to learn about on the space station. Distillation in itself is a very old technology. Making it work in microgravity is what makes it complicated. That's what the space station is there for—for us to check all these things we had never known in the past. If we had known them, of course we would have designed for them. If we go to Mars, we don't want to find out this information for the first time."

To improve the efficiency of the water recycling system, Roman says NASA advanced life support engineers are testing a number of concepts, including "concentrating all the water and distilling everything together, instead of distilling just the urine," which might make the recovery process "a little bit more effective."

Once the urine is fully distilled and processed, the potable water product is treated with iodine "to keep any residual microorganisms that might still be in your product water from regrowing and becoming a microbiological hazard," notes Robert Bagdigian, branch chief in NASA Marshall's Engineering Directorate. He says iodine is favored over chlorine as a disinfectant because "chorine is harder to handle, especially in a closed spacecraft environment." Because of medical concerns about the long-term effects of iodine on humans, Bagdigian adds that in a final filtration process the iodine is removed from the drinking water.



An oxygen generation system uses electricity from station solar panels to generate breathable oxygen through electrolysis.

Earthbound applications

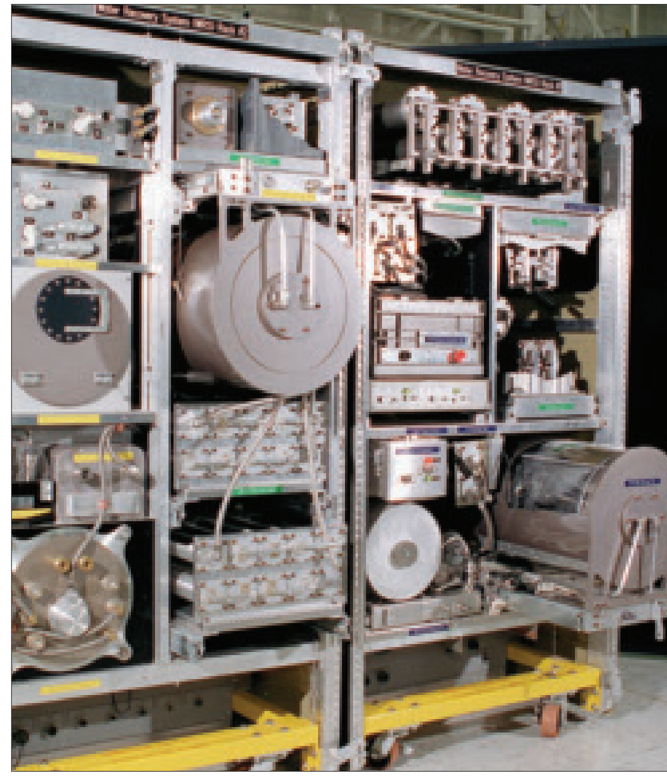
While recycling water in space has long-term human spaceflight implications, it also has immediate earthbound applications.

Ticker notes that Water Security, a private company, has used the technology NASA developed for this system to make "a product you can use in disaster recovery in the third-world areas where water purification is a big issue after earthquakes and other devastating events."

The system has been used to provide purified water for Kurdish villages in Northern Iraq and for earthquake relief in Pakistan. Adds Bagdigian, "We've gone out and talked to municipal water system operators, and businesses such as the pharmaceutical industry that want to learn how to produce high-purity water."

Operational lessons learned

A current challenge of operating ECLSS and other vital ISS systems is to make them more efficient. Regarding the filtration of dust, Roman notes, "The carbon dioxide removal system has issues with dust that we are trying to resolve by using a different kind of zeolites [molecular sieves] mix. Originally they put in a mesh that was too small. There was no flow of air. Now we have redesigned the mesh, so we should have a longer time in microgravity without the problem of dust clogging the air flow. As we learn to work the systems, they get more robust, and it takes less time for the crews to do repairs in flight."



The WRS provides clean water through the reclamation of waste waters.

NASA engineers are also seeking to make WRS equipment more efficient. "You would think we'd know how to make long-life pumps," says Bagdigian, "but in these applications, where we are trying to make these pumps as small as possible—relatively low-flow-rate pumps with high-pressure drop capabilities—you wind up having fairly unique pumps. So even with mundane things like pumps and valves, operating with this kind of complex waste water can be quite a challenge for us."

Regarding long-duration missions beyond LEO, NASA would also like to develop a way of efficiently laundering crew clothing in a closed-loop system. Bagdigian says this has not been an easy task: "Station crewmembers have taken some of their clothes, like socks and underwear, and on their own have been experimenting with putting them in bags and using a little water to push the clothes around. Operationally, we do not have the ability to do laundry. For exploration beyond space station, we are looking for technology to enable us to do it. We'd very much like to be able to reduce the amount of clothing we put on the vehicle." But for that to make sense, he says, they have to be sure any resulting weight savings "aren't more than offset by the weight that you'd add to the vehicle for all the equipment and supplies you'd need to do that laundering. There's a trade there."

Turning to the future of human spaceflight, Roman foresees regenerative life-support systems that are a hybrid of "basic chemical systems, and biological systems" such as "a greenhouse or system that will take the carbon dioxide out of the air using algae." She notes, though, that in-space greenhouses are not perfect solutions, because the carbon dioxide produced by humans will have to be scrubbed before it is absorbed by plants, and provisions must be made to provide the plants "with the right temperature and light. That's a lot of power that you need there, and a lot of area."

She adds that planners will need to figure out what to do with decomposed plant waste. "Greenhouses add a level of mass that you have to account for." Roman concludes, "I do not think NASA will send people to Mars completely dependent on one system or the other. I can tell you that regeneration is the right way to go. If you try to put together a trade study where you look at what it will take to keep a group of humans alive, it is still worth having a regenerative system in flight despite all the challenges."

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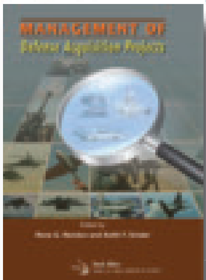

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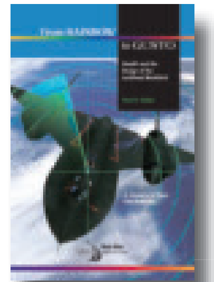

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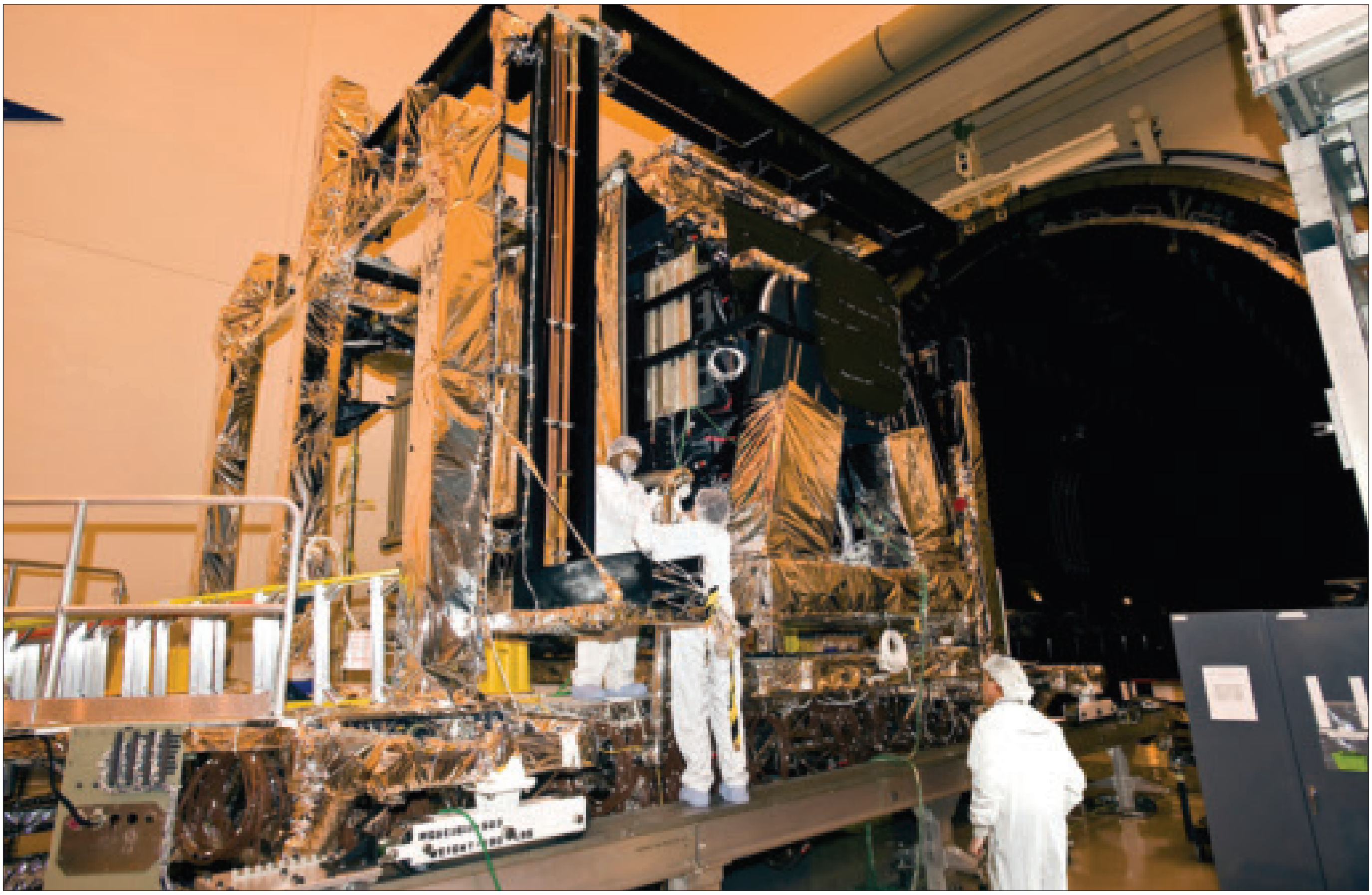
LOWS and HIGHS for

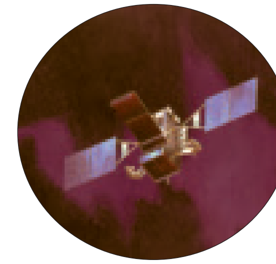
The first decade of this century brought mounting anxiety to defense officials responsible for alerting the U.S. and its allies to impending missile attacks. Early warning satellites in geosynchronous orbit were old and wearing out. The Air Force program for developing new and better satellites to augment and replace them was foundering amid cost and technical problems. A dangerous gap in missile warning coverage lay ahead.

At the heart of the problem was the Space-Based Infrared System (SBIRS) program, undertaken by the Air Force in 1996 to develop the next generation of heat-sensing sentinels in space. SBIRS had fallen far behind schedule and was verging on failure. Ballistic missiles were coming into play in more and more countries, most menacingly in North Korea and Iran.

Now things are looking up: The SBIRS program, with Lockheed Martin as prime

SBIRS GEO-1 undergoes work at Lockheed Martin Space Systems in Sunnyvale, California.





SBIRS early warning

Just as more nations began building ballistic missiles and acquiring nuclear weapons, U.S. early warning satellites were starting to wear out. Plans to replace them, however, proved overly ambitious, and defense officials redoubled efforts to overcome mounting problems. The resulting Space-Based Infrared System now appears to be exceeding expectations.

by James W. Canan
Contributing writer

contractor and Northrop Grumman as payload integrator, finally seems to have hit its stride. The first dedicated SBIRS satellite, GEO-1, is scheduled for launch from Cape Canaveral into geosynchronous orbit atop an Atlas 5 rocket this month.

Many missions, more coverage

Three additional GEO satellites are scheduled to follow in the near future to form a SBIRS constellation that will support multiple missions: missile warning, missile defense, technical intelligence, and battlespace awareness.

SBIRS will consist of more than just its dedicated GEO satellites, which are highly sophisticated, stabilized platforms featuring telescopes, supersensitive infrared sensors, and pointing/aiming mirrors. The system will also include four infrared sensor payloads on classified, multipurpose host satellites in highly elliptical orbit (HEO). SBIRS spacecraft transmit data to fixed and mobile ground stations and, by relay, to the mission control station at Buckley AFB, Colorado, which currently operates the Defense Support Program (DSP) satellites.

"SBIRS offers improved sensor flexibility and sensitivity compared to DSP," an Air Force paper claims. SBIRS sensors "cover short-wave infrared, expanded midwave infrared, and see-to-the-ground bands, allowing them to perform a broader set of missions," it says.

In recent months, GEO-1 and its sensors and associated systems have passed all prelaunch tests with flying colors. In late January, a major flight operations test of the performance characteristics and ground station linkage demonstrated that GEO-1 is ready to go, marking "one of the most significant milestones to date on the path to launch," Lockheed Martin announced.

Two SBIRS sensor payloads currently aboard a classified HEO satellite are said to be performing spectacularly. Subsequent SBIRS sensor payloads slated for launch on another HEO satellite have met the requirements of the National System for Geospatial Intelligence, which has officially accepted them for the technical intelligence mission.

Reasons for success

"We have confidence in the GEO sensors, in part due to their similarity in design to the HEO sensors," says Jeff Smith, Lockheed Martin's SBIRS vice president and program manager. "We fully expect SBIRS GEO-1 to meet or exceed our customer's expectation, and we are confident in delivering this first-of-its-kind spacecraft to meet our scheduled spring 2011 launch date."

Smith attributes the latter-day success of SBIRS development to "sound program fundamentals and rigorous, disciplined testing," and to the "accountability, trust, teamwork, and commitment" of the Air Force and its contractors. He says that

DSP 23, the last satellite in that constellation, reportedly lost contact with ground control shortly after launch.

steps taken in development and testing over the past year "have reduced program risk significantly, giving us great confidence in achieving mission success."

The Air Force and its contractor team adopted a more rigorous approach to the program in recent years in an attempt to reduce risk in technology development and control costs. There was concern in some defense circles that this would severely compromise the capabilities of the system as it was originally planned. By all accounts, this has not happened.

Over the past two years, the Air Force and its contractors have eliminated "almost all of the developmental risk associated with the first-time integration of a new satellite design," and "made major strides in restoring confidence in the program team's ability to execute [the activity] on plan and produce quality products," says Brig. Gen.-selectee Roger Teague, SBIRS program director and wing commander with Air Force Space and Missile Systems Center (SMSC).

In the process of developing SBIRS, the center is also focused on sustaining the DSP constellation. "Our goal," Teague says, is the seamless replacement of DSP with SBIRS, and "we are working closely with Air Force Space Command to ensure that the SBIRS satellites are available for launch to support their operational mission."

Last legs for DSP

The SBIRS program seems to have made a comeback in the nick of time—DSP satellites are almost out of gas. Defense officials do not openly discuss the operations or status of DSP spacecraft, but acknowledge that some of those still in operation are in danger of going dark.

Loren Thompson, a longtime national security observer and analyst with the Lexington Institute, recently observed, "there is evidence that some satellites in the [DSP] constellation are on their last legs. In fact, a few are already functioning well beyond their nominal design lives."

The Air Force launched its first DSP satellite in 1970. Since then, 22 more have been launched. The early versions reportedly weighed about 2,000 lb and had a very brief design life. Those launched in the past two decades are said to have weighed more than 5,000 lb and were designed to keep operating much longer. The last one to be launched—DSP 23, about two years ago—reportedly lost contact with ground control not long after launch into GEO ("It just disappeared," said one official).

"When a satellite no longer has the redundancy left to cope with a parts or circuit failure, it is said to have become a 'single-string' bird. It appears that some birds in the present [DSP] constellation have become just that as the government has waited for SBIRS to mature," Thompson observes.

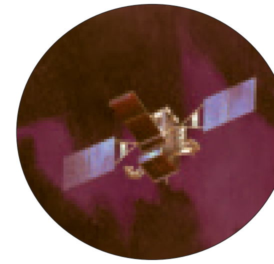
DSP satellites were the first line of strategic defense for the U.S. through much of its Cold War nuclear standoff with the Soviet Union. The satellites were built by the erstwhile TRW and then by Northrop Grumman to detect the intense infrared signatures of ICBM launches and nuclear bursts, and not necessarily to sense the less discernible signatures of shorter range theater, or tactical, ballistic missiles on the rise.

During Operation Desert Storm in 1991, a DSP satellite perched in GEO surprisingly picked up the heat from launches of Iraq's Scud tactical ballistic missiles. This drew praise from Gen. Thomas Moorman (then head of Air Force Space Command), who called it "enormously important" to the successful outcome of that conflict.

Long road to replacement

By the time of Desert Storm, the Air Force had shelved its plan for the Advanced Warning System, a constellation of satellites to replace the DSP system. Instead the Pentagon devised a more ambitious plan for a Follow-on Early Warning System (FEWS) to detect the launches of both theater ballistic missiles and ICBMs. FEWS was designed to improve on the DSP satellites but to have less capability and lower cost than the highly elaborate warning-and-targeting satellites envisioned in the Strategic Defense Initiative (SDI) program of the 1980s.

FEWS became too expensive and fell by the wayside. In 1994, after yet another study of missile threat and advance warning prospects, the Air Force incorporated an SDI early warning concept called Brilliant Eyes in plans for a newly conceived Space-Based Infrared System, or SBIRS, featuring sentinel satellites in various orbits.



Brilliant Eyes was renamed the Space and Missile Tracking System and then SBIRS Low. The DSP replacement element of the program was named SBIRS High.

Ten years ago, SBIRS Low was transferred from the Air Force to the national Ballistic Missile Defense Organization, now the Missile Defense Agency. This was done to emphasize the program's dedication to ballistic missile defense and to distance it from SBIRS High, which even then was running into troublesome cost and technical problems. SBIRS Low was renamed the Space Tracking and Surveillance System, and SBIRS High became simply SBIRS.

Air Force Space Command in Colorado controls the SBIRS and DSP satellites. The SMSC's Infrared Space Systems Directorate is in charge of SBIRS development. Lockheed Martin's original SBIRS High contract with the Air Force called for two HEO payloads, two GEO satellites, and the ground-based assets to receive and process the infrared data from space.

Early last year the SBIRS contract was modified to cover two additional HEO sensor payloads—HEO 3 and HEO 4—and follow-on production of two more GEO satellites. This increased the estimated program cost from $11.5 billion to $15.1 billion. HEO 3 is scheduled for delivery next year, Teague says.

An indication that the additional cost of the SBIRS contract will be well justified came in March 2010: An Air Force/Lockheed Martin preliminary design review of the third and fourth GEO satellites was pronounced highly successful.

"This represents an important step" in the SBIRS program, said Col. John Mueller, vice commander of SMSC's SBIRS wing. "Now we are ready to dig into the details on the design of the third and fourth spacecraft in preparation for production."

The Air Force had apparently overreached in devising the SBIRS High program, setting out to do much more than merely replace DSP satellites with SBIRS High spacecraft in the early warning mode. It had planned to adorn the SBIRS sensors with cutting-edge sensor technologies that would enable the satellites to perform multiple missions: warn of ballistic missile launches, anchor an advanced, digitally integrated system of ballistic missile defense, and provide technical intelligence and battlefield awareness data to combat commanders. This was asking too much of the sensors too soon, as it turned out.

SBIRS High quickly got into difficulty because the program was improperly structured, initial testing of parts and components was inadequate, and the investment in building and integrating hardware was premature and excessive, according to Air Force acquisition officials. In 2005 the service, under pressure from the Dept. of Defense, began work on a possible SBIRS backup program called the Alternative Infrared Satellite System (AIRSS).

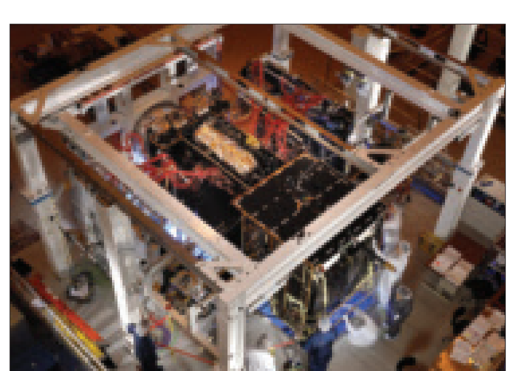
At the time, Air Force officials seemed hopeful that corrective measures were beginning to give the SBIRS program 'some traction,' as one put it. But they acknowledged that SBIRS had a long way to go, and would remain suspect.

Back to basics

In mid-2006, Gary Payton, then the chief of Air Force space acquisition, told *Aerospace America*: "In the beginning of the SBIRS High program, everybody said 'we're going to take a grand and glorious big leap forward to replace the old DSP missile warning satellites that are old and not good enough any more.' The problem was that we didn't have the technology that would be needed...but we went ahead anyway." The Air Force and its SBIRS High contractors "began doing the design work without having the technology in hand for the sensor that was supposed to go on the spacecraft," he explained.

"We've gone back to basics, simplified things," Payton said. "We're letting the technology catch up." He expressed hope that launches of SBIRS High GEO-1 and GEO-2 would take place in October 2008 and October 2009, respectively, and that the cost estimate for the program had peaked and stabilized at roughly $10 billion.

A year later, in 2007, SBIRS was in trouble again—the Air Force announced an additional cost overrun of around $1 billion. The cause was a problem with the GEO



Work on the GEO-2 is well under way.

The second HEO payload, a critical element of SBIRS, undergoes final inspection prior to delivery.

The final integrated system test of GEO-1, a major program milestone that verifies the spacecraft's performance and functionality in preparation for delivery to the launch site, was completed on December 13.

satellite's 'safe-hold' system, which takes control of basic functions such as positioning when the satellite runs into operational anomalies, and puts it on hold, in effect, until ground controllers can assess and rectify the situation.

That glitch was overcome, and the program went ahead but remained dubious. A General Accountability Office report noted that the cost estimate for the program had ballooned to $12.2 billion, that the number of satellites in the planned SBIRS constellation had been reduced from five to four, and that the launch of the first GEO satellite would take place many years later than originally scheduled.

Hedging its bets on SBIRS, the Air Force asked Congress for funds to start work on yet another space-based early warning program, the Third Generation Infrared Surveillance (3GIRS) system, an outgrowth of AIRSS, with Raytheon and SAIC the contractor team for both programs. The AIRSS/3GIRS endeavor was undertaken as a less costly alternative to the faltering SBIRS program. But now, with that effort apparently back on track, it is seen as a possible supplement to SBIRS if needed.

DOD's Operationally Responsive Space office, which considers options for preventing or closing a coverage gap in the U.S. space-based missile warning system, reportedly continues to pursue future possibilities for the use of AIRSS/3GIRS sensors. The first such sensor is said to be scheduled for launch this year on an Orbital Sciences satellite as part of a commercial space payload experiment.

Rising prospects

Steady progress in the development and testing of SBIRS sensors has given the program a big lift. Sensors on the host satellite currently in HEO have performed admirably, officials claim. The second HEO sensor payload and associated ground systems were certified for missile warning operations by Strategic Command last August.

At the time, Teague called the certification "another major operational achievement" in the program. "The HEO system is delivering revolutionary new surveillance capabilities to combatant commanders, and we look forward to continued strong progress," he declared.

The SBIRS infrared staring and scanning sensors are said to be demonstrably superior to those on GPS satellites in the scope, flexibility, and sensitivity of their coverage. The staring sensor "has high agility to rapidly stare at one Earth location and then move to other locations" and "will be used for step-stare or dedicated-stare operations over smaller geographic areas" than the scanning sensor can monitor, the Air Force claims.

Late last year, the Air Force and its contractors completed the final integrated system test of GEO-1, the first geosynchronous SBIRS satellite. The test verified that the spacecraft will perform as advertised, the Air Force announced.

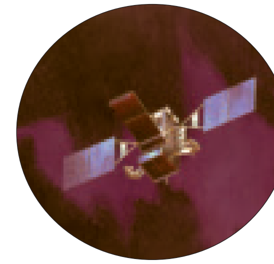
Lockheed Martin's Smith described the test as "disciplined and thorough" and called it "a major program milestone on the path to mission success." Lockheed officials also hailed another milestone: the successful baseline integrated system test of the first GEO satellite's updated flight software subsystem (FSS), in conjunction with satellite hardware.

Bringing the FSS software up to snuff and ensuring its stability required nearly two years of painstaking development, the Air Force says. FSS performs many tasks, such as operating and controlling the satellite's health, operational status, and safety; power management; fault detection and recovery; thermal control; and telemetry.

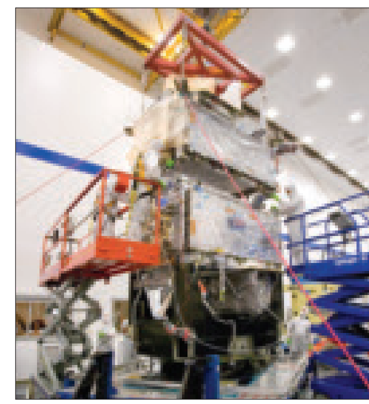
Development of the SBIRS stations on land also seems to have come along nicely, given last summer's successful system-level test of their interfaces with the satellites. According to the Air Force, that test validated the GEO satellite's command and control capability, demonstrating that the satellite and its ground stations are well able to transmit and receive data while frequency-hopping as planned.

Testing "validated the functionality, performance, and operability of the SBIRS GEO ground system" and demonstrated that "the ground system is on track to support launch of the first…GEO-1 satellite in the constellation," the Air Force claims. The test covered more than 1.5 million source lines of software code and 133 ground segment requirements, the service says.

With the launch of SBIRS GEO-1 nearly at hand, the outlook for the SBIRS program seems more upbeat than ever before. Lexington Institute's Thompson is among those who express that. Calling SBIRS "an absolutely essential space asset," he says that the Air Force and its contractors "succeeded in building SBIRS as originally envisioned," and that the reduction of SBIRS capabilities in the program's corrective retrenchment "did not happen."



The Space Tracking and Surveillance System, formerly named Brilliant Eyes, was an SDI early warning concept.



Fundamentals of Aircraft and Airship Design

Volume I–Aircraft Design

Leland M. Nicolai and Grant E. Carichner

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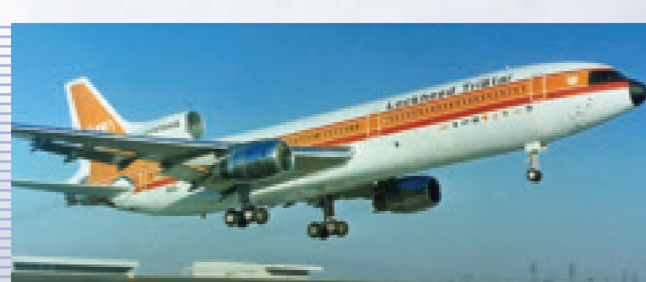

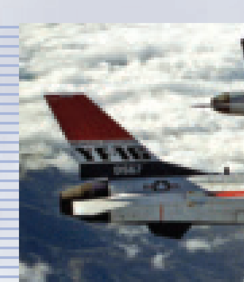

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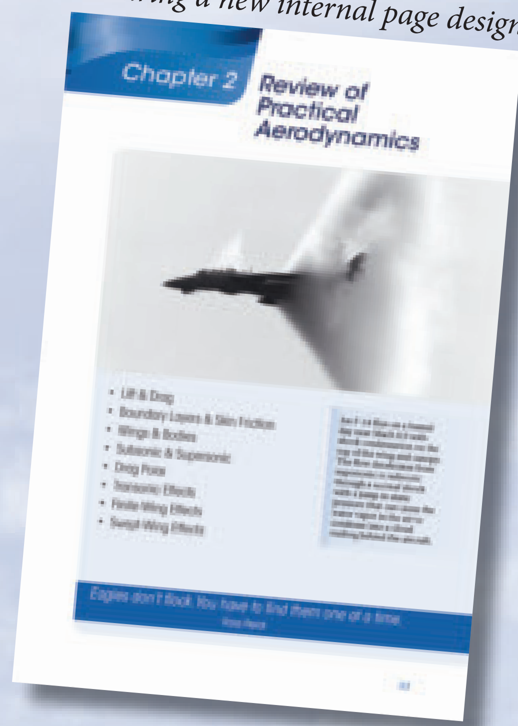

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For the past 50 years, NASA and its partners have made steady progress in reducing hazardous aircraft emissions. But environmental restrictions have grown stricter just when requirements for lower costs and improved fuel efficiency have also increased. Balancing these needs will take precision and persistence, but current research projects hold promise for meeting the challenge.

Long gone are the days when weekend airplane watchers could visit an airport and see a Boeing 707 take to the skies, its four Pratt & Whitney JT3C jet engines belching soot and smoke out the rear as the airliner roared down the runway. Propulsion technology advances introduced by NASA working with many others during the past 50 years have markedly reduced harmful engine emissions. But more still needs to be done.

NASA is collaborating with its government, industry, and university partners on a number of environmentally beneficial, or 'green,' aviation initiatives designed to eliminate as much potential harm to the ecosphere as possible while still making air travel as efficient and economical as it can be. Emissions, nuisance noise, fuel burn efficiency, air traffic management, and the use of alternate fuels all are on NASA's 'home improvement' radar.

Clearing the air

Depending on their chemical composition, the potentially harmful jet engine emissions of greatest concern to NASA researchers affect either the global atmosphere or the air quality in airport neighborhoods.

PART TWO

In search of

cleaner skies

by Jim Banke
Public Affairs writer,
NASA Headquarters;
President, MILA Solutions,
a NASA subcontractor

Landing and takeoff emissions—found on and around airport property—include nitric oxide and nitrogen oxide (collectively called NO_x), plus sulfur oxides and particulates, also known as soot, smoke, or aerosols. Both NO_x and particulate emissions create hazards for humans. In the lower atmosphere, smog is the primary concern. NO_x also contributes to atmospheric ozone depletion, which increases potential exposure to ultraviolet solar radiation, a situation linked to skin cancer. Particulates contribute to respiratory problems. Sulfur oxides can mix with airborne moisture and fall as acid rain, which can erode vehicle paint finishes, irritate exposed skin, and damage crops.

At altitude, carbon dioxide and water vapor contrails are the chief concerns. CO_2 traps excess heat from the Sun, exacerbating the greenhouse effect in the atmosphere. Water vapor from engine exhaust also traps solar radiation, but scientists have not yet determined whether that contributes significantly to the greenhouse effect.

Using data from NASA's atmospheric research satellites, Patrick Minnis, a senior research scientist in the Science Directorate at NASA Langley, has found that contrails formed as a result of jet engine water vapor emissions often spread out to become high-altitude cirrus clouds. "We are finding that in areas where there is air traffic, either locally over airports or on the nation's jet ways, there is an increased frequency of cirrus clouds," Minnis says. "What we don't know yet is the extent to which these cirrus clouds are having an effect on the total amount of radiative energy that is trapped in the atmosphere.

"The impact of these contrails may be no worse than what we see with [CO_2], or it may be many times worse. We just don't know enough yet," says Minnis.

NASA's aeronautics innovators are turning to the science community to develop a better understanding of the atmospheric impacts of aircraft emissions, because that will directly affect the technical direction of future aircraft and engine design changes intended to help the environment.

"Because of the uncertainty about the true impact of emissions on the global environment, future aircraft engines designed to eliminate one type of emission, such as NO_x, could create a bigger problem with something like contrails or water vapor," says Jay Dryer, director of NASA's Fundamental Aeronautics Program in Washington, D.C. “We just don’t know enough yet about what is really happening, so there’s a lot of discovery still to come.”

Setting new standards

For now, based on what is known and already established in terms of national and international standards (landing and takeoff NO_x is regulated while carbon dioxide is not), NASA has set several goals for enabling technology that will reduce emissions during the next decade or so. These goals are based on standards set forth by the Committee on Aviation Environmental Protection, or CAEP, which is part of the International Civil Aviation Organization.

The CAEP meets every three years. During the 2004 meeting, members set new emissions standards for aircraft engines. These standards—labeled CAEP/6 because the 2004 meeting was the sixth in the organization’s history—took effect in 2008. NASA’s goals, related to the current standard, are to create technology enabling engines that emit 60% less NO_x by 2015, 75% less by 2020, and over 75% less by 2025.

Although there are no carbon dioxide emissions standards or restrictions, the 2010 CAEP/8 committee members expressed a desire to develop a new CO_2 standard by 2013, when they meet again. If they reach an agreement at CAEP/9, new CO_2 standards would apply to all new aircraft engines in the 2016-2017 timeframe.

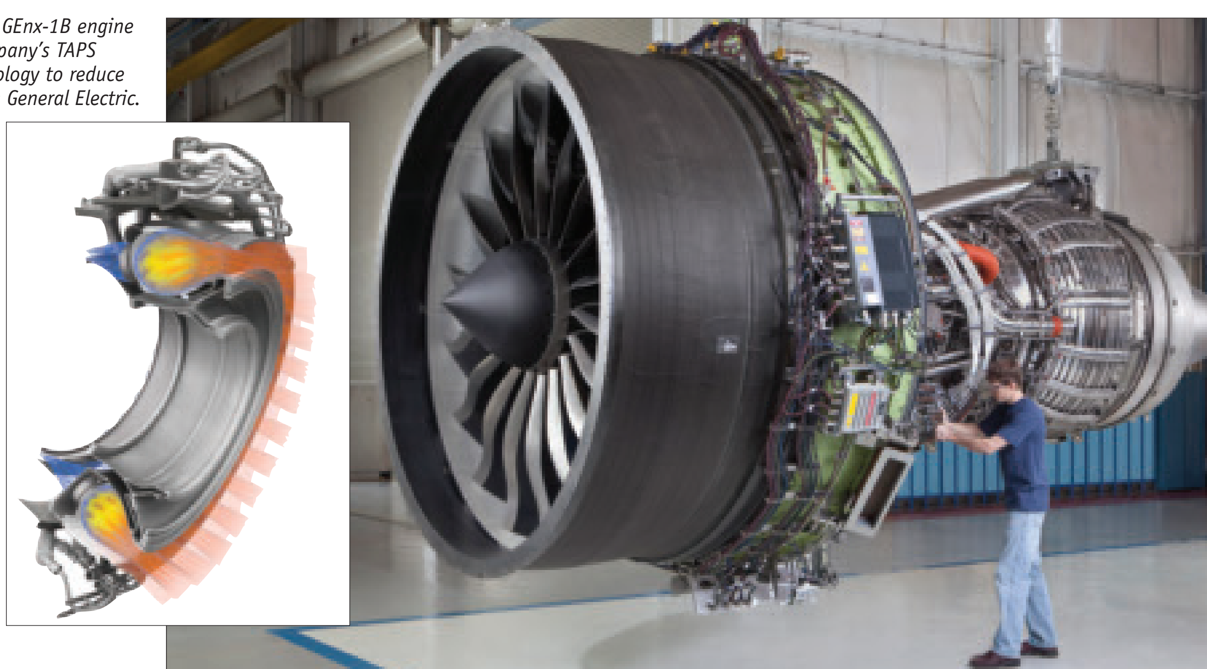
The continuing challenge for NASA researchers is to design aircraft and engines that not only meet stringent new goals for emissions, but also will satisfy simultaneous goals for noise reduction and fuel burn efficiency—no matter what type of fuel, alternative or otherwise, is in vogue 20-25 years from now.

Burn, baby, burn

The amounts of chemicals and particulates spewing from a jet engine exhaust nozzle have everything to do with the combustion process involving fuel and air. Change any one of the many variables that affect combustion and the resulting emissions get better or worse. An engine’s internal geometry, its operating pressure and temperature, the fuel injection method, the ratio of fuel to air and how well they are mixed together inside the combustor before ignition are just a few of the top-level variables. The type of aviation fuel used, whether fossil fuel based or not, also can affect the amounts and types of emissions.

Right now, NASA researchers and their industry colleagues are focused on reducing the amounts of landing and takeoff NO_x and particulate emissions, which are the direct result of burning standard aviation fuel inside today’s combustors. To that end, NASA has three teams—two from industry and one from government—looking at new ideas for reducing engine emissions. “The new concepts resulting from this

General Electric’s GEnx-1B engine includes the company’s TAPS combustor technology to reduce emissions. Credit: General Electric.



teaming will be tried out in a partial engine test in a ground test facility, as well as a full engine test on the ground or in flight, in order to conduct research at an integrated system level and demonstrate the benefits in a relevant environment," says Fay Collier, manager of NASA's Environmentally Responsible Aviation Project at Langley.

Ruben Del Rosario, project manager of the Subsonic Fixed Wing Project at NASA Glenn, says the agency and its industry partners "have some concepts that show potential for meeting our goals for reducing emissions," but notes that "we're very early in the process" of developing cleaner burning engine technology. "Now, as we continue to develop our concepts, we may find some of the ideas won't work as well as the others," Del Rosario says.

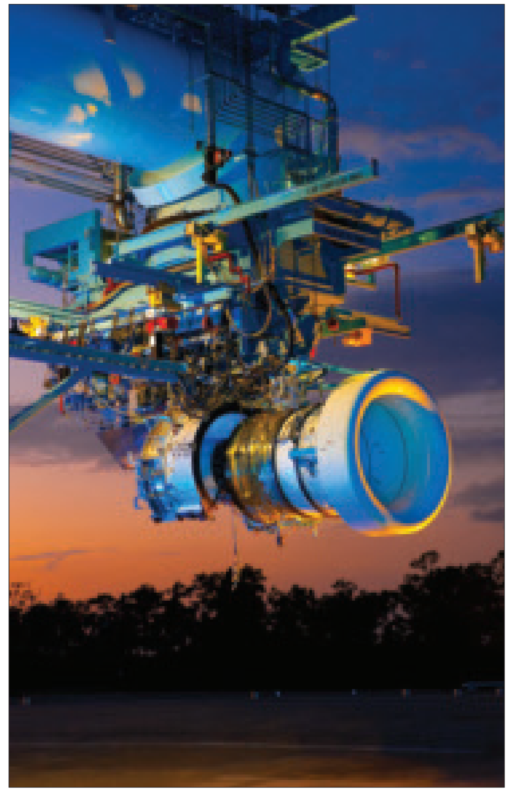
Of the three concepts now under development, General Electric is leading the first, Pratt & Whitney the second, and NASA the third, in-house. In each case, the designs are not necessarily brand new, but could best be described as evolutionary versions of concepts already flying. And in each case, engineers are concentrating on the mechanics and the resulting fluid dynamics of mixing the fuel and air more efficiently before it is ignited in the combustor—albeit with slightly different design philosophies.

"Our job is very difficult, because we have to reduce emissions regardless of how much pressure you operate at. So the key for NO_X reduction is to improve the fuel injector design to create a homogeneous mixing of fuel and air," says Chi-Ming Lee, head of the Combustion Branch at NASA Glenn.

A swirl of ideas

This NASA/GE technology program will further advance the industry's knowledge of ultra-high-pressure ratio engines, which GE considers to be the future of gas turbine engines in aviation. One area where the company has made great strides is in the engine combustor. GE has developed a concept called the twin annular premixing swirler, or TAPS. The company has been working on the concept for almost a decade and has recently introduced the technology on its GEnx engine, which powers Boeing's new 787 and 747-8, marking the first time TAPS is being used on a commercial product.

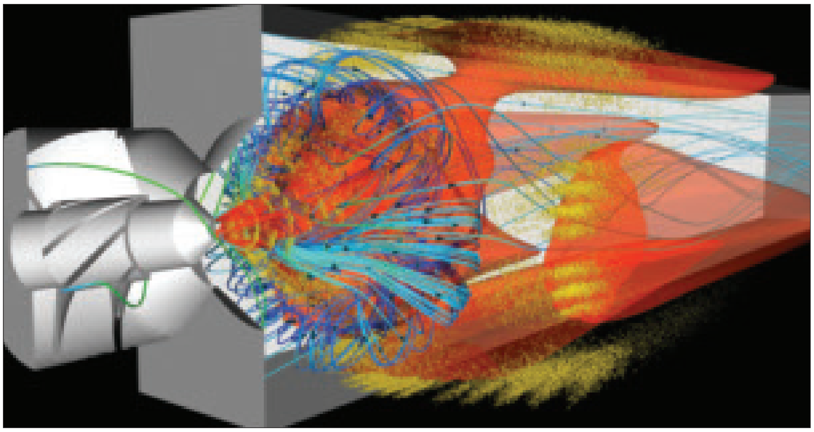
TAPS takes air from the engine's high-pressure compressor and directs it into a pair of ring-shaped, high-energy swirlers located next to the fuel nozzles. The swirlers, configured concentrically, create turbulence in the air flowing through the engine to help the air mix better with the fuel. The inner swirler operates when the airplane is idling or taxiing. The outer swirler operates at higher throttle settings. Combustion is staged. Fuel and air mix together at the front of the combustor and ignite. As hot gases move through the combustor, more air is added and the resulting mixture ignites again. This process distributes combustion to alleviate the hot spots responsible for unwanted emissions.



Pratt & Whitney's PurePower 1000G engine uses the TALON X combustor.

Tests have shown that swirling creates a more homogeneous and leaner mix of fuel and air, which then burns at a lower temperature and promotes fewer emissions without sacrificing overall engine stability. Operating the TAPS combustor at a lower temperature than would be the case with a fuel-rich mixture minimizes wear and tear on the combustor liner and other engine components further downstream.

Pratt & Whitney's approach calls for improvements to its long-established technology for advanced low NO_X, or TALON X, combustor. This design relies heavily on its ability to maintain a certain temperature profile that allows the emission reduction goals to be achieved. In this case, the initial mix of fuel and air in the combustor is fuel



In the LDI process, air flows through the swirler (shown as streamtubes, colored by velocity magnitude), producing a toroidal recirculation zone. Fuel is injected at the center of the venturi. The hot combustion zone (red isosurface) is shaped by the recirculation zone, which is critical to combustion stability, but also produces NO_X. Anthony C. Iannetti, NASA Glenn.

rich. Combustion gases combine rapidly with more air in what Pratt & Whitney calls an 'advanced quick quench zone,' which cools the hot gas and makes the mixture leaner. This is possible because of the combustor's ability to direct the flow of air and manage the overall heat load. As with the TAPS combustor, the TALON X minimizes operating temperatures, NO_X emissions, and engine wear and tear.

NASA's in-house concept is called lean direct injection. As the name implies, this combustor design is meant to operate with a fuel/air mixture that is leaner, thus lowering the operating temperature and making it more difficult for NO_X to form during the combustion process. In this case, a jet of liquid fuel is injected at high speed into a rapidly swirling airflow that promotes the mixing of fuel and air across the shortest possible distance. For this concept to work, the fuel and air must be mixed perfectly before combustion takes place.

Additional research contract awards are expected soon to further these combustor concepts and deliver hardware to NASA, says Dan Bulzan, the agency's technical lead for the clean energy and emissions subproject at Glenn. "The hardware is going to be different from what's out there, but the specific configurations and designs for the injectors, the pilots, the swirlers—all of that is considered proprietary right now."

NASA is working to get this technology mature enough for entry into service by 2025, but when it actually might see use in a commercial setting is not clear, according to Lee. Much will depend on what new regulations or standards are set on NO_X and carbon dioxide emissions in the near future, and on whether or not additional research on the hardware will be necessary to meet those goals.

"That's a very complex environment when you're talking about combustors. We are spraying fuel, mixing it with air. We need to understand how fuel flows and mixes, and be able to model it well so we can design newer, more efficient systems, and at the same time invent and test new materials. There's just a variety of ways we can work to reduce emissions in our engines," Dryer says.

Changing the fuel

Another way to change what is coming out of the engines is to find something different to put into the engine in terms of fuel. Using some types of alternative fuels could instantly eliminate whole categories of harmful emissions. Yet the cost to develop those fuels, in terms of price and their impact to other areas of the environment, makes it unclear what their ultimate value will be to the aviation industry.

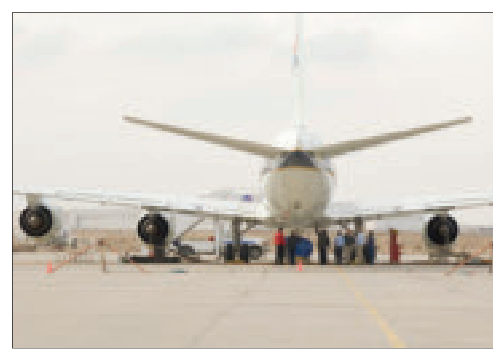
"I think they are promising, but we are a long way from having these alternate fuels available at the airport pumps," says Bruce Anderson, project scientist for the Alternative Aviation Fuel Experiment (AAFEX) at Langley. Through AAFEX, NASA has been working with the FAA, the U.S. military, industry, and universities to help characterize the potential value and effects of alternative sources of fuel on the environment and on aircraft systems.

The most comprehensive examination to date of alternate fuels was performed at NASA Dryden's Aircraft Operations Facility in Palmdale, California, in 2009. The experiment, known as AAFEX 1, used Fischer-Tropsch fuel, which is aviation fuel derived from coal and natural gas instead of the usual oil. Researchers used a DC-8 aircraft with four workhorse GE CFM-56 engines in a ground test. They equipped two of the four engines with sensors and put them through their paces with alternative fuel, running the engines at power levels representing idle, taxi, takeoff, climb out, approach, and landing.

The team showed that the fuel burned well and that particulates and NO_X were greatly reduced when pure Fischer-Tropsch fuel or blends of Fischer-Tropsch and standard JP-8 fuel were burned. Carbon dioxide emissions remained unchanged, and researchers noted problems with engine seals leaking when the aircraft fuel tanks were filled with pure Fischer-Tropsch fuel and not the JP-8 blend.

In March, researchers planned to con-


A maze of wires and tubing that connects data-collection instrumentation to the control centers is laid out on the pavement beside the DC-8 flying laboratory during synthetic fuels emission and performance testing.


Test instrumentation is set up behind the inboard engines of NASA's DC-8 airborne science laboratory during alternative fuels emissions and performance testing. Image credit: NASA Dryden/Tom Tschida.

duct a second round of ground tests, repeating many of the AAFEX 1 measurements of gas emissions and particle size, number, distribution, and composition with the same aircraft engines but with different fuel. This time, they planned to use a biofuel derived from the oil of algae or another natural source.

Competing demands

Complicating the picture for green aviation engine designers is the need to balance all the demands of increased fuel burn efficiency, reduced emissions, and quieter aircraft and engines—all with the promise and challenges of a new alternative fuel dangling in front of them.

It is easy to reduce NO_x emissions by lowering the temperature and the pressure within the combustor, but doing so decreases fuel efficiency. The reverse is true as well: Fuel burns more efficiently at higher temperatures, but more soot and carbon dioxide escape into the atmosphere.

"With the increasingly realistic expectation that alternative fuels will be adopted and served up at every airport, you can't expect to pick just one blend and stick with it," explains Rich Wahls, project scientist for the Subsonic Fixed Wing Project at Lang-ley. "The landscape of the future of fuels is wide open right now, and when someone buys an engine, they're going to use it for decades; so they're going to need to be able to use it with whatever fuels get developed in the future," he continues. "Fuel flexibility is key."

Achieving cleaner engines and cleaner skies rests on smart navigation through the landscape of possible solutions in the near term. What is clear for now is that propulsion technology is on the path to change.

Editor's note: *This is the second of four features describing the challenges associated with trying to invent a truly 'green' airplane. The first feature (March 2011) covered research into reducing nuisance noise around airports. Future articles will cover work on technology to boost fuel efficiency and enable the nation's air traffic management system to handle aircraft in a more environmentally responsible manner.*

After a historic 2005 encounter with comet Tempel 1, the Deep Impact spacecraft took on an extended mission that would provide a bonus for space scientists—and great savings to taxpayers. Its observations are helping astronomers recognize other Earth-like bodies and shedding light on the origin and history of our solar system.

Comet chasing makes deep impact on science

by Leonard David
Contributing writer

More bang for the buck: That is a fitting legacy for NASA's Deep Impact spacecraft. Launched in January 2005, it accomplished its primary mission later that year, in a celestial July 4 fireworks encounter with comet Tempel 1.

Deep Impact consisted of two parts: the Impactor and Flyby spacecraft. The Flyby segment unleashed the 815-lb copper-core Impactor that plowed into the comet, excavating debris from the interior of its nucleus. Images captured by cameras aboard both spacecraft caught the action: A large dust cloud billowed out from the comet but masked a clear view of the resulting impact crater. Still, the imagery revealed Tempel 1 to be far dustier and less icy than expected.

While Deep Impact's tangle with Tempel 1 was a history-making Independence Day event—one that delighted not just spacecraft designers but also comet specialists around the world—it was also a prelude of things to come.

Good to go

In the aftermath of the encounter at Tempel 1, mission scientists won approval from NASA to make use of the still healthy Flyby spacecraft—loaded with a 'good to go' set of instruments: two telescopes with digital color cameras and an infrared spectrometer.

In its extended mission mode, Deep Impact's name morphed into EPOXI—an abbreviation combining EPOCh (extrasolar planet observations and characterization) and DIXI (Deep Impact extended investigation—the flyby of comet Hartley 2). The spacecraft is still called Deep Impact.

During the initial phases of EPOXI, Deep Impact's EPOCh campaign that ended in August 2008 also provided scans of the Earth, in both visible and infrared wavelengths. Its observations are intended

Close-up view of Hartley 2 was taken during the flyby on November 4, 2010, by the spacecraft's medium-resolution instrument. Image credit: NASA/ JPL-Caltech/UMD.

to help gauge how to recognize Earth-like worlds around other stars. It was also one of three spacecraft to find clear evidence of water on the Moon.

The total cost of Deep Impact was $267 million (not including the launch vehicle)—$252 million for spacecraft development and $15 million for mission operations. The EPOXI extended mission price tag, $42 million, covers operations from 2007 to the project's ending at the close of FY11. This includes mission and science operations for both EPOCh and DIXI operations.

Stunning as well as surprising

On November 4, 2010, the spacecraft's onboard cameras captured spectacular images of comet Hartley 2 as part of the EPOXI mission. This was a much-heralded first: the first time in history that two comets—Hartley 2 and Tempel 1—had been imaged by the same spacecraft, by the same instruments, with the same spatial resolution.

The overall objective of the Hartley 2 flyby was identical to that of the trip to Tempel 1: to discover more about the origin and history of our solar system by learning more about the composition and diversity of comets. These objects hold material from the early days of the solar system, before the planets formed. Delving into the makeup of comets could help unravel the mysteries of planetary formation.

Moving from fuzzy to full-frame clarity, images of Hartley 2 took shape as Deep Impact drew closer to the surface, reorienting itself to maintain its focus on the comet nucleus. At the same time, the craft continued to point its high-gain antenna at Earth to begin downlinking nearly 5,800 images.

Hartley 2 proved stunning as well as surprising. Deep Impact flew through a storm of fluffy particles of water ice spewed out by the comet. Imagery relayed back to

Earth captured carbon dioxide jets streaming outward from the peanut-shaped body's rocky ends.

The comet's nucleus, or main body, is some 1.2 mi. long and 0.25 mi. across at the 'neck,' or narrowest portion of the object. The mass of the comet's nucleus is estimated at roughly 280 million metric tons.

An image montage shows Hartley 2 as the EPOXI mission approached and flew under it. The images progress in time clockwise, starting at the top left. The Sun is to the right. Image credit: NASA/ JPL-Caltech/UMD.

Deep Impact's visitation of Hartley 2 came in the midst of a cometary ice storm powered by jets of carbon dioxide gas carrying a couple of tons of water ice off the comet every second. The eye-popping images showed, at the same time, that a different process was causing water vapor to belch out of the comet's midsection.

"This is the type of moment that scientists live for," says Don Yeomans, a JPL senior research scientist who keeps a watchful eye on near-Earth objects.

Crystal snow globes

"We haven't even begun to get the science out of the data we have now," observes University of Maryland astronomer Michael A'Hearn, science team leader and principal investigator for the spacecraft's Deep Impact and EPOXI missions. "There should be a steady stream of results over a couple of years," he tells *Aerospace America*.

Recalling his reaction to the images of a hyperactive Hartley 2, "It was instantly obvious to all of us what we had," A'Hearn says. "Large chunks, and that they were probably ice…so our main reaction was elation. This was something that was sort of expected 10 years ago," he recalls, but not seen by other NASA missions, specifically the Deep Space 1 flyby of comet Borrelly in 2001, by the Stardust mission to comet Wild 2 in January 2004, or by Deep Impact's 2005 encounter with comet Tempel 1.

"It just wasn't there. So, in some sense, it was, 'Oh, this is what we've been expecting for the last four comets and not finding,'" he says. "What it illustrates is that there is a class of comets that really works in a different way from the other comets."

Jessica Sunshine, EPOXI deputy principal investigator at the University of Maryland, points out that the carbon dioxide jets blast out water ice from specific locations in the rough areas, resulting in a cloud of ice and snow. "Underneath the smooth middle area, water ice turns into water vapor that flows through the porous material, with the result that close to the comet in this area we see a lot of water vapor."

A'Hearn points to evidence of large chunks around comets such as Hartley 2 having been found with the powerful Arecibo radio telescope in Puerto Rico. But the Arecibo telescope is not able to detect individual particles or to determine the makeup of the chunks. Around Hartley 2, Deep Impact clearly imaged clouds of ice particles ranging in size from golf balls to basketballs.

Recalls EPOXI mission coinvestigator Peter Schultz of Brown University, "When we first saw all the specks surrounding the nucleus, our mouths dropped." Stereo images disclose that there are snowballs in front of and behind the comet's nucleus, "making it look like a scene in one of those crystal snow globes."

Sunshine notes that it was previously thought that water vapor from water ice was the propulsive force behind jets of material coming off a comet's nucleus.

"We now have unambiguous evidence that solar heating of subsurface frozen carbon dioxide, directly to a gas—a process known as sublimation—is powering the many jets of material coming from the comet," Sunshine says. "This is a finding that could only have been made by traveling to a comet, because ground-based telescopes can't detect carbon dioxide, and current space telescopes aren't tuned to look for this gas," she notes.

The spacecraft at Hartley 2 provided the most extensive observations of a comet in history, notes Ed Weiler, associate administrator for the Science Mission Directorate at NASA Headquarters. "Scientists and engineers have successfully squeezed world-class science from a repurposed spacecraft at a fraction of what a new science project would have cost the taxpayers."

A separate saga

Even as scientists exult over the comet Hartley flyby, the extended journey of Deep Impact is a separate saga.

Built and designed by Ball Aerospace & Technologies, Deep Impact has an extra dividend for space science discovery, says David Taylor, president and CEO of the Boulder, Colorado, company.

"Deep Impact is proving to be a spacecraft that keeps on giving," Taylor says. "When it launched in January of 2005, the Deep Impact mission [to Tempel 1] was the priority, so it's extremely rewarding to see a 'three-peat performance' six years later that provides more beneficial science data."

"Because the vast majority of mission costs are [for] the initial design, testing, and launch, the recycled Deep Impact provided savings on the order of 90% that of a hypothetical mission with similar goals, starting from the ground up," according to a Ball Aerospace press statement.

Tim Larson, the EPOXI project manager at JPL, also emphasizes Deep Impact's ability to take on the job of surveying comet Hartley 2. The comet was discovered in March of 1986 by Malcolm Hartley, an English-born astronomer currently based in Australia at the Anglo-Australian Observatory in New South Wales.

"The spacecraft was still in good shape, willing to do more work. It just needed a new reason for living," Larson says. "And NASA, in its effort to go green by reusing spacecraft and recycling as much as possible, approved a new mission for the project and enabled us to embark on this new effort of retargeting the spacecraft to go to comet Hartley 2."

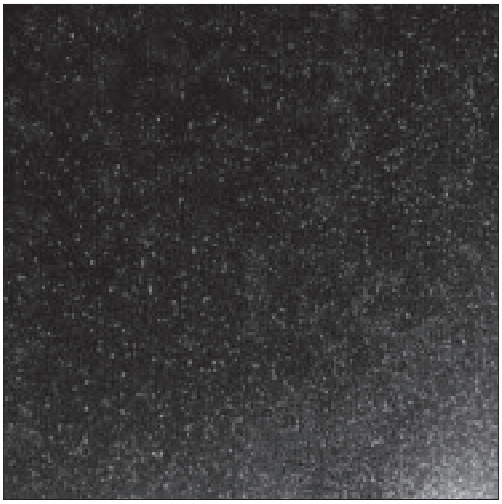
To get in synch with the comet, Larson explains, the EPOXI mission had to adjust the trajectory of the spacecraft. And after three-and-a-half orbits around the Sun, seven burns of on-board thrusters, and three gravity assists around Earth, Deep Impact got close to the comet to accomplish this bonus mission.

Humming along

In the months leading up to its closest encounter with Hartley 2 late last year, Deep Impact responded to multiple commands to align itself for optimum viewing. Approximately the size of a subcompact car, the spacecraft had already used about half of its 85 kg of hydrazine fuel to complete the encounter with Tempel 1.

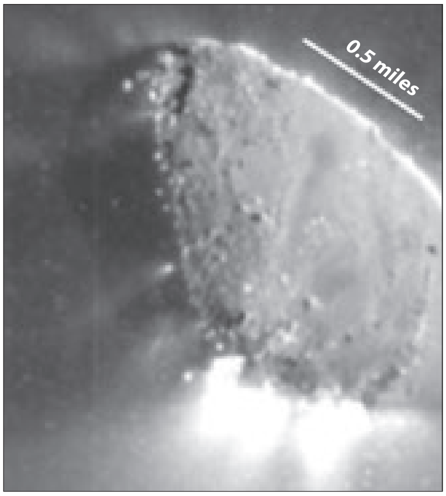
Before its Hartley 2 meeting, Deep Impact spent over a year and a half in 'hibernation,' with one brief wake-up (less than one day total in cruise state), says Amy Walsh, the systems engineering lead at Ball Aerospace for the EPOXI mission. "Essentially we ran our safing sequence and also disabled our autonavigation program…just to make sure that it didn't get confused."

It was in late July 2005 that the spacecraft was put in hibernation. For the next two years it was awakened roughly once every six months for health and safety checks, then put back to slumber.



This zoomed-in image from EPOXI's high-resolution instrument shows the particles swirling in a 'snowstorm' around the nucleus of Hartley 2. Scientists estimate the largest particles range in size from golf balls to basketballs. They have determined these are icy particles rather than dust. The particles are believed to be very porous and fluffy. Image credit: NASA/JPL-Caltech/UMD.

As Deep Impact was revved up for Hartley 2, the spacecraft was found to be stable in terms of electronics and other systems. "Everything was humming along," says Walsh. "So it ended up being a very clean and uneventful hibernation phase," she tells *Aerospace America*.



This enhanced image—one of the closest taken of Hartley 2—shows jets and where they originate from the surface of the object. There are jets outgassing from the sunward side, the night side, and along the terminator—the line between the two sides. The Sun is to the right. Image credit: NASA/JPL-Caltech/UMD.

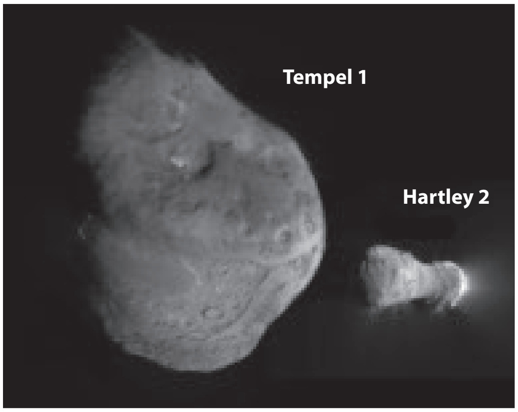
As plans for the Hartley 2 flyby jelled, spacecraft sequences were fleshed out, reviewed, and wrung out on test benches, with Ball Aerospace putting its seal of approval on the sequences, Walsh notes.

Still, there was a big unknown concerning the comet encounter: Exactly where would the celestial wanderer be?

"We had confidence in our spacecraft's ability to perform the encounter. We knew that the products we were putting onboard were those needed in order to follow the comet. But what we didn't know was whether the comet was going to hold still and let its picture be taken. It had moved around quite a bit. So the thing that we were doing at the last minute was updating target tables.

"We were doing trajectory correction maneuvers right up until two days before encounter, to try and make sure that our closest approach was right in the window that we were aiming for," Walsh explains. "It was pretty well spot on. The autonavigation solutions matched up really well with ground-based solutions. In the end, the

Deep Impact provided imagery of Tempel 1 and Hartley 2. Credit: NASA/JPL-Caltech/UMD/McREL.



comet did settle out and not do any moving around on us."

The spacecraft was clocked as traveling by Hartley 2 at a speed of 27,560 mph.

Nail biting on encounter day

On encounter day, the spacecraft team had further tension regarding just how energetic the comet would turn out to be…and there were sure to be surprises.

"Essentially, we were doing the same kind of thing we did on the last comet flyby, only without the Impactor," Walsh says. "One thing we decided not to do is go into our debris shield mode...instead we imaged comet Hartley 2 the entire way through."

That decision did not come without extra nail-biting, Walsh admits. "It was something that definitely got a lot of scrutiny," with concern over what Deep Impact would bump into in terms of particle hits of dust and ice. Although the comet was throwing off large bits of particles, the scientific consensus centered on the roughly 435-mi. separation between the spacecraft and Hartley 2.

From that flyby distance, "the risk to the spacecraft was less than on the prime mission," says A'Hearn. Also, given that all the big things are very close to the comet's nucleus, it was deemed fairly safe. "This is an extended mission. You are willing to take bigger risks. You don't need to push it down to smaller risks."

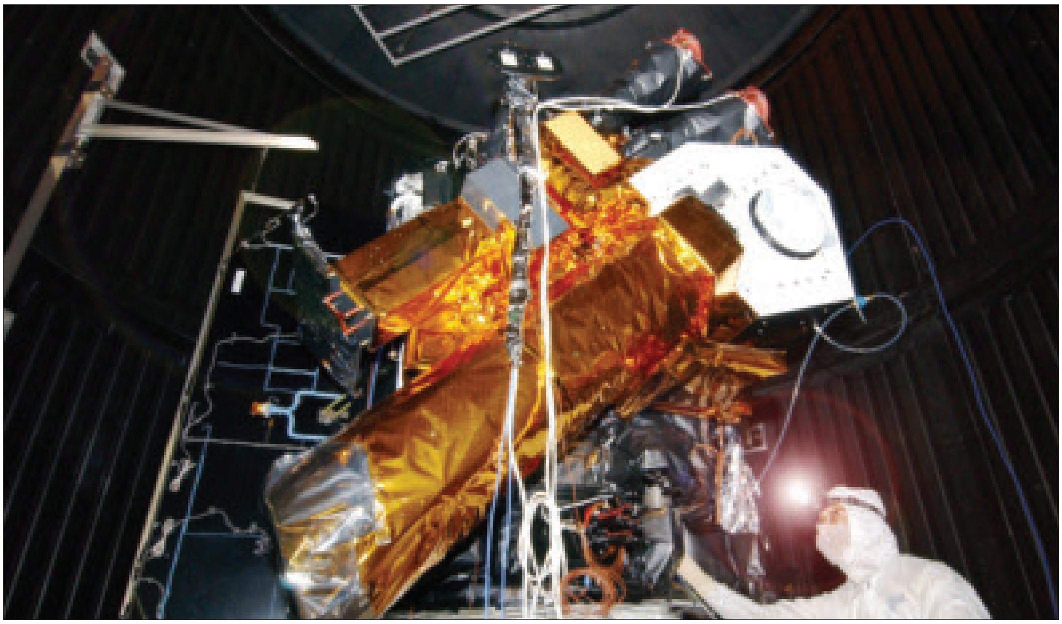
A'Hearn reports that a look back at data post-encounter points to about nine particle hits on Deep Impact. "The relatively small ones didn't do any damage, just enough to deflect the spacecraft. You see it in the gyros and in the attitude control system reacting," he explains.

One nagging problem has plagued the exploits of the Deep Impact spacecraft. Images taken by EPOXI's high-resolution camera were out of focus because of an error in its testing prior to launch. However, through a deconvolution algorithm, image processing experts have been able to "undo the defocus." That task is hard to do, with great care taken to sharpen the imagery while not introducing artifacts in the high-resolution photos.

Error bars and different cultures

Looking back on his experience as principal investigator for both missions, A'Hearn offers advice on the balance that needs to be struck between scientists and spacecraft engineers.

The Deep Impact spacecraft was designed and built by Ball Aerospace. Credit: Ball Aerospace.



A key lesson he learned is how important it is to sit with the engineers and do tradeoffs, to get the best you can without overstressing either the spacecraft or the instrument…or the engineers themselves.

"The engineers want to know your requirements, and they'll make sure these can be met. The scientists want to know what the spacecraft is capable of doing, and we'll use it as best we can. So that totally different mindset is why it's important to have an iterative discussion," A'Hearn says.

But, he continues, "The biggest thing is understanding the problems of language." So many common terms are used differently by scientists and engineers, he notes. "I still keep stumbling over terms that don't mean quite the same thing" in the two communities.

An example, he says, is error bars on data. "Astronomers nearly always think in plus and minus one sigma. Engineers always think plus and minus three sigma. Unless you are very precise in your terminology, you are liable to convey the wrong impression." He also highlights the nature of test beds and of critical sequences that can mean dissimilar things in the two different cultures.

Two days after the closest approach to Hartley 2, the spacecraft entered a departure phase, making look-back observations during this 21-day segment of the mission. At the end of that phase, and after a final calibration run, the spacecraft was set to be decommissioned, and destined to continue following its endless orbit of the Sun.

On the other hand, discussions of running Deep Impact in an observatory mode are now under way. Ideas on uses for the craft include watching for near-Earth objects, or serving as an additional test bed for an 'Interplanetary Internet' concept.

"I've enjoyed operating this spacecraft," says Walsh. "It has performed really well all the way around. The overall health of the spacecraft is excellent. I'd be happy to keep going and find new targets."

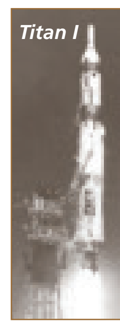
Out of the


Soyuz T-15

25 Years Ago, May 1986

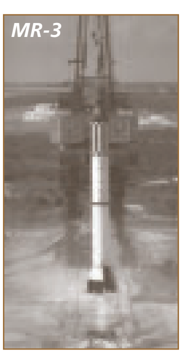
May 6 For the first time, a crew transfers from one space station to another, moving from Mir to Salyut-7. The cosmonauts use the Soyuz T-15 transport module to make the 1,800-mi. trip between the two outposts as the mission is broadcast over USSR television. NASA, *Astronautics and Aeronautics, 1986-90*, p. 37.

50 Years Ago, May 1961


Titan I

May 3 The Titan I ICBM achieves its first launch from an underground silo, at Vandenberg AFB, Calif. This is the first time any ballistic missile is fired from a silo, which in this case is 146 ft deep. Aircraft & Missiles, June 1961, p. 11; D. Baker, Spaceflight and Rocketry, p. 118.

May 4 An open-gondola Stratolab balloon carrying two Navy officers, Cdr. Malcolm D. Ross and Cdr. Victor A. Prather, is released from the deck of the USS Antietam in the Gulf of Mexico and ascends to a height of 113,500 ft. This breaks the previous balloon altitude record, set by Air Force Capt. Joseph Kittinger, who went to 102,800 ft. Tragically, however, in this latest attempt Ross loses his life during the subsequent recovery of the balloon. The Aeroplane, May 11, 1961, p. 510; *Aviation Week*, May 15, 1961, p. 39.


MR-3

May 5 Navy Cdr. Alan B. Shepard Jr. becomes the first American in space with the launch of the Mercury-Redstone 3 spacecraft on a 15-min 22-sec suborbital flight, using a modified Redstone missile as the booster. During the mission, in which the spacecraft reaches a 117-mi. altitude, 78 voice communications and 27 major capsule functions are monitored. *Aviation Week*, May 15, 1961, pp. 31-32.

May 9 The first B-52H is delivered to the 379th Strategic Wing, Strategic Air Command, Wurtsmith AFB, Mich. *Aviation Week*, May 15, 1961, p. 39.

May 9-10 Twenty-four Atlantic Research Arcas Robin solid-fuel sounding rockets are fired at 1-hr intervals from Eglin AFB, Fla. They of 16-45 mi. and provide the greatest amount of meteorological data recorded to date. *Aviation Week*, May 22, 1961, p. 33; *Aircraft & Missiles*, July 1961, p. 11.

May 10 The Gnome Augusta Bell 204B helicopter, powered by a De Havilland Gnome free turbine engine, makes its first flight after only 25 min of ground running of the engine. *The Aeroplane*, May 18, 1961, p. 540.

May 17 The experimental 'flying-saucer-shaped' Avrocar makes its first free flights at Toronto International Airport. Developed as a tactical weapon for the U.S. Army by Avro Aircraft, a subsidiary of A.V. Roe Canada, it makes two hover flights of about 15-20 ft from the ground for about 5 min each. English-born Jack Frost designed the plane. *The Aeroplane*, May 25, 1961, p. 573.

May 17 A new world's speed record for helicopters is set by a Navy twin-turbine Sikorsky HSS-2 when it reaches 192.9 mph at Bradley Field, Windsor Locks, Conn. *The Aeroplane*, May 25, 1961, p. 575; *Aviation Week*, May 22, 1961, p. 33.

May 29 The European Industrial Space Study Group is formed in Paris to evaluate possible European space programs, projects, and their budgets, as announced by Britain's Hawker Siddeley Aviation at the European Space Flight Symposium in London. *The Aeroplane*, July 6, 1961, p. 6.

And During May 1961


F-105

—Republic all-weather Mach-2+ F-105 fighter bombers begin phasing into the USAF in Europe, with the first F-105 arriving at Bitburg Air Base, Germany, about 300 air miles from the East German border. *Aviation Week*, May 22, 1961, p. 74.

—General Electric operates a liquid bipropellant plug nozzle rocket engine of 50,000-lb thrust at the Malta Test Station near Saratoga, N.Y. This is claimed as the first radical change in rocket engine configurations. *Aviation Week*, May 15, 1961, p. 68.

75 Years Ago, May 1936

May 7 Noted pilot Jean Batten of New Zealand is made a Chevalier of the Legion of Honor by the Aero Club of France for her record flight from England to Brazil in November 1935. *The Aeroplane*, May 13, 1936, p. 590.

May 9 Helen Richey achieves a women's altitude record for light planes in the fourth category, at Hampton Roads, Va., when she flies her Aeronca to 18,448 ft. *Aircraft Year Book, 1937*, p. 411.

May 12 The world's largest high-speed wind tunnel, with an 8-ft throat and air speed ranges of 85-500 mph, is placed in operation at NACA's Langley Aeronautical Laboratory, under the direction of Russell G. Robinson. E. Emme, *Aeronautics and Astronautics, 1915-60*, p. 34.

May 14 Germany's famed dirigible, the Hindenburg, completes its first passenger flight from Europe to the U.S. in the record time of 61 hr 38 min. This beats the earlier record of the dirigible Graf Zeppelin by 6 hr 54 min. The Hindenburg, with 51 passengers, lands at NAS Lakehurst, N.J. *Aero Digest*, June 1936, p. 72.

May 14 Howard Hughes makes a new unofficial nonstop record flight between Chicago and Glendale, Calif., piloting his Wright Cyclone-G-powered Northrop over the route in 8 hr 10 min 25 sec. The fastest previous time, established by a TWA Douglas DC-2, was 12 hr 45 min. Reportedly, Roscoe Turner had bettered that time in an unofficial test. *Aero Digest*, June 1936, p. 72.

May 15 All records for flights between England and Cape Town, South Africa, are broken by British pilot Amy Johnson Mollison in her Percival Gull. She lands at Croydon Airport, London, after covering the 6,700-mi. trip in 4 days 16 hr 16 min. Mollison made the outbound trip in 3 days 6 hr 26 min. The most laudable feature of her outward flight was the 2,000-mi. crossing of the Sahara, flying blind at night. Flight Lt. Tommy Rose of England made the previous outbound record in 3 days 17 hr 37 min, and the return trip in 6 days 6 hr 57 min. *Flight*, May 14, 1936, p. 513.

100 Years Ago, May 1911

May 16 After flying for only two months, the Zeppelin LZ 8 Ersatz Deutschland is destroyed by a strong crosswind while being pulled from its shed before a flight. There are no casualties, but the airship is a total loss as the nose is shattered and the hull broken in several places. LZ 8 was flying for Delag, the scheduled operator of a fleet of rigid airships that carry passengers on sightseeing flights around Germany. Since its inaugural launch in March, LZ 8 has completed 33 flights and carried 458 people over a distance of 1,478 mi. in a total flight time of 47 hr. J. Stroud, *European Transport Aircraft Since 1910*, pp. 374-375.

And During May 1911

—Great Britain passes the first British aviation bill, known as the Aerial Navigation Act of 1911, which lays down safety rules. *Flight*, June 3, 1911, p. 481.


STRATEGY FOR SUCCESS
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