7-8 AEROSPACE AMERICA JULY-AUGUST 2009

July-August 2009

AEROSPACE AMERICA

A hot rod for the solar system

ABL aims at final tests

Business aircraft market falls hard

A PUBLICATION OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

AEROSPACE AMERICA

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Aerospace America (ISSN 0740-722X) is published monthly by the American Institute of Aeronautics and Astronautics, Inc. at 1801 Alexander Bell Drive, Reston, Va. 20191-4344 [703/264-7577]. Subscription rate is 50% of dues for AIAA members (and is not deductible therefrom). Nonmember subscription price: U.S. and Canada, $163, foreign, $200. Single copies $20 each. **Postmaster: Send address changes and subscription orders to address above, attention AIAA Customer Service, 703/264-7500.** Periodical postage paid at Herndon, VA, and at additional mailing offices.

40,000 copies of this issue printed. This is Volume 47, No. 7-8.

AEROSPACE AMERICA®

is a publication of the American Institute of Aeronautics and Astronautics

Send materials to Craig Byl, AIAA, 1801 Alexander Bell Drive, Suite 500, Reston, VA 20191-4344. Changes of address should be sent to Customer Service at the same address, by e-mail at custserv@aiaa.org, or by fax at 703/264-7606.
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July-August 2009, Vol. 47, No. 7

American Institute of Aeronautics and Astronautics

Editorial

A winning combination

Even in the face of declining air passenger traffic and concomitant declining revenues, there is still much good news to be found on the aviation front. Efforts to conserve and improve fuel consumption, through a mix of streamlined numbers of flights and innovative air traffic management systems, combined with new engine start-ups that burn leaner and cleaner and the exploration of new fuel mixes and entirely new families of fuels, should not only save both fuel and cash, they are a net positive in efforts to protect the environment.

For example, in Europe, among the numerous efforts aimed at improving energy efficiency and lessening the environmental impact of air traffic is the European Commission's Single European Sky initiative. By restructuring the airspace based on usage rather than national borders, thus streamlining and harmonizing air traffic management throughout the continent, the resulting air traffic patterns should increase efficiency of fuel consumption while reducing aircraft emissions.

In the U.S., the Next Generation Air Transportation System is being developed with many of the same goals in mind. NextGen aims to transform the national airspace system, moving it from a ground-based operation to one using global positioning system satellites. According to the Federal Aviation Administration, "When fully implemented, NextGen will safely allow more aircraft to fly more closely together on more direct routes, reducing delays, and providing unprecedented benefits for the environment and the economy through reductions in carbon emissions, fuel consumption, and noise."

At the same time, the world's two largest commercial aircraft manufacturers, Boeing and Airbus Industrie, are designing their latest aircraft with fuel economy as a prime driver. According to company data, Boeing's newest airliner, the 787, was designed to use 20% less fuel than other aircraft on comparable routes. New engine advances by General Electric and Rolls-Royce, both suppliers to the Dreamliner, are expected to contribute up to 8% of increased efficiency. At the same time, Airbus boasts that its A350 XWB uses "innovative technologies and procedures that result in improved fuel efficiency, reduced emissions and lower noise levels during departure, cruise and arrival."

While all of this activity is going on, there are also exploratory efforts aimed at examining the use of alternative fuel sources. Everything from solar power to hydrogen fuel cells to algae-based fuels to a mix including oil from the tropical jetropha seed is being tested. Several airlines have already flight tested some of these—Continental Airlines flew a Boeing 737 with a 50-50 mix of regular fuel and an organic; Virgin Atlantic flew from London to Amsterdam with organic, oil-based fuel in one of its fuel tanks, and Air New Zealand and Japan Airlines have conducted biofuel test flights—and others are in the planning stages.

Although they account for only 2-4% of greenhouse gas emissions, airlines and aircraft and engine manufacturers have moved to the forefront in efforts to bring those numbers down. And while these may be expensive efforts in the short term, the long-term payoff should prove to be a boon not only to the world we live in but to the bottom line. Not a bad return.

Elaine Camhi
Editor-in-Chief

Fuel efficiency improvements escalate

It is 2050. Nearly 90% of the world's airliners have algae-derived fuel in their open-rotor engines. A new generation of blended-wing aircraft is about to enter service, powered by a global network of directed energy beams and flown, of course, without pilots on board. The airspace system is working at 98% efficiency. Every aircraft—at least, those subsonic aircraft that operate within the Earth's atmosphere—can fly the most fuel-efficient route possible, changing height and direction automatically to optimize the prevailing weather and traffic conditions.

Meanwhile at the world's busiest airport, in the Persian Gulf, aircraft land and take off every 20 sec. Their final descent paths vary between 3 deg and 7 deg, to offset the wake vortex problems caused by a 20-seat aircraft following 1 n.mi. behind a 2,000-seater. Once on the ground, planes taxi automatically at high speed to their gates. Fatal airliner accidents have been reduced to just one or two a year.

Short-term focus

For many in the aerospace sector, the burning issue is how the industry will survive the next few months, rather than how it will deliver an ideal air transport system in the next 40 years. Over the past year, manufacturers have come under intense pressure to concentrate on making the current aircraft fleet more affordable.

For example, Airbus and Boeing both have developed some fuel efficiency improvements to their current short/medium-haul models. In April Airbus announced that its A320 family would benefit from new aerodynamic improvements—a redesign of the surge tank inlet, a redesign of upper belly fairing, and a reshaped engine pylon—that together will produce a 1% cruise drag reduction. In the same month Boeing also announced an efficiency improvement package to its Boeing 737 NG range, targeting a 2% reduction in fuel consumption by 2011 through a combination of airframe drag reduction and CFM-56 engine improvements.

Reality check

To meet the targets manufacturers and research agencies have set for 2020, there will need to be some major "step-change" improvements in engine and airframe design, along with the year-on-year incremental fuel efficiency developments. For example, Europe's "Clean Sky" consortium of aerospace industries has pledged €1.6 billion over the next five years to develop technologies that will deliver a 50% reduction in CO_2 emissions through drastic reduction of fuel consumption.

But how realistic is this?

Historic trends in improving efficiency levels show that aircraft entering today's fleets are 70% more fuel efficient than they were 40 years ago, which suggests aircraft fuel efficiency is improving at a rate of 17.5% every 10 years. These efficiency levels have been achieved with one or two step changes in design—such as the introduction of high-bypass engines—coupled with year-on-year "tactical" improvements. The pace of these incremental, or short-term, improvements in fuel efficiency has been stepped up in recent years—IATA's efficiency goal of 10% fuel improvements between 2000 and 2010 was reached before the end of 2006.

Pressure to reduce the environmental impact of aviation and escalating fuel costs over the past few years has led to several initiatives for finding new ways to remove weight from aircraft, increase fuel efficiency, and provide the most direct—or the most efficient—routes from airport to airport. For example, CFM International's Tech Insertion, International Aero Engines' SelectOne, and Rolls-Royce's Extended Performance

Winglets can offer a 5-7% improvement in fuel burn.

upgrade for the Trent 700 all promise fuel burn improvements of at least 1% for engines currently in service.

Recent turbulent economic times have added further urgency to this process, creating even more pressure to deliver fuel-saving initiatives now, rather than in the next five years.

For manufacturers, there are four major areas where a current aircraft's economic performance can be improved—better aerodynamics, more efficient engines, lighter interiors, and innovative support packages to keep down maintenance, repair, overhaul, and ownership costs.

In Europe, where the costs of airline operations are higher than anywhere else in the world, recent months have seen the launch of several new weight-saving/efficiency-improving initiatives in current aircraft operations.

INTERNATIONAL AIRLINE FUEL COSTS (IATA)

Year	Percentage of Operating Costs	Average Price per Barrel of Crude, $	Breakeven Price per Barrel, $	Total Fuel Cost, $ billions
2003	14	28.8	23.2	44
2004	17	38.3	34.5	65
2005	22	54.5	51.8	91
2006	24	65.1	65.0	107
2007	28	73.0	81.1	136
2008*	32	99.0	93.6	168
2009*	25	50.0	46.8	116

*Forecast.

Another look at winglets

Around 85% of all new Boeing 737s are fitted with winglets, which can deliver a 5-7% improvement in fuel burn, according to winglet manufacturers Aviation Partners (API). Over 3,000 aircraft currently in service have saved an estimated 1.6 billion gal of fuel, according to API, but none of these are Airbus aircraft. In May, Airbus announced it was reconsidering its winglet policy and had recently completed a flight test campaign to identify both the performance and economic benefits that these devices could offer. According to Stuart Mann, director of product marketing for the Airbus A320 family, "The analysis of the winglet testing results is under way at the moment, but that is certainly one of the elements that we are looking at for the future to ensure that the A320 family stays competitive."

The cost-benefit analysis revolves around the tradeoff between increased aerodynamic efficiency and greater weight and cost. According to API:

"Winglets cost about $725,000 and take about one week to install, which costs an extra $25,000-$80,000. Once fitted, they add 170-235 kg (375-518 lb) to the weight of the aircraft, depending upon whether they were installed at production or a retrofit. The fuel cost of carrying this extra weight will take some flying time each sector to recover, although this is offset by the need to carry less fuel because of the increased range. In simple terms, if your average sector length is short (less than 1 hr), you won't get much benefit from winglets—unless you need any of the other benefits, such as reduced noise, or you regularly operate from obstacle-limited runways."

Losing weight

Decreasing weight of aircraft in service has been another feature of recent research. Airbus has created a new galley concept: SPICE, or Space Innovative Catering Equipment. "Instead of putting ATLAS trays in heavy trolleys, we put them in lightweight boxes," said Bob Lange, Head of Aircraft Interiors Marketing. "Foldable carts transport the boxes during service, bringing huge benefits in weight and space savings on board aircraft, assessed to be over one tonne on an A380 and potentially 10 more economy seats."

Meanwhile seat manufacturers are also developing new lightweight concepts. At the Hamburg Aircraft Interiors Exhibition in March, seat manufacturer Recaro showed a prototype Stingray economy class concept seat which, at 6 kg, is 4 kg lighter than the average economy seat. Weight savings have also resulted from integrating intelligent new designs and combining lightweight materials in new ways: In the concept seat a new aluminum alloy was used along with titanium and additional CFRP materials.

Other approaches

These new lightweight materials and interior structures are also bringing down the cost of ownership. But many believe the real savings are to be made outside the aircraft cabin.

According to IATA, each 1% improvement in fuel efficiency across the industry can lower fuel costs by $700 million a year. Its "save a minute" campaign is aimed at saving one minute per flight through better airspace design, procedures, and management, to reduce total industry operating costs by over $1 billion per year.

A key to this is opening new, more direct flight routes and realigning others to reduce fuel requirements. In April a new initiative was launched by European airport, airline, and air navigation service provider trade associations (ACI Europe, CANSO, Eurocontrol, and IATA) to implement continuous descent approaches (CDAs) at up to 100 airports across Europe by the end of 2013, saving airlines 150,000 tonnes of fuel and €100 million a year. In a CDA, an aircraft flies a smooth approach into an airport rather than the traditional stepped approach, reducing fuel burn by 50-150 kg for a short- to medium-haul aircraft.

As part of this initiative, Italy's air navigation service provider ENAV has launched a flight efficiency plan. During 2008-2009 the plan will save 67,300 tons of fuel for airlines flying into and out of Italy and will shorten routes by 2,588,000 km.

Step changes

But to reach the fuel efficiency targets set by researchers, manufacturers, and intergovernment bodies such as the European Commission, new step-changing technologies will be needed. In the medium term, aircraft operators can look forward to a new generation of more fuel-efficient engines pioneered by the Pratt & Whitney PW1000G geared turbofan engine. This engine has already achieved near double-digit improvements in fuel burn over current models and will make its appearance on the new Mitsubishi Regional Jet and Bombardier C-Series airliner.

Meanwhile, CFM International's advanced LEAP-X demonstrator engine is due to start tests in 2012 with possible certification in 2016. It reduces fuel burn by up to 16% over current CFM56 Tech Insertion models. Even greater savings will be possible with new open-rotor engines currently being researched; all these engines should be mature by the time the Airbus A320 and Boeing 737 replacement aircraft appear.

Also, the successful completion of the Single European Sky program by 2025—allowing for more direct routings in Europe's airspace and reduced delays on the ground—could in theory deliver reduced fuel burn by a further 6-12%. Operational improvements can bring an additional 2-6% fuel saving.

According to a March 2007 statement by Philippe de Saint-Aulaire, Airbus vice president for environmental affairs, Airbus is serious about targeting a 50% reduction in aircraft fuel consumption by 2020: Airframe improvements would provide about 25% of the reduction, engine improvements 10-15%, and improved air traffic management 10%. The 25% improvement is based on research by Airbus into drag reduction.

According to a paper given by Géza Schrauf of Airbus at the Fifth Community Aeronautics Days conference held in Vienna in June 2006, Airbus identified three major areas of drag reduction potential: a 15% improvement in the area of viscous drag (through the introduction of laminar flow technology, turbulence, and separation control technologies), a 7% improvement in lift-induced drag (through shape optimization, adaptive wing devices, wing-tip devices, and load control technologies), and a 3% improvement in other drag areas such as wave drag and interference drag (through the development of new shock control technologies and novel configurations).

A further step-change in aerodynamics would be the advent of blended and advanced swept-wing aircraft designs. The VELA project, part of the European Commission's sixth framework program (2000-2006), has already researched blended wing concepts that would deliver fuel consumption improvements of up to 30% over current aircraft designs. Led by Airbus, with a team of 17 partners, the program investigated the benefits, potential, and problems of a flying wing transport aircraft; two configurations were built for wind tunnel testing by the Institute of Aerodynamics and Flow Technology, DLR, Germany.

The net result

Taken together, these incremental and step-change improvements in fuel efficiency suggest that the long-term targets are indeed possible, though some aspects will be more challenging than others.

"Yes, the Single European Sky would reduce unnecessary flying by 12%, so it would reduce emissions by 12%, and costs by 12%. If you listened to the promises, anything seemed possible," according to Andrew Charlton of Geneva-based ATM consultants Aviation Advocacy. "Sadly, the figures do not support it. Particularly when you consider that air traffic is expected to double, does anyone actually believe that there is a 24% improvement just sitting out there? There is likely to be a 4% improvement in ATC to 2020, assuming that everything else works."

But with engine manufacturers advanced in their plans to turn next-generation concept powerplants into working models—and airframe manufacturers developing ever lighter interiors and subsystems—perhaps the highly ambitious targets of 50% fuel efficiency improvement in the next 10-15 years may not be so fanciful after all.

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Correspondence

UAV worldwide roundup—2009 (April, page 30) was enjoyable but not the "rest of the story." I'm not sure if the whole truth matters but the factual content regarding deployment of Pioneer in Desert Storm is in part misleading. I was a Navy lieutenant Pioneer mission commander and the assistant OIC of VC-6 Det 2 on board the USS Missouri. The first deployment of Pioneer against hostiles was from the Missouri just off Al Khafji in early February. For three days we pounded the southern KTO bunker, artillery sites, and targets of opportunity to help discourage any more Iraqi excursions into Saudi Arabia.

The Missouri was given the combat action citation for actual engagement and exchange of fire with enemy. The Wisconsin took the second mission, followed by a third Missouri mission. Both then moved into the northern KTO.

The Wisconsin took the northern gun line several hours prior to the ceasefire. This was her limited opportunity only after the Missouri expending all five Pioneer assets during the ground war (one was lost to hostile fire, the rest fatigue); having lost the last one in the wee hours on Monday (the last day). Capt. Kaise of the Missouri then decided to pull out and give the Wisconsin the closing rounds because he concluded that without his UAVs he was blind.

This was the real turning point, prior to the actual first engagement in early February and the first use of Pioneer in combat. All of the Pioneer units (two Navy, three Marine, and one Army) were instrumental in leading the aware-

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ness of UAVs, but the Missouri-UAV tactical mission successes were overshadowed by the historically sensational but tactically minor event on Failaka Island.

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✈✈✈

I just read the commentary **Addressing Climate Change with help from abroad** (April, page 3) by Jerry Grey. I apologize if I appear critical and I am not specifically criticizing Grey's commentary, but I grow weary of all these articles where AA is promoting the very questionable theory of climate change. Climate change appears to be more of a business and power grab, not any real environmental problem. There are no consequences of climate change that are going to affect the entire world. Climate research is interesting and informative, but way too much money has been spent on this.

Those who edit *Aerospace America* ought to be aware that most aerospace scientists and engineers with technical training and experience are very, very skeptical of the idea of man-made global warming being a genuine concern. That has been my experience with a high percentage of colleagues I've worked with. Just because politicians and journalists keep repeating this stuff over and over does not make it true. In fact, ABC-News polls leading up to last year's election showed that less than 1% of the respondents thought global warming was a major issue. No wonder no one I work with thinks much of it.

Frankly, I believe the theory of anthropogenic global warming is a farce and not anything close to being worthy of the aerospace industry, or Western countries for that matter, sacrificing what may amount to trillions of dollars of cost and economic growth in the coming decades for something that very likely is a nonissue, just like the ozone hole in the '90s and the global cooling scare in the '70s. In fact an ice age was predicted in the 1920s, and a global warming scare in the 1930s, always fueled by some people's eagerness to proliferate panic.

What many people don't realize is that the current theory of global warming, in which planet warming will accelerate monotonically unless we drastically reduce our CO_2 output, is based entirely on computer models. Temperature data does not support it. Global average temperatures are lower now than the last 10 years. The data shows we are at about the same global average temperatures as the early '90s and even at times in the '80s. And the temperature data does not track closely with atmospheric CO_2.

The computer models haven't accounted for actual fluctuations in the data (which means they are not accurate enough to start crafting policy to limit CO_2). Charts showing CO_2 and temperature tracking together show temperature leading CO_2 if examined closely. How then can CO_2 cause warming? Climate researchers themselves do not show a great deal of confidence in their models (also shown in the survey mentioned below).

Here are highlights of some climate change news you won't see on the evening news: The Japan Science Advisory board to their government has stated that the idea that the Earth's temperatures are going to monotonically increase is an improvable hypothesis; they compared the UN's IPCC report to ancient astrology. A British court found 11 inaccurate assertions in Al Gore's documentary *An Inconvenient Truth*. Two successful conferences on climate change have been held in the last two years dedicated to global warming skepticism. In 2008 Russian climate scientists predicted a coming global cooling because of a change in solar activity. Harvard astrophysicist Willie Soon recently has also stated that changes in the Sun's activity is a major driving force of the Earth's climate. In addition, a survey of climate scientists by Bray, Dennis and Hans von Storch (as condensed by Joseph Bast) found that 55% agree climate change has mostly anthropogenic causes, 35% agree climate models can accurately predict future climate conditions, 32% agree the current state of scientific knowledge can provide reasonable climatic predictions on time scales of 10 years, 27% agree reasonable predictions can be made on time scales of 100 years, 69% agree climate change might have some positive effects for some societies, and 45% agree that climate scientists have enough evidence to recommend policy makers enact climate change policies.

I skimmed through the IPCC report myself and found the word uncertainty many times in the body of the report with regard to their conclusions, but the 'Summary for Decision Makers' had a much different tone, one of certainty of the coming worldwide catastrophe. Maybe it would be a lot cheaper for the aerospace industry to conduct a public education campaign.

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Reply by author: As I pointed out in my response to the letter from Joseph Sheeley in the May issue, in my commentary I do *not* "…imply that it is mankind's generation of greenhouse gases (or aerosols) that is causing the observed global warming trend, although that conclusion has been drawn, not without opposition, by most climate scientists. Mr. Sheeley is correct in his contention that the link between man-made CO_2 and global warming is based on climate models that still require significant improvement, but nowhere do I imply that those models 'prove' such a connection."

Mr. Cento expresses a view that is strongly held by some climate scientists, but as I implied in the above response to Mr. Sheeley, I believe they represent a small minority of the entire qualified climate-science community.

✈✈✈

In the editorial **Lost in space** (May, page 3) you note that some see "jobs and funds flowing to Russia—at a time when both are critically needed at home."

I believe that I read in a recent article that the Russians will charge the U.S. $51 million per trip to the ISS. If this is for an entire crew change, it is a bargain—less than 10% of the cost of a shuttle mission. Even per passenger, it is not a bad price, but, perhaps we can bargain them down to the space tourism price of around $30 million.

I, as you, decry the loss of U.S. capabilities and prestige in this area, but from the taxpayer perspective using the Soyuz is not a bad idea, and cost should not be the main point of the discussion. Perhaps the money saved on shuttle flights could be used to support NASA's sorely underfunded science missions.

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Joining the space race, carefully

In recent years the race between China and India for manned spaceflight and for the Moon has drawn significant attention, as did North Korea's much-publicized rocket test in April. All this has overshadowed progress by South Korea, which is now on the verge of becoming a spacefaring nation in its own right.

Or so it hopes. If all goes well, South Korea's launching of a 100-kg (220-lb) satellite into LEO in July, aboard a largely Russian first-stage rocket topped by a South Korean-designed second stage, will make the country the ninth nation to launch a home-built satellite from its own territory. It would also mark a huge step up toward South Korea's goal of becoming an important presence in space.

But while its space program is important in building South Korea's reputation as a center of high technology, there is a refreshing air of realism about the first launch's prospects. Last year, Lee Mun-ki, director general of the Ministry of Education, Science and Technology's science support bureau, commented, "Considering the cases of other countries and our level of experience, you have to say the first launch is more than likely to fail." Officials said the chances of failure stood at around 70%.

Nor is much expected from the satellite, which is intended to do little more than report its position for its planned two-year life. The entire effort is a "proof of concept" exercise that the government in Seoul hopes will lead to a home-grown launch vehicle and locally designed and built 1.5-tonne multipurpose satellite being launched in 2017. Ultimately the intention is to send up a lunar orbiter in 2020 and a lunar lander in 2025.

In January 2008 South Korean spaceflight participants Ko San (right) and Yi So-yeon (center) took part in a space station hardware training session in the Space Vehicle Mockup Facility at NASA Johnson.

Learning the rocket craft

Quietly and cautiously, South Korea has navigated its way through the international maze of regulations and restrictions that govern technology transfer in rocketry, in much the same way as it has done with satellites. The country has gained experience in basic rocketry through the military, maintaining and modifying U.S.-supplied Honest John and Nike tactical missiles. By the 1990s South Korea was able to manufacture solid-fuel rocket motors weighing up to 1 tonne (2,200 lb).

In 1990, the Korea Aerospace Research Institute (KARI) was established to build sounding rockets using a modified version of the solid-fuel motor. One- and two-stage versions of the rockets, KSR 1 and KSR 2, were built in the 1990s. Next came development of a liquid oxygen/kerosene rocket motor with 12.5 tonnes of thrust (similar to the first stage of the U.S. Vanguard in the late 1950s). The intention was to launch a satellite, and the first stage was lofted just once as the KSR 3 in 2002.

By 2001 South Korea had become a signatory to the Missile Technology Control Regime, which enabled it to seek technology for peaceful space purposes from other nations. Anxiety in Washington about Seoul's possible military use of rockets against neighboring North Korea had the effect of driving South Korea's scientists into the arms of Russia. Problems developing the LOX/kerosene engine for the Korea space launch vehicle (KSLV) 1 led KARI to seek help from the U.S. But this plea was rejected, and instead South Korea signed a technical assistance agreement with Russia in 2004. Further diplomatic anxiety caused delays in implementing the program, and a Technology Safeguards Agreement was eventually signed by Moscow and Seoul in late 2006.

A closer look

The KSLV 1 first stage is based on the Angara booster—built at Russia's Khrunichev State Research and Production Space Center near Moscow—which itself has yet to fly. For the Korean version, a different (smaller) engine will be used.

A ground test vehicle was sent from Russia to the newly built launch complex at Naro, in Korea's southern Cholla Province, last August for integration and qualification testing. Khrunichev reported in April that assembly of the flight vehicle for KSLV 1's first stage had been completed and the vehicle was undergoing work in a test stand.

The second stage for the KSLV 1 is a solid-fuel rocket developed and made in South Korea to KARI's design, with Korean-made navigation and telemetry equipment on board. Total length of the KSLV 1 is 33 m, with the first stage occupying 25.8 m of that. Total weight is 140 tonnes.

All this just to put into space a 220-lb satellite? Actually, Science and Technology Satellite 2, as the spacecraft is called, has dual-channel radiometers to measure the Earth's brightness, and a laser reflector array for precise measurements between Earth and the satellite. But that is not really the point. According to Cho Gwang-rae, a KARI senior researcher, speaking to reporters last year: "KSLV 1's payload was designed to support a 100-kg satellite, and you can't be expecting much from such a simple device....The real test will be 2017, when we will be attempting to send a real-purpose satellite with a fully domestically developed rocket. If we succeed in that, we can then say we have a space industry."

KSLV 1 was scheduled to launch in July, delivering a 100-kg satellite to LEO.

International picture

South Korea has a long history of putting up scientific research and telecommunications satellites made variously by U.S. and European manufacturers, or built by Korean organizations and launched by European, U.S., or Russian rockets. Its four commercial satellites have been known as Koreasats, starting with Koreasat 1 in 1995 and so far culminating with Koreasat 5 in 2006. (The designation Koreasat 4 was avoided because the number four is regarded as unlucky, representing death in some Asian cultures.) The Koreasat family also goes under the Korean name Mungunghwa, which is the name of Korea's national flower, the rose of Sharon.

South Korea's efforts to play by international rules, complicated politically by its border with North Korea, contrast markedly with North Korea's rocket testing. April's launch of a rocket over Japan was said by North Korea's government in Pyongyang to have been a successful lofting of a communications satellite into orbit. The problem was that no one else could hear the North Korean songs Pyongyang said the alleged satellite was broadcasting. U.S. officials said the rocket had not reached orbit but had splashed into the Pacific Ocean. So the event was either an unsuccessful satellite launch or a successful missile test—successful in that it went about 50% farther than the last such launching in 1998.

Enter the Russians again: In late April, Russian Foreign Minister Sergei Lavrov visited both Koreas and offered North Korea help in launching satellites. He said, "Russia is cooperating with many countries in the peaceful exploration of space, including launching satellites by our boosters. We have such agreements with South Korea, and we are ready to develop similar projects with North Korea and hope our proposal will be examined."

Pyongyang offered no response, but it seemed likely that the offer was a move to try to get North Korea back to the table to discuss nuclear issues—its national pride would almost certainly preempt any use of Russian rockets, particularly since South Korea is already benefiting from Russian help.

Assuming the KSLV 1 launch goes well, and that its succeeding KSLV delivers the planned 1.5-tonne satellite in 2017, the next big hurdle for South Korea will be manned spaceflight. So far, only one Korean national has journeyed into space—bioengineer Yi So-yeon. She went on an 11-day mission to the international space station in April 2008, traveling on a Russian Soyuz.

Ripple effects

This first was unusual for male-dominated Korean society, but Yi had been pushed from being the standby into the prime spot after the intended prime candidate was involved in a controversy at the Russian training school over security regulations.

Yi became the 49th woman in space but just the second female Asian astronaut; the first was Japanese surgeon Chiaki Mukai, who made two shuttle trips, in 1994 and 1998. The third is likely also to be Japanese; aerospace engineer Naoko Yamazaki is due to fly in the space shuttle Atlantis next year on an ISS supply mission.

The relevance of these women becoming astronauts has little to do with women's liberation in its real sense; all three had excellent academic qualifications and had gone through the same selection procedures as their male colleagues. It has, however, much to do with local public perceptions of women and their place in society.

So for two heavily male dominated societies, what do their governments get for their investments in these women? Financial reward? Well, as an example, the Korea Aerospace University predicted that Yi's trip would boost the national economy by $381.2 million (478 billion won) from sales generated in items such as telescopes, books about space, and model spacecraft (her Soyuz trip was charged to the government at 26 billion won).

But the real payoff in all three cases is more likely in the "halo" effect that their experiences have on other people—the general public, and youth in particular. It is one thing for a former military test pilot to try to communicate what his or her time in space was really like; it is quite another for a civilian, and an extroverted female at that, to talk in everyday terms to a lay audience.

Consider this comment from Yi last year about her intentions now that she has achieved her dream of becoming an astronaut: "Before becoming an astronaut I was not as aware of the strides that we need to bring in our educational systems, and how important it really is to provide the young people—students in schools and colleges—with the right tools and, above all, inspiration. I am considering furthering research and being very active in inspiring the young generation."

Koreasats have been launched by a variety of companies, including Sea Launch.

Yi has further advice for would-be astronauts: "Enjoy what you do. Compete in the selection process and enjoy it. It helped me immensely to make it all the way. There is a proverb in Chinese that goes, '[The] person who does [not do] his/her best cannot like it and the person who does not like it cannot do his/her best.'"

Next steps

The KSLV 1 project is expected to cost about $377 million, including $198 million to be paid to Russia, whose services have been contracted for at least two missions. The second mission is expected to take place about nine months after the first, assuming it is successful. If not, then Korean officials anticipate needing about a year to analyze what went wrong and how to fix it.

Despite the apparently cautious or even downbeat official comments, KARI scientists and engineers are under huge pressure to deliver, with national pride and the public's hopes at stake. Yi's flight last year has whetted the national appetite for proof that South Korea truly does have the ability to stand up and be counted among the world's leaders of high-technology projects. KSLV 1 will be carrying a lot more than just a little satellite when it leaves the launch pad.

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Looking to new leaders

THE SHUTTLE ATLANTIS LANDED ITS SEVEN astronauts at Edwards AFB, California, on May 24, ending its 13-day STS-125 mission to repair and enhance the Hubble Space Telescope. In Washington, there had been hopes that the shuttle's success could coincide with the White House's announcement of President Obama's choice for NASA administrator: retired Marine Corps Maj. Gen. Charles F. "Charlie" Bolden Jr. When weather delayed and diverted the shuttle's landing, Obama's office proceeded with the nomination while the astronauts were still in orbit.

Bolden is a naval academy graduate, former A-6 Intruder attack pilot, Vietnam veteran, and astronaut who flew in space four times between 1986 and 1994, twice as a space shuttle commander, logging 680 hr in orbit. His crew put the Hubble observatory into orbit in 1990. Bolden is considered a protégé of Sen. Bill Nelson (D-Fla.), who flew with him in the shuttle on a 1986 mission. Washington observers say the senator used his clout in space policy to shoot down earlier Obama choices for the administrator's job while lobbying strongly for Bolden.

Lori B. Garver, a former NASA official and space policy advisor to Obama during the presidential campaign and transition, was expected to win easy confirmation as NASA deputy administrator.

The shape of NASA's future

NASA has been without a leader since Michael Griffin stepped down in January. The new administrator will face fundamental decisions about U.S. space policy but also could be preempted: An independent panel commissioned by the Obama administration in May, and led by former aerospace executive Norman Augustine, is looking at the Constellation program that will develop the next-generation Ares and Orion manned space boosters and vehicles.

It is unclear whether the new administrator can shape key decisions (or even spend appropriated funds) before late summer, when the commission issues its findings. Most observers in the capital feel, however, that the White House, the new NASA administrator, and Capitol Hill lawmakers must take an even broader look—going far beyond Augustine's mandate to study Constellation—at what the nation wants to do in space and whether the public will support it.

Charles F. Bolden Jr.

Obama inherited President Bush's "vision" for a new generation of manned spacecraft under the Constellation program, to be preceded by retirement of the shuttle fleet next year. As a candidate, Obama reversed an early position and supported the vision, which would take astronauts to the Moon by 2020 and eventually to Mars. As president, he has seemed lukewarm on human spaceflight and has made no significant statement about space policy.

The editorial board of *USA Today*, citing NASA's "diminished stature," urged a focus "not on fixing NASA's failures"—a reference to a string of unfulfilled human spaceflight programs under several presidents—"but on building on its successes." Those include probes to Mars, the Chandra X-Ray Observatory, and other robot platforms, the newspaper opined, but not space vehicles that carry astronauts.

Calling Constellation a costly program with "modest support," the newspaper implied that human spaceflight is not viable and that "NASA's real stars are its machines." On the day of this pro-robot editorial, it was reported that the NASA Mars rover Opportunity had discovered new evidence of water in a Martian crater called Victoria. However, the second of two Mars rovers, Spirit, has been foiled by technical glitches.

The administration's budget proposals for NASA do not respond to the view of some that space exploration ought to be conducted by robots. Many argue, however, that the proposals do not sufficiently support human spaceflight either. The administration endorses shuttle retirement in 2010 and a return to the Moon by 2020. But while the Obama team's proposals boost near-term NASA funding, they cut spending by $3.1 billion between 2011 and 2013. If that money is not restored, the Constellation program may be stalled, and expeditions to the Moon will be delayed or called off.

And some who strongly support a robust human spaceflight effort argue that, instead of Constellation, alternative boosters and vehicles can be developed faster and more economically. There is speculation that the commission could recommend scrapping Constellation.

NASA is struggling to complete the international space station with the final eight shuttle missions before the shuttle is put to pasture. After that, the agency will be able to put humans into orbit and aboard the ISS only by purchasing seats on the Russian Soyuz—until the Constellation effort produces a new vehicle, no earlier than 2015.

Sen. Richard Shelby

Sen. Richard Shelby (R-Ala.) is one of the lawmakers unhappy with the confluence of budget and technical issues confronting NASA, and with the question of who is in charge.

"The proposed budget has welcomed increases in the areas of science and exploration, and maintains aeronautics funding at an acceptable level," Shelby said in a statement. "However, more than 21% of NASA's budget, nearly $4 billion, is being set aside as a placeholder while NASA turns its manned space program over to [the Augustine commission]." Shelby also accused the White House of making Augustine "the de facto interim administrator" and of "delaying any plan for over $4 billion of NASA's budget until weeks before the start of the fiscal year."

In June, when the House appropriations subcommittee released the budget, it was lighter by $483 million. Rep. Alan Mollohan (D-W.Va.) insisted that the cut was a"deferral" while the Augustine commission completed its study.

Scrutinizing the regionals

A series of airline safety hearings held in May by the National Transportation Safety Board (NTSB) almost certainly are a precursor to a congressional crackdown on regional commercial carriers, which many call commuter airlines.

In the wake of the NTSB findings, four senators have called for an investigation. Manassas, Va., based regional carrier Colgan Airways operated Continental Flight 3407, which experienced an aerodynamic stall and plunged into a house in Buffalo, N.Y., on February 12, killing 50 people. It was the first time in 30 months that anyone died during a scheduled flight on a U.S. carrier. Since December 2001, the major airlines' big jets have gone without a fatal crash, while 150 people have died in regional airline accidents.

The senators wrote to Calvin Scovel, Dept. of Transportation inspector general, that the circumstances of the crash raised questions about the FAA's enforcement of regulations on pilot training and crew rest at regional carriers.

"Adequate pilot training and rest is a basic prerequisite to make certain the air transportation system achieves a high level of safety," they wrote. "Such regulations, however, must be paired with vigorous FAA oversight of airline compliance to have a credible effect."

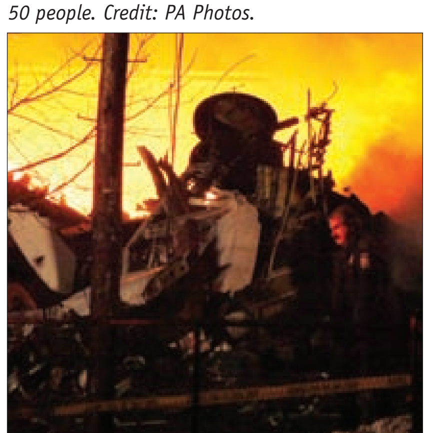
During a confirmation hearing May 19, Sen. Byron Dorgan (D-N.D.) took up the subject with J. Randolph "Randy" Babbitt, who won the Senate's blessing and became FAA administrator the next day. Dorgan said he was "just furious" about evidence of flaws on the part of the regionals in pilot hiring and training, and in averting fatigue, which may have been a factor in the Buffalo crash.

The NTSB hearings suggest that regional airlines pay their pilots very low wages, let them commute to work from hundreds of miles away, and do not provide proper facilities for food and rest. This adds up to a picture of pilots who are inexperienced, and often hungry and exhausted, while on the flight deck.

NTSB member Kitty Higgins said pilot fatigue was a factor in other crashes and is a major concern for the board and the FAA. NTSB's chairman, retired Maj. Gen. Mark Rosenker, said the Flight 3407 crew and their carrier were guilty of "cutting the salami too thin on being fit to fly."

Among revelations was the fact that first officer Rebecca Shaw worked part-time in a coffee shop and commuted 2,817 mi. to her work station in Newark. The day before the crash, she flew on a FedEx red-eye to Newark, with a stop in Memphis, going 36 hr without proper bed rest prior to the fatal flight. Shaw's family defended her as a professional with a flawless flying record, but cockpit recordings indicate that she had never before flown in serious icing conditions.

On February 12, Colgan Airways Flight 3407 plunged into a house in Buffalo, N.Y., killing 50 people. Credit: PA Photos.



Sen. Byron Dorgan

Capt. Marvin Renslow commuted to Newark from Tampa. The NTSB announced that, when hired, Renslow failed to list two FAA flight certification tests he had flunked. Mary Finnigan, Colgan vice president for administration, said that had the airline known, Renslow "would've been immediately dismissed." But critics wondered why the airline did not find out, and said that bashing the pilots was a ploy to draw attention from flaws in the regional airline industry and its oversight.

The *Buffalo News* wrote, "...flying turboprops and small jets, regional airlines now run nearly half of the nation's commercial flights. But those airlines, whose names remain unknown to much of the flying public, have been responsible for all of the nation's multiple-fatality commercial plane crashes since 2002." Many passengers do not even know that the name painted on the fuselage of a regional airliner is not usually the company that operates it.

A Colgan official testified that of 137 Newark-based pilots, 93 commute to work by air, with 20% of them living over 1,000 mi. away. Long-distance commuting by airline crews has never been limited to the regionals: USAirways Capt. Chesley B. Sullenberger, hero of the successful February 2 ditching of an A320 in the Hudson River, maintains his home on one coast and is based on the other. But he is among those who say harsh pay cuts are driving experienced pilots from the cockpit.

On May 21, the House passed the

FAA Reauthorization Act of 2009, which authorizes $70 billion in funding for FAA capital programs between FY09 and FY12. The Senate was expected to pass its own version. Having traditional funding for the first time since 2006 is expected to enable Babbitt and the FAA to make headway in resolving long-pending issues, including a pay freeze for air traffic controllers and delays with the next-generation air navigation system.

Defense budget debate

This summer and fall, many legislators are expected to challenge the administration's defense budget proposal for FY10. The White House plan halts production of the F-22 Raptor, C-17 Globemaster III, VH-71A Marine One helicopter, and an Air Force combat rescue helicopter, and pares down other programs. Part of the $3.4-trillion proposal for the entire federal government, the $533.8-billion defense budget is not everything the nation pays for defense: The figure does not include supplemental spending for wars in Iraq and Afghanistan, nuclear weapons budgeting for the Dept. of Energy, and funding for the Dept. of Homeland Security.

Lawmakers plan to challenge cuts in aerospace programs but were relatively mild when Defense Secretary Robert Gates and Joint Chiefs chairman Adm. Mike Mullen traveled to Capitol Hill to defend the Obama plan. "They're going easy for now," said one observer of Congress. "But supporters of the F-22, C-17, and other platforms will be wheeling out their big guns during testimony in the months ahead."

If legislators seemed inclined to hold their fire for the time being, one exception was Rep. W. Todd Akin (R-Mo.), who is bristling about the Navy's long-anticipated shortfall in strike fighter aircraft for its carrier groups. Lawmakers routinely defend aircraft programs in their home districts, but Akin, widely viewed as a spokesman for the conservative base of the Republican party, is sometimes more vocal than most. Rep. John McHugh (R-N.Y.) has made a point, in a more low-key fashion, of publicly supporting Akin's views.

Under current plans, the last F/A-18E/F will be delivered by September 30, 2012.

Today, the Navy's 10 carrier air wings fly aging, or legacy, F/A-18C Hornets and new F/A-18E/F Super Hornets, both assembled at a Boeing plant near Akin's district in St. Louis. Under the plan that Obama inherited, the 493rd and last Super Hornet will be delivered by September 30, 2012, and naval strike fighter production will shift to the F-35C Lightning II Joint Strike Fighter, built by Lockheed Martin at a government-owned plant in Fort Worth.

Akin and other proponents of the F/A-18E/F point out that the naval F-35C has not even made its first flight yet and that the F/A-18E/F has been proven in battle. Boeing is offering to sell the Navy 170 more of the 18E/Fs for a bargain basement price of $49.9 million each. The planemaker also has an order for 24 copies from Australia.

Washington debate over the strike fighter gap comes earlier than, and is a precursor to, expected hassling over other defense programs.

The Navy's stated requirement for strike fighters—now and in the future—is 1,056 aircraft. Based on this figure, a new estimate by the Navy says the Navy and Marine Corps will have a shortage of 15 aircraft this year, 50 next year, and a total of 243 by 2018, roughly double a previous estimate. A separate report by Congress itself says the gap is 50 this year and will rise to 312.


Rep. W. Todd Akin (left); Adm. Gary Roughead

Akin is one of many who gripe that inconsistent numbers are being bandied about. In a statement he said: "Unfortunately, our Navy faces a significant strike fighter shortfall in the near future, and what good is an aircraft carrier without aircraft? Last year the chief of naval operations, Adm. Gary Roughead, testified to a fighter shortfall of approximately 125 planes for the Dept. of the Navy by 2017. This year, based on an updated analysis, the Navy has told Congress that a more realistic estimate is a shortfall of over 240 planes.

"This assumes that JSF delivers on time, and that the Navy will continue to resource its carrier air wings with fewer aircraft than are called for in the national military strategy. Should the Navy resource to its full strike fighter requirement, the shortfall would be greater than 300 aircraft."

Following Gates and Mullen up to Capitol Hill, Roughead testified that legacy F/A-18A/Ds are undergoing a service life extension program that could help fill the strike fighter shortfall. However, a separate report by the Navy says the legacy Hornets will not be able to last until their 10,000 flight-hour lifetime but instead will have to retire after 8,600 flight hours, suggesting they will not be able to fill in after all. In Iraq and Afghanistan, F/A-18C/Ds and E/Fs have been flying more hours than projected when they were built, and under more difficult conditions.

Akin wants more consistency from the executive branch in reporting strike fighter gap numbers. "I feel like I'm trying to nail Jell-O to a wall, gentlemen," Akin said to Roughead and other naval officers during testimony. "No matter how you look at the numbers, you're coming up short on fighter planes."

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Ken Hodgkins

The State Dept. Office of Space and Advanced Technology has a wide and diverse range of responsibilities. Tell us about the international space arena, and describe your role at the U.N. and in bilateral and multilateral relations.

I represent the U.S. at the United Nations Committee on the Peaceful Uses of Outer Space [COPUOS]. There are now greater opportunities to accomplish things through this committee and its subcommittees, because the Cold War is over and because more and more countries are active in space.

There are over 50 countries and international organizations that now have space assets and a stake in what happens in space. Furthermore, almost all nations have access to space systems such as global navigation satellites, communications satellites, remote sensing satellites, and weather satellites, and incorporate them in their infrastructures.

What does that mean in terms of the committee's work?

Nations now tend to approach space more pragmatically and less politically than they did before, because their space assets have matured and they have more to offer. And there is a greater awareness, at the scientific and policy levels, of the utility of space systems and of what they can do. There are still commercial and security issues that we have to be mindful of, but the level of technological capability has risen among a lot of countries. So a lot of the committee's work has become more businesslike than before, with a lot more countries actively participating.

How much of that work deals with the growing problem of space debris?

One of the big areas we work on in COPUOS is the whole concept of "best practices in space operations." This is currently being spearheaded by France, and we are very supportive. The committee developed a set of guidelines on debris mitigation over a period of several years that has been endorsed by the U.N. General Assembly. In a similar manner, it is now considering the development of guidelines that will spell out all the things that constitute responsible behavior in space, including the sharing of information on orbital locations of satellites and debris among all the space operators for space situational awareness, or SSA. We, the U.S., have started a series of discussions with the European Space Agency and European Union about cooperating on SSA.

China's ASAT test in January 2007 generated a massive amount of space debris. How did it play into all this?

That test was a big driver of the committee's interest in this subject—safe and sustainable space operations. The atmospherics for the Chinese could not have been worse. They came under a lot of criticism, and within weeks of their test they had to attend a meeting of COPUOS where we were adopting the debris guidelines that I mentioned. They simply said that the test was an experiment, and that nothing happened to anybody else's space assets as a result.

But the fact is that their test created a huge amount of debris that will remain in space for a long, long time. In the U.N. debris mitigation guidelines, the intentional breakup of objects is allowed as long as the debris isn't long-lived—more than 25 years. The debris from the ASAT test will be up there much longer.

Back to what you said about sharing information on space situational awareness: How does that work?

Collecting and exchanging data is the most important element of SSA. The Air Force operates the commercial and foreign entities [CFE] program that gives other spacefaring nations and organizations access to space-tracking data on space objects. The data comes from the U.S. space surveillance network, and management of the CFE program will be transferred in October from the Air

Ken Hodgkins is director of the Office of Space and Advanced Technology in the State Dept.'s Bureau of Oceans, Environment and Science. His office is responsible for bilateral and multilateral cooperation in global navigation satellite systems, the International Thermonuclear Experimental Reactor, and nanotechnology, and represents the department in national space policy review and development.

Hodgkins serves as the U.S. representative to the United Nations Committee on the Peaceful Uses of Outer Space. He has been the State Dept.'s representative for major presidential policy reviews on remote sensing, GPS, and orbital debris.

Before joining the State Dept., Hodgkins was director for international affairs at the National Environmental Satellite Data and Information Service (NESDIS) of the Dept. of Commerce's National Oceanographic and Atmospheric Administration. He joined NOAA/NESDIS in 1980.

Interview by James W. Canan

Force to U.S. Strategic Command.

The CFE is linked to debris mitigation in the overall context of space situational awareness. Space operators use CFE data to maintain their own positioning and make sure that they do not run into each other up there.

Can data sharing cause security problems for the U.S.?

There are security implications, of course. Within our national security community there has been extensive debate about the program and how improved tracking data and other information can and will be provided to foreign and commercial space operators to make their calculations more precise, and about how to sort out and properly prioritize national security, civil, and commercial requirements.

What about security in relation to other nations?

There's now solid consensus in the U.S. government on the need to move beyond a security approach rooted in Cold War paradigms, but changing processes and procedures in a program that's been operating for nearly half a century is challenging. Part of our discussions with the Europeans about SSA is aimed at trying to address the evolving SSA security policy concerns and to give European experts a better appreciation of what goes into our surveillance system and of our need to protect certain types of data for proprietary and security reasons.

What are the Europeans doing with regard to SSA?

They want to develop their own SSA capability, and we need to work with them to make sure the two systems are compatible, and to have a common understanding of what kinds of information should be exchanged.

How would you describe Europe's status, its progress, in space?

For the most part, Europe's investment in space is for commercial and civil applications. They have significant capability in launch, in telecommunications, and in remotely sensing the Earth, as we have. Now they have developed systems that provide them with reconnaissance data that they share. They recognize that their Galileo program—their GPS equivalent—is a major undertaking and a big investment, but they believe it will provide crucial services as their other investments in space have done.

What is the significance of this from the standpoint of international cooperation and agreements? Will such cooperation become more complex and problematic as more spacefaring nations, such as Iran, get involved?

Well, sure. That is something that we have to consider. But the importance here is that Europe has come to the realization that we came to many years ago, that space systems are a critical part of their infrastructure and need to be protected from human-induced interference as well as from naturally occurring interference like space weather. Europe has also recognized that all of the actors in space need a common understanding of how we are going to behave up there. That is why defining "best practices in space" is a good idea, so that all of us can agree on measures that should be taken, including debris mitigation guidelines, to make sure that space is sustained for future generations.

Is the U.S. leading the way in tackling the space debris problem?

Yes. The U.S. government is actively working within the U.N. as well as with our European partners to develop guidelines that will enhance international transparency and confidence-building in space operations, and to identify elements that constitute responsible actions in space, such as reducing the amount of orbital debris and exchanging more information on space situational awareness. Our domestic debris mitigation regulations are equivalent to, or exceed, those that have been endorsed by the U.N.

When did this begin?

Back in the early 1990s, NASA created an informal group called the Inter-Agency Space Debris Coordination Committee [IADC], consisting of all the major spacefaring countries, China included, which was separate from the U.N. The idea was for all of the countries to exchange information on their experiences with space debris, what we know about it, and see if we could come up with guidelines that everybody could use at the international level. What we were already doing in the U.S. was the point of departure for the guidelines defined by the IADC.

"...all of the actors in space need a common understanding of how we are going to behave up there."

When did the U.N. get involved?

Starting in 1994, we said it is not enough that we are doing this among a small group of countries, because by then there were many more countries and organizations operating in space, and we needed a higher level of guidelines on debris mitigation that would be universally applied. The Scientific and Technical Subcommittee worked for about a decade on examining research and mitigation activities undertaken by the IADC and member states of COPUOS. On the basis of that work, we—the U.S.—introduced a proposal in the COPUOS to begin developing debris mitigation guidelines that would be adopted at the governmental level. The U.N. General Assembly adopted those guidelines in 2007, and they track very closely with those of the IADC.

What do the guidelines deal with?

There are two areas. First, there are measures that curtail the generation of potentially harmful space debris in the near term, and second, measures that limit the generation of such debris over a longer term. This means that we try to limit the production of mission-related debris, avoid breakups, and implement end-of-life procedures that remove decommissioned spacecraft and launch vehicle orbital stages from areas populated by operational satellites.

How does the U.S. go about mitigating debris from its satellites?

The Dept. of Defense, NASA, and NOAA have specific policies dealing with debris mitigation in their operations—internal documents that they and their contractors use. When the FCC issues a license to an operator of a communications satellite, it requires the operator to submit a debris mitigation plan for disposing of the satellite at the end of its life. The FAA requires commercial launch providers to show what they will do to mitigate debris generated by their launches. NOAA also requires operators of commercial remote sensing satellites to do the same.

Is there opposition to some of the debris mitigation measures?

There is some reluctance, because debris mitigation costs money. If, for example, you have a communications satellite up there that is generating revenue, you want to run it until the very last minute. Under the guidelines, you can run it only until you have enough fuel to move it, and that costs you money. However, there is a recognition that it is in everyone's self-interest to maintain a safe space environment, and so long as all operators are playing by the same rules, everyone is happy.

Can the U.N. enforce its agreements and guidelines?

Treaties governing space activities are binding, but there are no enforcement mechanisms. They are all based on cooperation and resolving differences through diplomatic means. Subsequent to the original outer space treaties, we have developed nonbinding principles within the U.N. on such things as the use of nuclear power sources in space, remote sensing of Earth from space, and most recently, the guidelines on debris mitigation. These also do not have enforcement mechanisms, but they are documents that people can point to and say that the international community, through the U.N., has agreed on specific steps that should be taken [by those] engaged in these activities.

Do other nations look to the U.S. as the example to follow in space operations and practices?

Yes, absolutely, and over the years we have worked very hard within COPUOS to provide leadership in areas where we think the committee can make a useful and unique contribution in promoting international cooperation in the peaceful uses of outer space. We also seek to use the committee to demonstrate the value of space technologies for promoting the quality of life and advancing economic growth around the world.

On the other hand, we resist in that committee the introduction of measures dealing with the "militarization" and "weaponization" of space. They are not within the committee's mandate. Arms control issues are better suited to the First Committee of the General Assembly, or to the Conference on Disarmament in Geneva.

What else does your office do?

We do many other things that depend heavily on the expertise of NASA, NOAA, DOD, the USGS [U.S. Geological Survey], and the private sector. We handle the application of the treaties that govern space activities, such as the Outer Space Treaty, the Agreement on the Rescue of Astronauts and the Return of Space Objects, the Convention on Liability Caused by Space Objects, and the Convention on Registration of Space Objects.

We led the negotiations of the intergovernmental agreement that established cooperation on the International Space Station. We lead the U.S.-EU space policy dialogue that began several years ago. The Europeans are trying to develop European-wide space policy, and we thought that having a dialogue with them early would give us an opportunity to influence their policy, give us insights into where they are headed, and have them better understand what the U.S. is doing in the space policy arena. We also lead, with NASA, the U.S./India joint space working group that was undertaken back in 2004 to strengthen our bilateral space cooperation. And then we work closely with other agencies to assist them in implementing their own programs of international cooperation.

How does your office interact with U.S. agencies that are involved in space operations?

We represent the State Dept. in the interagency space policy development and implementation activities—policies on commercial space transportation, remote sensing, space exploration, and space-based positioning, navigation, and timing [GPS] policy, which has become a priority area for the office. We are responsible for leading U.S. engagement with the international community focused on maintaining GPS as a kind of gold standard for worldwide use, and to enhance interoperability and compatibility among all current and future navigation satellite systems.

Which nations are involved in all this?

First, on a bilateral basis, we have an agreement with the European Union and its member states on cooperation in GPS and the EU's Galileo program. There are four working groups that deal with interoperability and compatibility, with security issues, with commercial and trade issues, and with enhancement of future services. We also have joint statements with Japan, India, and Russia on similar cooperation with their programs. And we have a working group that deals with cooperation in satellite search and rescue, involving distress signals received and transmitted by navigation satellites.

What do you mean by interoperability

among international navigation satellite systems?

Interoperability simply means that the civil signals will be transmitted at the same frequency, so that the receiver manufacturers can build one unit to receive multiple signals from multiple constellations. We are well on our way to achieving that. We have agreed on two civil signals that will be interoperable on all systems, including the GPS satellite that was launched last month.

And compatibility?

Compatibility is a different concept, or actually two concepts. First, it means that the signals provided by each and every navigation satellite system will not create radio frequency interference with others. This is vital to providing useful service to all users worldwide.

Second, it means that there will be spectral separation between the authorized services of all the various systems and all other signals. This is a very important national security consideration for the U.S. We consult with the providers of systems from the EU, Russia, China, India, and Japan to ensure that they understand and pursue this principle of compatibility that protects spectral separation for M-code signals.

How about on the multilateral agreements side?

On the multilateral side we strongly supported the creation of the recently established International Committee on Global Navigation Satellite Systems. It currently has about 25 members, associate members, and observers, including nations that are current and future operators of navigation satellite systems or ground-based networks that utilize these systems for many applications, and major international associations and organizations that represent various users of navigation satellite services.

What does that committee do?

Several things. One is promoting the use of global navigation satellite systems around the world, but especially in the developing world, through training and workshops. Another is to foster dialogue between organizations representing users and the nations that provide service to these users.

Finally, the committee includes a providers' forum where current and future navigation satellite system providers discuss topics of mutual interest, such as compatibility and interoperability.

Four test flights that boosted Apollo 11

THE DAY APOLLO 11 LANDED, 40 YEARS ago this July, my Baltimore family was in southern California, halfway through a cross-country road trip. Fresh from the beach, the six of us skipped the campground that night and clustered around our motel room TV, watching the ghostly shapes of Neil and Buzz bound across the lunar surface. With billions of others, we witnessed the culminating moment in a series of daring steps mounted by the U.S. since the shocking blow delivered by the 1967 Apollo fire. In fewer than 10 months beginning in the fall of 1968, NASA undertook four challenging test flights whose successes led directly to the achievement of President Kennedy's Moon-landing goal.

Apollo 11's triumph did not occur in isolation. It built on a string of ambitious missions of ever-increasing complexity, each venturing into unexplored dimensions of operational risk. A serious failure in any of the four Apollo missions preceding the landing would probably have caused NASA to miss JFK's 1970 deadline. Consider: Had events gone only slightly differently, the USSR might have notched the first manned flight around the Moon, and made a more vigorous bid to preempt Apollo with a robotic sample return and an eventual manned landing. Instead, the Soviets could do little but watch as NASA marched inexorably toward its lunar goal. The lessons of that test flight series are useful today as the agency grapples with technical and managerial challenges every bit as daunting as Apollo's.

Rising from the ashes

The January 1967 Apollo 1 fire brought NASA's new lunar program to a standstill. The entire Apollo command and service module (CSM) design had to be reviewed and revalidated. Astronaut Walt Cunningham, originally assigned to Apollo 2 with Wally Schirra and Don Eisele, had backed up Apollo 1's Virgil Grissom, Edward White, and Roger Chaffee. "We on Apollo 7 were beneficiaries of that thorough scrub—any possible defect related to the fire was eliminated," he says. Earlier, unmanned flight tests had proven some of the Apollo CSM systems, but Schirra, Eisele, and Cunningham would fly what was practically a brand new spaceship.

Their 11-day mission, launched October 11, 1968 from the same pad where the Apollo 1 crew had perished 21 months before, tested fuel cells, life support systems, computers, navigation systems, and the all-important service propulsion system (SPS) engine. The 20,500-lb-thrust SPS would get future crews into and out of lunar orbit, and it had to work: A failure could leave an orbiting crew stranded in space. Cunningham reports that before Apollo 7, Wally Schirra had insisted on an extra ground test firing of the SPS; no one was taking any chances.

Technicians move the Apollo 7 CSM into position for mating with the spacecraft LM adapter.

Once in orbit, the crew ran docking approaches to the Saturn IB's expended S-IVB second stage. The SPS then got a thorough workout, passing with flying colors, as did every systems test.

"I never heard of a test flight that had so little go wrong," says Cunningham today. "It was confirmation of what we'd all done to get ready." Their face-to-face debrief to the Apollo 8 crew took just a single day, and it was mostly "negative reporting," he says—"we mostly told them what didn't go wrong."

A lunar gamble

In August 1968, two months before Apollo 7 flew, Apollo spacecraft program manager George Low proposed to his colleagues that Apollo 8 should fly a lunar orbit mission. The audacious idea was based on three factors. First, the lunar module (LM) was behind schedule and would not be ready to fly with Apollo 8; why waste a mission repeating the Apollo 7 mission profile? Second, intelligence reports indicated the Soviets were

The crew of Apollo 7, ready for takeoff: Don Eisele, Wally Schirra, and Walt Cunningham (l.-r.).

Apollo 8 launches from Kennedy Space Center, December 21, 1968.

readying a revamped Soyuz for launch, perhaps to loop around the Moon. Such a success by the Russians would undercut the prestige of a later Apollo lunar mission, even one that entered lunar orbit. Finally, sending Apollo 8 to the Moon would prove software, navigation, and operations techniques for the later landing missions, an invaluable jump in deep space experience.

Some thought the risks too great. When Chris Kraft's flight control team met in August to weigh the mission's pros and cons, someone objected that the flight plan's timing dictated a night splashdown. According to *A Man on the Moon* author Andrew Chaikin, commander Frank Borman answered with characteristic bluntness: "What the hell difference does it make?...If the parachutes don't open, we're dead anyway, whether it's day or night."

In a series of such frank discussions, managers hammered out a decision in

The Apollo 8 crewmembers stand in the doorway of their recovery helicopter aboard USS Yorktown, following their splashdown on December 27, 1968. Left to right are Frank Borman, James A. Lovell Jr., and William A. Anders.

early November: Apollo 8 would shoot for the Moon.

On December 21, 1968, Borman, Jim Lovell, and Bill Anders thundered moonward on the first manned Saturn V launch. The previous Saturn V test, Apollo 6, had barely staggered into orbit, suffering multiple engine failures. Worse, its third stage had failed to reignite for a simulated translunar injection. But Wernher von Braun's booster team at Marshall stated confidently they understood the failures—and fixed them in time for Apollo 8.

Late in their second Earth orbit, 186 km up, Apollo 8's crew commanded ignition of the S-IVB's J-2 engine. For 5 min 18 sec, it powered the stack out of Earth orbit, building its speed to 10.82 km/sec on a free-return path around the Moon. Chris Kraft radioed the crew: "You're on your way—you're really on your way now!"

The rest of the mission unfolded like clockwork. On December 24, Apollo 8 swung behind the Moon, firing the SPS to slow into an initial 311 x 112-km orbit. Each revolution took 2 hr.

In the new book, *Apollo: Through the Eyes of the Astronauts*, Frank Borman recalls that first lunar orbit: "…The first view of the Moon was mesmerizing, as we were aware that no other humans had seen the far side of the Moon directly. The Earth, however, captured my attention. It was the only object in the universe that we could see that had color. It was beautiful—blue with white clouds—serene, and majestic. It was home."

For nearly an entire day the crew scrutinized landing sites, proved out communication and navigation routines, and later televised a moving Christmas Eve broadcast, reading from the Book of Genesis. Just after midnight on Christmas Day, on the lunar far side, the crew fired the CSM's SPS engine for the burn that had to work. When Apollo 8 reappeared from behind the Moon's trailing limb, Jim Lovell's voice confirmed that the SPS had done its job: "Houston, Apollo 8….Please be informed there *is* a Santa Claus."

Gumdrop and Spider

Apollo 8's safe return removed any worries about a Soviet Moon surprise and proved the Apollo spacecraft and ground team could handle lunar operations. But a landing still depended on a crucial test

The Apollo 9 crew, James McDivitt, David R. Scott, and Russell L. Schweickart, smile for the camera.

Apollo 9 LM pilot Rusty Schweickart stands in "golden slippers" on the LM porch on March 6, 1969.

of a spacecraft that had never carried astronauts: the lunar module.

Flown unmanned just once, the LM would now get a workout in LEO from the Apollo 9 crew: Jim McDivitt, Rusty Schweickart, and Dave Scott. Aboard their command ship Gumdrop, they were hurled into orbit by the fourth Saturn V on March 3, 1969. Three hours after orbit insertion, the crew turned the CSM around and docked gently with the LM, named Spider, nestled inside the top of the S-IVB third stage. Extracting the LM from the Saturn, the crew conducted test firings of the SPS engine to evaluate the structural integrity of the joined spacecraft.

Schweickart recalls: "We did a somewhat hairy structural test of the CSM/LM tunnel by purposely 'sawtoothing' the SPS engine back and forth during a burn. We also fully tested the ability of the LM to control the docked CSM/LM configuration...although that was never intended to be used." Schweickart finds it ironic that just over a year later, "many of the things we tested which seemed either incidental or even somewhat silly turned out to be essential to Apollo 13's successful return."

On the fourth flight day, he and McDivitt in the LM donned their lunar surface suits. Schweickart opened Spider's forward hatch, gingerly exiting onto the "front porch" platform for the EVA.

His spacewalk almost didn't happen. Schweickart had experienced space motion sickness on flight day 3, and the crew prudently canceled the planned EVA—getting sick inside a space helmet would be disastrous. Schweickart was crestfallen, but the next morning, he recalls, "based on my looking fine, and following a very brief discussion, Jim [McDivitt] pressed the transmit button and said 'Houston, we're going ahead with the EVA.'" He calls McDivitt's move "the most courageous command decision I've ever seen in operations."

Schweickart's hour-long spacewalk proved the life support backpack would perform under lunar conditions; CSM pilot Dave Scott, using umbilical suit connections, monitored and photographed Schweickart while standing in Gumdrop's open hatch.

The next day, Schweickart and McDivitt powered away from Gumdrop in the LM, the first independent flight of a piloted spacecraft without a heat shield for Earth return. For nearly 7 hr the men wrung out the LM systems, easing out to more than 179 km from Gumdrop. Both Spider's descent and ascent engines functioned well, as did the staging mechanisms to cut loose the lower stage of the lander. The pair returned in the ascent stage to dock with Gumdrop, proving the LM was ready. Schweickart says proudly that "Apollo 9 was rightly called the great engineering test flight of the program."

Snoopy is moved for mating with the spacecraft lunar module adapter.

Snooping the Moon

NASA launched Apollo 10 on May 18, 1969, the fourth Apollo test in seven months. Astronauts Tom Stafford, John Young, and Gene Cernan embarked on a lunar orbital flight that was to rehearse every aspect of a Moon landing except the final descent and touchdown. Flight controllers would work simultaneously with the CSM and LM in lunar orbit. Swooping low over the Moon in their

In June 1969, the crews of Apollo 10 and Apollo 11 conduct a debriefing session in Houston on the Apollo 10 "dress rehearsal" flight results. Clockwise, from left foreground, are Michael Collins, Edwin E. Aldrin Jr., Eugene A. Cernan, Thomas P. Stafford, Neil A. Armstrong, and John W. Young.

LM, Snoopy, astronauts Stafford and Cernan would reconnoiter the planned landing site for Apollo 11.

The command and service module, Charlie Brown, with Snoopy attached, dropped smoothly into lunar orbit three days after launch. On May 22, John Young backed away in Charlie Brown while Stafford and Cernan prepared Snoopy for the simulated landing approach. The pair fired the LM descent engine for 27 sec, dropping their perilune to only 15.7 km, or 50,000 ft above the Moon (an overburn of just 2 sec would have sent the LM crashing into the surface).

From the cockpit they watched the landscape rise impressively toward them: The stark rims of impact craters loomed above the horizon, and gigantic boulders dotted the rugged hills of the lunar highlands. To capcom Charlie Duke, Cernan radioed his excitement: "We is GO and we is down among 'em, Charlie!"

Stafford reported that Apollo 11's landing area looked acceptably smooth, but much as he and Cernan might have wanted to pull off that first touchdown, Snoopy was too heavy to make the attempt. Completing their reconnaissance, they prepared to jettison the descent stage and fire up the ascent engine for rendezvous.

Aboard Charlie Brown, Young was enjoying his solo piloting stint. He had tracked Snoopy in his sextant, photographed landing sites, and studied the Moon's geology. "The back side of the Moon is an incredible sight, full of impact craters," Young says. On Charlie Brown, he had readied a backup rendezvous maneuver, just in case Staf-ford and Cernan were stranded down low. "I was set up to go get 'em," he recalls.

For a few seconds it looked as if he might have to do just that. Just before Stafford jettisoned the descent section, the LM gyrated wildly. "Son of a bitch!...What the hell happened?" asked Cernan. But the scare, the result of a bad switch setting, was momentary: Stafford regained control within 20 sec. The rendezvous and docking with John Young were normal. Racing home after nearly 62 hr in lunar orbit, Apollo 10 hit Earth's atmosphere at a record-setting 11.08 km/sec. "We made the fastest entry in Apollo," says Young, "and landed within a couple of miles of the recovery ship, the USS Princeton."

Apollo 10 approaches splashdown.

Cernan says his crew was never disappointed at not being assigned the first lunar landing. In *Apollo*, he argues that "...we painted the white line in the sky so Neil [Armstrong] wouldn't get lost!"

Testing NASA

Armstrong, Aldrin, and Collins indeed found their way to the Moon and back, following the trail blazed by the preceding four flights. Apollos 7 through 11 followed a building-block approach toward the ultimate goal, each flight building on the lessons of the last. Every piece of vital hardware was thoroughly tested, as were the people and their complex, far-flung organization.

Walt Cunningham hopes that today's astronauts will participate as closely in the design and testing of Orion as his crew did in the dark days after the Apollo fire. "I believe Apollo was so successful because the astronauts *lived* with their spacecraft. We worked constantly with the engineers, looked at the drawings, sat on all the change boards, and made our inputs. We were amazingly well-listened-to. Everyone was interested in our thinking."

During 1968-1969, the fast-moving Apollo test series was based on reasoned decisions by a NASA leadership that successfully weighed risk against the national directive to accomplish a landing before 1970. During that time, NASA's managers made all the right calls, measuring the length of each forward step against that presidential deadline, opportunities enabled by previous successes and, to some extent, what the Soviets might do.

The NASA Constellation team is preparing its first flight, the Ares I-X flight, for early this fall. Pending the results of the Augustine review panel and the administration's budget choices, NASA's Exploration Systems Mission Directorate will mount future Ares/Orion tests to support the new spacecraft's first piloted orbital mission.

The value of the clear-eyed approach taken by Apollo's managers, flight controllers, engineers, and crews is inescapable. Their decisions are a model for success today, and a reminder that testing shortcuts, whether imposed by constrained budgets or demands to shorten "the gap," are counterproductive. Now more than ever, it is essential to remember that thorough testing and prudent decision-making will be keys to making our next giant leap successful.

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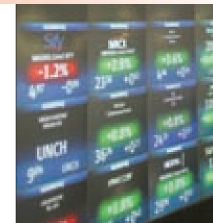

Industry's strength offers options in downturn

THE GENERALLY STRONG POSITION OF U.S. aerospace companies is giving them the flexibility they need to deal with a deep worldwide recession and with the beginning of a stagnation and potential downturn in defense spending.

The impact of the downturn varies by sector. Business jet manufacturers, through their connection with corporate profits, are the most vulnerable aerospace sector and have been hardest hit. The commercial airliner market has been hit more slowly, although it is also feeling the bite. Defense companies are in the strongest position of all—having the government as their customer gives them the firmest backlogs in the industry, and any downturn will be felt in future years as they begin to work off those large backlogs.

The boom years

In recent years, companies have benefited from a simultaneous boom in commercial aviation and defense. Military spending has been in the midst of the largest period of defense spending growth since WW II. Since 2001 the defense budget has risen by 38% in real terms, reaching $534 billion in the proposed 2010 base budget. If supplemental budget requests are included, the increase has been even more substantial, reaching 52% real growth to $664 billion in the proposed 2010 defense budget.

There was also a strong boom in commercial jet transports, which grew from $39.66 billion in deliveries in 2003 to $55.16 billion in 2008. Business aircraft deliveries have more than doubled in five years, increasing from $9.5 billion in 2003 deliveries to $21 billion in 2008.

Leading U.S. defense and aerospace companies were able to generate considerable profits. For the five largest U.S. aerospace and defense contractors, operating income increased to $15.3 billion combined, up 120% in five years. During the same period, industry operating profit margins were up more than 50%.

Backlog is at record levels. For major defense companies it represents two years of sales. It is even greater in commercial aerospace, but that backlog is now of more dubious quality because of the difficulties customers are having in financing their purchases.

The leading prime contractors have used that money well. Long-term debt for the five aerospace and defense prime contracts fell 45% over the period, to $19.9 billion.

Consider the position of Boeing, the world's largest aerospace contractor. In the proposed FY10 defense budget, the company faces threats from the proposed termination of the C-17 strategic transport, a scaling back of the Future Combat System, and cutbacks in its missile defense programs. It is also struggling from delays in its 787 program and from problems with customers obtaining financing for commercial airliners.

Yet despite these problems, Boeing is in a much stronger position than it was five years ago. Its long-term debt has declined from $14.4 billion in 2003 to $7.4 billion in 2008, a 49% reduction. Net earnings grew from $1.9 billion in 2003 to $2.7 billion in 2008.

Cash conservation is now a top priority for most companies, particularly for those with significant exposure to the commercial market. The pace of acquisitions has slowed considerably, in part because tight capital markets make it difficult to obtain financing, and in part because of the need to maintain a strong balance sheet in the downturn. EADS stopped a significant acquisition in the U.S. late last year because of concerns about its need to preserve cash.

Targeting R&D

The strong financial position of prime contractors gives them a wide range of options for dealing with the current downturn. The rapid growth in expenditures on plants and R&D means there is room to cut.

Commercial aerospace companies have been rapidly increasing their R&D spending. Boeing's $3.8 billion in 2008 was up $2.2 billion from 2003. That increase of approximately 140% reflected the costs of the 787 development program and the 747-8 widebody. Boeing Commercial Airplanes spent $2.8 billion of the $3.8 billion of company-wide R&D spending in 2008.

Major commercial aircraft subcontractors followed suit in their research and development. United Technologies' $1.7 billion in company-funded R&D spending in 2008 is up $600 million, or more than 50%, in the past five years. Honeywell's company-wide $1.5 billion of research spending in 2008 was up $700 million over five years, in part because of increasing expenditures on products for new aircraft.

This aggressive growth in commercial R&D spending will be a prime target as companies seek to retain strength during the downturn. Companies are making unannounced moves to go more slowly in development programs and taking other steps to stretch their research dollars.

Laying off and selling off

R&D is only one of the cost-cutting targets companies are using to stop the bleeding.

Layoffs are increasing rapidly. Boeing has announced that this year it will cut 10,000 workers, or 6% of its workforce, largely in commercial aircraft but

The strong financial position of prime contractors gives them a wide range of options for dealing with the current downturn.

also in defense. Other major aerospace companies also have announced cutbacks, including GE Aviation, with 1,000 layoffs, and United Technologies, with 11,600 layoffs company-wide.

Business aircraft manufacturers have been hit particularly hard. Since November Hawker Beechcraft has announced plans to cut 2,800 positions, more than a third of its workforce. Cessna plans to cut its workforce by 45%, to 8,900, by the end of this year. It is closing its Oregon single-engine facility and consolidating five leased facilities into other Wichita sites. General Dynamics' Gulfstream is laying off 1,200 workers and furloughing another 1,500 for five weeks this summer. Bombardier has announced two rounds of cutbacks amounting to 4,360 jobs out of a 30,000-person workforce.

Some of the hardest hit companies, because of their exposure to financing arms, have opted to sell assets to raise cash. For example, in April General Electric announced that it would sell an 81% stake in its homeland security business to French aerospace manufacturer Safran for $580 million.

While the sale fit with GE's need to raise cash, it also reflected its long-standing desire to exit the business that provides technology to detect hazardous or illicit materials in checked baggage. An earlier proposed sale of the business to Smiths Group fell through after the two companies failed to agree on its final valuation. The business has been a rare disappointment for GE. Its sales have actually declined since it purchased InVision in 2003 for approximately $900 million. GE Homeland Protection, which combines both Ion Track and InVision, reported sales of $260 million in 2008. InVision alone reported sales of $417 million at the time of its 2003 acquisition. Combined InVision and Ion Track made $460 million in 2004.

Textron has been the hardest hit by possible problems in its financing arm and by the business jet downturn. The company announced in February that it would sell HR Textron, a supplier of actuation systems for aircraft, guided weapons, and vehicles, for $365 million to Woodward Governor, and would sell its Fluid and Power business in November. In May it made public offerings of 23.8 million shares of common stock at $10.50 each, and $540 million worth of convertible senior notes. The offerings, which raised $821 million, served to quiet reports that Textron might be sold in its entirety.

Building portfolios

Defense companies less exposed to the commercial sector can even take advantage of the current downturn to build their portfolios in growth areas of the future. Strong balance sheets are critical in the present environment because financing is difficult to arrange. Defense firms often are able to make niche acquisitions without resorting to capital markets thanks to the strength they have built up over the past several years.

Homeland security has been a particularly active area for acquisitions this year. In addition to their prospects for continued growth in the coming years when the defense budget will be stagnant or declining, defense companies are comfortable with their ability to apply their expertise in systems integration to another federal market. Safran, for example, has not only proposed the acquisition of a major stake in GE Homeland Protection, but has also made another homeland security purchase of Motorola's biometrics business. The two acquisitions give Safran a major presence in the U.S. homeland security business. Harris agreed in April to make a $675-million acquisition of Tyco Electronics Wireless Systems. The purchase is intended to bolster Harris's position in the public safety radio network market.

Intelligence and cyber security represent key growth areas in which defense companies can apply their expertise. Intelligence agencies tend to be loyal customers because of their need for contractors with large numbers of security clearances. They also tend to offer higher profit margin work because of difficulties in finding qualified companies.

In intelligence, General Dynamics purchased one company earlier this year for $170 million. The transaction, disclosed only in a filing to the Securities and Exchange Commission, was so secret that General Dynamics never released even the name of the company acquired.

Cyber security alone is expected to be at least a $10-billion market over the next five years as the White House undertakes new initiatives designed to blunt Chinese and Russian advances in cyber warfare capabilities. QinetiQ announced in May that it would purchase Cyveillance for $40 million to bolster its cyber security position. The company provides Internet threat and risk analysis. Harris also purchased a company called Crucial Security. Its expertise involves defense against outside attacks and enables customers to launch attacks against their own systems to detect vulnerabilities. It also has computer forensics expertise for the extraction of counterintelligence and counterterrorism evidence.

UAVs are a prime area for acquisitions. The Teal Group's 2009 UAV forecast estimates that UAV spending worldwide will total $62 billion in 10 years. U.K.-based BAE Systems announced in March that it would purchase U.S.-based Advanced Ceramics Research, manufacturer of three small UAVs. Northrop Grumman built up its portfolio with its purchase of the Killer Bee UAV line from Swift Engineering earlier this year. In July 2008, Boeing purchased Insitu, manufacturer of the Scan Eagle UAV.

The Teal Group's 2009 UAV forecast estimates that UAV spending worldwide will total $62 billion in 10 years.

Obviously aerospace and defense companies are showing that they can use the financial strength they have built up in the past few years and take steps to buffer the current downturn. A few losers are emerging, but generally the industry remains in sound condition.

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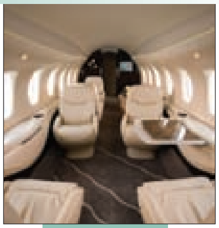


Business aircraft market falls hard

As the world economy struggles to recover from the massive financial shock of late 2008 and early 2009, the business aircraft market has lately found itself in free-fall. After growing at a record 17.1% compound growth rate between 2003 and 2008, business jet deliveries look set to fall even faster.

There are few hopes of a recovery any time soon, and signs point to a three-year downturn. The only consolation is that the fundamental drivers behind this market's transformation—it has almost quintupled in size since 1995—remain intact.

Citigroup was pressured to cancel its order for a Dassault Falcon 7X.

Some awful numbers

By any measure, the leading indicators of business jet demand are in terrible shape. Many world economies are shrinking, with the U.S. suffering a 6.1% drop in the first quarter of this year, following a 6.3% drop in the last quarter of 2008. There are fewer high-net-worth individuals—for example, two-thirds of Russia's billionaires in 2008 are no longer billionaires.

Worst of all, corporate profits, the indicator with the closest correlation to business jet demand, are slumping. From an annualized peak of $1.7 trillion in the third quarter of 2007, U.S. corporate profits fell to $1.3 trillion in the fourth quarter of 2008. Most forecasts call for a more serious drop this year. Typically, deliveries of new jets begin to fall about 12-24 months after profits fall. This market cycle looks set to fit the pattern.

The indicators of market health are in terrible shape too. Business jet utilization in the U.S., as measured by cycles (takeoffs and landings), has been falling by double-digit rates for eight consecutive months. March cycles are down by a disastrous 30% relative to a year ago. Used aircraft pricing is down across the board. Availability has reached record levels, with 16.2% of the fleet (well over 2,000 jets) up for sale as of April.

Typically, when 13% of the fleet is on the market, it has been a clear sign of a serious market downturn. The current level is unprecedented and indicates a severe oversupply problem. However, one possible explanation of this high number is that companies and individuals are putting their aircraft up for sale as a demonstration of frugality, either to politicians or to stockholders, but with no actual intent to sell the plane. That is the only possible silver lining in a dark cloud of numbers.

Meanwhile, backlogs, long vaunted as a large cushion for the manufacturers against any serious downturn, have been proven to be completely meaningless. All manufacturers had been reporting backlogs sufficient for several years of full production, yet they all have announced production cuts for this year or next. Clearly, backlogs offer no guarantee that a broad section of customers will not defer.

Cessna provides the best illustration of backlog weakness. Up until the fourth quarter of last year the company had planned to build 525 Citations this year, up from 467 in 2008. In November, it cut the number slightly, to 495. In late January, it cut anticipated 2009 production to 375. In April, this number was reduced to 290-300.

Notably, Cessna's backlog did not change much with these announcements. In late 2008 the company said it had a $14.5-billion backlog. When the first quarter of this year ended, the company announced a $13-billion backlog. Orders had slowed to a trickle, so the only changes were due to deliveries of existing orders and a relatively light number of cancellations (92 net in the quarter). This means these massive production rate plan reductions have been almost purely due to deferrals, against which backlog announcements are meaningless.

Has anything really changed?

These market health indicators and delivery outlook numbers are truly dire. But only two possible events threaten the future of the business aircraft market: an end to world economic growth, or an end to the link between that growth and

Public and political pressure drove GM to cancel its Gulfstream leases.

business jet utilization. The first is a very remote risk. The second risk is easily overstated.

First, there is no disguising the magnitude of the world economic downturn. Until April, the International Monetary Fund had tentatively forecast that the world economy would grow at a 0.5% pace this year. But that has since been revised, with expectations of a 1.3% shrinkage. This means that 2009 will be the first year without world economic growth since WW II. It is quite possible that the world faces a prolonged period of structural readjustment, or that it is reaching the limits of growth. Several prominent economists and commentators have stated the risk of this development at about 20%. But nobody believes that a depression of this magnitude is a baseline scenario.

Second, it is clear that the business jet industry is facing cultural headwinds. Key politicians in both U.S. political parties have criticized business jet users, and there have been some high-profile events that have cast a pall over business jet ownership. The CEOs of Chrysler, Ford, and General Motors came under heavy criticism for taking private planes to Washington to plead for aid money. GM promptly terminated leases on seven Gulfstream jets.

Similarly, Citigroup, the recipient of billions in U.S. government funding during the financial crisis, was pressured to cancel its order for a Dassault Falcon 7X. "The notion of Citigroup spending $50 million on a new corporate jet, even as it is depending on billions of taxpayer dollars to survive, does not fly," Sen. Carl Levin (D-Mich.) said on his Web site. Citigroup also put two older Falcon 2000EXs up for sale, although this might be an example of jets put on the market with no actual intent to sell.

Not long after, both Cessna and Hawker Beechcraft began advertising campaigns designed to defend the image of corporate aviation. Cessna President Jack Pelton pointed to the pressure on executives to avoid private aviation, saying, "That stigma is a factor we've never experienced in the past."

Yet it is not really clear that this cultural antipathy is entirely new to the market. History is replete with anti-business-jet pronouncements during recessionary times. In 1987, the movie *Wall Street* was widely viewed as putting bankers and their private jets to shame.

In the last downturn, one *USA Today* article commented that "sales of business jets, once the ultimate status symbols, have cooled with the U.S. economy…. The sleek stratospheric board rooms have come to represent corporate greed for some, and for others are simply no longer affordable."

That was in February 2003, a few months before the greatest growth spurt in business jet market history.

Moving forward

Nobody can say where the world is headed in terms of economic recovery, but one thing is becoming clear: The cause of this downturn—a devastating near-collapse of credit markets and financial liquidity—was a discrete event. There might be additional similar shocks ahead, but the crisis that led the world's economy to its current condition ended sometime in the first quarter of this year. That means the world will gradually resume growth sometime in 2010.

One alternative scenario posits that a sharp economic drop will be followed by an equally fast recovery. Possibly, this will involve inflation, which could hit the economy as a vast amount of government spending combines with an extremely loose fiscal policy. This would cause a rapid recovery in business aircraft market conditions, but it would likely produce anemic growth rates after that initial recovery.

A third alternative would be a

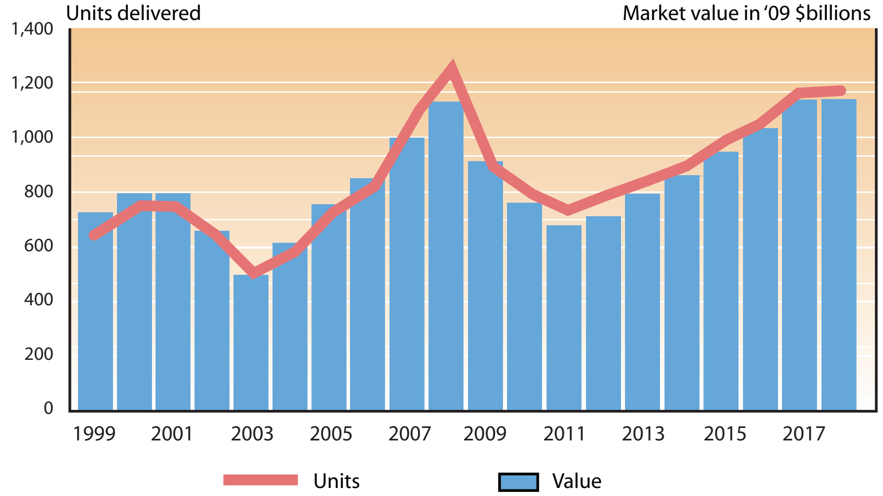
Last year, Cessna planned to build 525 Citations this year. By April, this number was reduced to 290-300.

decade-long depression. This would produce a "swimming pool" market trend, with a market drop followed by a long flat bottom. But as noted above, nobody regards this as a baseline scenario.

Assuming that our baseline scenario is the correct one, we can expect the economy to remain in recession through 2009 and 2010. This means business jet market conditions will stay poor through 2010, or early 2011, with no recovery in deliveries until 2012. If the number of available jets keeps rising beyond the present 16.2% of fleet, and if those jets are actually on the market, it might take an additional six months for new deliveries to recover as the market absorbs all of the used planes.

But making the assumption that the credit shock has produced a downturn that is relatively "front-loaded" (that is, with the sharpest market drop felt initially), a forecast of a 40% peak-to-trough ratio seems appropriate. This market drop is in line with past downturns, only longer.

BUSINESS JET FORECAST: A SUDDEN DROP
Excludes jetliners, RJ, and turboprops



Why the future still looks bright

Although business jet ownership and use have been equated by many with excess and abuse, the extraordinary transformation of the business aircraft market over the past 14 years has been closely linked with corporate profits. And the composition of these profits indicates encouraging trends too.

It is impossible to state empirically that one type of profit is more conducive to business jet demand than any other. But it is notable that manufacturing profits have made the strongest leap of all the business sectors. According to the U.S. Bureau of Economic Analysis, U.S. manufacturing profits leaped from $53 billion in 2001 and $48 billion in 2002 to $317 billion in 2007 and $240 billion in 2008. The strength of the U.S. economy in 2003-2008 had almost as much to do with manufacturing as it did with financial services. Profits in the financial services segment were stronger but flatter, going from $228 billion in 2001 and $276 billion in 2002 to $450 billion in 2007 and $309 billion in 2008.

There is a very strong likelihood that U.S. and other developed-country manufacturers are prospering because they are transforming themselves into product integrators. That means they are farming out labor-intensive production to work in developing countries, keeping higher value integration, development, and marketing for themselves. The establishment of new facilities in less developed areas increases the attraction of private aviation. And of course the profits that result from a successful new manufacturing strategy are also good for business jet demand.

This hypothesis is boosted by business jet demand in Europe. Just as U.S. companies are likely to transplant production to Latin America, European manufacturers are looking to new European Union entrants in Eastern Europe, as well as Turkey, for lower cost manufacturing. These Eastern European countries lack the excellent public infrastructure—airlines and trains—that have traditionally hobbled business aircraft demand in Western Europe. Companies setting up shop in Eastern Europe are looking increasingly toward private aviation. In 2001, only 10.7% of the global business jet population was domiciled in Europe. In 2008, Europe's share of the fleet was nearing 15%.

Meanwhile, economic development in emerging markets is gradually boosting business jet demand from customers in many of those countries, too. Relatively high commodity prices are further increasing demand, particularly in Latin America and the Middle East. Markets outside the U.S. accounted for 23.5% of the fleet in 2001, rising to 30% in 2008. Most business jet manufacturers in 2008 reported a majority of sales from outside the U.S.

Asia remains largely quiet as a source of demand, for reasons of geography, politics, and excellent airline service, but there are signs that this could change. Because of its economic growth, poor infrastructure, and great geography, China could emerge as a huge market as its airspace rules are liberalized. But as of 2008, the country had only about 20 business jets in civilian use.

If demand in China grows, the rest of Asia could easily follow. This is particularly true since many Asian manufacturers in higher cost economies such as Singapore, Japan, and Taiwan look to China as a source of lower cost manufacturing sites. Basically, Asian businesses located in high-cost manufacturing countries could emulate their U.S. and European equivalents, looking to private aviation as they follow an integrator model of manufacturing.

In short, despite the current grim market conditions and negative short-term outlook, there are solid reasons to assume that this market will recover and resume its growth in the future.

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The Gravity Field and Steady State Ocean Circulation Explorer, an ESA satellite launched earlier this year, will take measurements of unprecedented precision, providing information not just for esoteric scientific purposes but also for down-to-earth applications.

GOCE adds gravity to ESA's agenda

This year has seen several milestones in international space programs, from claimed first satellite launches by Iran and North Korea to the launch of the first satellite that will seek Earth-like planets elsewhere in the galaxy to delivery of the final U.S. component of the ISS. On March 17, ESA made a major contribution to the list with its launch of the Gravity Field and Steady State Ocean Circulation Explorer (GOCE) from the Plesetsk cosmodrome in northern Russia.

The first of a new generation of European satellites dedicated to studying the Earth, GOCE was developed to bring about a whole new level of understanding of one of the planet's most fundamental natural forces: gravity.

Lifted into near-Sun-synchronous LEO by a Rockot launcher, GOCE will measure minute differences in the Earth's gravity field at points all over the globe. It is also the first in a series of ESA satellites designed to expand scientific understanding of a host of planetary system processes involving Earth's atmosphere, biosphere, hydrosphere, cryosphere, and interior, and how they interact with each other and with human activities—including a possible impact on global climate change.

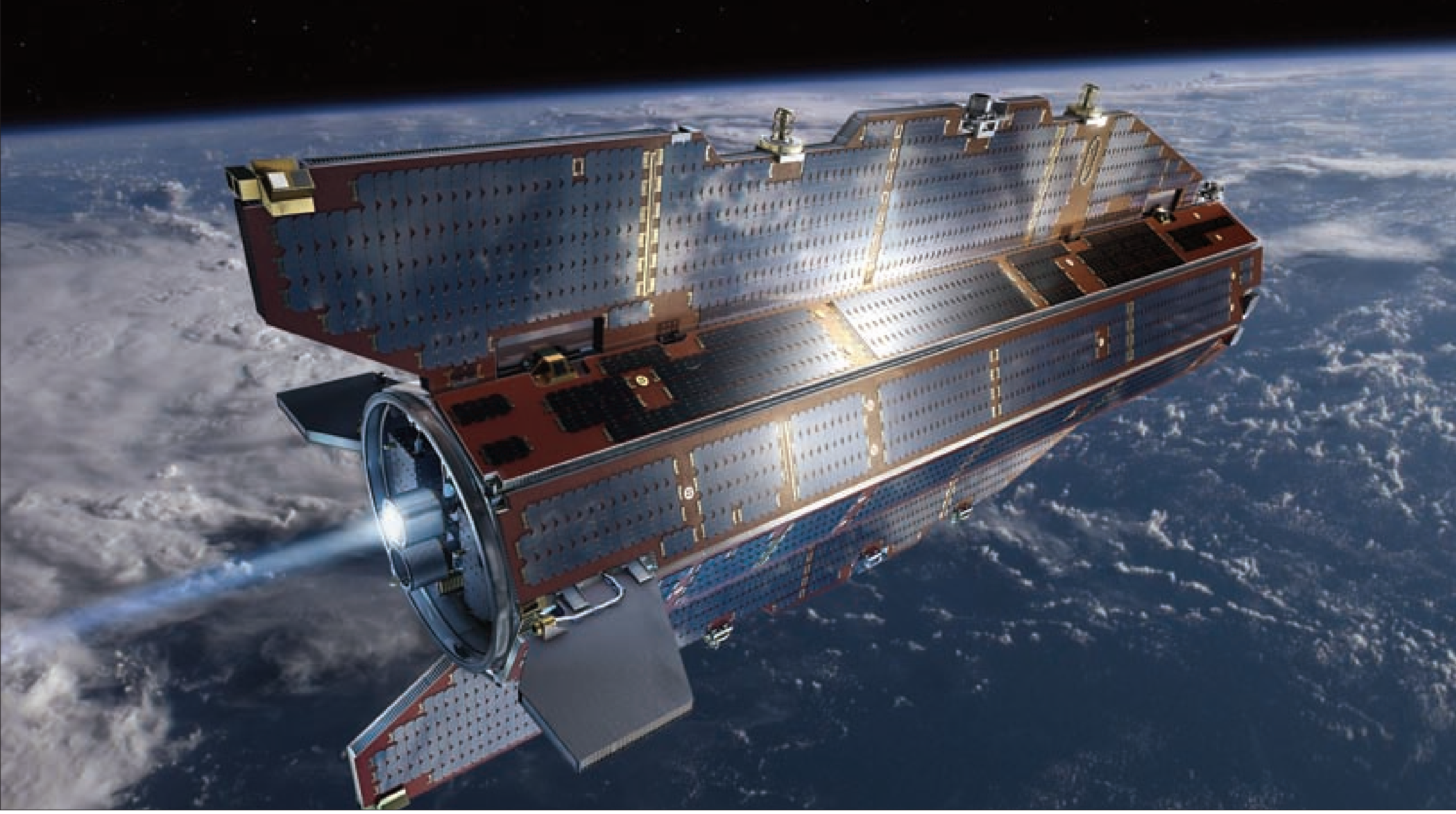
"GOCE is ESA's first science satellite dedicated to Earth observation since Envisat in 2002. The size has changed, but the rationale remains the same: To provide the best science our technology can deliver for the maximum benefit of the science community and ultimately the citizens of Europe and the world," said ESA Director General Jean-Jacques Dordain after the successful launch.

Timing the mission cycle

Selected in 1999 as the first Earth Explorer Core Mission under ESA's Living Planet Program, GOCE originally was intended for launch in 2006, but was delayed by a series of setbacks. The most recent, which negated the last 2008 launch window in October, resulted from a launch vehicle problem discovered last fall during ground tests.

"When the mission was designed, we determined there were periods of the year that are optimal for launch," ESA GOCE project manager Danilo Muzi tells *Aerospace America*. "The period in which we can perform measurements also

by J.R. Wilson
Contributing writer



depends on solar activity, which influences the Earth's atmosphere; during periods of high solar activity, we would have higher air drag. Right now we are in a minimum solar activity period, which allows us to fly low.

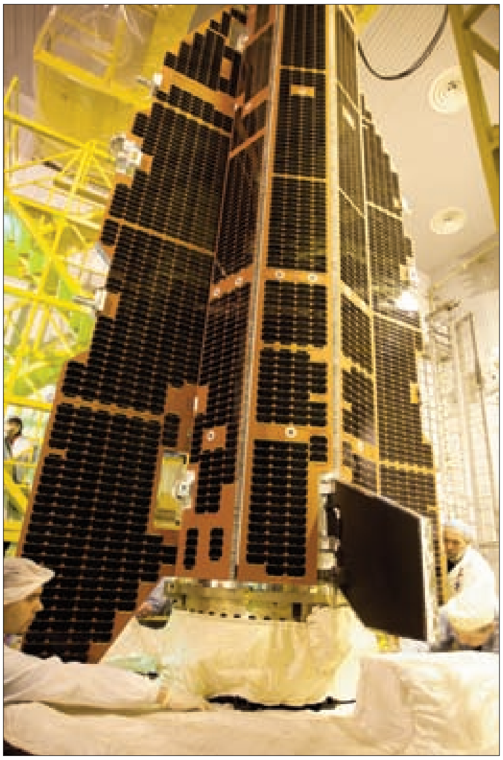
"If we'd waited too long and solar activities had gone up, we would have had to raise the altitude of the orbit, which would have impacted the quality of the measurements. The orbit also dictates the utility of the ion track. For all those reasons, and because of all the delays we had incurred, we were determined to launch as soon as possible [rather than shoot for the optimal window]."

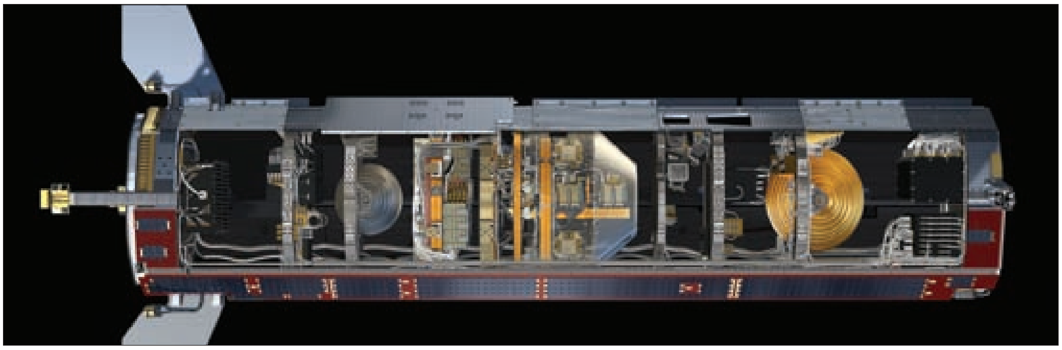
The nominal mission duration is about 20 months, including two measurement phases of six months each, with the possibility of extending the lifetime for about 10 months, based on expendables aboard the satellite. The time between measurement phases represents periods of long eclipses, each lasting about four months, during which the satellite will hibernate. The 20-month mission begins with about three months of calibration and commissioning, followed by six months of measurement, four months of hibernation, and a final six-month measurement cycle.

If onboard fuel stores are sufficient at the end of that period, ESA may elect to put GOCE into one more hibernation and conclude an extended mission with a third measurement phase.

"We are hoping, then, for two more years of relatively low solar activity, based on current predictions on the evolution of solar activity. But that is open to change and could be quite different a year from now when we are in our second period of measurement," Muzi says. "By using the ion tracker, we can raise the orbit. That will

GOCE is equipped with four body-mounted and two wing-mounted solar panels. In orbit, the same side always faces the Sun. Images courtesy ESA-AOES Medialab.





GOCE is 5 m long and about 1 m in diameter. It consists of a central octagonal tube with seven internal 'floors' that support the equipment and electronic units. It is built largely of carbon-fiber-reinforced plastic sandwich panels to guarantee stable conditions and minimize mass. The gradiometer is mounted close to the satellite's center of mass.

take time, but we will increase the altitude by about 15 km when we move from a measurement period to a hibernation period—going from, say, 263 km to 280 km, then descending back to 263 if we can, or staying higher if there is increased solar activity."

The satellite can fly at a minimum altitude of 250 km, based on thermal influences, air drag, and so on; the maximum for quality measurements is roughly 290-300 km, with an optimal altitude of about 260 km to meet all of the mission requirements. After completing its first orbit, the 1,052-kg spacecraft was successfully released into a circular polar orbit at 280-km altitude with a 96.7° inclination to the equator. After six weeks of initial checkouts, it will be moved into a 263-km operational orbit for payload calibration before beginning mission operations this summer.

Modeling the geoid

"The data to be collected from this satellite will be used to devise a really precise gravity field [map] of our planet and create a model of the geoid," Muzi says of the 3D gravity data GOCE will collect from across the globe. "These two models are of high interest to a quite wide scientific user community, from geophysicists to geodetics to geographers."

The geoid is the irregular gravity field that shapes a virtual surface at mean sea level. According to Muzi, this is the surface of equal gravitational potential of a hypothetical ocean surface at rest and is often employed as a reference for traditional height systems used for leveling and construction. However, the surface of the geoid can deviate by as much as 100 m from an ellipsoidal model representing the Earth.

"By having this precise geoid and Earth gravity model, we will be able to increase our understanding of ocean currents; this plays a significant role in improving climate models, because the oceans are an important mechanism of heat transfer from the equatorial regions to the poles," he notes. "Once you have the precise geoid, you also are able to determine sea levels in a uniform and global way, rather than just using local reference systems.

"With a unified measurement of sea levels, you can determine gravity field anomalies and how the field differs from the theoretical distribution of densities. So this will refine the characteristics of the gravity field and provide more information on the interior of the Earth, especially magma under volcanoes and tectonic movement.

"This information will not be able to forecast an earthquake, but it will certainly help geophysicists better understand the areas subject to earthquakes by giving them indirect information on the characteristics of the interior of the Earth. Until now, scientists have had to make some assumptions on key elements; with GOCE, those now can be refined, making these models more accurate and precise, providing better analysis and extrapolations."

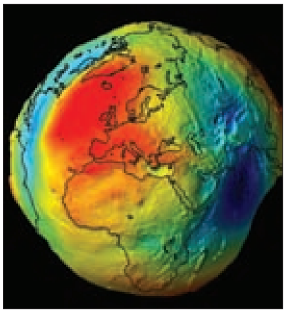
Outdoing ancient Rome

Other uses for the geoid include the measurement of height for engineering applications, such as building long bridges or canals or a tunnel through a mountain ridge. That is especially important for projects that cross national borders, where countries may have different methods of measurement.

The ancient Romans, in building aqueducts that carried water hundreds of miles over terrain of varying heights, managed to accomplish that through extensive local measurements and adjustments, a difficult, time-consuming process given the limited instruments available to them. Despite advances in surveying equipment and the use of computers, that process has remained essentially the same—and with limited application—for more than 2,000 years.

"With GOCE, we have a reference system that is planet-wide. In theory, you could say you could do these measurements on the

GOCE will measure high-accuracy gravity gradients and provide a global model of Earth's gravity field and of the geoid, which serves as the classical reference for all topographical features. The accuracy of its determination is important for surveying and geodesy, and in studies of Earth interior processes, ocean circulation, ice motion, and sea-level change.



ground, but it would take a lot of time and money, making certain everyone was using the same instruments and measurement systems," Muzi says. "Planet-wide, that would be very difficult, if not impossible; using the satellite, you know you are using the same instruments and measurements and so have uniform data."

Polar ice, ocean currents

GOCE's advanced instruments and orbital perspective also will provide monitoring of sea levels and distributions across the Earth's surface that can be used to help measure the size, location, and changes in polar ice sheets. The satellite's data also will be combined with other measurements, including those from radar satellites that measure the actual height of the sea at specific times and locations to determine sea levels.

"When we say GOCE will actuate sea level measurements, we mean using the GOCE geoid information in combination with other satellite data on the height of the sea at a specific location," Muzi points out. "Because the geoid actuates to a level of 1-2 cm and provides a global reference system, a better understanding of this huge flow of water will be a highlight of this mission. In respect to those things that are not known, and now will be better known, the main area will be the ocean currents."

To accomplish its goals, GOCE is equipped with a state-of-the-art electrostatic gravity gradiometer that is being flown on a satellite for the first time.

"Basically, it is able to measure differences in gravity in two forms. It comprises six accelerometers, aligned in pairs, and will enable us to recover data for the gravity field model and geoid," Muzi says. "We also have a satellite-to-satellite tracking instrument, a special GPS receiver that will be used to determine very accurately the orbit of the satellite and deviations with respect to the radial line. These differences are considered to be characteristics of anomalies in the gravity field. Variations across big expanses will be determined by looking at these perturbations in the satellite's orbit."

Achieving extremes

Combined, the information from these two sources will be processed to determine differences in the model with far greater accuracy than scientists and engineers have been able to achieve before. To accomplish that, the team had to develop ultrasensitive accelerometers—which can measure acceleration 100 times better than anything previously available—and also needed to provide extreme stability for the instrument package.


The star trackers on GOCE were tested in a dimmed clean room.

"To be able to do this very accurate measurement, we are compensating for air drag. We are flying quite low, where there is still some remnant of the atmosphere. These remaining molecules tend to slow down the satellite. That will be seen in the accelerometers as a deceleration that would dilute our measurements. But we compensate for that by tracking along the velocity vector. We use an ion propulsion tracker to precisely compensate for the deceleration the satellite otherwise would have due to air drag. This drag-

> **"This launch success marks the dawn of a new generation of Earth sciences satellites in Europe."**
>
> ***Volker Liebig,*** *director, ESA Earth Observation Programs*

free control system is unique in satellites and required the development of new control algorithms," Muzi notes.

Each of the two low-power xenon ion engines—one primary and one backup—deliver 1-20 mN of thrust, roughly equivalent to the force of a human exhaling. That such a minute amount of thrust can be so critical to a low-altitude platform such as GOCE demonstrates the extremes required for successful space missions.

"Overall, the satellite is quite advanced because of the technology being used and represents quite a piece of engineering work, because it has no moving parts—no electric motors or anything that would create disturbances that would perturb the measurements of the accelerometers. We spent quite some effort to ensure, for example, the thermal gradient does not create disturbances. And the satellite will be extremely quiet as well."

A group effort

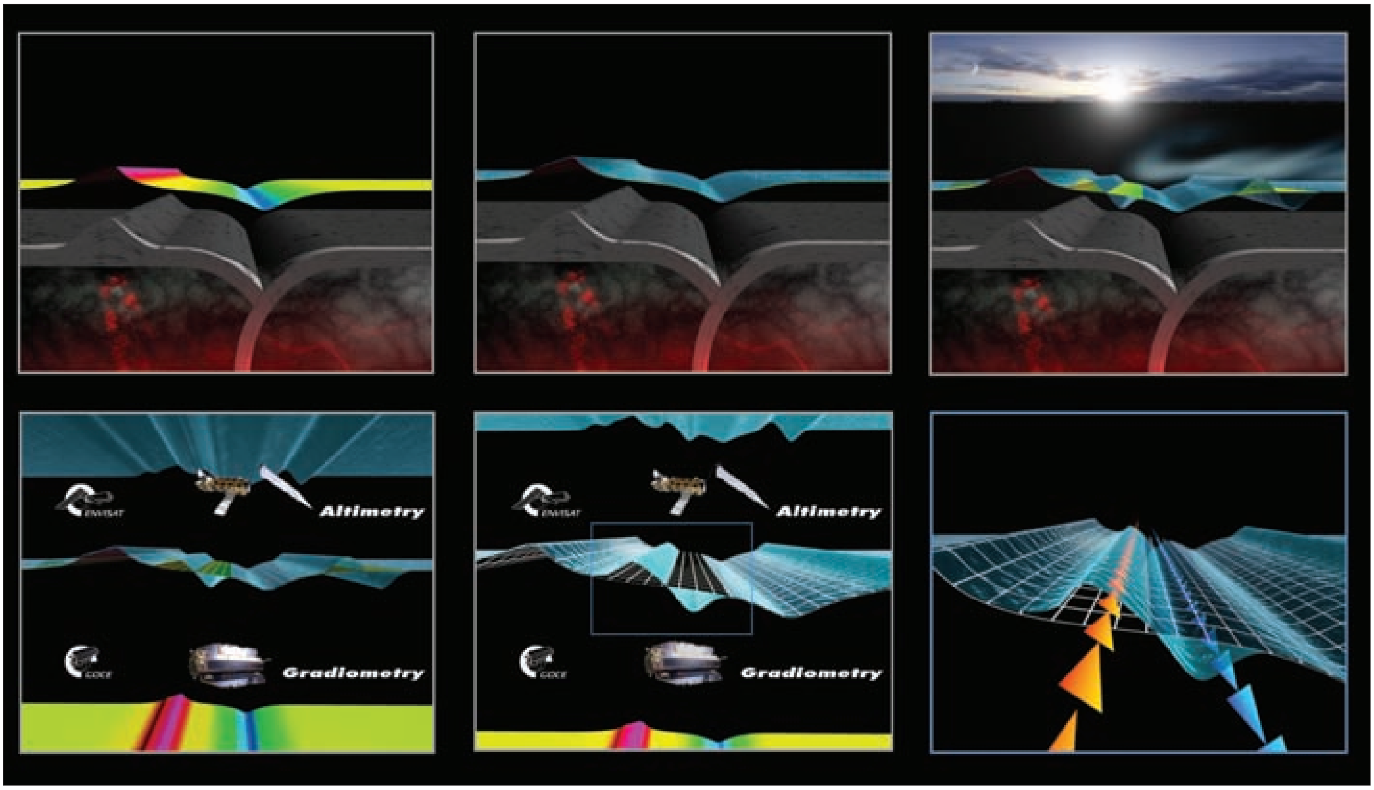
Thales Alenia Space in Italy was prime contractor for GOCE, but the satellite and its components were the result of input from a consortium of about 45 companies from throughout Europe. EADS Astrium Space in Friedrichshafen, Germany, provided the platform, for example, while Thales Alenia Space in Cannes, France, developed and integrated the main instrument using ultraprecise sensors developed by Onera of France.

"For the ground segment, we divide data processing into two stages," Muzi adds. "A consortium of 10 leading scientific institutes and universities across Europe have developed the infrastructure for the processing facilities. This consortium is led by the Technical Institute of Munich."

Some of the technologies developed for GOCE are expected to make significant contributions to other space systems in the future.

"Whenever you need a dimensionally stable structure or large carbon-carbon construction—for a space telescope, for example—we will be able to do that better," Muzi explains. "And if you need to very accurately measure acceleration, what we have developed is the best so far.

"Another advance is the ion tracker, which is capable of continuously modulating its track level in a very precise way. In the past, ion propulsion engines were used more for on-off activations with a constant thrust, especially on communications satellites for station-keeping. We are using these thrusters to compensate for air drag, so we had to expand the capability of this type of engine to move the satellite track in a very precise way.



Density variations in the Earth's crust are an important factor in shaping the geoid. External forces such as the wind cause the sea surface to deviate from the geoid. The combination of sea-surface height mapped by altimeters and the knowledge of the precise ocean geoid will improve our understanding of surface currents. Credit: ESA-AOES Medialab.

Anyone who needs that kind of actuator on a future mission will now have it available."

Gravity varies

While most people assume gravity is a constant on the Earth's surface, it actually varies, by minute degrees, depending on a variety of factors. "If you jump from a window, you accelerate at 1 *g*. At [an altitude of] 160 km, the acceleration is attenuated and compensated by centrifugal acceleration in orbit; you remain in orbit because your centrifugal acceleration matches gravitational acceleration," Muzi says. "If centrifugal acceleration is less than gravitational acceleration, you will begin to drop; if it is greater, you will move away from the Earth.

"For a satellite, the rotational speed creates a perfect match between centrifugal and gravitational acceleration. The six GOCE accelerometers, by being in a diamond configuration as close as possible to the center of gravity, but not exactly at the center, experience and measure acceleration. The distance between the accelerometers in each pair is just 50 cm, so they can measure the mismatch between centrifugal and gravitational acceleration over very small distances, with a sensitivity much greater than the human mind can appreciate."

The satellite instruments will not measure gravitational waves, so Muzi says it is unlikely the sensors involved will lead to any major discoveries in physics.

"What we may find are features in the gravity field that were not known, at least at that level of spatial resolution," he adds. "We may find there are some areas on the Earth where the local gravity field looks pretty strange and unexpected, which may give rise to future investigation. This interests geophysicists because it gives information about characteristics of the composition of the Earth's mantle. If you have areas of dense material, you would have a strong local gravity field; where the material is less dense, you have a lower local gravity field.

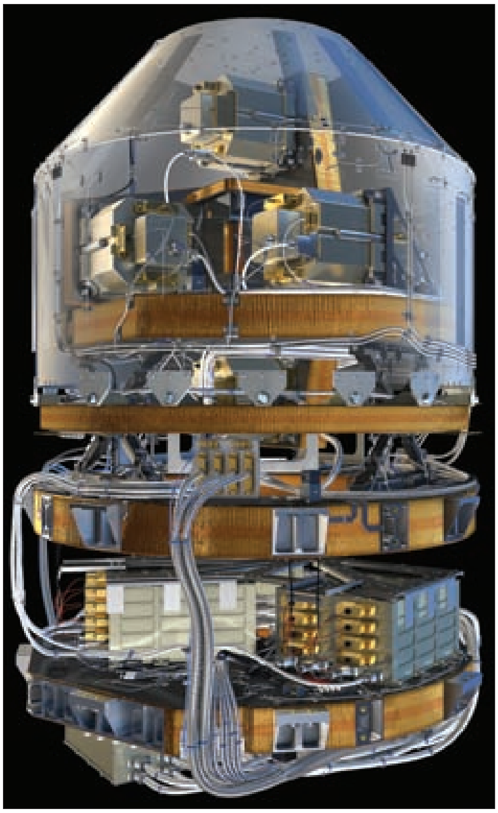
"For example, 1 *g* is 9.8 m/sec^2. The Earth is shaped like a potato, with a bigger radius at the equator than at the poles, so at the equator you might have a *g* that is 9.78 and 9.83 at the poles. And that has implications. Smaller changes than that influence ocean circulation, for example."

Data for future efforts

As with any experiment that collects new data in new ways from a new place, exactly what will be learned from GOCE, near- and long-term, is not predictable. How the satellite operates at the very edge of the atmosphere may be of great interest to those who plan to launch suborbital and low-orbit spacecraft carrying tourists into space, for example, while fractional variations in gravity could affect the location of future launch sites or even the viability of the space elevator concept.

"[GOCE] is the first of a new generation of small, dedicated science satellites, and it paves the way for more Earth Explorer missions," says Volker Liebig, director of ESA's Earth observation programs. "The scientists are urgently awaiting the data sets from these missions. We have four more launches due over the next two years."

Those include the ADM-Aeolus satellite, to be launched in 2011 to study atmospheric dynamics, and EarthCARE, a 2013 mission to investigate Earth's radiative balance. Also under development are three smaller Earth Explorer Opportunity Missions, including two for launch later this year—Cryosat 2, to measure ice-sheet thickness, and SMOS to study soil moisture and ocean salinity. The third, in 2011, is Swarm, a constellation of satellites to study the evolution of Earth's magnetic field. As Liebig points out, "This means that we are in for a very busy time."



The GOCE gradiometer consists of three pairs of identical ultrasensitive accelerometers, mounted on three mutually orthogonal arms. One arm is aligned with the satellite's trajectory; one points toward the center of the Earth; the third is perpendicular to the other two. This allows the simultaneous measurement of six independent but complementary components of the gravity field.

A hot rod for the

A plasma rocket concept that could drastically reduce travel time to deep space destinations passed an important milestone late last year that could lead to testing of the system on the ISS by 2012. If early experiments are successful, such a rocket could someday cover the distance to Mars in little more than a month's time.

If your idea of an advanced rocket factory does not include swaying palm trees, sun-drenched skies, and low overhead, then maybe you should get out more. Far down south, in fact, to the tranquil soil of Costa Rica. There, in a small plant a stone's throw from an airport linked to the U.S. mainland, the employees of Ad Astra Rocket are hard at work on a radical new engine design.

The concept, a plasma rocket called the VASIMR (variable specific impulse magneto-plasma rocket), holds new promise not just for commercial applications in LEO and cislunar space, but also for drastically reducing the transit time between the Earth and deep space destinations such as Mars or the asteroid belt.

The path to VASIMR began more than 30 years ago as the brainchild of Franklin Chang-Diaz, then a graduate student at MIT, where he earned a doctorate in plasma physics. In 1980 he continued to refine his idea at the Charles Stark Draper Laboratory and MIT's Plasma Fusion Center.

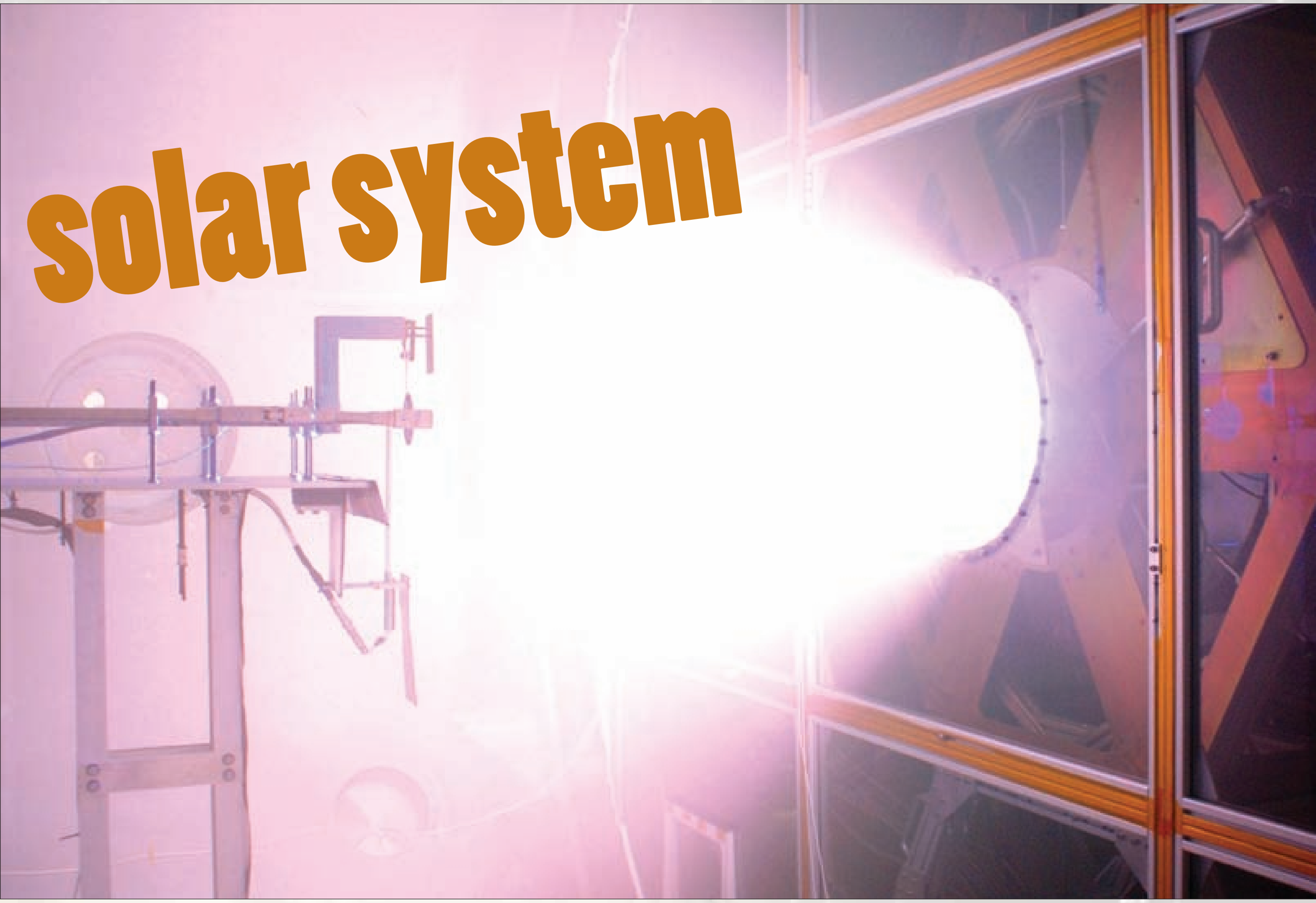
Chang-Diaz joined NASA as an astronaut in 1980 and flew seven missions aboard the space shuttle, including a flight to the ISS. From 1993 to 2005 he served as director of NASA Johnson's Advanced Space Propulsion Laboratory, where he refined the plasma rocket concept. In 2005 he left Johnson to form Ad Astra Rocket, with test facilities near the space center and in Costa Rica, his birthplace. NASA Johnson and Ad Astra worked jointly on the VASIMR design, forming a more structured partnership announced in 2008.

A different kind of rocket

All rockets achieve propulsion by expelling exhaust—action and reaction, Newton's Third Law of Motion. In the case of chemical rockets, the exhaust is usually a gas expelled from a specially designed nozzle. Typically it is expelled at great heat and at a high temperature relative to the rocket's structure. A chemical, or thermal, rocket carries fuel on board in the form of either liquid or solid materials, along with an oxidizer that burns the fuel in a controlled combustion. The combined fuel and

by Frank Sietzen Jr.
Contributing writer

solar system



The plasma plume exits the rear of the rocket at extremely high temperatures and speeds.

oxidizer make up most of the vehicle's weight; its structure and usable payload account for the relatively small remainder.

The exhaust velocity generated by chemical rockets is powerful enough for lifting the rocket vehicle into space to speeds that allow escape from the Earth's gravity field. But the velocity achieved does not make for high-speed travel, and the flow rate of the burning of the propellant usually is so high that most of the chemicals are consumed in the early stages of powered flight.

But engineers have been able to create much higher exhaust speeds using a plasma-powered rocket. Here, a gas is heated by means of electrical energy, producing an electrically charged exhaust, or plasma plume. Temperatures of plasmas usually exceed 10,000 C, but in laboratory test beds they are sometimes much higher, comparable to that of the interior of the Sun. Because no known structure could withstand these temperatures, a plasma rocket "delivers" its exhaust by means of a magnetic or electrical field that is used to control, heat, and direct the plasma plume created by the heating of feedstock gas such as hydrogen or argon.

Via a special type of engine magnetic nozzle, the plasma plume exits the rear of the rocket at extremely high temperatures and speeds, an order of magnitude higher than those produced by a chemical rocket engine.

In lieu of chemical energy, the plasma rocket requires large amounts of electrical energy to produce and heat the plasma and produce thrust.

The VASIMR

The rocket engine design consists of three linked magnetic cells. The plasma source cell contains the main injector of a gas and the ionization system that converts it into a plasma plume. The RF booster cell acts as an amplifier that further energizes the plasma to the temperature desired for the mission, using electromagnetic waves. The magnetic nozzle cell converts the energy of the plasma ions into directed motion and thrust.

In the overheated gas plume, electrons, which hold a negative charge, and ionized atoms, which hold a positive charge, are mixed together to produce a "soup" of charged particles called a plasma. No known rocket structure could contain the temperatures produced by the electromagnetically charged plasma. This job is performed by the engine's magnetic field.

Chang-Diaz notes that the VASIMR's ability to vary its thrust and specific impulse is unique to electric plasma rockets. The engine is controlled by electromagnetic waves and thus has no electrodes that contact the hot plume. This, he says, results in a safer combustion process and higher reliability as compared to other chemical or plasma rockets.

For LEO missions, solar array technology would be sufficient to produce the electricity required. For long-duration deep space missions, thermonuclear power systems would be required. A 200-MW version of the VASIMR with extreme temperature plasma exhaust could propel a manned spacecraft from the Earth to Mars in about 39 days, a fraction of the 7-10-month-long one-way trajectories typical of chemical rocket propulsion.

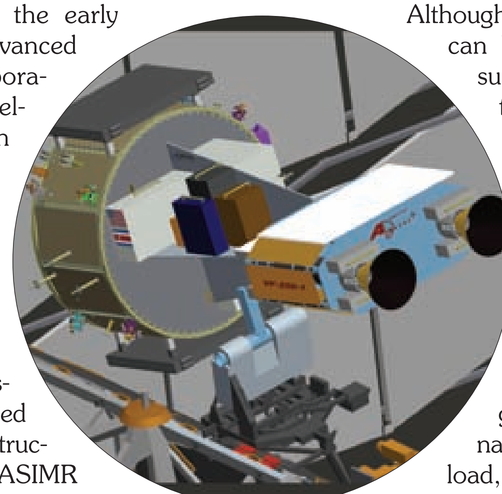
coils consisted of hollow copper conductors wound around a composite mandrel. The magnets were inexpensive and durable, could be switched on and off quickly,and did not need to be cooled to cryogenic temperatures.

Inside the magnet bore, a helicon plasma generator and an ion cyclotron plasma booster produce and heat the plasma respectively by means of electromagnetic waves. Individual components could be easily replaced, developing a test-bed record for system performance and durability. These results were factored into the development of the more powerful VX-200, a 200-kW system that went into operation in May 2007.

Unlike the previous experiments, the VX-200 is much more flight-like, featuring a superconducting magnet and integrated systems in an engine package that operates in a vacuum. Partner Nautel of Canada provides the solid-state RF generators; the superconducting magnet was manufactured by Scientific Magnetics of Oxford, U.K. The system also tests prototypes of onboard computer control software and hardware. Testing is done in the 150-m^3 vacuum chamber "El Monstruo" at the company's headquarters in Houston.

Test and engine evaluation

In the 1990s, during the early years at the NASA Advanced Space Propulsion Laboratory, the project developed partnerships with a number of universities and the national laboratories at Oak Ridge and Los Alamos. These relationships resulted in advances in understanding the controlling physics of the concept and led to the design and construction of the VX-10 (VASIMR experiment at 10 kW), which derived from the early MIT experiment and became the first experimental physics test bed at NASA.



The company plans to take a flight test version of the VX-200 to the ISS for test firings.

Then, in 2005, the newly formed Ad Astra Rocket Company took the project from NASA, upgraded it to 50 kW (the VX-50), and tested new technologies in antenna design and solid-state radio frequency power generators. These experiments led to the VX-100, a 100-kW test engine built in 2007 that used a magnetic field created by conventional water-cooled electromagnets. Each of the magnet's

Missions

Although the plasma rocket engine can build to high-temperature sustained thrust, its low thrust-to-weight ratio makes it unsuitable for use as a booster stage engine to lift a rocket and payload from the ground into orbit. Instead, VASIMR is envisioned for use in upper-stage rocket designs, propelling cargo to in-space destinations such as geosynchronous orbit or lunar escape, where a high-payload, albeit prolonged, multimonth cruise to the Moon is more economically attractive than the conventional chemical approach.

"We aim to fill a developing high-power transportation niche for orbital maintenance for the maneuvering of satellites and positioning of large space structures for commercial space projects, such as space hotels or space tourism," Chang-Diaz says.

Ad Astra plans to take up a flight test version of the VX-200 for test firings at the ISS. The rocket and its associated battery system would be launched aboard either the Orion crew exploration vehicle or a COTS derivative, using a commercial launch booster to reach and rendezvous with the ISS. Diaz says the unit could also be packaged for launch aboard the space shuttle if they are still in use. But a commercial lift to the ISS—or Orion—seems like the more likely vehicle to take the VASIMR into space for the first time, possibly as early as 2012.

The VF-200-1 flight engine will consist of a pair of 100-kW units with opposite magnetic dipoles to have a "zero torque" magnetic system. Electrical energy will be provided at the ISS, stored in batteries carried aloft with the rocket unit and used to fire up the test unit at the station, throttling to 200 kW of power.

Partnerships with NASA

"We see it as the type of project that is a perfect partnership with commercial space companies," says Michele Brekke, director of innovative partnerships at NASA Johnson. Brekke says NASA has been studying ion and plasma rocket engines since the 1980s, with Glenn developing the ion engine for spacecraft propulsion on interplanetary probes.

On December 8, 2008, following years of work between the company and NASA Johnson, the agency announced an agreement defining the terms of the spaceborne test flight. Under the structure of a Space Act Agreement, NASA and Ad Astra will develop the flight test version of the VF-200-1 under what Bill Gerstenmaier, NASA associate administrator for space operations, called a series of performance "gates." These were built into the agreement to allow the parties "to assess the requirements on an incremental basis while at the same time proceeding to flight.

After completion of the developmental milestones set forth in the agreement, such as sustained test firings in a vacuum chamber simulating space conditions, the VASIMR would be flown to the ISS. A specially trained station crew would install the rocket on an ISS truss. The engine would be ignited and fired up to varying power levels, with a maximum of 200 kW. Each engine burst will be restricted to 10 min at maximum power settings, with the batteries trickle-charged from ISS power stores.

At some point during the test firings, the VASIMR will be used to demonstrate a station reboost capability, much like that performed by the Russian Soyuz and Progress and the European ATV. "This will be the first time a high-power electric rocket thruster has been used on a manned spacecraft," says Diaz.

Ad Astra will be responsible for designing the training procedures for the station crew, and will work at Johnson to prepare the astronauts for the flight. "We haven't manifested [the VASIMR] yet, but a flight in the 2010-2012 period is probable," Brekke says. She also says that Johnson and Chang-Diaz are still early in designing the training protocols for the project. Following a successful ISS demonstration, the unit would be ready for commercial deployment.

Reaching a milestone

Late in 2008, the engine test bed reached a major development milestone. Using argon gas as the propellant, the VX-200 first stage reached a full power setting of 30 kW at the Houston facility. The helicon first stage generates the initial plasma that is subsequently accelerated by the second stage to produce the sustained thrust.

With the milestone achieved, the engine's 170-kW ion cyclotron resonance heating second stage was integrated with the first stage. The second stage completes the heating process and expels the plasma plume out of the rear of the rocket in a sustained, controlled thrust. The first stage's 30 kW and the second stage's 170 kW combine to produce the full 200 kW of power. As of this writing, the VX-200 has achieved a record total power of 149.2 kW in tests. In contrast to a chemical multistaged rocket, in the VASIMR both stages fire nearly simultaneously.

Chang-Diaz defined the test milestone as a major challenge for his design. It marked an

Late last year the VX-200 first stage reached a full power setting of 30 kW.

absolute record for power, using the RF solid-state power generator developed by Nautel, which also makes the RF generator for the second stage. "We worked for weeks to integrate the first and second stages," he explains. New computer algorithms were developed to control and stabilize the plasma.

"Another challenge was the startup phase, because of the extreme changes in the electrical environment that accompanies the initial plasma," he says. The new control algorithms "overcame these difficulties" and allowed the power ramp-up to continue. These new control systems will be used extensively in the continued evolution and development of the more powerful second-stage system.

Testing is done in the company's facility in Houston, Texas.

Long-term prospects

Chang-Diaz points to the series of commercial space projects now in development that could make use of the VASIMR system to maneuver and position large space structures, or carry cargo packages to the lunar surface.

"For lunar missions without humans on board, a slow cruise using very small amounts of fuel but sustained thrust would be an effective way of moving large payloads between the Earth and a lunar base," he predicts. He also says the Moon's surface would be an ideal place for a VASIMR test facility, to mature the the multi-megawatt engines required for deep space human missions.

And if the U.S. ever decides to begin planning seriously for humans to travel to Mars, the VASIMR might well be ready for use. The former astronaut and bona fide rocket scientist is optimistic. After all, he points out, Ad Astra means "to the stars."

Airborne laser aims at final tests

Killing missiles at the speed of light, a capability long heralded in science fiction, may soon find practical application in the form of the airborne laser. After several delays, the technology has overcome some barriers once considered insurmountable, achieving major advances in power and performance. If upcoming tests are successful, the system could see deployment as early as next year. The greatest challenge, however, may be securing sufficient funding to keep the program alive.

by J.R. Wilson
Contributing writer

The idea of using a beam of light to shoot down an enemy platform has been part of popular fiction since before the first Buck Rogers story was published 80 years ago. More than three decades later, the concept began to draw real-world military interest with the invention of a device capable of light amplification by stimulated emission of radiation—the laser.

For the remainder of the 20th century, however, laser beams were either too weak to neutralize a missile or aircraft at any tactical distance, or too large and heavy, in concert with a power source, for practical use aboard an aircraft. But new, smaller, lighter, and more powerful devices began coming out of the labs just as computers evolved sufficient power and speed to handle the complexities of acquiring a target in flight and fixing the aim-point long enough to produce lethal damage.

The airborne laser (ABL) was the first serious attempt to design, build, demonstrate, and deploy a high-energy laser device—specifically, a chemical oxygen iodine laser (COIL) carried aboard a Boeing 747-400F freighter, described as the most heavily modified 747 in the world. The program began with a definition and risk reduction contract award to Boeing by the Air Force in 1996. Since being transferred to the Missile Defense Agency in October 2001 and converted to capability-based acquisition, the ABL has undergone dozens of tests, including ground tests of the laser and flight tests of the beam control/fire control system, in preparation for full system flight tests scheduled for this year.

Boeing, the team leader, is responsible for weapon system integration, the 747-400F aircraft, and BMC4I (battle management, command, control, communications, computers, and intelligence). Northrop Grumman designed and developed the COIL and the beacon illuminator laser, while Lockheed Martin supplies the beam control/fire control system.

The first attempt to shoot down a live missile of the type ABL would likely confront in actual combat is currently scheduled for August or September. The exact target remains classified, but program officials have identified it as a "foreign missile asset."

In one series of flight tests, the beam control/fire control system, mounted in the nose of the 747, engaged a Boeing NKC-135 "Big Crow" test aircraft. Lessons learned from the resulting data were parsed throughout 2008 in preparation for this year's tests, in which the full-scale COIL will use the system to fire outside the aircraft while in flight.

Air Force photo by Jim Shryne.

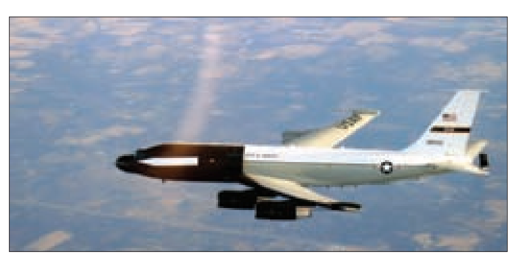
"We learned there were some jitter forces we had not anticipated in our system, although we arguably have one of the best jitter mitigation programs in the world," Boeing Missile Defense Systems vice president and ABL program director Michael Rinn tells *Aerospace America*. "We've put in dampeners to knock down those frequencies and now expect even more big things from the beam control system.

"On the high-power laser in back, we ran it in the system integration lab at Edwards [AFB] in 2005 and got a lot of lessons learned from that—some material, some mechanical and fluid timing. We rolled those into the laser design with Northrop Grumman, reintegrating all that laser hardware into the flight aircraft and firing it up to high power. We now appear to have a very bright, very powerful laser, although we still have a little fine-tuning to do—very minute, small adjustments in chlorine iodine and some of the key flows in the COIL—before we lock it down for the next flights."

Delays and cautious optimism

Despite a series of successes in the past two years, however, Rinn remains cautious, noting that significant technology, engineering, and funding challenges have plagued the program repeatedly since its inception. These have led to dramatic changes in the schedule, which has run longer than originally expected.

"If you go back to the beginning, ABL had to deal with a number of issues, both internal and external, which was not such a good story, but not unusual in terms of transitional technologies. The early predictions called for the first shoot-down in 2001-2003, so we're five or six years off that. But if you look at the schedule laid down five years ago, we're pretty close. And the amount of schedule slippage has definitely gone down in the last two years," he says.



Big Crow No. 38050 is one of two identically named NC-135Es, based at Kirtland AFB, that served as a surrogate target for the ABL's two illuminator lasers.

"During the low-power series of missions, we finished about three months late from where I really wanted to be. That's pretty good in this business, but not good enough. On the other parts of the program, however, I've gained back more than half that in the past year, so I'm still well within my window of what we promised our customer—in fact, a little ahead. But I'm driving my team to a much harder schedule to have some margin to deal with unknown unknowns. We do have some hard stuff in front of us."

A Northrop Grumman laser technician checks the fittings of a redesigned pump responsible for pumping chemical laser reactants through the ABL modules (top); then technicians double-check procedures for integrating and testing the first flight laser module.

Col. Robert McMurry, MDA program director, believes the successful ground and flight tests of 2007-2008 have proven the technology is now mature enough to take to the next level: killing a real missile in boost-phase flight.

"We are still on track for the missile shootdown demonstration in mid-2009, although there are a lot of first-time testings we have to do between now and that demonstration, so we could have some unknown events pop up. But as of now, the schedule still has that in August, and we're tracking toward it. We just have a lot of things to prove between now and then," he says.

"In the long history of the program, it is disingenuous to say we are tracking to the original schedule—ABL clearly is taking longer than originally expected. But we moved to a knowledge point in 2004-2005 and have made all our milestone commitments since that date," McMurry continues.

Thus ABL entered this year with all its systems having successfully completed individual tests, on the ground and in flight. Now they are being married for the first time in the 747 platform and gearing up to hit a real boosting missile—at full power—rather than the outline of one painted on the side of a comparatively slow-moving test aircraft target.

Testing sequence

"The sequence of testing, roughly, is repeating low-power tests to show we can do the acquisition-track-illuminate sequence we finished in 2007 as a kind of regression test. We'll also fire the laser again, not exiting the airplane, for a short-duration test in-flight, says McMurry. "Then we will propagate through the beam train into empty space, purposely firing at nothing, to make sure we see no stray lines or odd issues. At that point, the target program comes in, and we will launch and shoot against three different types of targets. The first is designed to check out the low power—what we did against the aircraft target—but now against an instrumented boosting target to see how we are keeping the spot on target.

"We will fire the high-energy laser against a Terrier Lynx missile, uninstrumented, then against an instrumented target—a MARTI (missile alternative range target instrumentation)—and measure how much energy hits the target. All that builds us up to confidence we are ready to fire against a demonstration target and shoot it down."

The MARTI target has a cylindrical body with holes in it, behind which are detectors to measure the laser energy that hits it. That information is quickly downlinked through the range instrumentation to show how much energy has been effectively put on the target. A very quick downlink is required so the target instruments are not destroyed before sending their data. Both tests will involve ground-fired boosted ballistic flight missiles with approximately the same body size as the short-range classified shootdown target missile.

That process, Rinn adds, has been laid out in great detail, incorporating all of the lessons learned to date.

"We start with safety of flight stuff, then we'll load some inert chemicals in the laser to make sure it's all tight and holding together, as it did quite well on the ground. After that come some low-power lasing tests using a new target—a Gulfstream with the profile of a foreign missile asset painted on it—to show we can find it and do atmospheric compensation," he says.

"Then we load real chemicals and fire the laser, first internally in the airplane, at a calorimeter—a device made out of copper plates that traps the light from the laser and turns it into thermal. You can only fire so long before you start melting it, but it allows us to bring the laser up without worrying about the beam going out of the aircraft. The next step is firing the laser end-to-end in flight. We won't aim for a target, just make sure the beam is aligned and the safety systems are working.

"Then we are ready to engage our first rockets, beginning with acquisition tracking and pointing at accelerating rockets at range, then run through another series with an instrumented rocket with sensors to measure how well we are pointing our beacon illuminator laser and high-power laser," Rinn continues. "We'll do that [at] low and high power.

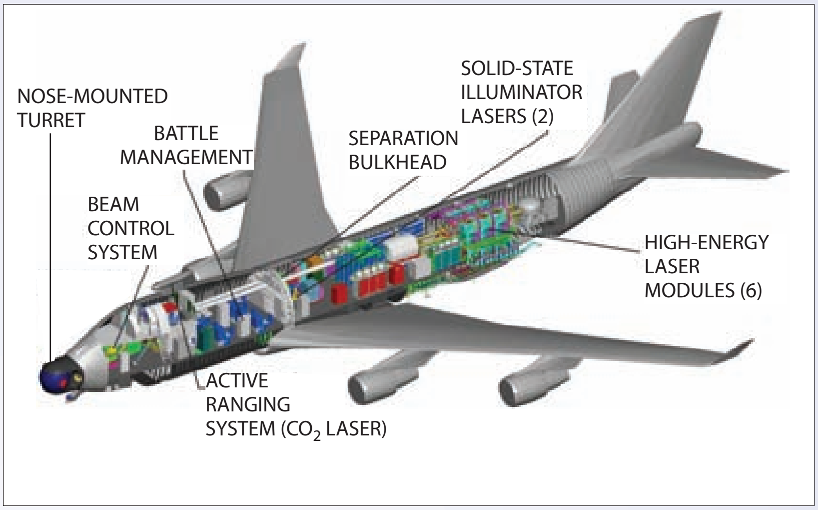
"Finally, we will fire high power against a foreign missile asset. The 2009 test is very important because, even though we have brought down the risk with all the different parts of the weapons system, there is nothing like flaming missile wreckage to show the world the system is viable and works."

Schedule and funding

Rinn believes ABL could be ready for combat application, using the test aircraft, as early as next year, much as the prototype J-STARS was deployed to the first gulf war. And while the primary stated mission is to shoot down enemy ballistic missiles in boost phase—that is, while they are still over their launch sites—he also says the technology could be applied elsewhere on the battlefield, further justifying the time and money invested in its development.

"Based on what I know of the system, I believe we will have some emergency deployment capability if the nation or our allies require it shortly after shootdown, in 2010. There are some limitations, clearly, such as logistics streams, and there is definitely more work to be done. But you would have a single ABL with some strong possibilities, similar to J-STARS during Desert Storm," he says. "In demonstrating the capability of this system, both for boost phase and potentially alternative missions—SAMs, cruise missiles, air-to-air missiles—there will be a tremendous potential.

"We're working with our customer to lay out the postmissile shootdown period, which will be driven by funding. The plan is to fly the first tail through a series of envelope expansions and potentially, if we can, work in some multimission stuff. But predominantly we will work with boosting missiles, engaging other targets at different ranges, different scenarios. It is imperative to keep the momentum going and move into deployment as soon as we can; there is some congressional language about affordability and military suitability that needs to be answered to allow us to go into a second aircraft."



Team ABL members are responsible for various elements of the system: Boeing is responsible for supplying the 747-400 Freighter, developing crew safety and the Battle Management system. Lockheed Martin is responsible for the nose-mounted turret, illuminator lasers, and beam-control system. Northrop Grumman is responsible for the system's COIL.

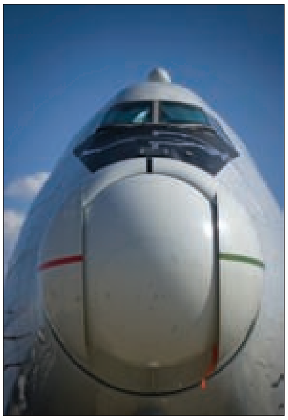
The next decision

McMurry expects a decision on a second aircraft in 2011-2012 and initial operational capability around 2018-2019. He says the go-ahead for a second aircraft, almost certainly another modified 747, would be based less on effectiveness and more on manufacturing and production qualities, with some marginal improvement in basic design characteristics, effectiveness, and performance. But the majority effort would be focused on getting a good production approach.

If a second aircraft is authorized, he adds, "the natural follow-on would be to ramp up to a full production fleet—currently envisioned as seven aircraft by Air Combat Command—along with a reasonable amount of training and sparing to maintain operational presence where needed.

"It is not entirely clear at this point whether the second aircraft would be an independent prototype or sort of an early production item. We're looking at whether it becomes the first of the fleet, which is my expectation, rather than building a second prototype, so we could move toward a fleet as soon as possible. The production timeline is similar to a satellite—about seven years, driven right now by the time to manufacture some of the larger optics, although there are other fairly long-lead elements in there as well," notes McMurry.

"We would be looking at a mid-2020s operational capability, with one new aircraft added each year, beginning with that second. You might go faster with a larger investment, but the expectation at this point is on a one-year center. We're not wed to the 747, but it does have to be a pretty large platform, and a great deal of learning has been done by the in-



A Lockheed Martin Space Systems engineer in the company's Sunnyvale, Calif., facility inspects the turret ball conformal window on the flight turret assembly for the ABL. The window is the exit for the high-energy laser and exit and return window for the beacon illuminator and tracker illuminator lasers.

dustry team on this aircraft. The big issue is, you need a large platform because of the last optic in the train, which is 1.7 m. That's a big lens, and the physics of the laser propagation are driven by the size of the last optic. So you need a large platform to have a large optic to have long-distance propagation of the beam."

Operationally, an ABL mission will resemble that of an AWACS or J-STARS, in terms of being escorted by fighter jets. In that respect, officials say they still need to determine exactly how the ABL will interact with combat aircraft, both enemy and friendly.

It has taken ABL a long time to reach the shootdown phase from its inception 13 years earlier, including a substantial restructuring of the schedule in 2005, some four years after it originally was expected to hit a missile in flight. As a result, the program's fight for funding and continuation has often equaled, if not exceeded, the technological challenges.

"There are critics saying we spent $5 billion to develop this technology, but if you look at ABL and other technologies, even some not so transformational, those numbers are well within the envelope of what these kinds of systems cost to develop and to get into the production phase," Rinn says. "There is still a lot of work to be done to drive the costs down, which I think already is happening," he says, noting the team has "shown how to set up a cost-effective production line.

"Also, there is a huge advantage this particular boost-phase weapon system brings to ballistic missile defense. Having the ability to thin the raid in a real ballistic missile warfare scenario, with a platform that can go anywhere in the world very quickly and stay on station for long periods, then use a speed-of-light weapon to destroy a missile in boost phase, is a very powerful asset. I think that's one reason we are still alive today, along with showing the technology really does work."

The challenges

The most serious problems ABL has encountered in recent years have involved optical coatings, some mechanical components, and some electronic and sensor issues, all of which Rinn says are fairly common in any major laser program.

"You can't just flip a switch and have somebody deliver a new part the next day. But [for] the worst issues I've seen, we were able to find work-arounds in days, weeks or, in worst cases, months, where we worked that fix in parallel with the rest of the program and then came back," Rinn points out. "I wouldn't say any of our problems have been unique, which is a testament to some of our design work and system integration trades. ABL began as a COTS rapid acquisition, something on which you inevitably get 'bit,' but the technology has matured.

"The thing about ABL and directed energy in general is there have been a lot of promises for years, while the technology was still maturing; but today the vast majority have matured, and we have demonstrated rapid firing and atmospheric ranges and have gotten through some problems considered nearly impossible in past years. Transformational technologies, such as computer chips, typically develop over a period of years or decades. Today, after a number of decades of laser technology efforts, we are at the beginning of these high-power and performance-level capabilities."

Even so, Rinn acknowledges concern about the possibility of new budget cuts, especially with a new administration taking over in Washington. But he believes ABL is now in a position to prove itself and what it will bring to warfighters and commanders—the ability to kill missiles at the speed of light.

"A system like this takes vision and a national will, and we are seeing a lot of support. Although the program has been around a number of years, with the recent breakthroughs, it is important to keep going," he says. "When decision-makers look at the system as a whole for boost phase and other missions, I think they'll see the added value there." [When Secretary of Defense Robert Gates released the Pentagon's budget propsal in April, ABL had moved to an experiment program and the number of aircraft was reduced to one. At this writing, the final outcome is undecided.]

Both he and McMurry also are concerned about the impact of any future delays on the industrial base supporting ABL technology.

"There are real issues, because there is a limited demand for these high-power optics; lower power tactical optics probably can feed off the telecom industry, but there are very limited vendors in optical coatings, adaptive optics (deformable and steering members), even some of the fluid mechanical components unique to a chemical laser," Rinn warns.

"So it is imperative that we fund ourselves enough to do this and spend money on a second airplane and not have a long gap before we start that. We need to get going on it right after shootdown. If we want to lead the world in directed energy technology, as we now do, we need to move on."

Out of the

25 Years Ago, July 1984

July 17 The Soyuz T-12 mission to Salyut 7 is launched from Baikonur. The crew includes Svetlana Savitskaya, who on July 25 performs the first space walk by a woman. During this activity she conducts welding and soldering. Savitskaya is also the first woman to make two space flights. Her first was in August 1982. NASA, *Aeronautics and Astronautics, 1979-84*, pp. 491-492, 669.

50 Years Ago, July 1959

July 1 Kiwi-A, a nuclear reactor from the National Nuclear Rocket Development Program, operates successfully in its first test at Jackass Flats, Nev. One of a series of atomic reactors for studying the feasibility of nuclear rocket propulsion, it is developed by the Los Alamos Scientific Laboratory. The effort is sponsored jointly by the Atomic Energy Commission and NASA as part of project Rover/NERVA (nuclear engine for rocket vehicle application). E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 110; D. Baker, *Spaceflight and Rocketry: A Chronology*, p. 90.

July 7 The all-solid-fuel Javelin (also called the Argo D-4), the first U.S. four-stage test rocket, is launched from Wallops Island, Va., to an altitude of 750 mi. It carries a 40-lb Air Research and Development Command scientific payload to measure natural radiation surrounding Earth. This is the first in a series of Air Force/NASA-sponsored experiments. The Argo D-4 consists of an Honest John, two Nike booster rockets, and an Alleghany Ballistics Lab X-248 motor. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 110; *Aviation Week*, July 6, 1959, p. 87; *Aviation Week*, July 13, 1959, p. 28.

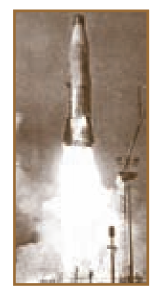
July 9 A model of an ion-propelled rocket becomes the first such missile to be tested in the new electric test rocket facility at NASA Lewis. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 110.

July 13 The Office of Naval Research launches the world's largest upper atmospheric plastic balloon to date, 6 million ft^3, at Fort Churchill, Canada. It carries a 173-lb payload of science instruments. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 111.

July 14 The U.N. releases the report of its Ad Hoc Committee on the Peaceful Uses of Outer Space. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 110.

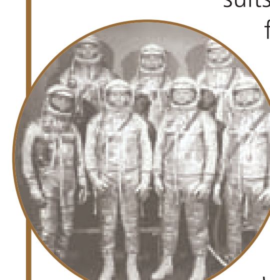
July 16 The world's second-largest reflector telescope, measuring 120 in., is dedicated at the Lick Observatory at Mount Hamilton, Calif. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 111.

July 20 NASA chooses Western Electric as the prime contractor to develop and construct a worldwide tracking and ground station network in preparation for the upcoming Project Mercury manned space program. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 111; D. Baker, *Spaceflight and Rocketry: A Chronology*, p. 90.



July 21 For the first time, a full-scale Atlas ICBM nose cone is successfully recovered after a flight across the Atlantic Missile Range. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 111.

July 22 NASA selects B.F. Goodrich to design and manufacture the one-piece pressure suit for its Project Mercury suborbital and orbital manned space flights. The development time is rapid—on Nov. 5, the seven Mercury astronauts are fitted with prototype suits in Goodrich's factory in Akron, Ohio. Each suit cost $75,000. D. Baker, *Spaceflight and Rocketry: A Chronology*, p. 90; *Aviation Week*, July 27, 1959, p. 41.



July 24 A Thor IRBM data capsule is successfully recovered near Antigua in the Caribbean. It contains movie footage taken of the nose cone separation. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 111.

July 29 At the start of the Sunflare II program, a two-stage solid-fuel Nike-Asp sounding rocket is fired from the Naval Missile Test Facility at Point Arguello south of Vandenberg AFB,

Past

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

Calif. This is the first of a dozen such rockets to measure radiation and Sun flares 150 mi. up and is the first rocket fired from this facility. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 111; *Aviation Week*, July 20, 1959, p. 29.

75 Years Ago, July 1934

July 12 The British Rocket Syndicate of London, with capital of £1,000, is registered. The company is to "carry on all kinds of business connected with rockets or rocket-like projectiles capable of long range or travel, and adaptable to hold articles, to acquire inventions pertaining to rockets or rocket-like projectiles, aeroplanes, gyroscopes, gliding planes, vehicles, and boats." But because of a 300-year-old law that prohibits private rocket experimentation, the company does not survive. In addition, the British public is apathetic about rocket propulsion, and there is little money during the depression years for investment in such a speculative venture. *Flight*, July 12, 1934, p. 724; F. Winter, *Prelude to the Space Age: The Rocket Societies 1924-1940*.

July 13 Over 30 countries sign an International Sanitary Convention for Aerial Navigation white paper. They agree to establish special sanitary organizations at every airport in their territories, with the necessary staff and equipment for examining and, if necessary, isolating passengers, and means for disinfecting airplanes. The signatories must also give adequate notification of the existence of plague, cholera, yellow fever, typhus, and smallpox, and ensure that aircraft coming from infected localities land only at prescribed airports. *The Aeroplane*, July 18, 1934, p. 86.

July 13-14 Flight Lt. H.M. Schofield wins the 13th King's Cup Race for light planes. He averages 134.16 mph in the final heat in a new Monospar S.T. 10 monoplane. The object of the race, which began in 1922, is to "improve the breed of British aircraft and to stimulate interest of the public in civil aviation." Participants must all be British subjects, and the airplanes entirely constructed in the British empire. *The Aeroplane*, July 18, 1934, p. 68.

July 25 Louis Bleriot, who made the first aerial crossing of the English Channel in 1909, is made an honorary life member of the British Royal Aero Club at special anniversary ceremonies in London. The French ambassador is present as are many early British aviation pioneers, including J.T.C. Moore-Brabazon, holder of British pilot's license No. 1, Frederick Handley-Page, Sir Alliott Verdon-Roe, Sir Alan Cobham, and C.F. Fairey. *Flight*, Aug. 2, 1934, p. 792.

July 28 Explorer I, the Army Air Corps/National Geographic Society stratospheric balloon, reaches an altitude of 60,613 ft from its takeoff site near Rapid City, S.D. The crew consists of Maj. W.E. Kepner, pilot; Capt. A.W. Stephens, scientific observer; and Capt. O.A. Anderson, alternate pilot. The metal gondola carries instruments to measure temperatures, cosmic ray activity, solar radiation, and pressure, but these are demolished when it crashes. Only the barographs, in their insulated balsa wood box, are recovered. The crewmembers return unharmed via parachute. *Aviation*, August 1934, pp. 264-265; E. Emme, ed., *Aeronautics and Astronautics 1915-60,* p. 111.

And During July 1934

—The four-engine Fokker F.XXXVI monoplane undergoes test flights. It is designed to carry 32 passengers on European airlines or 16 passengers on the Amsterdam-Batavia (Jakarta) Dutch service. For the latter, the plane offers fold-up sleeping berths. The craft has a top speed of 174 mph and a crew of five: two pilots, a wireless operator, a mechanic, and a steward. *Flight*, July 26, 1934, p. 763.

100 Years Ago, July 1909

July 25 Frenchman Louis Bleriot crosses the English Channel at the Straits of Dover in an airplane. This is considered the first significant step in aviation since the Wright brothers' 1903 flight. He covers the 31-mi. distance in his 11th airplane, the Type XI, powered by an Anzani three-cylinder motor rated at 35 hp. His altitude does not exceed 150-200 ft. Bleriot wins the £1,000 prize offered by *The Daily Mail* for the feat. This is the first practical demonstration of the potential of airplanes; earlier flights were usually of very short duration and distance. Bleriot, who had made a fortune manufacturing lamps for the first cars, began flying experiments in 1900. Earlier in the month he made a preliminary long-distance flight of 36 min 55 sec in Paris. C. Gibbs-Smith, *Aviation*, pp. 144, 148, 224, 245; *Flight*, pp. 453-461.

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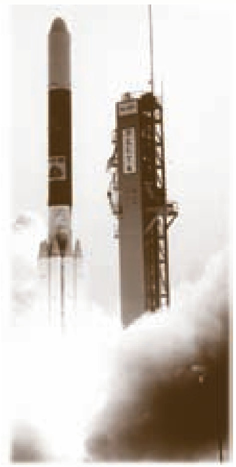
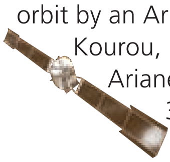


25 Years Ago, August 1984

Aug. 16 Using a three-stage Delta 3294 booster, NASA launches the active magnetospheric particle tracer explorers (AMPTE) from Cape Canaveral AFS. AMPTE consists of three subsatellites designed by the U.S., Great Britain, and West Germany to gather data about the transfer of mass from the solar wind to the magnetosphere. NASA, *Aeronautics and Astronautics, 1979-1984*, p. 495.

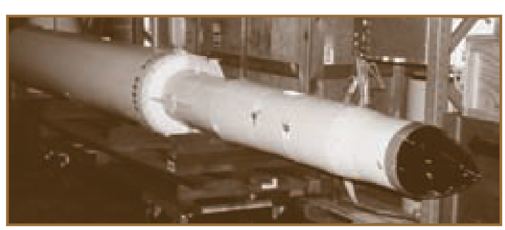


Aug. 24 Telecom 1 and ECS-2 satellites are placed into orbit by an Ariane 3 booster from Arianespace's facility in Kourou, French Guiana. This is the 10th flight of an Ariane and the first of the more powerful Ariane 3. NASA, *Aeronautics and Astronautics, 1979-1984*, p. 495.

Aug. 30 After four postponements, the new space shuttle Discovery is launched on its maiden flight. Its six crewmembers are commander Henry Hartsfield, pilot Michael Coats, mission specialists Judith Resnick, Richard Mullane, and Steven Hawley, and the first commercial payload specialist, Charles Walker of McDonnell Douglas. The crew deploy the SBS-4 communications satellite, which later uses its solid rocket booster to place itself in a geosynchronous orbit. Discovery also carries the Leasat-2 communications satellite leased by the Navy, and AT&T's Telestar-3. NASA, *Aeronautics and Astronautics, 1979-1984*, p. 495.

50 Years Ago, August 1959

Aug. 3 The Subroc antisubmarine missile makes its first test flight from the Naval Ordnance Test Station at China Lake, Calif. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 111.



Aug. 7 Explorer VI, a small satellite designed to study cosmic rays, trapped radiation of various energies, and other phenomena in the upper atmosphere, is successfully launched into a highly elliptical orbit by a NASA Thor-Able 3 launch vehicle. Known as a "paddlewheel satellite" because of its four solar cell paddles, it also tests a scanning device designed to photograph Earth's cloud cover. The satellite transmits the first pictures of Earth from orbit. It also acquires valuable data on radiation levels. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, pp. 111, 144; *Aerospace Year Book 1960*, p. 455.

Aug. 7 Naval reserve officer Malcolm Ross and Robert Cooper ascend to 38,000 ft in their open gondola Strato-Lab high-altitude observatory balloon. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 111.

Aug. 13 The Discoverer V reconnaissance satellite is placed into a polar orbit by an Air Force Thor-Agena A launch vehicle. However, on Aug. 19 its reentry capsule, which an Army-Navy task force was to have caught in midair as it parachuted down, is not retrieved because of malfunctions. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 112.

Aug. 17 The Nike-Asp solid-fuel sounding rocket, using a Nike-Ajax antiaircraft missile booster as its first stage and an Asp motor for the second stage, is successfully launched for the first time at NASA's Wallops Island Station, Va. The vehicle is designed to climb to 150-mi. altitudes to gather geophysical data on wind activity. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 112.

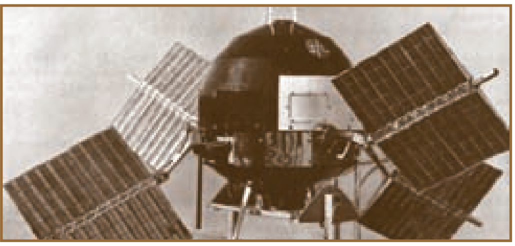
Aug. 19 A Soviet Il-18 turboprop transport with a 15-ton payload flies from Moscow to Melitopol, Ukraine, and back, at an average speed of 447 mph. Later the Soviets claim the flight broke five new records for piston and turboprop transports with payloads. *Aviation Week*, Aug. 31, 1959, p. 31.

Aug. 21 A Project Mercury "boilerplate" mockup capsule is launched by a Little Joe booster for purposes of activating and testing the escape and recovery rocket system atop the capsule. However, the escape rocket ignites 30 min prematurely. The capsule is carried up to 2,000 ft, then falls into the Atlantic Ocean. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 112; *Aviation Week*, Aug. 31, 1959, p. 33.

Aug. 27 A test version of the Polaris IRBM is successfully fired for the first time at sea from the USS Observation Island, off Cape Canaveral, Fla. *Aerospace Year Book 1960*, p. 456.

Aug. 27 The satellite tracking station at Woomera, Australia, successfully photographs the U.S. satellite Explorer VI from a distance of 14,000 mi. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 112.

Past



Aug. 29 A Navy technician withstands an acceleration of 31 *g*s in a centrifuge at the Aviation Medical Acceleration Laboratory at Johnsville, Pa. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 112.

75 Years Ago, August 1934

Aug. 5 G.E. Collins of the London Gliding Club soars in a glider from Dunstable Downs to Hunstanton, England, a distance of 95 mi. On the same day Philip Wills ascends to 6,000 ft in a glider from Sutton Bank, near Thirsk, England. Both feats are claimed as British gliding records. *The Aeroplane*, Aug. 8, 1934, p. 182.

Aug. 12 James Melrose sets a new around-Australia record in his De Havilland Puss Moth. His time of 5 days 11 hr beats by two days the record set by H.F. Broadbent in 1931. Melrose learned to fly 16 months before his Australia flight. *Flight*, Aug. 16, 1934, p. 836.

Aug. 17-Sept. 2 The International Aero Exhibition, the second to be organized by Denmark, takes place in Copenhagen. Great Britain dominates the foreign exhibitors at the show, which also features French, Czech, Soviet, and Danish military craft. There is no room to exhibit the Ant-20 (Maxim Gorki) and Ant-14 (Pravda) Soviet aircraft except as models. The only full-sized Russian plane, flown by Vasily Molokov, is the two-seater that rescued nine members of the Chelyuskin Expedition from the Arctic Ocean ice floes. The 850-hp M-34 and 650-hp M-48 Russian engines are also on display. *Flight*, Aug. 16, 1934, pp. 851-855.

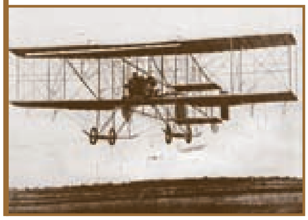
Aug. 18 Today, Soviet Aviation Day, the giant Soviet airplane Ant-20, called the Maxim Gorki, officially becomes the flagship of the Maxim Gorki Propaganda Squadron. Designed by Andrei Tupolev, the all-metal monoplane has a wingspan of 210 ft and eight engines providing a total of 7,000 hp. It holds a crew of 23 and accommodations for 40 passengers. The plane has editorial offices, an onboard printing press for producing propaganda, a photo lab, cinema room, radio transmitting room, cafe, buffet, lavatory, saloon, microphone room, and passenger cabins. The Gorki has a maximum speed of 137 mph and a range of 600 mi. It also has a loudspeaker to broadcast lectures, music, and news bulletins to the ground from 3,000-ft altitudes. *Flight*, Aug. 9, 1934.

Aug. 18 Max Cosyns and Nere Van der Elst ascend in a stratospheric balloon fitted with a new aluminum gondola, from Hour-Havenne, Luxembourg, and reach 52,329 ft. After drifting 1,000 mi. across Europe, they land at Zenalvje, Yugoslavia. The balloon is the same one used in 1931 by Jean Piccard, the Swiss physicist, who ascended to 51,777 ft and 53,152 ft in 1932 on his second flight. Cosyns accompanied Piccard on that latter flight. *Flight*, Aug. 23, 1934, p. 872.

And During August 1934

—The first tailless fighter, Westland-Hill's Pterodactyl Mk. V, makes its debut. The two-seat plane has a Rolls-Royce Goshawk engine and is said to be very maneuverable. The absence of fuselage or tail unit behind the wings gives the gunner in the stern an excellent field of view. The large upper wing is swept back and tapered; the lower wing is smaller and tapered but not swept back. The plane has performed well at RAF displays at Hendon. *The Aeroplane*, Aug. 15, 1934, p. 197.

100 Years Ago, August 1909



Aug. 22-29 The first international aviation meet takes place at Rheims, France, and demonstrates that the airplane is now a practical vehicle. During the meet, Henri Farman achieves the first flight over 100 mi. and the first flight to carry two passengers. C. Gibbs-Smith, *Aviation*, pp. 145-146, 245; *Flight*, Aug. 28, 1909, pp. 518-523; and Sept. 4, 1909, pp. 532-540.

AIAA Systems Engineering Papers

Systems engineering (SE) papers supporting aircraft design and operations are requested. Papers that summarize SE case studies, developmental work and technical analysis are especially desired, but others will be considered. Major topics of interest include but are not limited to systems engineering applications, integrated disciplines and technology, future trends and predictions in systems engineering, systems engineering education and research, systems engineering life cycle processes, and systems effectiveness. Examples of these subject topics are: 1. Application of Complexity and Change – How does systems complexity affect the practice of SE in different application areas? How do organizations apply SE in their change programs? What is complexity in SE? 2. Future Trends and Predictions – Can experience from today enable needs for the future of SE impact in program change and technology? Do we see new areas of applied SE emerging? 3. SE for systems of systems (SoS) - How will the System-of-Systems Engineering process be developed? Do SE approaches change when applied to SoS vs. a single system? 4. Integrated Disciplines and Technology – How is information technology/knowledge management linked to SE? Is integration a task for the production personnel, Systems Engineers and others? How has project management and SE interaction been achieved and is it really effective? 5. SE Education and Research – Has teaching SE in organizations and universities been successful when measured both absolutely and relative to other disciplines? Is balancing cost, technical performance, schedule, and risk specifically taught and if so at what level of detail (e.g., single lecture or entire course)? What are the ongoing research programs within SE, and what have we learned from the past years? Presentations of student research programs are encouraged, including findings and challenges. 6. SE Life Cycle Processes and Systems Effectiveness - How is Integrated Logistics Support/Acquisition Logistics integrated with SE? How have the new life cycle and SE standards proved useful?

Special Edition – The Journal of Aircraft will issue a special section for system engineering papers. Please send your abstracts and papers to Dr. John C Hsu (john.c.hsu@boeing.com) or Dr. Satoshi Nagano (Satoshi.Nagano@aero.org).

Submission Due Dates:

Abstract:	September 30, 2009
Manuscript:	February 28, 2010