

UNITED NATIONS  
OFFICE FOR OUTER SPACE AFFAIRS

# Highlights in Space 2009

*Prepared in cooperation with the International Astronautical Federation  
and the International Institute of Space Law*



UNITED NATIONS



OFFICE FOR OUTER SPACE AFFAIRS  
UNITED NATIONS OFFICE AT VIENNA

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Prepared in cooperation with the International Astronautical Federation  
and the International Institute of Space Law

Progress in space science, technology and applications,  
international cooperation and space law



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## INTRODUCTION

This publication has been compiled from reports prepared for the United Nations Committee on the Peaceful Uses of Outer Space and covers the period from 1 November 2008 to 31 October 2009.

The report was prepared by the International Astronautical Federation (IAF). In addition, the International Institute of Space Law (IISL) provided information for the section on international cooperation and space law. Many international experts from various specialized fields have contributed to the drafting of this comprehensive report. The information contained therein indicates a wide variety of ongoing space activities in national as well as international space programmes. This publication is available in English only.

This 2009 review of latest developments in space science, technology, space applications, international collaboration and space law has the aim to inform a broad worldwide audience of recent advancements in the manifold field of outer space.

We hope that “Highlights in Space 2009” can significantly contribute to all the efforts undertaken by the United Nations family, in particular the United Nations Office for Outer Space Affairs, in attempting to disseminate information on space activities and on the benefits involved to all nations of the world.



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## I. OVERVIEW

Space Transportation. The major space transportation events of 2009 were the launch of JAXA's Ibuki spacecraft by a Mitsubishi H-2A, the launch of Japan's H2 Transfer Vehicle (HTV) to the International Space Station (ISS) by the first H-2B rocket, the suborbital flight of NASA's Ares I-X test vehicle, and four NASA space shuttle launches to the ISS.

WhiteKnightTwo, the carrier aircraft for Virgin Galactic's SpaceShipTwo tourist vehicle, conducted ten test flights this year, including an overpass of New Mexico's Spaceport America site. Virgin Galactic signed a lease with New Mexico as the "anchor tenant" for that spaceport, and the spaceport's operator signed an agreement with Spaceport Sweden, which will be located at the Esrange Space Center in Kiruna, to coordinate commercial space industry activities.

Satellite Communications. Intelsat and SES spearheaded the creation of an industry-wide global database to collect information on interference and to endorse standardized training and certification for the personnel who install and operate satellite uplink ground stations. It will not deal with interference by terrestrial wireless broadband transmitters, which are governed by national regulating agencies.

The heaviest and the most powerful commercial satellites ever launched were orbited this year: the 6.91-tonne mobile-communication satellite TerreStar-1 and the 20-kW Sirius-FM5 radio broadcast satellite.

A new midrange satellite platform design was created by Boeing Satellite Systems International. Intelsat ordered the first four of these 702B spacecraft, which are in the 5.4-6.2-tonne, 6-12 kW range and employ components adapted from Boeing's lighter 601 bus and the heavier 702.

Earth Observations. ESA's Gravity field and steady-state Ocean Circulation Explorer (Goce) satellite was finally launched after a year's delays. It is now measuring Earth's gravity field, modeling the geoid, and studying ocean circulation. It has no moving parts and uses a unique throttleable electric ion propulsion system to compensate for upper-atmosphere drag.

NASA's Orbiting Carbon Observatory (OCO) was lost due to the failure of its Taurus XL launcher's payload fairing. It was to have measured miniscule changes in carbon dioxide and oxygen concentrations in the atmosphere in order to identify sources and sinks for carbon dioxide. Similar but different data are being received from Canadian microsatellite CanX-2 and Japan's Ibuki satellite, launched successfully earlier in the year.

The Eumetsat Council approved a \$90-million contribution to the Jason-3 ocean altimetry satellite, enabling initiation of its development. It will follow the previous French-U.S. projects Topex-Poseidon, Jason-1, and Jason-2 in measuring wave heights and ocean currents.

Earth-Orbit Operations for Humans. The fourth and final solar-power wing was delivered to the International Space Station, as were both the pressurized and external modules of the Japanese Kibo laboratory. The crew size was increased from three to the station's full complement of six.

NASA contracted with the Russian space agency Roskosmos for crew transportation to and from the station after the planned Shuttle retirement in 2010, and issued seven-year contracts to two commercial firms for station resupply flights following that retirement. The companies will be solely responsible for designing, building, and launching the rockets, a first for NASA.

During nearly 37 hours of spacewalks, NASA astronauts replaced or fixed nine major components of the Hubble space telescope, extending its useful life by five to ten years. The mission's cost of \$1.1 billion, including the new instruments, raised the investment in Hubble's 24 years of operation to \$10 billion.

A new chapter in cooperation between the U.S. and China began with a visit by U.S. astronauts to China's space facilities and upcoming mission spacecraft to discuss cooperation in human space flight with Chinese astronauts and programme directors. Subsequent invited visits to China are planned by NASA Administrator Charles Bolden and U.S. President Barack Obama.

Canada selected two new astronauts and NASA named nine. The European Space Agency (ESA) announced a roster of six new astronauts, including one from the UK. This served as an incentive for a UK decision to become involved once again in human spaceflight. Roskosmos announced that for the first time in over ten years Russia will resume the recruiting and training of female cosmonauts, and India approved a six-year human spaceflight programme that envisions the launch of two astronauts, with opportunities for female candidates.

Space Studies and Exploration. Three powerful new astronomical telescopes were launched: NASA's Kepler, which is searching for Earth-like exoplanets circling distant stars; ESA's Herschel, which is studying the evolution of stars and galaxies and examining relatively cool and diffuse matter, which has gone largely unseen to date; and ESA's Planck, which is measuring the temperature fluctuations of the cosmic microwave background radiation left over from the Big Bang and determining its polarization state, which has never been done before. Herschel and Planck together constituted ESA's costliest science mission ever.

NASA and ESA closed down operations of the Ulysses solar probe after nearly 19 years of successfully observing the Sun's polar regions. The spacecraft was designed to last five years.

India's Chandrayaan-1 entered lunar orbit, released its Moon Impact Probe, and found for the first time incontrovertible clues to the presence of water and ice in the polar regions of the Moon. China's lunar probe Chang'e 1 was guided to a controlled crash on the Moon after completing its 16-month mission. Japan's Kaguya lunar orbiter ended its 21-month mission and was guided to a collision with the Moon. NASA's Lunar Reconnaissance Orbiter (LRO) and Lunar Crater Observation and Sensing Satellite (Lcross) were launched to map the Moon and coordinate data with

Chandrayaan, Chang'e, and Sweden's Odin, and Lcross was guided to a crash in a lunar crater with the intent of studying the resultant debris plume for traces of water.

Orbital Debris. A low-Earth-orbit Iridium-33 communications satellite collided with an inactive Russian satellite, Cosmos 2251. The collision, which created over 600 observable pieces of debris, was the most severe spacecraft collision ever recorded. The debris cloud could pose some threat to all low-orbit operational satellites, including the "A-train" of civil Earth-observing satellites following one another in a 705-km orbit. Nevertheless, Iridium Satellite LLC judged the risk sufficiently low to place their next-generation constellation in the same orbit as the current one.

Global Space Market Issues and Opportunities. Despite the global economic downturn, the commercial satellite industry reported glowing results for the first and second quarters. Also, the satellite insurance industry cited positive results for 2008, encouraging more underwriters to enter the market. Nevertheless, two space companies, Sea Launch and ProtoStar, filed for bankruptcy court protection.

International Cooperation and Space Law. In March, the Democratic People's Republic of Korea (DPRK) ratified the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (the Outer Space Treaty). The Outer Space Treaty has thus reached an important milestone, having been ratified by 100 States. The Democratic People's Republic of Korea also acceded to the 1975 Convention on Registration of Objects launched into Outer Space. In July, Nigeria also acceded to the 1975 Convention on Registration of Objects launched into Outer Space.

## **II. SPACE TRANSPORTATION**

### **A. Current Launch Activities**

An Orbital Sciences Corporation Minotaur-1 rocket launched several satellites from the Mid-Atlantic Regional Spaceport into a 420-km orbit on 19 May. The U.S. defense department's Operationally Responsive Space Office (ORS) TacSat-3 was the primary payload. Secondary payloads were NASA's 4.5-kg Pharmasat biology research spacecraft and three tiny CubeSats: CP6 for California Polytechnic State University, HawkSat 1 for the Hawk Institute for Space Sciences, and AeroCube 3 for the Aerospace Corporation (all USA). The 400-kg TacSat 3, built by Alliant Techsystems (USA), carried a high-resolution imager and user-friendly software that demonstrated the value of responsive spacecraft. PharmaSat was loaded with yeast cells in 48 microscopic sample containers within a fully functional miniature laboratory. Its mission was to incubate the yeast samples in a microgravity environment, and then challenge them with some antifungal chemicals to see how effective those antibiotics are in space. Experiments aboard the International Space Station have indicated that yeast and other organisms are more virulent in space. The data from PharmaSat are helping determine the best way to treat astronauts' infections in space.

Mitsubishi Heavy Industries Ltd received Japan's first commercial order for an H-2A launch on 12 January. The H-2A will launch the Korea Aerospace Research Institute's multipurpose Arirang-3 satellite in April 2011, along with four other "piggyback" spacecraft.

Early in February Arianespace (France) ordered 35 additional Ariane 5 ECA boosters from prime contractor EADS for \$5.1 billion. This is expected to carry Ariane operations through 2015, when the new Ariane 5 ME model is expected to debut. As of 12 February, Arianespace had a backlog of more than 20 Ariane 5s and 10 Soyuz boosters (not including Galileo launches), more than half the global market. Current price of an Ariane launch, which normally covers two spacecraft, is about \$200 million.

AsiaSat canceled the launch of AsiaSat 5 by Sea Launch's Land Launch rocket on 23 February because Land Launch would not be able to launch it until mid-2010. Instead, AsiaSat contracted with International Launch Services (ILS) for a Proton-M launch, which was successfully carried out on 12 August using a launch schedule slot originally planned for EchoStar's CMBStar, whose development was suspended. The switch was dictated by the need to replace AsiaSat 2 in its geostationary-orbit slot at 100.5 degrees east longitude with enough time to field a replacement in the event of a launch failure. The 13-year-old AsiaSat-2 was scheduled to be retired in mid-2011, but its pan-Asian traffic was taken over by AsiaSat 5 late this year. The 3.76-tonne AsiaSat 5, built by Space Systems/Loral (USA) on the company's 1300 platform, carries 26 C-band transponders for pan-Asian service stretching from Russia to New Zealand, along with 14 Ku-band transponders, a Ku-band beam for coverage of south Asia, and a steerable beam for backup service to other AsiaSat spacecraft. It cost \$215 million, including the costlier ILS launch and insurance.

Then on 7 September Eutelsat announced their decision to transfer the launch of the W7 satellite from Sea Launch to an ILS Proton because of uncertainty over Sea Launch's ability to launch the satellite this year. The ILS launch of W7 could occur as early as November. Eutelsat did not cancel their contract with Sea Launch, but will use it for another as-yet unspecified satellite, and both SES (Luxembourg) and Intelsat (Bermuda), the world's largest commercial satellite fleet operators, stated on 7 September that they were willing to provide written promises of future launch contracts with Sea Launch to aid the company in exiting from bankruptcy (see below), as did Eutelsat (France) and DirecTV (USA).

On 20 April the launch of Malaysia's RazakSAT remote-sensing satellite was delayed for an indefinite period following the last-minute scrub of a planned launch by a Space Exploration Technology (Space-X) Falcon 1 rocket from Omelek Island on the Kwajalein Atoll in the Marshall Islands. The scrub was attributed to a potential compatibility issue between the rocket and the satellite. Both the vehicle and satellite passed all preliminary checkouts, including a static test firing of the rocket April 15, and were cleared for launch. But a concern was identified regarding the potential impact of the predicted vehicle environment on the satellite.

The fifth launch of Falcon 1 on 13 July was finally successful, carrying the RazakSAT spacecraft into orbit following a four-hour delay due to an anomaly in the

rocket's helium system and passing rain showers. RazakSAT was then placed in a 685-km orbit at an inclination of 9 degrees. Built by Astronautic Technology (M) Sdn Bhd (ATSB, Malaysia), the satellite is being used to take high-resolution images of Malaysia for studies of land management, resource development and conservation, forestry, and fish migration. Its panchromatic resolution is 2.5 m and color resolution is 5 m.

Then on 6 August Space-X announced the replacement of Falcon-1 by Falcon-1e, an upgraded version of the launcher that uses a more powerful regeneratively cooled Merlin engine, enabling an upgrade in the vehicle's avionics and structure and a larger payload fairing. The new version can launch a 900-kg payload, vs the older version's 420-kg. Slightly more costly than the Falcon-1's price of \$8 million, a Falcon-1e launch will still be priced under \$11 million. First launch is scheduled for 2010, and a satellite launch for the Swedish Space Corporation is planned for 2011.

On 3 September Orbcomm (USA) selected SpaceX to launch 18 second-generation Orbcomm messaging satellites aboard the new Falcon 1e rocket, starting as early as the fourth quarter of 2010 and completing the launches by 2014. Sierra Nevada Space Systems (USA) is building the 18 satellites under a \$130 million contract that includes options to build up to 30 more. They will provide enhanced data and messaging services worldwide, including machine-to-machine communications, and will also incorporate Automatic Identification System (AIS) features for global maritime detection from space. The second-generation satellites weigh about 130 kg each, and the nominal launch configuration would be to place three satellites on a single rocket. Orbcomm is paying a total of \$46.6 million for the launches, subject to adjustments. That corresponds to \$7.7 million per launch, assuming three satellites each. The contract includes an option for re-flight at no additional charge in the event of a launch failure. On 10 September SpaceX secured a second launch contract for the Falcon 1e: a small satellite to be built by Astrium (Europe) or its new subsidiary, Surrey Satellite Technology Ltd. (UK).

Iran launched a small (27-kg) store-and-forward UHF-band communications satellite named Omid (Hope) into a 242 x 382-km 55-degree Earth orbit on 3 February, following 3 years of design and construction of the satellite. Both stages of the 26-tonne Safir-2 two-stage launch vehicle, built in Iran. A week later, Iran announced a 12-year project to send an astronaut into space, and on 30 April announced that Omid had completed its mission and had splashed down in the Pacific Ocean. The Iranian Space Agency (ISA) has drawn up a comprehensive plan for various academic and research institutions to work on a mission to be launched in 2021.

On 11 March ViaSat Inc. (USA) canceled its contract for launching the 6-tonne ViaSat-1 by an Ariane-5 in mid-2011, a transaction which was completed at the end of April. Instead, ViaSat booked the launch with International Launch Services (ILS, USA) aboard a Russian Proton rocket. ViaSat's rationale for the switch was an estimated \$20-million reduction in launch cost, even including the \$4.6 million paid to Arianespace (France) in advance fees and the contract cancellation penalty. ILS was able to offer the low price due both to the decline in the value of the Russian ruble (22% in the four months preceding the switch) and to Khrunichev's streamlining of Proton production and operations.

Then on 19 March Intelsat also announced a switch in its launcher for the IS-16 satellite from Land Launch (booked in February 2008) to an ILS Proton rocket at an expected price of \$75 million. The relatively small (2.45-tonne) IS-16 is being built by Orbital Sciences Corporation (OSC, USA) on the company's Star-2 platform. It will carry 18 Ku-band transponders into a geostationary-orbit slot at 43 degrees west longitude, to serve as a backup for DirecTV Latin America's satellite-television customers.

An Ariane-5 ECA launched two commercial communications satellites on 30 October. The 5.7-tonne NSS-12 satellite, owned by SES World Skies (Luxembourg), will deliver television broadcasts to Europe, the Middle East, Africa, Asia and Australia. The 3-tonne Thor-6 spacecraft is broadcasting television programmes to Scandinavia and central and eastern Europe for Telenor (Norway).

A Russian Dnepr rocket launched six small satellites on 29 July for organizations in four countries on a mission designated RS-20. UK-DMC2 and Deimos 1, which are two satellites for the Disaster Monitoring Constellation (see prior reports), were built by Surrey Satellite Technology Ltd. (UK); the United Arab Emirates' (UAE's) first satellite, DubaiSat-1, was built for the UAE's Institution for Advanced Science and Technology by Satrec Initiative (South Korea); two 12-kg communication satellites, AprizeSat-3 and AprizeSat-4, are owned by Aprize Satellite; and Spain's 22-kg Nanosat 1B testbed satellite was built by the country's National Center for Aerospace Technology.

The 120-kg UK-DMC2 carries a multispectral camera that can image a 660-km swath of Earth with 22-km resolution. Its first images, of the U.S. states Texas and Oklahoma, were transmitted a week after launch. Under an ESA contract signed on 18 August, UK-DMC2 is mapping sub-Saharan Africa to track deforestation and agricultural land use, especially in the Congo Basin, the world's second-largest rainforest. ESA wants all 48 countries in the region to be covered by September 2010. The satellite's data are being incorporated into Europe's Global Monitoring for Environment and Security (GMES) network (see prior reports).

The UK also announced on 21 August that Deimos-1 too had transmitted its first imagery. Deimos-1 is owned by Deimos Space (Spain), a subsidiary of the Elecnor Group. The AprizeSats are being operated by SpaceQuest (USA) as part of an Ultra-High-Frequency (UHF)/S-band wireless network. DubaiSat-1 was the second of two 200-kg remote-sensing spacecraft built by Satrec; the first was RazakSAT, launched for Indonesia by SpaceX on 14 July (see above).

On 23 September the Indian Space Research Organization (ISRO) successfully launched seven satellites from the Satish Dhawan Space Centre in Sriharikota aboard a Polar Satellite Launch Vehicle (PSLV), its 16th mission. The primary payload was India's 958-kg Oceansat-2, which is carrying a new scatterometer instrument able to measure wind speed over the surface of the ocean and to help track monsoons and cyclones. On 12 October ISRO reported satisfactory operation of all three payloads: an ocean color monitor, the scatterometer, and a radio occultation sounder for atmospheric studies. During its five-year design lifetime Oceansat-2, from its 720-km Sun-synchronous orbit, will help spot fishing zones in the sea by monitoring ocean temperatures. It will also provide data to help forecast ocean conditions, forecast

weather, carry out coastal-zone research, and conduct climate studies. The PSLV's 20-kg secondary payload consisted of six smaller satellites built by universities in Germany, Switzerland and Turkey.

Breaking a 13-year streak of successful launches, a Chinese Long March 3B rocket failed to deliver Indonesian communications satellite Palapa D1 to its planned orbit on 31 August. The satellite was built for PT Indosat Tbk by Thales Alenia Space (France and Italy). The failure occurred about 20 minutes after liftoff when one of two identical engines in the rocket's upper stage did not deliver its full thrust during its second burn of the mission, resulting in a payload orbit with an apogee of 21,150 km instead of the planned 50,000 km. However, the satellite was maneuvered into a standard geosynchronous transfer orbit on 3 September, and Thales Alenia Space said it was expected to be guided into its final geostationary-orbit position at 113 degrees east longitude by mid-September. Nevertheless, the maneuver compromised its life, which is now limited to about 10 years vs its design life of 15 years. Hence Indosat will be compensated about \$100 million by their insurance underwriter. Because the Long March 3B upper stage had flown satisfactorily 25 times, the fault was deemed to be a straightforward workmanship issue rather than a design failure, allowing the rocket an early return to service.

On 5 April North Korea launched a three-stage Taepodong-2 rocket carrying an experimental communications satellite. About four hours after the launch, North Korea said that the satellite was in orbit and that it was transmitting patriotic music. But the U.S. and South Korea, who had been tracking the launch, claimed that the satellite had not reached orbit; the U.S. military's Northern Command reported that the payload flew for about 13 minutes and then plunged into the Pacific Ocean after traveling a total distance of 3,230 km.

Space officials aborted South Korea's first rocket launch just seven minutes before liftoff from the Naro Space Center on Oenara Island in Goheung on 18 August. The problem was traced to software controlling a high-pressure tank that helps operate valves in the launch vehicle, which affected the automatic launching sequence. The software erroneously recognized a pressure decrease, but there was no problem with the hardware. The Korea Space Launch Vehicle-1 (KSLV-1) launch, which was to have placed the 100-kg STSAT-2 atmospheric monitoring satellite into a 1,500 x 300-km elliptical orbit, was claimed to be for peaceful purposes and was conducted transparently. South Korea had communicated its plans before the launch and conformed to international agreements, which may enhance space cooperation between the Asian neighbors. Japan has proposed cooperating with South Korea on satellite launches and should be able to strengthen that cooperation henceforth.

South Korea hopes to launch an indigenous satellite-carrying rocket, KSLV-2, by 2018, and send a probe to the moon's orbit by 2020. They had been responsible for the KSLV-1's second stage, payload fairing, and overall vehicle integration, and are developing a 735-kN thrust engine for the KSLV-2, which is being designed to orbit payloads of 1.0 - 1.5 tonnes and is planned for launch in 2018. The vehicle will use four engines for its first stage and a single one for its second stage. The third stage will be powered by a new engine.

The 140-tonne KSLV-1 was developed in collaboration with Khrunichev (Russia), who provided the rocket's first stage and technology from the yet-to-be-flown Angara rocket, which has been under development for about ten years (see prior reports). Subcontractor Energomash (Russia) supplied the propulsion system. The software that caused the launch failure was different from that used by Khrunichev and had never been flight-proven. Since repairs were deemed to be simple and were indeed accomplished in three days, a re-launch was scheduled for 25 August and was carried out successfully on that date. However, STSAT-2 did not enter its intended orbit, because the fairing protecting the satellite during launch was improperly released, forcing the rocket's second stage to carry the payload plus the extra mass of the fairing to an additional 35 km in altitude. The Korean Aerospace Research Institute (KARI) was notified by the Australian Embassy that unidentified remnants, possibly from the satellite launch, had been found near Darwin, Australia. Korea plans a second launch of the KSLV-1 vehicle, which they consider to be only a technology development exercise, in April 2010. Total cost of the KSLV-1 was about \$434 million, which was about a third the projected cost of KSLV-2.

On 31 August, following the failed launch, South Korea announced their intent to spend \$19.2 million over the next three years to fund research and development in space exploration technologies. The Ministry of Education, Science and Technology selected six core investment areas for funding, including development of light- and heat-resistant materials, infrared space sensors, and S-band transmitters and receivers for satellites and next-generation data processing systems. The selected core technologies cannot be purchased abroad and are expected to have the greatest impact on other industries.

Indonesia's National Institute of Aeronautics and Space (Lapan) successfully launched an indigenous rocket into space on 2 July as the next step in their plans to send a satellite into orbit. The RX-420 rocket, which reached an altitude of 50 km, is the second rocket Indonesia has tested. Another type of rocket which was successfully tested last year, the smaller RX-320, will be combined with the RX-420 to carry a satellite into orbit in 2014.

## **B. Development Activity**

NASA revealed plans on 10 December 2008 to spend at least \$68 million through 2013 on the development of the largest rocket ever, the Ares V cargo launch vehicle (CaLV; see last year's report). Ares V's first design analysis cycle will last from July 2011 to the system definition review in March 2012, with the preliminary design review (PDR) starting in late 2013 and the critical design review (CDR) in 2016. Ares V's testing requirements could mean investment in new facilities. The only test flight is planned for June 2018, and is planned to carry the Altair Lunar Lander's first test flight with in-orbit propulsion firings. These plans may undergo change as a result of an overall review of the U.S. human space flight programme completed in October by an expert panel commissioned by U.S. President Obama and chaired by Norman Augustine (see below).

A request for proposals (RFP) on the first Ares V procurement was issued on 5 January, setting out five Phase-1 (preliminary design) work packages with 18-month



base periods and two one-year options. They are based on NASA's internal concept for a Saturn V-class rocket able to lift a minimum of 188.13 tonnes to an orbit of at least 240.8 km. Bidders' responses were due on 9 February, and final contractor selections on the five work packages were made this spring. The procurement is being managed by the agency's Marshall Space Flight Center.

The Ares V concept consists of a core stage powered by six RS-68 engines, boosted by two five-and-a-half-segment versions of the five-segment solid-fuel first stage of the Ares I crew launch vehicle. The extra half-segment on the strap-on boosters will allow structural headroom in the core stage for a larger liquid hydrogen tank to meet the performance criteria.

Work packages will cover the core stage; the strap-on solids; the Earth Departure Stage (EDS) that would take the Orion crew exploration vehicle and the four-seat Altair lunar lander on to lunar orbit; the fairing that would shelter the Altair during launch and ascent; and the avionics and software that will be needed for the complex lunar-launch flight profiles, which will include the need for launch-vehicle power in orbit while an Ares I delivers the crew in an Orion capsule.

Among the questions NASA asked its contractors to answer during the Phase I procurement, designed to take the project through system requirements and system definitions reviews, are what it would take to human-rate the Ares V, the layout of the RS-68 engines and related plumbing, and evaluation of large composite dry structures for the core stage and other elements of the Constellation programme.

On 20 May the largest rocket parachutes ever built successfully lowered a simulated Ares-1 first-stage dummy load of 19,000 kg. The three-parachute package was dropped from a C-17 aircraft at 1.6 km altitude, and landed at an Army base on Arizona. Based on the design used for many years in the space shuttle's solid rocket boosters, each parachute weighs 900 kg and is 45 m in diameter. Then on 8 July NASA conducted a successful flight test of a prototype alternative launch-abort escape system for the Orion spacecraft. The Max Launch Abort System (MLAS) test lasted about one minute and cost \$30 million. The vehicle used four rocket engines and weighed about 20.4 tonnes. It was named after NASA engineer Max Faget, who had designed the original escape tower concept used on the Apollo missions to the Moon.

On 14 August NASA announced that the Ares I-X rocket was fully assembled and mounted on its mobile launch platform at Kennedy Space Center in preparation for its sub-orbital test flight later this year. NASA then put the Ares I-X through numerous tests, such as modal testing that shook the stack slightly to test its stiffness. Engineers attached 700 sensors to the test rocket for a series of systems checks to be sure the Ares I-X was ready to fly.

The test rocket was launched successfully on 28 October to a sub-orbital altitude of 46 km. The launch verified aerodynamic, structural, and trajectory performance characteristics predicted for the flight vehicle. Additional tests included verification of ground operations, countdown procedures, and recovery of the 5-segment first-stage solid rocket booster, with the only misadventure being a failed parachute that was to return the first stage motor to a soft landing in the ocean. The

failure resulted in denting of the rocket's first stage and cracking of its casing on landing.

WhiteKnightTwo, the carrier aircraft for Virgin Galactic's SpaceShipTwo tourist vehicle (see prior reports), undertook its first flight test on 20 December 2008 from the Mojave Air and Space Port (USA). WhiteKnightTwo (christened Eve, in honor of Sir Richard Branson's mother; see last year's report) flew for an hour with a minimum flight test crew and reached an altitude 1,200 m above the original test plan. The flight followed taxi trials on 12, 16, and 20 December. A second 1-1/2-hour flight on 5 February followed control-surface modifications aimed at improving the craft's directional stability. A third flight on 25 March lasted over 2-1/2 hours, reaching a maximum speed of 257 km/hr and an altitude of over 5.4 km. The flight addressed technical issues, including in-flight engine re-starts and engine thrust asymmetry assessment. A fourth test flight up to 36 km altitude on 20 April, at 4 hours the longest to that date, was marred only by some slight damage to Eve's tail, apparently due to a crosswind during a landing strip maneuver. The damage was minimal, with Eve later making a smooth landing on the tarmac. Subsequent analysis indicated that Eve lacked stability augmentation: main landing gear wake vortices prompted some rudder modifications that included the addition of vortex generators to the vertical stabilizers. No further rudder modifications were planned. The craft's sixth test flight was held on 2 June. The 3-hour mission tested pressurization and the environmental systems up to an altitude of 56 km.

Subsequent flights in June included one on 11 June (the eighth) during which the FAA monitored the flight to type-rate its pilot, Peter Siebold. The awarding of this type rating was a first for a twin-fuselage multi-engine all-composite aircraft. During the ninth test flight on 15 June reached 15,980 m, close to SpaceShipTwo's air-launch altitude, and set the stage for overflying the ground-breaking ceremony for New Mexico's Spaceport America on 19 June. However, pilots opted to land the aircraft in Phoenix, Arizona that day when an actuator alarm activated. The plane subsequently circled over the Las Cruces International Airport in New Mexico three times before returning to its base in Mojave, California the next day (construction on the spaceport began that day, 20 June). Between January and October the aircraft will have achieved over 80 flying hours, several long-distance flights in excess of 1600 km, and altitude in excess of 15 km.

On 31 December 2008 Virgin Galactic signed a lease with the U.S. state of New Mexico as "anchor tenant" for Spaceport America (see prior reports). Although Virgin Galactic is considered the anchor tenant, it will be one of several companies that will use the spaceport. Signing of the lease cleared the way for construction to continue during the first quarter of this year, with the terminal and hangar facility scheduled for completion in 2010. Road construction to Spaceport America was begun in 2008.

The New Mexico Spaceport Authority, operator of Spaceport America, signed an agreement with Spaceport Sweden on 29 January to coordinate efforts to develop and promote the commercial space industry. Spaceport Sweden is to be located at the Swedish Space Corporation's Esrange Space Center in Kiruna.

The second batch of Russian equipment was dispatched to French Guiana for building the Soyuz launch pad at the Kourou spaceport on 22 December, 2008. The shipment by the General Machine Building Design Bureau and the Lavochkin Research and Production Center consisted of 95 containers and 51 cargo units of CSKB-Progress.

On 2 April the Russian space agency Roskosmos awarded a two-year \$11.5-million contract to TsSKB Progress to begin designing a new two-stage Rus-M launch vehicle that can carry a 20-tonne payload to a 200-km orbit from Russia's planned new Vostochny Cosmodrome in far eastern Russia. In its first stage the Rus-M will use the liquid oxygen-kerosene Energomash RD-180 engine, currently powering the U.S. Lockheed Martin Atlas-V rocket, and the oxygen-hydrogen Khimavtomatika RD-0146 engine in its second stage. Variants of the Rus-M are expected to be developed subsequently, with payloads of about 30 tonnes and 50 tonnes.

Roskosmos also issued a \$24-million contract to Russian Space Center (RSC) Energiya to begin designing a 6-person space capsule to succeed the Soyuz in missions that will be launched by the Rus-M rocket. The 20-tonne Advanced Crew Space Transportation System (ACSTS) will be capable of carrying crews of four and 100 kg of cargo to the Moon on 14-day lunar flights. First launch of the new launcher and capsule is planned for 2015, with the first launch carrying human crews planned for 2018. Khrunichev State Research and Production Center was the losing bidder on both contracts, but will be a subcontractor to Energiya on the ACSTS. Subcontractors to TsSKB Progress on the Rus-M launcher are Energiya and the Makeyev Rocket Design Bureau.

Late in May three agencies of the French government -- the space agency CNES, the defense procurement agency DGA, and the nuclear agency CEA -- issued a report to Prime Minister Françoise Fillon urging ESA to start definition studies for development of Ariane 6, to be deployed in 2020 – 2025. The report also called for considering a Soyuz replacement and evolutions of the Vega launcher. Ariane 6 is viewed as being highly modular, to encompass different payload requirements in the range 3 – 6 tonnes, and will be designed to achieve lower development and production costs. The report supports ESA's planned upgrades to Ariane 5, which will need to continue operations until 2025, to increase its geosynchronous transfer orbit payload from 8.7 tonnes to 10.4 tonnes beginning in 2017 at a cost of about \$1.4 billion.

On 16 June ESA signed a \$52-million contract with Thales Alenia Space (Italy) for the second development phase of the Intermediate Experimental Vehicle (IXV), a lifting-body re-entry technology demonstrator to be launched aboard a Vega rocket in late 2012 or 2013. The 1.8-tonne IXV will make nearly a full Earth orbit, reaching an altitude of 475 km and a maximum speed of 7.5 km/sec before splashing down in the Pacific Ocean. Part of ESA's Future Launcher Preparatory Programme, IXV is intended to test thermal protection systems and guidance, navigation, and control technologies.

Astrium GmbH (Germany) received a \$29-million contract on 9 July from the German space agency DLR to begin design work on an unmanned vehicle to shuttle cargo to and from the international space station (ISS). Over 18 months, Astrium is studying ways to modify the existing Automated Transfer Vehicle (ATV) to extend its

mission beyond current one-way trips to the ISS. ESA will decide in 2011 whether to pursue the work to full development of what is being called an Advanced Re-entry Vehicle, or ARV, which Astrium stated could make its first flight in 2016 if approved. The ARV would weigh about 20 tonnes, with a dry cargo capacity of 2 tonnes up and 1.5 tonnes down. It could remain docked to the ISS, like the ATV, for six months, but could also serve as a 14-day free-flyer.

Then on 20 July ESA issued a \$70-million contract to Thales Alenia Space (France and Italy) for the 440-kg Experimental Re-entry Testbed (Expert) suborbital vehicle to test re-entry technologies. Expert will be launched in 2010 to a 120-km altitude by a three-stage Russian Volna rocket from a submarine in the Pacific Ocean into a ballistic trajectory, reaching a speed of 5 km/sec at an altitude of 100 km. The Expert programme is aimed at improving the understanding of physical phenomena occurring during the return of space vehicles to Earth. As part of the programme the Italian aerospace research center CIRA designed a winged experimental payload to assess the thermomechanical behavior and resistance of ultrahigh temperature ceramics (UHTC) in real-flight aerothermal environments. Particular attention was devoted to the design of the interfaces between the UHTC winglet and the Expert capsule thermal protection system, since mechanical interfaces represent one of the most critical points in the field of UHTC materials. The attachment of the winglet to the capsule is by means of dedicated bolts that must tolerate mechanical loads occurring during the early stages of the flight: lift-off, ascent, and stage separation. The UHTC winglet qualification model, as well as the final flying model, underwent all the required ground qualification testing by CIRA in readiness for the capsule flight, including arcjet qualification in the Scirocco plasma wind tunnel.

Japan's new H-2B rocket was rolled to its oceanfront launch pad at the Tanegashima Space Center and its two main engines were briefly fired for 10 seconds on 2 April, concluding the heavy-lift booster's first practice countdown after a six-day delay due to faulty ground equipment. The engines, the actual first and second stage powerplants that the rocket used for its first launch (see below), performed well during the test. Rocket builder Mitsubishi Heavy Industries (MHI) performed the second and final 150-second captive firing test on 22 April. A final successful ground test of the entire vehicle on 11 July prepared the rocket for its first flight. The H-2B is an upgraded version of the current H-2A, developed by the Japan Aeronautical Exploration Agency (JAXA) and MHI.

On 20 November 2008 Brazil's Aerospace Technology Center (CTA) awarded an 18-month, \$5.6-million contract to the PyroAlliance division of SNPE (France) to provide hardware for Brazil's VLS-1 satellite launcher and to oversee the procurement of components from other manufacturers. The contract guarantees that no component will be subject to U.S. export regulations. SNPE is using techniques they developed for the Ariane-5 and Vega small-satellite programmes. The first series of ignition ground tests for the VLS-1 engine was completed successfully by PyroAlliance on 23 September.

On 7 October Rocket Lab (New Zealand) completed its final ground-based test of what they claim is the first commercial sounding rocket to use hybrid propellant technology. The test has set the stage for the launch of Atea-1 late this year, which they also claim, if successful, will be the first privately built rocket launched from the

Southern Hemisphere to enter space. The fuel is polymer based and suspended in a solid form; the oxidizer is liquid nitrous oxide.

### **III. ROBOTIC EARTH ORBITAL ACTIVITIES**

#### **A. Telecommunications**

##### **(1) Fixed-Base Communication Systems**

SES Astra's Astra-1M satellite (Luxembourg) was launched from the Baikonur Cosmodrome on 6 November 2008 by an International Launch Services Proton-M rocket. Placed in its geostationary-orbit slot at 19.2 degrees east longitude, the 5.3-tonne spacecraft carries 36 high-power Ku-band transponders and three antennas. It was built by Astrium Satellites (Europe) on the company's Eurostar E3000 platform, which generates 10 kW of power. It is providing customers throughout Europe with direct-broadcast television, including high-definition programming, over a design lifetime of 15 years.

SES's Astra 5A satellite lost control on 15 January and began drifting eastward along the geostationary arc from its slot at 31.5 degrees east longitude. Ground controllers were at first unable to re-establish sufficient communications to restore control, but finally managed to stabilize it on 30 March. Although control was then successfully reestablished, most of the satellite's fuel had been used in an unsuccessful attempt to halt its spin in the hours following the initial loss of attitude. However, sufficient fuel remained to boost it 200 km into a "graveyard" orbit on 3 April, and it was then switched off on 15 April. The spacecraft was built by Thales Alenia Space (France and Italy) on their Spacebus-3000 platform. Astra 5A's owner SES Astra (Luxembourg) had informed owners of neighboring satellites, in case one or more spacecraft needed to perform a collision-avoidance maneuver, but it turned out that no such maneuvers were required.

On 12 February an Arianespace Ariane 5 ECA launched two communications satellites, Eutelsat's Hot Bird 10 and SES New Skies' NSS-9. The same rocket also orbited two 117-kg French Spirale satellites, whose 14-month mission is to build a reference database against which future missile flights can be checked for possible false alarms. They were built by Astrium Satellites (Europe) and Thales Alenia Space (France). Hot Bird 10, a 4.89-tonne satellite built by Astrium Satellites (Europe), carries 64 Ku-band transponders to serve mainly the middle-east market. It was placed in a geostationary-orbit slot at 7 degrees west longitude for two years, after which it will be moved to 13 degrees east longitude to provide backup capacity there. The 2.24-tonne NSS-9, built by Orbital Sciences Corporation (USA), carries 44 C-band transponders to serve the Pacific Ocean region from a geostationary-orbit slot at 183 degrees east longitude. It replaced NSS-5, which is being sent to another orbital position.

Telesat Canada's Telstar 11N satellite was successfully orbited on 26 February by a Land Launch Zenit-3SLB rocket from the Baikonur Cosmodrome, replacing Telstar 11, which was launched in 1995. The 4-tonne spacecraft, built by Space Systems/Loral (USA), carries 39 Ku-band transponders. Its four geographic beams are

delivering video and data services to customers in North America, western Europe, and Africa from its geostationary-orbit slot at 37.5 degrees west longitude. Telstar 11N also includes a beam over the Atlantic Ocean for maritime and aviation customers. Its service includes IP networking and video, including mobile broadband to very small aperture terminals.

Telesat then placed an order with Space Systems/Loral (USA) on 16 July for the Telstar 14R satellite, to be launched by an International Launch Services Proton rocket in mid-2011. It will be placed in a geostationary-orbit slot at 63 degrees west longitude, replacing Telstar 14/Estrela do Sul, which was launched in January 2004 but suffered reduced life due to a partial solar array failure and is not expected to last beyond 2011. Telstar 14R will weigh 5 tonnes, generate 11 kW of power, and carry 46 active transponders, 19 of which are to be configurable in orbit. It will be able to switch power to different regions in North America, South America, and the Atlantic Ocean, whose beam will extend maritime and aeronautical communication services currently provided by Telstar 14 and Telstar 11.

Ciel Satellite Group's Ciel-2 (Canada) was launched into a geosynchronous transfer orbit by an International Launch Services (ILS) Proton Breeze M rocket from the Baikonur Cosmodrome on 10 December 2008. Built by Thales Alenia Space (France and Italy) on the company's Spacebus 4000 C4 platform, the 5.6-tonne, 10.6-kW Ciel-2 was subsequently placed into a geostationary-orbit slot at 129 degrees west longitude. It is serving customers of EchoStar's Dish Network (USA) throughout Canada and the U.S. with high-definition television and other video services. Ciel-2 carries 32 Ku-band transponders and features high-frequency re-use with both regional and 55 spot beams. Its design lifetime is 15 years. Ciel Satellite Group is owned by Borealis Infrastructure, a Canadian pension fund, and SES Americom (Luxembourg).

On 17 September Telesat's Nimiq 5 satellite (Canada) was launched from the Baikonur Cosmodrome into a geostationary-orbit slot at 72.7 degrees west longitude by an International Launch Services Proton-M Breeze rocket. The fifth satellite in the Telesat group, the 4.75-tonne Nimiq 5 carries 32 Ku-band transponders, all of which were leased by EchoStar Corporation (USA). It is expected to become operational in 2010 to provide high-definition and specialty television services to Bell TV and Dish Network subscribers in Canada and the U.S. Nimiq 5 was built by Space Systems/Loral (USA) on their LS1300 platform, and has a service life of 15 years.

NigComSat-1, owned by Nigerian Communications Satellite Ltd., was powered down on 11 November 2008 after an abnormal battery discharge in a non-eclipse situation. The satellite, built by China Great Wall Industry Corporation on its DHF-4 platform and launched in May 2007, had a design lifetime of 15 years. NigComsat-1 went off orbit as a result of power exhaustion attributed to a technical error in the satellite's solar array. On 21 January the China Great Wall Industry Corporation signed an agreement with Nigerian Communications Satellite Ltd to replace NigComSat-1, covering the construction of a new spacecraft and the procurement of a launch vehicle and other launch services at no cost to Nigeria. Construction of the new satellite, NigComSat-1R, was begun after Nigerian President Umaru Yar'Adua gave the go-ahead for a fresh contract with the Chinese firm, which was signed in Beijing on 24 March. It calls for a modified version of the DFH-4

platform, and like NigComSat-1 will carry 8 Ka-band, 14 Ku-band, 4 C-band, and 2 L-band transponders. Despite the NigComSat-1 failure, on 10 February Nigeria contracted with China Great Wall Industry for three more communications satellites, the first of which will be NigComSat-1R (see above), planned for launch in 2011.

On 26 November 2008 SES (Luxembourg) and EchoStar Corporation (USA) signed an agreement to co-finance a large direct-broadcast television satellite, QuetzSat-1, to be placed in 2011 into a Mexican geostationary-orbit slot at 77 degrees west longitude that both companies have been cultivating for more than three years (see prior reports). This follows the creation of Dish Mexico, a joint venture of EchoStar and MVS Comunicaciones, a Mexican telecommunications company, and of QuetzSat, a joint venture of SES, which owns 49 percent of the company, and Grupo Medcom (Mexico). QuetzSat-1's satellite-television service will feature 25 Spanish and English language channels for \$10.18 per month, including tax.

Early in April Intelsat (Bermuda) and SES (Luxembourg) joined forces to address the long-standing problem of unintentional interference with satellite transmissions. They called on other satellite operators to join in creating an industry-wide global database to collect information on interference and to endorse standardized training and certification for the personnel who install and operate satellite uplink ground stations. The new effort will not deal with interference by terrestrial wireless broadband transmitters, which is the province of national regulating agencies, but will focus only on satellite transmissions.

On 18 May Boeing Satellite Systems International (USA) announced that ProtoStar-2 was operating as planned in orbit following its launch on 16 May into a geostationary-orbit slot at 107.7 degrees east longitude aboard an International Launch Services Proton-M rocket from the Baikonur Cosmodrome. Boeing had planned 12 to 14 days of in-orbit tests before handing the satellite to ProtoStar for operations. ProtoStar-2 is a Boeing 601HP model satellite that was originally designed in 2000 for Intelsat's Latin American business before being placed, nearly completed, in storage for four-and-a-half years and then resold to ProtoStar (Bermuda) in 2007. The refurbished spacecraft, originally intended to carry an all-Ku-band payload, is now equipped with 27 Ku-band transponders and 13 S-band transponders, the latter intended to replace the aging IndoStar 1/Cakrawarta 1 satellite launched in 1997. It was planned to deliver direct-to-home television services in Indonesia, India, the Philippines, and Taiwan (Province of China). However, possible interference and frequency coordination problems with ProtoStar-1 (see last year's report) have motivated ProtoStar to offer ProtoStar-2 for sale to SES Global, who operate SES's NSS-11 satellite at 108.2 degrees, just 0.5 degrees away.

But then on 29 July ProtoStar filed for bankruptcy protection under U.S. Chapter 11, and hoped to use the resulting reprieve from their creditors to conduct an auction of both ProtoStar-1 and ProtoStar-2. The world's three largest satellite operators, SES Global, Eutelsat, and Intelsat, expressed interest in purchasing at least one of the two ProtoStar spacecraft, and both Eutelsat and SES confirmed that interest on 31 July. ProtoStar's creditors offered \$16 million in emergency "tide-over" funding to permit the company to continue operations, which were costing ProtoStar about \$2 million per month, until the two satellites could be sold at an auction mediated by the Delaware Bankruptcy Court. The court set a deadline date of 8

October for bids on the two spacecraft and 14 October for the open auction, which dealt with the two satellites separately. The bid deadline was subsequently delayed to 23 October and the auction to 29 October. Intelsat (Bermuda) bought ProtoSrar-1 at the auction for \$210 million in cash. Other bidders in the final round included SES (Luxembourg), EchoStar (USA), Thaicom (Thailand), and Measat (Malaysia). Results were to be reviewed by the court for subsequent approval, but Intelsat expected to be operating the spacecraft in 30 days with the new name Intelsat 25.

Intelsat (Bermuda) ordered four communications satellites of a new midrange design from Boeing Satellite Systems International (USA) in April. The \$500-million order, which was finalized on 10 July, inaugurated the 5.4 – 6.2-tonne, 6-12 kW Boeing 702B platform design, which adapts components from the lighter 601 bus design and the heavier 702. One of the satellites, Intelsat IS-22, is planned for launch in 2012. It will carry a UHF-band payload for the Australian Defence Force, in addition to 48 C-band and 24 Ku-band transponders that will serve Africa, Asia, and the middle east from IS-22's geostationary-orbit slot at 72 degrees east longitude. IS-21, to be launched about three months later than IS-22, will be co-located with IS-9 at 58 degrees west longitude, and IS-23, to be launched subsequently as will IS-24, which will be placed in a slot at 307 degrees east longitude.

Late in March Eutelsat (France) contracted with Thales Alenia Space (France) to build the 5.4-tonne W3C satellite, planned for launch in mid-to-late 2011. The 12-kW spacecraft will carry 53 Ku-band and 3 Ka-band transponders along with three deployable and two fixed antennas, providing backup broadcast and communications services to Europe, the middle east, and north Africa from Eutelsat's geostationary-orbit slot at 7 degrees east longitude.

On 11 February a Proton M rocket launched AM44 and Express MD-1 for the Russian Satellite Communications Co. (RSCC). AM44, built by Reshetnev ISS (Russia) with a payload built by Thales Alenia Space (France), weighs 2.53 tonnes and carries one L-band, 16 Ku-band, and 10 C-band transponders. It is located in a geostationary-orbit slot at 11 degrees west longitude, with a design service life of 12 years. The smaller 1.14-tonne Express MD-1, built by Khrunichev and Space Production Center (both Russia) also carries a Thales payload consisting of one L-band and 8 C-band transponders. It is delivering voice, data, and radio broadcast services from a slot at 80 degrees east longitude, and has a design life of 10 years.

Eutelsat's W2M satellite, launched on 20 December 2008, suffered a sudden failure of its electric-power subsystem on 22 January as it was being moved from its in-orbit test location toward its final geostationary slot at 16 degrees east longitude. The satellite had functioned without incident during four weeks of in-orbit tests. The failure was not due to an operator error, but was traced to a system on the I3K platform provided by Antrix, the commercial arm of the Indian Space Research Organization (ISRO). Antrix and Astrium Satellites of Europe had signed a joint-venture agreement in February 2006, under which EADS Astrium was prime contractor for the 3.4-tonne spacecraft, built the communications payload, and was responsible for programme management. Antrix and ISRO built the satellite bus and had responsibility for operating W2M during its first weeks in orbit before transferring control to Eutelsat. W2M remained under control after the failure,



in emergency Sun-acquisition mode to keep its batteries charged while recovery efforts continued.

A second Antrix-Astrium satellite is under construction for Avanti Communications Group of London and scheduled for launch late this year. Avanti's Hylas satellite uses the Antrix/ISRO I2K platform, not the I3K version employed for the W2M. On 10 July Avanti received a commitment of \$68 million from institutional investors and the British government to cover the cost of changing the Hylas launch from Space-X's Falcon-9 to a mid-2010 launch by an Arianespace Ariane-5 or Soyuz, due to customers' and prospective investors' concerns about Falcon-9's viability.

The same Ariane-5 that launched W2M on 20 December 2008 also orbited Eutelsat's Hotbird-9, which was placed in a geostationary-orbit slot at 13 degrees east longitude. Built by Astrium, it replaced Hotbird-7A, which was moved to a slot at 9 degrees east longitude. Hotbird-9 is now providing digital and high-definition television to Europe, north Africa, and the middle east.

On 12 February an Ariane 5 launched Hotbird 10, to be eventually placed in a geostationary-orbit slot at 13 degrees east longitude but temporarily placed at 7 degrees west to replace Atlantic Bird 4; and also NSS-9. Hotbird 10 provides the same kinds of services as Hotbird 9. NSS-9, manufactured by Orbital Sciences (USA), carrying 28 active C-band transponders and featuring 3 beams that can be interconnected on a transponder-by-transponder basis, was placed at 183 deg east longitude for SES New Skies. It replaced NSS-5 and provides communications service to broadcasters, governments, carriers across the Pacific Ocean, and the maritime industry.

Eutelsat and Astrium Satellites (Europe) signed a contract on 14 May for Eutelsat's Atlantic Bird 7, which will strengthen capacity over the middle east and north Africa and cement Eutelsat's partnership with Nilesat (Egypt). Launch is planned for 2011 to the geostationary-orbit slot at 7 degrees west longitude, where Nilesat-1 and Nilesat-2 are located and to which Nilesat-3, currently under construction, will be launched in 2010. The 4.6-tonne Atlantic Bird 7, which was built on Astrium's Eurostar 3000 platform, carries two main beams, one (with 44 transponders) to provide direct-to-home television to the middle east and north Africa, and one (with 12 transponders) for consumer broadcast and Internet access from northwest Africa to the Gulf of Guinea. The bus provides 12 kW end-of-life power to the payload, which has a 15-year design lifetime. Atlantic Bird 7 will replace Eutelsat's Atlantic Bird 4A, which will then move back to its original slot at 13 degrees east and revert to its original name, Hot Bird 10.

Eutelsat's W2A spacecraft was launched from the Baikonur Cosmodrome to the company's geostationary-orbit slot at 10 degrees east longitude on 4 April by an International Launch Services Proton Breeze M rocket. The 5.9-tonne satellite, built by Thales Alenia Space (France and Italy) on the Spacebus 4000 C4 platform, carries 46 Ku-band and 10 C-band transponders, along with an S-band payload for mobile satellite services by Solaris Mobile (Ireland), a joint venture of Eutelsat (France) and SES (Luxembourg). The platform provides the payloads with end-of-life power of 15.4 kW. S-band communications are conducted via a 12-m deployable antenna built by Harris Corporation (USA). W2A's design lifetime is 15 years.

That antenna was unfurled successfully on 9 April, but during the subsequent 4-week test period it developed an anomaly which degraded its coverage and radiated power, although the antenna continued to operate in both transmit and receive modes. However, on 10 September Solaris announced that the antenna was so badly damaged that it could not offer a commercially viable service. The company would be able to meet the early service and coverage requirements that they committed to, so the satellite was valuable from that perspective, but the payload could not be used much commercially. Hence Solaris owners SES and Eutelsat filed a \$186 million insurance claim when it became clear that Solaris' in-orbit asset was badly damaged, and they have not made plans to launch a replacement satellite for Solaris.

The TerreStar-1 spacecraft, built for TerreStar's North American S-band service by Space Systems/Loral (USA), also carries an 18-m Harris antenna, but both Harris and Space Systems/Loral claimed that this antenna was free of the issue affecting the Solaris antenna. TerreStar-1 was delivered to the Guiana Space Center on 15 May, and was launched uneventfully by an Ariane 5 ECA on 2 July (see below).

Coincidentally, Solaris and Inmarsat (London) were selected by the European Commission (EC) on 14 May as winners of the competition to provide S-band services in Europe (see last year's report). Their licenses split the 30-MHz band into two 15 MHz bands. Bids by TerreStar Europe (UK), a subsidiary of TerreStar Networks (USA), and ICO Global Communications (USA) were rejected. On 28 May TerreStar Europe filed an appeal in The European Court of First Instance protesting the EC award, on the basis that the EC had excluded TerreStar Europe under the mistaken impression that its TerreStar-2 spacecraft had not met a critical design review deadline, confusing TerreStar Europe with the U.S. company TerreStar Networks.

On 1 October an Ariane 5 ECA launched Hispasat's (Spain) Amazonas 2 spacecraft, built by EADS Astrium (Europe) on their Eurostar E3000 platform. The 5.45-tonne satellite is equipped with 54 Ku-band and 10 C-band transponders for communications services to North, Central, and South America. At 12 kW, it was the most powerful satellite built by Astrium to date, with 25% more transponders, 60% more power, and only 20% greater mass than Amazonas 1, launched in 2004. Amazonas-2 was placed in a geostationary-orbit slot at 61 degrees West longitude, from which it can reach from Alaska to Tierra del Fuego.

The same Ariane-5 also launched the 2.54-tonne COMSATBw1, the first of two such satellites for the German Armed Forces' military communications architecture. They were built by Thales Alenia Space (France and Italy) on the Spacebus 3000B platform, which delivers 3.5 kW to a mixed SHF, UHF, and Ku-band payload built by Tesat Spacecom (Germany). COMSATBw1 was placed in a geostationary-orbit slot at 63 degrees east longitude, where it will serve for its design lifetime of 15 years.

On 18 June Hispasat (Spain) signed a \$67-million contract with OHB System (Germany) and Thales Alenia Espana (Spain) for Hispasat AG1, whose development by OHB System was largely funded by ESA's Small Geo programme (see last year's

report). OHB will build the satellite platform; Thales the Redsat communications payload under a separate \$28-million contract. Launch is planned for late 2012.

Space Systems/Loral (USA) shipped SES World Skies' satellite NSS-12 to the Guiana Space Center on 1 October for an Ariane-5 launch late this year. NSS-12, which is to replace NSS-8 (lost in a Sea Launch explosion in January 2007; see prior reports), carries the equivalent of 40 C-band and 48 Ku-band transponders. Based on SS/L's 1300 platform, its two hemispheric C-band beams will cover Europe, the middle east, Africa, Asia, and Australia for telephone, cable distribution, and corporate networks from its geostationary-orbit location at 57 degrees east longitude. Its direct-to-home video coverage using four Ku-band spot beams will serve Europe, the middle east, central and south Asia, and east Africa. NSS-12's antennas can beam signals to two-thirds of the world's population.

On 21 January Reshetnev Information Satellite Systems company (Russia; previously known as NPO PM) was awarded a turnkey contract to develop and deliver to the geostationary orbit the TELKOM 3 telecommunication satellite for PT Telekomunikasi Indonesia Tbk. Launch is scheduled by mid-2011. The 1.6-tonne satellite, with 32 C-band and 10 Ku-band transponders, is based on Reshetnev's medium-class Express-1000N platform. The power level is 5.6 kW, and the spacecraft has a design lifetime of 15 years. Reshetnev also will develop the ground-control segment and provide training and technical support to the service operator. The communications payload will be provided by Thales Alenia Space (France). The contract was signed on 31 January.

ISS Reshetnev also was selected to receive a \$370-million contract on 19 May, in partnership with Thales Alenia Space (France and Italy), to build two large multiband satellites for Russian Satellite Communications Company (RSSC). The contract was signed on 14 August, with Thales Alenia Space (France and Italy) supplying the payloads. The losing bidders were RSC Energia and the Khrunichev State Research and Production Space Center (both Russia). Express-AM5 and Express-AM6 will each deliver 14 kW of power to their payloads, will be launched into geostationary-orbit slots at 140 degrees and 53 degrees east longitude by Proton rockets in 2012, and will have design lifetimes of 15 years. Express-AM5 will carry 36 Ku-band, 30 C-band, 14 Ka-band, and 3 L-band transponders; Express AM-6 will have 36 Ku-band, 14 C-band, 20 Ka-band, and 3 L-band transponders.

Gazprom (Russia) ordered two large satellites and their launches from European vendors early in February. Thales Alenia Space (France) will build both 5-tonne-class spacecraft on the company's 4000C3 platform. Gazprom also contracted with Arianespace (France) for their launches, planned for the second half of 2011. They will be the first non-Russian launches of a satellite operator from a former Soviet-Union country. Yamal 401 will carry 30 Ku-band and 17 C-band transponders, and will be placed in a geostationary-orbit slot at 90 degrees east longitude. Yamal 402 will have 46 Ku-band transponders, and will provide service from a slot at 55 degrees east longitude.

Kazakhstan's KazSat-1 went out of control on 26 November 2008, and there has been no response to commands since then. The satellite had stopped broadcasting to the country's territory on 8 June 2008. Khrunichev space research and production

center (Russia) is currently building KazSat-2, planned for launch later this year (see last year's report).

On 15 June Asia Broadcast Satellite (ABS, Hong Kong) announced a contract with Space Systems/Loral (USA) to build the ABS-2 satellite, and a contract with Arianespace to launch the satellite aboard an Ariane 5 in 2012. The 6-tonne ABS-2 will carry a total of 78 C-band, Ku-band, and Ka-band transponders using 8 different beams, and will provide its payload with 14 kW of power. It will be co-located with ABS-1 in a geostationary-orbit slot at 75 degrees east longitude. ABS-1, formerly owned by Lockheed Martin (USA) and called LMI-1, was launched in 1999 and has a contract life of 15 years, but has sufficient propellant to last well beyond 2020. On 22 June Singapore Telecommunications (SingTel) invested \$69 million to support the construction and launch of ABS-2. SingTel also invested \$55 million over two years for ownership of a number of C-band transponders on ABS-2, to be marketed as ST-3/ABS-2 in Africa, the Middle East, and Asia. ABS subsequently announced on 2 July their purchase of Koreasat-2 from South Korea's KT Corporation, moving it to ABS's slot at 75 degrees east longitude, collocated with ABS-1, and renaming it ABS-1a.

Space Systems/Loral (USA) also received contracts on 16 June for a new Ka-band satellite from Hughes Network Systems (USA) and on 18 June from Intelsat (Bermuda) for Intelsat 19 and Intelsat 20, which will replace Intelsats 7, 8, and 10. Intelsat 19 will be launched in 2011 to provide C-band and Ku-band service to customers in Asia and the Americas from a geostationary-orbit slot at 166 degrees east, replacing Intelsat 8, and Intelsat 20 will replace Intelsat 7 and Intelsat 10 in 2012 at 68.5 degrees east longitude. The two new satellites are among the highest power spacecraft ever built by Space Systems/Loral.

The new Hughes satellite will augment Spaceway 3, a Ka-band satellite launched to a geostationary-orbit slot at 95 degrees west longitude in April 2008. It accommodates 600,000 to 700,000 customers with a throughput capacity of 10 GB/sec. The new satellite, based on SS/L's 1300 platform, is expected to weigh 6.1 to 6.2 tonnes at launch and will accommodate 2 million to 3 million customers at 100 GB/sec throughput. It will feature 60 beams and the same bent-pipe architecture as Spaceway 3, which requires no on-board processing. It will provide Internet service to North American customers at downlink speeds from 5 to 25 MB/sec, vs Spaceway 3's 1 to 5 MB/sec.

Thales Alenia Space (France and Italy) received a \$189-million contract on 1 October from APT Satellite Holdings Ltd (Hong Kong) for the Apstar 7 communications satellite. To be built on the company's Spacebus 4000 C2 platform, it will carry 28 C-band and 28 Ku-band transponders, and will replace Apstar 2R in a geostationary-orbit slot at 76.5 degrees east longitude. The contract included a satellite control center and on-line support for post-launch satellite operations. Apstar 7 is rated at 11.4 kW, and is planned for launch in the first quarter of 2012. It will contain no U.S. components, so it could be launched by a Chinese Long March rocket, although its design makes it compatible with Proton and Ariane 5 as well.

Italy's Sicral 1B communications satellite was launched aboard a Sea Launch Zenit-3SL rocket from the Sea Launch Odyssey platform in the Pacific Ocean on 20

April. The 3.05-tonne spacecraft, built by Thales Alenia Space on the company's Italsat 3000 bus, carries one EHF/Ka-band, three UHF-band, and five SHF-band transponders to serve the Italian defense ministry, the North Atlantic Treaty Organization (NATO), and allied nations.

SkyPerfect JSAT Corporation (Japan) ordered their JCSAT-13 from Lockheed Martin Commercial Space Systems (USA) on 16 April. Planned for launch to its geostationary-orbit slot at 124 degrees east longitude by an Ariane rocket in 2013, the spacecraft is being built on Lockheed's A2100AX bus. It will carry 44 Ku-band transponders to service Japan, eastern Asia, and the Pacific Ocean region. It will also carry two steerable beams to deliver video and data to southwest Asia, the middle east, and the Pacific region. JCSAT-13, which will replace JCSAT-4A, is the seventh spacecraft SkyPerfect JSAT has purchased from Lockheed Martin. On 21 August an Ariane-5 ECA launched Sky-Perfect JSat's 4-tonne JCSAT-12, also built by Lockheed Martin and carrying 30 Ku-band and 12 C-band transponders. It replaced JCSAT-R as an orbital spare, providing JSat backup capability for broadcast and broadband services to operators in Japan, Oceania, the Asia-Pacific region, and Hawaii.

The same Ariane-5 ECA also launched the 2.5-tonne Optus D3 for Optus Networks (Australia), which is providing television broadcast services to Australia and New Zealand from a geostationary-orbit slot at 156 degrees east longitude during its 15-year service life. Carrying 32 Ku-band transponders, it was the largest geostationary-orbit satellite ever built by Orbital Sciences Corporation (USA).

On 23 July India's cabinet approved construction by the Indian Space Research Organization (ISRO) of a \$104-million advanced communications satellite. GSAT-11 will have 16 Ku-band beams and a frequency re-use factor of 4, giving it 10 GHz effective bandwidth, equivalent to about 220 36-MHz transponders. It also will have Ka-band capability. Expected to weigh 4.5 tonnes, it will be heavier than any previous ISRO spacecraft and twice as massive as any of the eleven multipurpose Insat satellites currently in orbit. GSAT-11 is planned for launch in 2011 aboard India's new GSLV-3 rocket.

The joint venture of SingTel (Singapore) and Chunghwa Telecom (Taiwan, Province of China) placed an order on 2 December 2008 with Mitsubishi Electric Corporation (Japan) for the ST-2 communications satellite. To be built on Mitsubishi's DS2000 platform, it was the company's first commercial order for a non-Japanese spacecraft. Planned to replace the ST-1 spacecraft in the geostationary-orbit slot at 88 degrees east longitude in late 2010 or early 2011, its estimated cost is \$266 million, including the launch. Chunghwa took a 38% stake in the joint venture, worth \$42 million; Singtel holds the balance of 62%.

Measat's (Malaysia) Measat-3a satellite was launched to a geostationary-orbit slot at 91.5 degrees east longitude on 22 June by a Land-Launch Zenit-3SLB rocket from the Baikonur Cosmodrome. The 2.366-tonne satellite, built by Orbital Sciences Corporation (USA) on the company's Star-2 platform, carries 12 active Ku-band transponders plus three spares, and 12 active C-band transponders plus three spares. It will provide Measat a 50% increase in capacity over Measat-3, which it will join in the same orbital slot. The satellite cost \$70 million to build and \$44 million to launch,

and is insured for launch plus a year of operations under a \$185-million insurance policy that cost \$28 million. Measat-3a is delivering fixed satellite services to Africa, the Asia-Pacific region, Australia, Europe, and the Middle East, as well as direct-to-home television in Indonesia and Malaysia.

On 9 February Smartlink (Jordan) announced the formation of a new commercial satellite operating company, SmartSat, to be based in Dubai, UAE. Along with a Kuwaiti investment partner, Smartlink claims to have secured an initial investment of \$500 million to provide broadband satellite services to the middle east and north Africa. As the first private satellite operator in the Arab world, SmartSat has leased capacity aboard New Skies NSS-6 and also plans to lease space on Arabsat's Badr-4.

During the First Communications Summit, held in the Democratic Republic of Congo on 13 November 2008, the satellite communications industry association Global VSAT Forum (UK) announced agreement on a broadband communications network for schools in the Congo capital Kinshasa. To be deployed and operated by wireless service provider Microcom, the network will carry educational content for primary-school students. Unlike prior programmes in developing countries, which relied on funding from aid organizations, this project and subsequent efforts of a similar nature being planned by Congo are designed to pay for themselves through affordable user fees from the school system and monthly subscriptions from enterprises that rely on the network. The Global VSAT Forum will help certify technicians and provide technical assistance. The Forum's Nation-Building campaign hopes to develop hybrid communications systems using satellite, wireless, and broadband technology to provide access to thousands of people.

Intelsat (Bermuda) and investment firm Convergence Partners (South Africa) formed a joint venture called New Dawn on 8 December 2008. The \$250-million New Dawn satellite, already under construction with \$350-million financing secured through advance transponder-leasing contracts, will go into operation early in 2011 in Intelsat's geostationary-orbit slot at 33 degrees east longitude, replacing Intelsat-11 there. Launch of the 3-tonne spacecraft late in 2010 was contracted to Arianespace (France) on 14 April. Being built by Orbital Sciences (USA), New Dawn will carry 28 C-band and 24 Ku-band transponders. Intelsat owns 74.9% of New Dawn with Altirah Telecoms (South Africa), and will oversee satellite construction and operations; Convergence Partners, in addition to its 25.1% ownership, will help Intelsat find additional customers for New Dawn. Initial customers holding 15-year leases include Vodacom International Ltd (South Africa), Gateway Communications Africa, and Gilat Satcom (Israel). Debt financing has been provided by Nedbank Group and the Industrial Development Corporation (both South Africa).

Argentina's space agency CONAE announced on 8 September that Astrium Satellites (Europe) and Thales Alenia Space (France and Italy) are providing platform and payload components for the Arsat-1 communications satellite currently under construction by CONAE's satellite-building affiliate Invap. The 2.8-tonne Arsat-1 will carry 24 Ku-band transponders and generate 4.7 kW of power for its 880-kg payload. It is to be placed in Argentina's geostationary-orbit slot at 71.8 degrees west longitude and has a design life of 15 years. Astrium is building the 50-kg

carbon-composite support structure for the satellite, its bipropellant propulsion system, and its on-board computer; Thales is supplying the payload electronics.

On 18 September China granted Pakistan a \$200-million loan for construction of a new communications satellite. The Paksat-1R spacecraft, which is to carry 12 C-band and 18 Ku-band transponders, will replace Paksat-1 in 2011. It will be built jointly by the Great Wall Industry Corporation (China) and Pakistan's Space and Upper Atmospheric Research Commission (Suparco).

More than a quarter-century after its launch aboard the shuttle Challenger, TDRS-1, the first of NASA's Tracking and Data Relay Satellite System constellation, was retired from service on 12 October and moved out of its geosynchronous orbit for final decommissioning on 28 October. It had operated for 26 years, almost four times longer than its design lifetime. Two new TDRSS craft are being developed by Boeing Satellite Systems International (USA) for launch in 2012 and 2013.

## **(2) Mobile Communication Systems**

TerreStar-1, at 6.91 tonnes the largest commercial telecommunications satellite ever built, was launched by an Ariane 5 ECA from the Kourou Spaceport on 2 July, following delays imposed by insurers to investigate the cause of an anomaly in the W2A satellite's antenna, launched on 4 April, which is of the same design as TerreStar-1's (see above). TerreStar Networks (USA) is using the satellite to provide voice, data and video communications to satellite and terrestrial mobile devices the size of a typical smart phone, using the 2-GHz (S-band) portion of the spectrum from its geostationary-orbit slot at 111 degrees west longitude. TerreStar-1, insured for \$200 million to cover the launch and first year's operations, was built by Space Systems/Loral (USA) on the company's LS-1300 platform. It features a ground-based beam-forming system, which allows TerreStar to adjust the satellite's coverage from the ground, and is designed to work with ground-based signal amplifiers, called the Ancillary Terrestrial Component, to permit service in areas the satellite cannot reach. Its payload can form over 500 spot beams. Terrestar-1's 18-m S-band antenna was successfully deployed on 14 July, and on-orbit testing was completed in mid-August.

Globalstar (USA) obtained sufficient financing on 1 July to build, launch, and insure their 24-satellite second-generation constellation, after an 11-month series of negotiations. The key factor was a \$738-million commitment by the French export-credit agency Coface, who guaranteed 95% of the credit facility. Fabrication of the first six-satellite batch by Thales Alenia Space (France) is expected to be completed early in 2010, and three more six-satellite batches are expected to be delivered later that year. Arianespace (France) has reserved four Soyuz rockets and prepared a Soyuz-mounted dispenser to enable the launches from the Baikonur Cosmodrome by Arianespace affiliate Starsem, six at a time, in 2010. The first disbursement of \$276 million was issued to Thales on 1 July.

On 4 September Thales Alenia Space announced that Coface had also guaranteed a \$465 million loan to O3b to support the company's construction and launch of eight medium Earth orbit Ka-band satellites (see last year's report). The loan guarantee is part of a total O3b debt package of \$525 million to be provided by a bank syndicate. O3b has already raised about \$86 million in equity and will need to

raise additional funds to complete the project's financial package, estimated at around \$750 million. That is the approximate amount it will take for O3b to build, launch and insure its first eight satellites, to be launched four at a time starting in 2011 on Russian Soyuz rockets operated from Europe's Guiana Space Center in French Guiana. O3b claims to have binding contract commitments totaling close to \$600 million for services to be provided over the first five years of the company's operations. The spacecraft are being built by Thales Alenia Space.

The Newfoundland and Labrador governments in Canada established a satellite telephone service on 24 August for motorists on the 1,500-km Trans-Labrador Highway. The system uses Iridium 9555 satellite telephones, available to motorists from local hotel operators, and pre-programmed to direct calls to the Royal Newfoundland Constabulary for emergency service and response via the Royal Canadian Mounted Police. The telephones are being manufactured by Roadpost (Canada) and supplied by their dealer Newfound Mobility.

On 27 April Intelsat (Bermuda) signed a \$167 million, 15-year contract with the Australian Defense Force (ADF) to provide an ultra-high-frequency (UHF) mobile-communications payload aboard IS-22, scheduled for launch in 2012 to a geostationary-orbit slot at 72 degrees east longitude. IS-22's main payload will provide maritime users and customers in Africa and Asia with communications services using 48 C-band and 24 Ku-band transponders. The satellite will be built on Boeing Satellite Systems International's new 702B platform (see above). The 400-kg UHF payload, consisting of twenty-eight 25-kHz channels, will consume 2 kW of power, about 20% of the spacecraft's capacity. Australia expects this unit to save over \$150 million compared with a dedicated military spacecraft and come on line in 2012, much sooner than otherwise possible. Intelsat is now examining every new satellite it orders to see what mass and power it would have available for such "hosted" payloads that can accommodate the special needs of various governments at much lower cost than dedicated satellites.

On 22 February Orbcomm (USA) lost control of one of the six satellites it launched in June 2008, declaring it a total loss following a power failure. The failure delayed the entry into full service of the other five satellites, in order to determine whether their power systems might suffer the same problem. Loss of the satellite did not have any material impact on the company's overall operations. But then on 11 May Orbcomm filed a \$50-million total-loss insurance claim for all six satellites. In addition to the one that failed completely, as noted above, the other five experienced lower-than nominal transmission power on one; lower-than-expected nominal subscriber transmission on another; intermittent computer resets on a third; and outages of the attitude control systems on all five. Their Automatic Identification System (AIS) was not affected by the multiple anomalies. The six satellites were built by KB Polyot (Russia) under contract to OHB System (Germany). The first six of Orbcomm's second generation of at least 18 satellites, under construction by Sierra Nevada Corporation (USA), are scheduled for delivery in late 2010. Orbcomm's current constellation in low Earth orbit consist of 28 satellites, including those built by Polyot.

Telesat (Canada) announced on 3 November 2008 that the two new MSV-1 and MSV-2 satellites owned by Mobile Satellite Ventures (MSV, USA) will be



operated by MSV from Telesat's ground stations in Toronto, Canada, and Mount Jackson, Virginia. Boeing Satellite Systems International (BSSI, USA) is building the two mobile communications spacecraft, due for launch in 2010. MSV changed its name to SkyTerra, its parent company, in December 2008. On 23 September Harbinger Capital Partners (USA), which had owned 48% of SkyTerra, bought up the rest of the company's shares and now owns 100% of SkyTerra.

New Canadian regulations aimed at enhanced security in the monitoring of industrial explosive stockpiles, announced early in April, have created a new application for satellite services. Blue Ocean Satellite Systems (Canada) have met this new requirement with a surveillance system called SkyHawk, which employs the Iridium satellite network's Short Burst Data service. Storage-site door sensors, operated by solar power during daytime hours and solar-charged batteries at night, activate an alarm that is transmitted to the site operator via the satellite system, which offers coverage of remote sites not served by terrestrial communications services. The bidirectional SkyHawk system allows site operators, who commonly use explosives in oil exploration, construction, mining, and avalanche control, to remotely access the controls that govern the storage site in order to deny entry by discharged employees or to remotely diagnose problems that may occur there. This function eliminates the need for sending crews periodically to the often-remote sites. The SkyHawk system is also used in Canada to detect the springing of grizzly-bear traps, reducing the frequency of visits to the remote trap sites to free the bears, and could be used to provide security monitoring for remote vacation homes.

On 20 May Inmarsat announced that their 6.6-tonne I-XL mobile communications satellite, also known as Alphasat-1, will be launched in 2012 into a geostationary orbit slot at 25 degrees east longitude by an Ariespace Ariane 5 ECA rocket. The satellite is based on ESA's Alphasat spacecraft, developed for commercial use by Astrium Satellites (Europe) and Thales Alenia Space (France and Italy). ESA is funding several experimental payloads to be carried by I-XL along with Inmarsat's primary L-band payload.

SES (Luxembourg) began offering maritime mobile satellite services to commercial ships and yachts in the North and Baltic Seas and the northern Mediterranean on 18 September, using SES's Astra2Connect interactive broadband service. SES also announced agreements with KNS Inc. (UK), to develop stabilized antennas for maritime use, and with H<sub>2</sub>O Satellite (UK) to distribute the service in Europe.

On 12 October Thales Land and Joint Systems (France) announced a contract with the Dutch navy to supply four ocean patrol ships with Surfsat satellite communications terminals, to be installed in 2012 – 2013. The terminals, whose diameters range from 1.9 to 2.6 m, will have dual-band antennas for communications via both the commercial Ku-band and the military X-band frequencies. Similar terminals are in use by several other North Atlantic Treaty Organization (NATO) nations.

The 5.28-tonne Sirius-FM5 radio broadcast satellite was successfully launched from the Baikonur Cosmodrome in Kazakhstan on 1 July by an International Launch Services Proton-M rocket. It was placed into a geostationary-orbit slot at 96 degrees

west longitude, the first of Sirius XM Satellite Radio's four spacecraft to operate outside their highly elliptical orbits with apogees over North America. FM-5, built by Space Systems/Loral (USA), is one of the most powerful commercial spacecraft ever built, delivering over 20 kW (end-of-life) to its payload. It carries an X-band receive payload and an S-band transmit payload, with a 9 meter diameter antenna built by Harris Corporation (USA) to provide more than 130 channels of satellite radio and 3 television channels to subscribers in North America and Canada. Its design lifetime is 15 years.

On 5 August the U.S. Federal Communications Commission (FCC) approved an application by Row 44 (USA) to operate an aeronautical mobile-satellite service (AMSS) in the conventional Ku-band segment. The technology is currently being used on a trial basis by operators Southwest and Alaska Airlines. Row 44's system is the first to offer true broadband communications to airline passengers, delivering service comparable to the high Internet speeds available from ground-based systems.

### **(3) Navigation and Position Location**

On 25 December 2008 Russia launched three Glonass navigation satellites aboard a Proton-M rocket from the Baikonur Cosmodrome. The new satellites underwent 45 days of testing before joining the operational fleet. The system then consisted of 19 satellites, 15 of which are operational and four of which were down due to technical problems or operational maintenance. Eighteen functioning satellites are needed for continuous navigation services in Russia, and 24 for worldwide coverage. Glonass also announced plans to increase the size of the operational constellation from 24 satellites to 30. On 25 September Russia delayed the launch of another three Glonass-M satellites from the Baikonur Cosmodrome to 29 October, and then again to February 2010. The cited reason for the delays was to correct faults identified by a malfunction on an identical spacecraft launched on 25 September 2008.

A United Launch Alliance Delta-2 rocket launched GPS-IIR-20(M), the seventh of eight in the U.S. Air Force's modernized Block IIR-M Global Positioning System (GPS) satellite series, from Cape Canaveral on 24 March. The new satellite includes a modernized antenna panel that increases signal power to ground receivers; a second, open-access civil signal on a different frequency; and a demonstration payload transmitting a third civil signal in the L5 frequency band at 1176.45 MHz. The last Delta 2 launched the last of the GPS 2R satellites, GPS IIR-21(M), into a highly elliptical orbit on 16 August from Cape Canaveral. It replaced the 13-year-old GPS 2A-26 spacecraft, which will remain as a backup for the new satellite. GPS IIR-21(M) also carries the new civilian signal that can be used to correct for ionospheric effects on the GPS signal, as well as improvements to jam-resistant capabilities. It was declared operational on 3 September.

On 15 June ESA signed contracts with Astrium GmbH and OHB System (both Germany) for procurement of long-lead items required for the Galileo satellite constellation, and on 16 June signed a contract with Arianespace (France) for the launch of the first four Galileo satellites on two Soyuz ST-B launchers with Fregat MT-adapted upper stages. The launches are expected to take place near the end of 2010.

Giove A, the first Galileo test satellite, was repositioned to a parking orbit on 2 October after completing its planned mission. Built by Surrey Satellite Technology Ltd. (UK) and launched in December 2005 (see prior reports), Giove A performed far beyond its two-year design life, securing international frequency filings, collecting data to characterize Galileo's medium Earth orbit, and demonstrating atomic clocks and other key system technologies. The spacecraft remains operational and will continue broadcasting test signals from its new position, 113 km above the planned orbit of the Galileo operational satellites, until it is finally decommissioned. The second test satellite, Giove B, built by an Astrium-led team (see last year's report), remains in operation.

The European Commission (EC) announced on 18 March that it had issued a \$23-million initial contract to SES Astra (Luxembourg) to cover the first two years of operating an L-band payload aboard SES's Sirius-5 satellite for the European Geostationary Navigation Overlay Service (EGNOS). EGNOS (see prior reports) improves the reliability and accuracy of the U.S. Global Positioning System (GPS) from 20 m to 2 m. Sirius-5, being built by Space Systems/Loral (USA), is scheduled to launch in 2011, when the new L-band payload will replace a similar system on ESA's retiring Artemis data-relay spacecraft. It is expected that the EC will extend SES's operating contract for the full 15-year life of Sirius-5. Losing bidders were Eutelsat (France) and the Nigerian space agency, which had proposed using the since-failed Nigcomsat-1.

EGNOS's freely accessible service was declared ready for use by the European Commission on 1 October. A higher-reliability version with accuracy better than 1 m, the EGNOS Commercial Service, will be deployed next year, along with a freely accessible safety-of-life service. EGNOS is managed by European Satellite Services Provider (ESSP), a France-based consortium of seven European air-navigation agencies. The \$514-million system includes 34 ranging and integrity-monitoring ground stations to receive satellite signals, four control and processing centers to validate satellite-signal integrity and send correction messages, and six ground stations that receive corrected data and upload them to the satellites for later dissemination as a GPS-type navigation signal.

China launched a geosynchronous Compass (Beidou 2) satellite, built by the China Academy of Space Technology (CAST), on 14 April. It joins the initial medium-Earth-orbit (MEO) Compass M-1 satellite launched in April 2007, and will be one of 5 geostationary-orbit satellites and up to 30 MEO spacecraft in the Compass regional and global satellite navigation system. China announced that it plans to launch 10 Compass spacecraft by the end of 2010.

## **B. Remote Sensing**

### **(1) Earth Observations**

On 5 February GeoEye (USA) began commercial sales of high-resolution images from GeoEye-1, launched in September 2008 (see last year's report). At 0.41 m, GeoEye-1 is claimed to be the world's highest-resolution civil satellite. Sales began initially to government customers in Europe, Asia, and the Middle East, as well as to commercial users. Following certification on 20 February by the U.S. National

Geospatial-Intelligence Agency (NGA), who financed \$237 million of the satellite's \$502-million construction and launch cost under the NextView programme (see prior reports), NGA began paying GeoEye \$12.5 million per month for images via a one-year NextView contract modification signed in December 2008. On 12 May GeoEye reported a minor malfunction in GeoEye-1's camera, causing small portions of some color images to appear in black-and-white. Because of the limited nature of the defect, however, GeoEye announced on 22 May that it would not have any effect on imaging for the company's major customer, the U.S. NGA, and that the maximum loss of revenue would be below 5%.

Late in March the U.S. Congress authorized NASA to spend \$9 million to begin recertifying the \$100-million Deep Space Climate Observatory (DSCOVR) Earth-monitoring satellite. NASA had already completed three months of testing in February to check its performance capability after having been stored at the Goddard Space Flight Center for eight years. Originally proposed in 1998 as the Triana mission by then-U.S. vice-president Albert Gore, it was to be the first Earth-observation satellite to operate at Lagrange libration point L-1, between the Earth and the Sun about 1.5 million km away, and thereby offer continuous observation of the Earth's sunlit side. The new funds are being used to refurbish the spacecraft's two Earth-science instruments, the Polychromatic Imaging Camera and the Advanced Radiometer. DSCOVR also has a third instrument for space-weather monitoring, the Plasma-Magnetometer Solar Weather Package. Total cost of reconditioning and launching the spacecraft and operating the mission, which NASA still has to commit, would be \$205 million. If approved it would work in concert with the current A-train climate-research constellation (see prior reports).

Canada announced in April a successful experiment in the use of high-resolution imagery from Radarsat-2 to spot ships suspected of illegal fishing and other infractions in its territorial waters. The test programme, called Operation Drift Net, involved 80 Radarsat scenes scanning portions of the coastal area. That area is 243,770 km long, with 250 ports and a traffic volume of 1,700 ships per day, the airborne surveillance of which takes up to 180 hours of aircraft flight time at a cost of \$22,300 per hour. The Radarsat test, in which the satellite called for an overhead aircraft pass whenever it spotted a suspicious ship, demonstrated confirmation by the aircraft six hours after takeoff. Canada now plans to extend its maritime surveillance with the next-generation Radarsat system, the Radarsat Constellation, by adding an Automated Identification System (AIS) to each satellite in the constellation.

EADS Astrium (Europe) received approval from parent company EADS on 18 June to begin work on two high-resolution successors to Spot-5. Spot 6 and Spot 7, formerly known as Astroterra, will have 2-m resolution *vs* Spot 5's 2.5 m, and will be equipped with control moment gyros that permit pitch as well as roll control. Their design life is to be 10 years, *vs* 5 years for Spot 5 (although Spot 5 is projected to last well beyond that, from its launch in 2002 to 2014). Customers will be able to upload up to six mission plans daily, to ensure cloud-free imagery, and the two new satellites enable daily revisits. Launches are planned for September 2012 and early 2014. Although an anchor tenant for the estimated \$690-million undertaking has yet to be found, detailed spacecraft design and production of long-lead components have already been completed, and Astrium is moving ahead with development and

fabrication of the two spacecraft. Spot Image reported sales of \$150 million in 2008, their seventh straight year of growth, with an operating margin of 15%.

Then on 23 July, the French space agency CNES announced that Spot-2, designed for a three-year lifetime but in uninterrupted service for 19 years, would be retired into a 600 x 800-km “graveyard” orbit, from which it is expected to re-enter the atmosphere and burn up within 25 years. Although Spot-2 was launched in 1990, well prior to the formulation in 2002 of orbital-debris amelioration guidelines on the disposal of obsolete satellites, CNES’s action in complying with those guidelines was commended. The agency had also followed the guidelines in disposing of the even older Spot-1 in 2003.

On 6 November 2008 Spain’s Center for the Development of Industrial Technology (CDTI) issued an authorization to proceed with development of an optical satellite called Ingenio or SEOSAT. The CASA division of EADS Astrium (Spain) is the prime contractor for the \$112-million project. They will supply the spacecraft platform; Thales Alenia Space (France) was tasked by payload contractor Sener (Spain) to provide the electronics for Ingenio and also the X-band and S-band communication subsystems under their \$21-million contract. Planned for launch in 2012, Ingenio will be integrated into Europe’s Global Monitoring for Environment and Security (GMES) programme (see prior reports). On 6 November Spain’s defense ministry also contracted with CASA for a small (600-kg) radar satellite named Paz, to supply all-weather imagery to Spain’s armed forces. It and the 600-kg Ingenio will be operated by Hisdesat, a joint venture of CASA, Hispasat, Sener, and other Spanish companies.

On 2 December 2008 The European Union announce an agreement with France, Italy, and Germany for the EU’s Satellite Center in Torrejon, Spain to access their high-resolution satellite imagery. The agreement covers optical imagery from France’s Helios-2, which has a resolution of about 35 cm, and radar data from Italy’s 4-satellite Cosmo-Skymed and Germany’s five-satellite SAR-Lupe constellations (see prior reports).

RapidEye (Germany) initiated selling of imagery and services on 26 January from its 5-satellite constellation, launched in 2008 (see last year’s report). The system images about 4 million square km per day with a ground resolution of 6.5 m and a picture width of 78 km. Prices are \$1.23 per square km, with a minimum order of \$3,250 and discounts for larger orders. The 150-kg satellites, built by Surrey Satellite Technology Ltd (UK), carry five-band multispectral imagers built by Jena-Optronik (Germany).

RapidEye then selected Beijing Earth Observation Incorporated (China) as their distributor in China; in February RapidEye contracted with Bufete de Ingenieria en Telecomunicaciones y Sistemas SA de CV (Mexico) to be their sole distributor in Mexico; in April they signed up Sovzond (Russia) to distribute imagery in Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Russia, Tajikistan, Turkmenistan, and Uzbekistan; and also MakaLani LLC (Hawaii, USA) as their agent for distribution in the USA. Then in October they signed with Lotus H&R for distribution in Taiwan (Province of China). RapidEye also contracted in April with their constellation’s prime contractor, MacDonald Dettwiler and Associates (Canada),

to be the sole distributor of RapidEye-compatible ground stations to customers with large data requirements.

On 3 March ESA's Earth Observation Directorate announced the selection of three finalists of the six proposed Earth Explorer missions for launch in 2015, and awarded Phase A study contracts of about \$3.2 million to each of two competing teams for each selected mission. The selections, based on a two-day review in Lisbon, Portugal during January by 400 Earth scientists, were Biomass, CoreH2O, and Premier. Biomass would use a P-band synthetic-aperture radar, never flown before in space, to map the global distribution and evolution of forest biomass. The CoreH2O satellite is designed to measure fresh water stored in snow, in ice sheets, and in glaciers, using X-band and Ku-band synthetic-aperture radar. Premier would determine the composition of the atmosphere in the altitude band 5 km to 25 km, to improve chemistry and climate models for use in predicting future climate changes.

Earth observation satellites played a major role in the recovery of Honduras following the 28 May earthquake. Relief to needed areas was coordinated by Servir (Panama), whose function is to combine satellite imagery and ground observations to map areas hit by natural disasters and then send those data to government officials and emergency response agencies. Servir partners are NASA, the U.S. Agency for International Development, the Regional Center for Mapping of Resources, and the Latin American and Caribbean Development and Resource Management Organization CATHALAC. The Servir team at CATHALAC assembled before-and-after satellite images of the earthquake-struck region, which included parts of Belize as well as Honduras, from Landsat 7, NASA's Terra, Taiwan's (Province of China) Formosat-2, and GeoEye's Ikonos. It was the 24<sup>th</sup> time that Servir had provided disaster response in Latin America and the Caribbean region, and the 6<sup>th</sup> in 2009 alone.

ESA's Gravity field and steady-state Ocean Circulation Explorer (Goce) satellite was finally launched on 17 March by Eurockot's Russian Rockot launcher from the Plesetsk cosmodrome, after having been delayed for a full year by various launcher issues. Following two six-week checkouts, Goce is now measuring Earth's gravity field, modeling the geoid, and studying ocean circulation from an unusually low 263-km near-polar orbit. Besides making Goce the fastest scientific spacecraft, this low orbit permits more precise measurements of the gravity field. Accurate measurement of the geoid is critical not only in the understanding of ocean circulation currents needed to construct climate models, but also to help understand earthquake formation and to provide an international datum for the elevation of engineering projects such as bridges, canals, and tunnels.

The first of ESA's Explorer satellites, Goce was built by a 45-company consortium led by Thales Alenia Space (Italy) at a total mission cost of \$537 million including launch and 30 months of operation. The 1.1-tonne spacecraft is equipped with an electrostatic gradiometer consisting of six accelerometers built by Onera (France), each of which is capable of three-axis measurements, providing a gravity-field precision of one-millionth of Earth-normal gravity. It is claimed to be sufficiently sensitive to measure the impact of a snowflake on an oil tanker. The spacecraft has no moving parts, taking advantage of a unique electric ion propulsion capability built by Qinetiq (UK) to achieve near-perfect compensation of the upper-atmosphere drag effects, a large variation associated with the orbital period, and a

high-frequency (~10 Hz) “juddering” effect. The Qinetiq ion propulsion system, launched with 40 kg of xenon propellant, can be throttled between one and 20 mN thrust. Goce was activated on 6 April, conducted its first mapping survey on 22 September, and has since been performing successfully.

Radar data from ESA's Envisat and the Italian Space Agency's COSMO-SkyMed were used to analyze the movement of Earth during and after the April earthquake in central Italy. Data taken before and after the event were combined to create an interferogram composed of rainbow-colored interference patterns. A complete set of colored bands, called fringes, represents ground movement relative to the spacecraft of half a wavelength, which is 2.8 cm in the case of the Envisat. The data were verified by comparing them with displacements measured at five ground location sites equipped with Global Positioning System (GPS) receivers.

On 11 August French winegrowers announced the use of infrared images from Formosat-2 (Taiwan, Province of China) to improve their grape harvests. The satellite data enable growers to determine when grapes planted in varying conditions across large estates will be ready for harvest. They also uncovered a vital link between the amount of vegetation on the vines and the quality of the grape, which allows them to prune each vine carefully to help the grapes reach their optimal ripeness. Formosat-2 overflies France twice daily.

On 17 August DMC International Imaging Ltd. (UK) was awarded a \$5.5-million contract by ESA to provide satellite imagery of sub-Saharan Africa as part of the European Global Monitoring for Environment and Security (GMES) programme. The company, which is a subsidiary of Surrey Satellite Technology Inc. (SSTI, UK), is using the SSTI 5-satellite Disaster Monitoring Constellation of small satellites (see prior reports) to map all 48 sub-Saharan African countries by September 2010. The imagery will be used to monitor deforestation trends and for environmental and resource management.

The Japanese Aerospace Exploration Agency (JAXA) announced on 2 December 2008 that they have signed an agreement with UNESCO to use their space satellites to monitor UNESCO's World Heritage sites. JAXA joined 25 space agencies in this project, which was initiated in 2001 by an ESA-UNESCO agreement (see prior reports).

China launched the Yaogan-4 remote-sensing satellite on 1 December 2008 aboard a Long March 2C rocket from the Jiuquan Satellite Launch Center. Built by the China Academy of Space Technology, Yaogan-4 is being used for scientific research, crop monitoring, and disaster mitigation and relief.

India launched their first radar satellite on 20 April from the Satish Dhawan Space Centre aboard a Polar Satellite Launch Vehicle (PSLV). The 300-kg Risat-2, built by the Indian Space Research Organization (ISRO) in collaboration with Israel Aerospace Industries, who supplied the synthetic aperture radar payload, was placed in a 550-km circular orbit inclined at 41 degrees. With a 3-year design lifetime, it is being used for disaster management, especially floods and cyclones, and also for military surveillance. The 38-kg Anusat, launched along with Risat-2 on the same PSLV, was India's first university-built satellite. It was designed and constructed with

ISRO funding by the Anna University, and is providing store-and forward messaging of academic material along with drought management and urban planning information.

On 12 August ISRO released a three-dimensional web-based mapping tool named Bhuvan (Sanskrit for Earth), patterned after Google Earth. It combines satellite imagery with geographic information, allowing people to explore India on their computer screens. Bhuvan's satellite imagery resolution of 6 m provides "zoom" images of any place in India, along with thematic information on soil, wasteland, water resources, and other geographic data.

A report issued by NASA's Goddard Space Flight Center on 12 August cited data from the joint NASA-German Gravity Recovery and Climate Experiment (Grace) satellites, launched in March 2002, showing that groundwater levels in northern India have decreased by as much as 33 cm per year from 2002 to 2008. Over 108 cubic km of groundwater have disappeared from aquifers in Haryana, Punjab, Rajasthan and Delhi, primarily as a result of human activities such as irrigation consuming water faster than it can be replenished by natural processes.

Telespazio (Italy) received a \$353-million contract on 16 July from the Turkish government's Defense Ministry (SSM) for Gokturk-1, a high-resolution (<1m) Earth observation satellite, plus launch, two ground stations (one fixed, one mobile), and training and ground facilities to develop a Turkish space industry. These include a satellite assembly, integration, and test facility to be built at Turkey's TAI A.S. company, with assistance from Turksat. The satellite, to be built by Telespazio and Thales Alenia Space (France and Italy), will use the Proteus platform developed by Thales under contract to the French space agency CNES. Its payload will be patterned after that of the French Pleiades (see last year's report). The agreement also specifies that Turkish industry will receive contracts worth the equivalent of at least 20% of the satellite's value. Gokturk-1, to be launched in 2012 or 2013, is to be used for disaster monitoring, national mapping, and environmental surveillance.

On 1 April the National University of Singapore signed the first commercial contract with DigitalGlobe (USA) to task and download imagery directly from the company's WorldView-1 satellite (see prior reports). The university's Centre for Remote Imaging, Sensing, and Processing (CRISP) now has access to WorldView-1's 0.5-m resolution black-and-white imagery. The contract also covered CRISP's access to the imagery provided by DigitalGlobe's WorldView-2.

That spacecraft was launched from Vandenberg Air Force Base into a 763-km polar orbit by a United Launch Alliance Delta-2 rocket on 7 October. The high-resolution satellite was built by Ball Aerospace (USA). DigitalGlobe's most capable satellite to date, Worldview-2 is designed to produce black-and-white imagery at 0.5-m resolution and multispectral imagery in eight bands at 1.84-m resolution, a first for a commercial satellite. It can collect 975,000 square km of imagery per day, doubling DigitalGlobe's overall collection capacity.

South Africa launched its first space satellite on 17 September from the Baikonur Cosmodrome aboard a Russian Soyuz 2.1b rocket, almost three years later than first planned. SumbandilaSat is the first South African-owned satellite to collect



images for the government, with applications ranging from crop monitoring to town planning. The project is also intended to provide South Africa with access to space technology. Politics and technical issues repeatedly held back its launch, which was originally supposed to be in December 2006 from a Russian submarine in the Barents Sea. Russia's space agency Roskosmos eventually agreed to launch the satellite as a secondary payload, along with a Russian Meteor 3-M1 weather satellite and four other small secondary-payload satellites, including Russia's contribution to the international COSPAS-SARSAT system, Sterkh 2. The 81-kg SumbandilaSat was commissioned by the Department of Science and Technology from the Stellenbosch company SunSpace & Information Systems.

## **(2) Atmosphere and Ocean Observations**

The U.S. National Oceanic and Atmospheric Administration's (NOAA's) NOAA-N-Prime satellite was delivered to the Vandenberg Air Force Base launch site on 4 November 2008. Following a period of testing and launch preparation, the 1.42-tonne spacecraft was launched on 6 February by a United Launch Alliance Delta-2 rocket from the Vandenberg Air Force Base. The last of the current generation of U.S. polar-orbiting weather satellites, the \$233-million NOAA N-Prime is the 16th satellite in the current series, built by Lockheed Martin Space Systems and NASA on behalf of NOAA. It is the 43<sup>rd</sup> Television and Infrared Observation Satellite (Tiros), the first of which was the world's first weather satellite. After a 21-day checkout, it was placed in an 854-km 99-degree Sun-synchronous orbit, where it replaces NOAA-18 as the primary afternoon satellite.

Originally planned for launch in 2003, the spacecraft suffered \$135 million in severe damages when it fell to the assembly-plant floor, and was again delayed from a planned April 2007 launch by a safety-motivated stand-down and extensive tests required on its A-1 Advanced Microwave Sounding Unit (AMSU). It carries the same core instruments as NOAA-18 plus an advanced data collection system and an improved search and rescue processor provided by France. After achieving its proper orbit N-Prime was renamed NOAA-19, and NASA ceded its operational control to NOAA in late February. Total mission cost was \$564 million, including the spacecraft, instruments, repairs and testing, launch, and operations.

GOES-O was launched aboard a United Launch Alliance Delta-4 rocket from Cape Canaveral to its geostationary orbit slot at 89.5 degrees west longitude on 27 June, after a day's delay due local thunderstorms at Cape Canaveral. Following six months of testing, GOES-14, as it was renamed after reaching orbit and being turned over by manufacturer Boeing to the U.S. NOAA, will be moved to a slot at 105 degrees west longitude and held in reserve by NOAA as a spare. Its ITT imager has a resolution of 1 km. It is the second of the more advanced GOES satellites to be launched, containing sensors that can provide better location data and higher resolution images of storms.

On 2 December 2008 NASA awarded Lockheed Martin Space Systems a \$1.09-billion contract to build the first two spacecraft of the next generation of geostationary weather satellites for the U.S. National Oceanic and Atmospheric Administration (NOAA), along with two one-spacecraft options. Boeing and Northrop Grumman were the losing bidders. The two GOES-R spacecraft were to have been

launched in 2015, with Lockheed Martin providing launch support in addition to the spacecraft. A separate \$736-million contract for the GOES-R ground segment was awarded on 27 May to Harris Corporation (USA). This subsystem will control the GOES-R satellite system and will receive, process, and disseminate its data. Raytheon Intelligence and Information Systems (USA) was the losing ground-segment bidder.

However, in response to a protest filed with the U.S General Accountability Office (GAO) on 15 December by Boeing, who built the current-generation GOES spacecraft, NASA decided on 17 February to reconsider the Boeing and Lockheed Martin proposals and make a new selection decision. As a result, GAO dismissed Boeing's protest on 19 February and on 24 February NASA suspended, but did not terminate, Lockheed Martin's contract award pending the results of their re-evaluation, and finally awarded the contract to Lockheed Martin on 7 May. Again, however, Boeing protested the award, and on 21 May NASA announced that it had terminated Lockheed's work on the contract and again referred the dispute to the GAO for a 100-day decision. Boeing's protest filing had said the NASA decision includes "serious flaws and a lack of transparency in the selection process," and appears to go beyond questioning the technical merits of Lockheed Martin's bid to raising questions about NASA's basic fairness in evaluating the bids. But then on 21 July Boeing withdrew its protest and cleared the way for Lockheed Martin to sign the contract.

The GOES-R satellites will carry six instruments able to scan the U.S. every five minutes, improve weather forecasting, and provide greater precision than the previous GOES-N generation in monitoring sea-surface temperatures, aerosols, dust, volcanic ash plumes, and lightning. The total GOES-R life-cycle cost projection of \$7.7 billion includes spacecraft, instruments, launch vehicles, ground systems, and operations through 2028.

GOES-R will provide about 50 times more weather and climate data than are available with NOAA's current fleet of geostationary-orbit satellites, and better sea-surface temperature monitoring. The new spacecraft will update images of hurricanes every 30 seconds instead of the 7.5-minute updates provided by current systems. They also will carry a new Geostationary Lightning Mapper to pinpoint the thunderstorms that spawn deadly tornadoes, as well as advanced instruments to monitor conditions on the Sun that help predict solar storms.

On 6 June NOAA awarded ten contracts totaling \$250,000 to seven companies in the second of three rounds of studies to validate the price and technical feasibility of obtaining Earth and space-weather data on a commercial basis. Contract recipients were GeoEye, Iridium (2 contracts), ITT Space Systems (2 contracts), Mississippi State University, Orbital Sciences Corporation, Sierra Nevada Corporation, Space Systems/Loral, and Surrey Satellite Technology U.S. LLC (all USA).

NASA's Orbiting Carbon Observatory (OCO) was delivered to Vandenberg Air Force Base on 19 November 2008. It was launched from there on 24 February by an Orbital Sciences Corporation (OSC) Taurus XL rocket, but failure of the payload fairing to open dumped OCO into the Pacific Ocean. The root cause was subsequently traced to one of four potential modes of the separation mechanism's failure to operate, and the 17 July failure report identified a number of procedural recommendations to

prevent future problems with any of the four suspected components. OCO was to have been placed into a 637-km orbit to undergo testing for 10 days, and then to have taken 20 days to be raised to its final 700-km near-polar Sun-synchronous operational orbit.

Built by OSC on the company's LEOStar-2 platform to study carbon dioxide and the atmosphere's carbon cycle, OCO was to have joined the A-train climate-study constellation Aqua, Aura, Calipso, Cloudsat, and Parasol (see prior reports). It was to have preceded Aqua, the A-train's lead satellite, by 3.3 minutes. The 442-kg OCO carried three cryogenically cooled high-resolution spectrometers built by Hamilton Sundstrand (USA) to measure miniscule changes in carbon dioxide and oxygen concentrations in the atmosphere and thereby identify sources and sinks for carbon dioxide. Circling the Earth in 99 minutes, it was to have mapped the globe every 16 days, conducting 12 soundings per second while over the sunlit hemisphere. OCO's measurements were to have been correlated with and confirmed by observations from ground stations, airborne instruments, and Japan's Ibuki satellite (see below). OCO carried sufficient fuel for 5 – 10 years. Its total mission cost, including a planned two years of observations, was \$273 million. OSC obtained an insurance payment of \$5.3 million to cover the loss of an incentive fee the company would have earned by a successful launch.

Meanwhile the Argus instrument on Canadian microsatellite CanX-2 is making similar measurements to those OCO would have if it had been successfully launched, at much lower cost than OCO. Argus, built by York University, had begun sending a stream of data in December following its launch in April. Japan's Ibuki (see below) is also collecting atmospheric carbon dioxide data of a different kind.

On 16 January the U.S. Climate Change Science programme published a report titled "Atmospheric Aerosol Properties and Climate Impacts," calling for a network of sophisticated satellite, ground-based, and airborne sensors to measure the quantity of atmospheric particles being produced by human activity. Such a network is needed to provide the critical data for climate-change computer models, because the climate impact of aerosols is believed to be comparable to that of the greenhouse gases. One such sensor, the Aerosol Polarimetry Sensor (APS) built by Raytheon (USA) will be launched aboard NASA's Glory satellite late in the year by another Orbital Sciences Taurus XL rocket. This multi-angle, multi-spectral polarimeter is the first space-based instrument designed specifically to address the complexity of aerosol measurements from space. Glory also carries a total solar irradiance monitor and a cloud camera to identify any APS data that are contaminated by cloud cover.

On 3 March NASA's Ames Research Center announced a Space Act Agreement with Cisco Systems (USA) to initiate an international effort addressing climate change by monitoring and reporting global carbon stocks and carbon flows. The Planetary Skin system will use space-based, airborne, and terrestrial sensors to guide world leaders in determining the best ways to address climate change, and to provide a verification mechanism for future carbon pricing policies. The first Planetary Skin prototype established by the 3 March agreement, an online platform called Rainforest Skin, will gather data on the world's rainforests to help forest managers and regional leaders monitor the ecosystems. Satellite platforms for Rainforest Skin, NASA's Terra, and Landsats 5 and 7 have begun generating data from which to create detailed pictures of forest carbon cycles as they change from

week to week throughout the seasons. This information can determine the value of living trees and other forest vegetation in absorbing carbon, and perhaps could motivate the development of a mechanism to compensate nations for protecting their forests. Rainforest Skin information is expected to help conferees at December's United Nations Climate Change Conference in Copenhagen begin to establish national targets for reducing carbon emissions and to help guide the formulation of carbon pricing mechanisms.

On 27 May the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite for the first time measured remotely the amount of fluorescent red light emitted by ocean phytoplankton, enabling an assessment of how efficiently the microscopic plants are turning sunlight and nutrients into food through photosynthesis. This is one way to monitor the "health" of the ocean. On time-scales of weeks to months, these data can be used to track plankton responses to iron inputs from dust storms and the transport of iron-rich water from islands and continents. Over years to decades, this information can be used to detect long-term trends in climate change and other human perturbations to the ocean.

Every year, the north Atlantic ocean turns green with plankton, and for more than fifty years, scientists had attributed that growth to spring and summer warming of the ocean. But on 5 August NASA released a decade's worth of SeaWiFS satellite measurements suggesting that the plankton blooms began during the winter, when solar and nutrient availability were low. This would imply that phytoplankton are brought up to the surface by convection during the winter, where the lack of zooplankton allows the phytoplankton to bloom. If verified, the new model would have dramatic implications for ocean health in a warming world.

NASA's ICESat-1 mission, launched in 2003 to survey polar ice sheets (see prior reports), ended in April, but its main instrument, the Geoscience Laser Altimeter System (GLAS), continued to be used for limited scientific observations despite slow deterioration of the last of its three lasers. NASA reported on 7 July that ICESat data recorded a dramatic thinning of Arctic ice between 2003 and 2008, and that for the first time on record thin seasonal ice had replaced thick older ice as the predominant type of Arctic ice. Whereas 62% of the total ice volume in 2003 had been older, thick ice, by 2008 68% was thinner, first-year seasonal ice.

Because ICESat-1's successor ICESat-2 is not scheduled for launch until 2014, NASA elected to fill in the gap using airborne instruments. An Aerial Topographic Mapper and a Pathfinder Airborne Radar Ice Sounder, both carried by a P-3 aircraft, began operations on 30 March. An Uninhabited Aerial Vehicle Synthetic Aperture Radar and a Glacier and Land Ice Surface Topography Interferometer, flying on a Gulfstream-3 aircraft over Greenland, started conducting surveys on 1 May. One objective of these flight missions, in addition to capturing valuable data, is to assess the potential use of these instruments for future space-based radars.

On 23 July the Canadian Space Agency (CSA) issued a \$3.96-million contract to MacDonald, Dettwiler and Associates (MDA, Canada) to develop a mission concept for the Polar Communications and Weather (PCW) Mission. The PCW will consist of two optical satellites, to be launched in 2016 into a highly elliptical orbit, about 38,000 x 1,000 km, to provide continuous communication services and weather

observations of Canada's northern regions. They are expected to weigh between 1 and 1.5 tonnes. The mission includes a ground segment to process meteorological information and to manage the communications services.

NASA and the Japan Aerospace Exploration Agency (JAXA) signed an agreement on 30 July defining the terms of cooperation on the multi-satellite Global Precipitation Measurement (GPM) mission. NASA will be responsible for designing and building the spacecraft platforms, which JAXA will launch in July 2013 aboard an H-2A rocket. NASA will provide a multi-channel microwave imager and JAXA a dual-frequency precipitation radar. As part of the agreement, Japan will share data from a conical-scanning microwave imager on JAXA's Global Change Observation Mission planned for launch in 2011.

On 28 May the U.S. National Oceanic and Atmospheric Administration (NOAA) created a Cooperative Institute for Climate and Satellites in cooperation with the University of Maryland and North Carolina State University. The new institute is using satellite observations to detect, monitor, and forecast climate change, initially with current spacecraft constellations and eventually adding NOAA's next-generation systems, the Geostationary Operational Environmental Satellite-R series (GOES-R) and the National Polar-orbiting Operational Environmental Satellite System (NPOESS).

On 1 July the Eumetsat Council (France) approved a \$90-million contribution to the Jason-3 ocean altimetry satellite (see prior reports). It will follow the previous French-U.S. projects Topex-Poseidon, Jason-1, and Jason-2 in measuring wave heights and ocean currents. France is contributing a spare satellite platform, identical to Jason-2's, and will provide payload integration and other services. Other sponsors include the European Union's Global Monitoring for Environment and Security (GMES) programme, ESA, and the U.S. NOAA, who will provide the launch in 2013 as well as a microwave radiometer, precision orbit components, elements of the ground system, and the satellite's operations.

Eumetsat and ESA signed a framework agreement in June that will enable them to work together on the Global Monitoring for Environment and Security (GMES) programme, following the cooperative pattern set by the two agencies on Europe's weather satellites. Under the agreement, Eumetsat will contribute data from its satellites to GMES, operate elements of the dedicated GMES Sentinel constellation (see last year's report), and provide data and products from future missions, especially GMES atmospheric sensors to be carried on Eumetsat's Meteosat Third Generation and second-generation Metop polar-orbiting satellites.

On 21 September ESA announced that data from three European Earth observation satellites suggest that the 7%-per-decade degradation of the Earth's protective ozone layer has ceased in the last decade, and there are preliminary indications that it may be regenerating. However, ESA cautioned that it is too early to declare victory, because the slight regeneration in the ozone layer registered between 1997 and 2008, 0.8% – 1.4% per decade, is not that much different from a zero-change trend. The satellite instruments that recorded these data were the Gome ozone-monitoring instrument aboard ESA's ERS-2 radar satellite, the Sciamachy imaging

spectrometer on the Envisat radar satellite, and the Gome-2 instrument on the polar-orbiting Metop-A satellite operated by Eumetsat.

The German aerospace center DLR issued a \$112-million full-scale development contract on 12 November 2008 to the Kayser Threde division of OHB System (Germany) for the hyperspectral EnMap (Environmental Mapping and Analysis Programme) satellite. Primary objective of the 766-kg spacecraft is to provide the data for an improved model of global biospheric and geospheric processes, and to serve as a bellwether for operational use in soil and land management, water monitoring, mapping, and crisis management. RapidEye and Definiens (both Germany) are on the programme team, which also includes DLR and the Deutsche GeoForschungsZentrum. Planned for launch in 2012 with a design lifetime of 5 years, EnMap will carry 218 spectral channels, of which 122 are in the short-wave infrared band and 96 are very-near-infrared, nearly double those of current multispectral sensors. Its spatial resolution will be 30 m over a 30-km swath, and it will have a repeat frequency of less than 4 days.

On 5 November 2008 China launched Chuangxin 1-02 and Shiyao 3 aboard a Long March 2D rocket from Taiyuan. Chuangxin 1-02, developed by the Chinese Academy of Sciences, is collecting and relaying hydrological and meteorological data for disaster relief. Shiyao 3, developed by the Harbin Institute of Technology, is checking out new instruments for atmospheric monitoring.

China launched a new geostationary-orbit weather satellite on 23 December 2008, setting a new record for Chinese space activity. The Feng Yun 2E satellite was lofted from the Xichang launch center to a geostationary-orbit slot at 105 degrees east longitude by a Long March 3A rocket. It is collecting real-time weather imagery for weather forecasting in China and neighboring countries and is also being used for disaster reduction. It replaced Feng Yun 2C, which was launched in 2004.

The Japan Aerospace Exploration Agency JAXA launched the Greenhouse Gases Observing Satellite (GOSAT) Ibuki (Breath) aboard an H-2A rocket on 23 January, along with seven "baby satellites" that were developed by JAXA, research centers, and private companies. Working in conjunction with the Environment Ministry and the National Institute for Environmental Studies, JAXA is using Ibuki to monitor emissions of carbon dioxide and methane from 56,000 locations on Earth from its orbit of 666 km, updating every three days. JAXA also is using Ibuki to visualize the changing distribution of carbon dioxide around the world with the changing seasons, and the University of Alaska, Fairbanks, is looking into the possibility of using Ibuki to detect leakage of methane from natural gas pipelines.

Weighing 1.75 metric tons, the spacecraft carries two main instruments, TANSO-FTS (Thermal And Near infrared Sensor for carbon Observation - Fourier Transform Spectrometer) and TANSO-CAI (Cloud and Aerosol Imager). TANSO-FTS will measure the spectrum of infrared rays emitted or reflected from the Earth's surface to distinguish the level of greenhouse gases, and TANSO-CAI will assist by checking to see if the observation site is free of clouds and aerosols that could mar measurements. The satellite's spatial resolution is 10 km, and it has a projected lifetime of 5 years.

The satellite has double X-band antennas for communication, two independent mirror systems, and two solar panels on each side of the satellite that work separately. This redundancy assures mission continuation in the event of a failure. Official observations began in April. Ibuki is jointly funded by JAXA and Japan's Ministry of the Environment and the National Institute for Environmental Studies.

#### **IV. HUMANS IN EARTH ORBIT**

##### **A. International Space Station Deployment and Operations**

The Progress M-65 cargo spacecraft undocked from the international space station (ISS) on 14 November 2008, but remained in orbit until 6 December before reentering the Earth's atmosphere. As with the previous Progress re-entry, it was used as part of the Plasma-Progress programme to explore the reflective properties, the size, and the density of plasma particles formed in the spaceship's exhaust.

Shuttle Endeavour was launched to the ISS on 14 November 2008, carrying a 14.5-tonne payload made up mostly of Italy's Leonardo module loaded with equipment and materials to support an ISS crew of six. On arrival at the ISS on 17 November, the ISS crew examined Endeavour for any damage to its thermal protection system. The Leonardo module was then lifted from the Shuttle's payload bay and docked to Node 2 between the Kibo and Columbus laboratories, and the crew spent several days unloading its 6.1 tonnes of cargo. The cargo included an improved galley refrigerator, an advanced resistive exercise system, a second toilet, two sleep stations, and a water-recycling system. The Shuttle crew conducted four spacewalks, during which they replaced a depleted nitrogen tank, cleaned and lubricated the damaged starboard solar alpha rotary joint (SARJ; see prior reports), replaced 11 of its 12 trundle bearings, lubricated the port SARJ and the station's robotic arm, and installed GPS antennas on Kibo.

Setting up the new water recycling system, whose function is to recycle water from cabin air, urine, and crew hygiene water for potential use by ISS crews, was delayed by a number of difficulties, but it eventually was checked out satisfactorily. The system made back-to-back 5-hour test runs, then operated continuously on 25 November without the power spikes that had shut it off earlier. Recycled-water samples were sent back to Earth for analysis. Lubrication of the balky SARJ was so successful that it might not be necessary to conduct the anticipated repairs. By the end of the mission, it was drawing only 0.17 amperes of current, which is almost identical to the 0.15 amperes it drew when it first went into operation. Endeavour undocked from the ISS and landed at Edwards Air Force Base in California on 30 November, bringing ISS Expedition 18 crewmember Gregory Chamitoff back to Earth and leaving astronaut Sandra Magnus on the station to join the ISS crew. Unfavorable weather conditions at Florida's Cape Canaveral, the Shuttle's normal operational site, dictated against landing there. A Progress cargo vehicle delivered supplies to the ISS the same day, but had to employ manual docking when the usual automatic docking system failed to operate properly. Endeavour was returned to Cape Canaveral by its carrier 747 aircraft on 8 December to prepare for its next launch.

On 22 December 2008 astronaut Fincke and cosmonaut Lonchakov conducted a 5-1/2-hour spacewalk to install a high-priority Langmuir probe outside the ISS to monitor the local electrical field and provide data that could help Russian investigators explain why the Soyuz capsules made rough, off-course landings (see last year's report). They also installed an ESA experiment on the Zvezda module, the Expose-R device, that was supposed to gather data on the effects of the space environment on a variety of materials, but had to return it to the station because it failed to power up.

During a routine 2-minute, 22-second thruster firing on 14 January to boost the station's orbit, ISS sensors detected vibrations that exceeded specified limits. Cause of the unusual event was uploading of the wrong gimbal-control parameters prior to the burn. Although the vibrations shook some objects loose from the walls, results of subsequent analyses revealed on 4 February that the station's 15-year design lifetime had not been affected.

Expedition-18 crewmembers Fincke and Lonchakov conducted a four-hour, 49-minute spacewalk on 10 March, during which they used digital cameras to document handrails, vents, antennas, radiator panels and other hardware outside Russia's Zvezda service module and Zarya cargo block, which were later used by Russian engineers to gauge the condition of the station exterior and plan any needed maintenance and repairs. They also reinstalled the European space exposure experiment, Expose-R, that didn't work after it was emplaced in December 2008 because of a wiring error (see above). The experiment produced good telemetry after it was reset.

On 12 March the three Expedition-18 crewmembers evacuated the station into the Soyuz lifeboat due to a possible collision with a piece of space debris. The evacuation lasted 11 minutes, after which the piece of an old rocket motor sped safely by, missing the ISS by about 5 km. The debris was only about 12 cm long but traveling at 9 km/second. It was probably part of the payload-assist motor (PAM-D) on the Delta upper-stage that launched a global positioning system satellite in 1993, not a product of the recent (10 February) collision of two spacecraft (see below). NASA had identified the threat on 11 March as coming within the "red box" distance of 25 km that requires action, but it was then too late for an evasive maneuver by the ISS. The odds of its hitting the ISS were estimated at one in 10,000.

Shuttle Discovery was launched on 15 March following a month of delays due to replacement of its gaseous hydrogen fuel-tank pressurization-system valves because of concerns about possible cracks in the older valves. A final two days of delay were imposed by the need to fix a hydrogen fuel leak in the launch platform. Discovery brought the fourth and final solar array to the ISS, adding the 20 kW of power needed to support the full ISS crew complement of six people. The 73-m solar wings, folded into a 13.7 x 4.9 x 4.5-m package with the 14.1-tonne S6 truss element, completely filled the Shuttle's payload bay. The truss element was placed in position outboard of the solar alpha rotary joint by the Canadian station robot arm, which had to extend to its full 17.3-m length to line up the S6 truss properly. The truss was then bolted in place during a spacewalk by Shuttle crewmembers Steve Swanson and Richard Arnold, the first of three during this mission. The next two were employed unfurling and checking the solar array blankets and conducting some maintenance



tasks, but the last, which was to have begun the process of replacing six aging batteries at the other end of the truss and carrying out other assembly and maintenance tasks, was canceled due to the Shuttle's delayed launch and the imminent arrival of a Soyuz vehicle carrying the Expedition-19 crew (see below).

Discovery also re-delivered the station's complex water recycling system, including a repaired urine processing assembly which appeared to be working normally after installation of a new distillation centrifuge. Water samples from recycled astronaut urine were returned to Earth by Discovery for analysis to determine whether the system's reprocessed water can be declared fit for human consumption. Discovery also brought Japanese astronaut Koichi Wakata to replace Sandra Magnus on the ISS Expedition-18 crew, returning Magnus to Earth on 25 March and bringing back about five months' worth of blood and other biological samples from experiments, many of them conducted by Magnus.

On 26 March Russian cosmonaut Gennady Padalka, American astronaut Michael Barrat, and space tourist Charles Simonyi were launched aboard a Soyuz capsule from the Baikonur cosmodrome. Commander Padalka and flight engineer Barratt joined Japanese astronaut Wakata to make up the station's Expedition-19 crew, the last three-person crew before expanded six-person teams took up residence in May (see below). The increase of the station crew from three to six meant that Simonyi was to be the station's last tourist for the foreseeable future. He paid \$35 million for the trip, \$10 million more than for his previous journey to the ISS. He returned to Earth on 8 April aboard a Soyuz capsule with Expedition-18 crewmembers Fincke and Lonchakov.

The second launch of an updated Progress supply capsule took place aboard a Soyuz rocket from the Baikonur Cosmodrome on 7 May, docking with the ISS on 12 May. The five-day trip was longer than usual, because Russian space officials wanted to test the updated capsule's avionics after having corrected several abnormalities discovered during its first flight in November 2008. The Progress M-02M spacecraft delivered 1,500 kilograms of dry cargo and nearly 900 kilograms of propellant to the ISS Expedition-19 crew. Progress 32 had been filled with trash and other discarded items and been undocked from the station on 6 May, after which it deorbited and burned up during reentry over the Pacific Ocean on 18 May.

On 27 May a Soyuz TMA-15 was launched from the Baikonur Cosmodrome with three astronauts to fill out the first six-person ISS crew. The three were Canadian astronaut Robert Thirsk, Russian cosmonaut Roman Romanenko, and Belgium's Frank De Winne, whose capsule docked with the ISS on 29 May. The six-person Expedition-20 crew, which is the first to represent all the major ISS partner agencies, was also the first to drink recycled water aboard the ISS, which was approved by NASA on 20 May after extensive testing of the samples returned from the ISS.

On 5 June Expedition-20 crewmembers Gennady Padalka and Mike Barratt conducted a successful spacewalk that prepared the station for a new Russian module, Mini Research Module-2, to be launched late this year, which will serve as an additional docking port for Russian vehicles. The spacewalkers installed a pair of antennae for automated rendezvous equipment, hooked up electrical connectors for the antennae, and took photos of a manually operated crane. During a second 12-

minute indoor spacewalk on 10 June, Padalka and Barratt replaced a Zvezda hatch with a docking cone while attached to life-support umbilicals in Zvezda, to allow Mini Research Module-2 to latch onto the station. Mini Research Module-1 is planned for launch in May 2010.

On 1 July Expedition-20 crewmember Robert Thirsk, Canadian astronaut, performed a simple experiment on the ISS that was a demonstration of international co-operation. The Image Reversal in Space (IRIS) experiment, which Thirsk developed with students at the International Space University last year, measured how astronauts respond to a series of optical illusions and compared their reaction time for recognizing the different images to data recorded while the crew was on Earth. Students from over 30 countries watched the experiment through a NASA Ames Research Center downlink. The result of IRIS wasn't really the point of the exercise; rather, it was an attempt to bring the science of the cosmos down to Earth.

Then on 8 July Thirsk received the first honorary degree granted to a person in space: an honorary Doctor of Law degree from his alma mater, the University of Calgary in the Canadian province of Alberta, during a long-distance telephone call from the university. Thirsk performed a somersault in weightlessness to show his excitement and answered questions from students at the university, stressing the importance of education to Canada's space exploration efforts. On 19 September a team of 600 students from the Schulich School of Engineering at the University of Calgary sent an illuminated message entitled "Lift up Your Eyes" to Schulich graduate Thirsk aboard the ISS as it passed overhead, using 1,200 light-emitting diodes (LEDs) with an estimated total brightness of 120,000 lumens.

On 2 July NASA conducted a successful fueling test on space shuttle Endeavour that uncovered no hydrogen gas leaks from its fuel-tank vent pipe, allowing the agency to schedule a long-delayed 11 July launch to the ISS. In the test, the level of hydrogen gas was only 12 parts per million compared with more than 60,000 parts per million during several previous attempted launches. Hence Endeavour attempted to launch to the ISS on 11 July, and after being delayed twice more due to bad weather, finally left Earth on 15 July. It brought to the station the 5-tonne external experiment section of Japan's Kibo module: the Japanese Exposed Facility ("Jeff") and an accompanying pallet carrying science experiments, called the Japanese Logistics Element ("Jelly"). Endeavour also delivered a pallet with three science experiments, including an astronomical observatory that will monitor X-ray spectra from the station and an instrument to measure particles such as heavy ions, high-energy photons, and cosmic dust in the space environment. Shuttle astronauts installed these units during five two-person spacewalks, and also replaced a set of six batteries at the far port end of the P6 truss that had been in operation since December 2000. Endeavour's crew raised the station population to 13, setting a record for the biggest off-planet gathering in Earth's history. The shuttle brought NASA astronaut Tim Kopra to the ISS to join the Expedition-20 crew and departed the station on 28 July, returning JAXA astronaut Koichi Wakata to Earth on 31 July.

Russia's Progress M-02M cargo carrier, filled with refuse and decommissioned equipment from the ISS, undocked from the station on 1 July. The Russian Mission Control Center then tested the spacecraft's systems for two weeks, since it was the first of a new Progress spacecraft series, as mentioned above. Progress M-02M

vacated the Pirs docking port, to which the Soyuz TMA-14 manned spacecraft was then transferred from the Zvezda module's docking port. On 29 July the Russian Progress M-67 spacecraft carrying supplies to the Expedition-20 crew docked with the ISS using manual controls. The automatic docking system wasn't used in order to save fuel, because Progress M-67 wasn't lined up properly for the linkup. Expedition-20 commander Gennady Padalka guided it in manually.

The launch of Shuttle Discovery to the ISS, originally scheduled for 24 August, was delayed first by weather and then again by an instrument indication that the propellant fill-and-drain valve failed to close. Five subsequent tests verified the valve's satisfactory closing, so the launch was rescheduled for 28 August and was finally accomplished during the early morning of 29 August. Discovery docked with the ISS uneventfully the next day, delivering the Leonardo logistics module with over 7 tonnes of cargo, including equipment for a new bedroom, a treadmill, a backup carbon-dioxide removal assembly, an atmospheric revitalization system rack, a freezer, food, several scientific projects, and other supplies. The scientific experiments were a Fluids Integrated Rack, a Materials Science Rack, and a Minus-80-Degree Laboratory Freezer. Discovery also brought astronaut Nicole Stott, who replaced Tim Kopra on the ISS Expedition-20 crew.

Discovery astronaut Jose Hernandez filed regular Twitter updates on the mission, the first to do so in two languages, English and Spanish. Shuttle astronauts Nicole Stott and Danny Olivas removed a 600-kg empty ammonia coolant tank and retrieved two space-exposure experiments from the exterior of ESA's Columbus module during a 6-1/2-hour spacewalk on 2 September. The 770-kg full coolant replacement tank was installed by Olivas and Swedish Shuttle astronaut Christer Fuglesang during a second spacewalk the next day. On a third spacewalk the astronauts installed three new racks in the U.S. Destiny laboratory module: the Fluids Integrated Rack, Materials Science Research Rack-1, and a second Minus-Eighty Laboratory Freezer. Discovery undocked from the station and landed uneventfully at Edwards Air Force Base in California on 11 September, after being diverted twice from the customary landing site at Cape Canaveral due to bad weather.

Following Discovery's return to Earth, NASA announced that under a Space Act Agreement the agency had signed last year, Astrogenetics, a subsidiary of Astrotech Corporation (USA), had flown commercial drug-experiment packages in mid-deck lockers on Discovery and the four previous Shuttle missions. The experiments' goal was to use changes in virulence of pathogenic microorganisms that occur in microgravity to isolate the genes that cause the virulence, and thereby learn how to produce a vaccine against potentially deadly bacteria. Their first success was identifying a candidate vaccine for salmonella, which is now in the process of being submitted to the U.S. Food and Drug Administration (FDA) for human clinical trials. Another prospective candidate is a vaccine against the methicillin-resistant staphylococcus aureus (MRSA) bacteria, responsible for the deaths of about 19,000 U.S. hospital patients annually.

The first operational task of Japan's new H-2B rocket (see above) was to launch Japan's H-2 transfer vehicle, HTV-1, from the Tanegashima Space Center to the ISS on 11 September. The HTV-1, built by the Japan Aerospace Exploration Agency (JAXA), is a 16.5-tonne solar-powered cylinder about 10 m long and 4.4 m in

diameter with a payload capacity of 6 tonnes, although its initial load on 11 September was only 4.5 tonnes. Its development cost was \$680 million; it was the heaviest payload ever launched by Japan. Instead of docking with the station directly, like ESA's ATV, the HTV-1 is designed to rendezvous with the ISS and to be brought in to its dock on the U.S. Harmony module by the station's robotic Canadarm 2. This was accomplished successfully and uneventfully by ISS crewmember Nicole Stott on 17 September, the first time an unmanned vehicle was retrieved in this manner.

Besides its internal payload of about 2.5 tonnes, which the ISS crew transferred to the station in about 70 hours, the HTV-1 delivered two external experiments to the ISS: Japan's Superconducting Submillimeter-wave Limb Emission Sounder (Smiles), which is studying the effects of trace gases on the Earth's ozone layer, and NASA's Hyperspectral Imager for the Coastal Ocean and Remote Atmospheric and Ionospheric Detection System Experiment Payload (HREP), which is studying the oceans and mapping the ionosphere and thermosphere. The pallet carrying both experiments was removed from the HTV-1 and the two experiments then installed on the exposed experiment platform of Japan's Kibo module (see above) by ISS crewmember Robert Thirsk, using the station's robotic arm. The HTV remained docked to the ISS for about 6 weeks, after which it was scheduled to re-enter the atmosphere and burn up over the southern Pacific Ocean.

On 20 September the Progress 34 cargo craft departed the ISS and moved to a parking orbit to conduct several thruster firings associated with a science experiment for Russian researchers before deorbiting and burning up in the atmosphere on 27 September. On 23 September the ISS crew moved the HTV's pallet of science experiments from inside the HTV's hull to the exposed facility science platform at the back end of Japan's Kibo module, where they were installed the next day.

Prime contractor Thales Alenia Space (Italy) shipped the Node 3 pressurized connecting module for the ISS to the Kennedy Space Center on 17 May. Named Tranquility, the node was officially transferred to NASA in September. It is the last element of the barter agreement by which ESA supplied NASA with ISS hardware, including two node modules (Nodes 2 and 3) and the Cryo freezer. In return, NASA ferried the European Columbus laboratory to the ISS in February 2008 (see prior reports). Tranquility has the capacity for eight refrigerator-sized racks, and will hold environmental control and life-support systems, including an air revitalization system, an oxygen generator system, a water recycling facility, a waste and hygiene compartment, a treadmill, and the Advance Resistive Exercising Device for crew exercise, now stored in various places around the station. Node 3 is also the home of the European-built observation post Cupola, which allows for a 360-degree view of the ISS and Earth. It is scheduled to be launched to the ISS in February 2010, where it will be installed on the port side of the Unity node.

NASA signed a \$141-million firm fixed-price contract extension with the Russian space agency Roskosmos on 2 December 2008 to launch three U.S. astronauts to the ISS in the fall of 2011, after the planned retirement of the Shuttle, and return them to Earth in the spring of 2012. The agreement, which was approved by the U.S. Congress in October 2008 (see last year's report), calls for the three to be carried on two separate Soyuz flights, and also permits NASA to use Soyuz flights to meet NASA's obligations to its international partners for trips to and from the ISS. It

further allows each astronaut to carry up to 50 kg of cargo up to the station and bring 17 kg back to Earth. On 13 May Roskosmos and NASA agreed on a new price for ferrying US astronauts to the ISS from 2012 on: \$51 million per seat. NASA had said it planned to buy a minimum of three and a maximum of up to 24 seats aboard Soyuz spacecraft after shuttle retirement. The formal \$306-million contract extension, signed by NASA and Roskosmos on 28 May, specifies four Soyuz capsules to be launched in 2012 carrying the six ISS crewmembers, two in the spring and two in the fall, and the same four to return them to Earth in the fall of 2012 and the spring of 2013. The contract extension includes training, launch preparation, and crew rescue.

On 23 December 2008 NASA awarded SpaceX and Orbital Sciences (both USA) seven-year Cargo Resupply Services contracts valued at up to \$3.5 billion to resupply the ISS after the shuttle is retired. The companies will be solely responsible for designing, building, and launching the rockets, a first for NASA. Both companies will use generic docking ports with the ISS robotic arm performing the final docking. Orbital Sciences would get up to \$1.9 billion for eight flights starting in 2011; SpaceX would get up to \$1.6 billion for 12 flights starting in 2010. The losing bidder was a team led by PlanetSpace that included Lockheed Martin, Boeing and ATK (all USA). NASA left the contract open to bring in another company in case either of the winning contractors stumbles. If both fail, NASA would have to severely cut research, and possibly crew, aboard the station. NASA expects SpaceX and Orbital to transport 40 – 70% of the agency's cargo to the ISS: 20% in 2011 and a peak of 70% in 2013. NASA will also rely on services from Europe's ATV and Japan's HTV cargo carriers.

The PlanetSpace team subsequently filed a formal protest with the U.S. General Accountability Office (GAO) against NASA's selections, based on the fact that their bid was rated second best during the source selection process. However, on 22 April the GAO formally denied the protest, ruling that NASA's concern about Planetspace's extensive outsourcing to its large-company subcontractors was indeed valid. Nevertheless, on 23 July Planetspace filed a new protest with the U.S. Court of Federal Appeals, asking NASA to either reconsider the awards or re-open the competition.

NASA announced on 29 April that the agency plans to spend \$150 million on commercial efforts to deliver astronauts to the ISS, using funds from the \$1 billion U.S. stimulus-package money allotted to NASA in February, which directed the agency to spend \$400 million on human space exploration. The remaining \$250 million was to have been committed to the Ares-1 rocket and the Orion crew capsule. The \$150 million will include \$80 million to develop enabling technology, \$42 million for a common docking system on the ISS to accommodate commercial spacecraft, \$8 million to set human-rating requirements for commercial spacecraft, and \$20 million to accelerate the pace of commercial flights to the ISS. This new effort is not related to the COTS-D option in Space-X's contract to deliver cargo to the space station, which calls for demonstrating human-rated capability.

On 13 November 2008 the chief of the Kazakh National Space Agency Talgat Musabayev announced that a Kazakh cosmonaut would fly to the Russian segment of the International Space Station (ISS) late this year. The Kazakh government gave the go-ahead for the flight, and the ministry of economy and budget planning earmarked funds in the national budget. The most likely candidates for the astronaut and his

backup were said to be Mukhtar Aimakhanov and Aidyn Aimbetov, who had already undergone astronaut training at Russia's Gagarin space center.

On 4 June Guy Laliberte (Canada), founder of Cirque du Soleil and the One Drop Foundation, announced that he was to be the next spaceflight participant (heretofore called "space tourist") to visit the ISS. Laliberte announced his "Poetic Social Mission" at a press conference; its focus would be on water quality. He created an artistic performance and a work of poetry for the trip, which lasted 13 days and cost him \$35 million (see below). Like all the other private space flyers so far, he opted not to participate in a spacewalk, which would have cost an extra \$15 million. Accompanying him during his training period at Russia's Gagarin Cosmonaut Training Center in Star City was his backup, Barbara Barrett (USA), former deputy administrator of the U.S. Federal Aviation Administration (FAA) and U.S. ambassador to Finland from April 2008 to January 2009.

Laliberte and two crewmates, U.S. astronaut Jeffrey Williams and Russian cosmonaut Maxim Surayev, were launched to the ISS by a Soyuz rocket from the Baikonur Cosmodrome on 30 September; their Soyuz TMA-14 capsule then docked with the station on 2 October. Laliberte returned in a Soyuz capsule on 10 October, following his 9 October artistic broadcast to raise awareness for his One Drop Foundation, dedicated to water conservation, along with Expedition-20 crewmembers Gennady Padalka and Michael Barratt. Williams and Surayev joined ISS Expedition 21, which was led by the first European ISS commander, ESA astronaut Frank DeWinne.

On 31 December 2008 Space Adventures (USA) published a price list for space services that included an increase in the price of flights to the ISS to \$35-45 million, and also offered spaceflight participants for the first time the unique opportunity to walk in space at a price of \$45-55 million. As noted above, however, on 21 January Roskosmos chief Anatoly Perminov stated that Russia will not send tourists to the ISS after this year because of plans to double the size of the station's crew; Charles Simonyi's flight on 26 March was originally said to be the last. The Kazakh cosmonaut (see above) was also to fly this fall, and Perminov said that Russia would not cancel any space launches slated for 2009 because of the global financial crisis.

However, Canadian Guy Laliberte flew to the ISS on 30 September, as noted above, and then on 2 October Space Adventures (USA) announced that Roskosmos had authorized them to select and contract candidates for space tourist trips beginning in 2012. Each Soyuz will carry a professional cosmonaut and two tourists, one of whom will have to pass a year-and-a-half training course as a flight engineer. Space Adventures will pay for the construction of the spaceship, the launch services, and the salary of the Russian cosmonaut. The company said that they already had a number of candidates who were willing to pay the price of a 10-day trip to the ISS, estimated at about \$35 million, including Google co-founder Sergey Brin.

On 12 October, at the International Astronautical Congress in Daejeon, Korea, South Korea and India announced their plans to begin negotiations in 2010 to seek membership in the International Space Station (ISS). The 2010 timetable is partly because the ISS partners were waiting for the U.S. government to officially approve

the extended use of the station to 2020 and beyond. The original plan had been to de-orbit the ISS in 2016. Once the USA decides to agree to an ISS extension, the station's partners can start to negotiate the changes to the inter-agency framework agreement that underpins the project.

## **B. Other Earth-Orbital Flight Operations**

On 11 May NASA launched Shuttle Atlantis on the long-delayed final repair and refurbishment mission to the Hubble Space Telescope, the first since 2002. Due to the high risk of damage to Atlantis by space debris, which is far more dense in the Hubble's orbit than in the lower ISS orbit, combined with the lack of a "safe haven" for the crew in the event of serious shuttle damage, the unprecedented step was taken of having a backup shuttle, Endeavour, on a second launch pad at the Kennedy Space Center, ready for a rescue mission if needed. About 106 seconds after the launch, a piece of debris was observed to strike Atlantis' thermal protection tiles, leaving a 53-cm-long series of nicks encompassing 4 or 5 of the tiles at the wing-fuselage juncture. The scratches were subsequently ascertained to be shallow, and because they were in a noncritical region of the thermal protection system were judged to pose no danger during the shuttle's subsequent re-entry.

Atlantis pulled alongside the 11-tonne, 13.3-m-long Hubble on 13 May, and astronaut Megan McArthur used the Canadarm to place it in the shuttle's payload bay, where it was attached to a berthing mount that provided easy access to its instruments. The first of five spacewalks was conducted on 14 May to begin the complex process of replacing six gyroscopes, six batteries, four cameras and spectrographs, and other "housekeeping" equipment. On that first 7-hour spacewalk astronauts John Grunsfeld and Andrew Feustel installed the new piano-sized No. 3 wide-field camera whose predecessor had been responsible for many of the telescope's most dramatic images, along with a new computer to replace the one that had given so much trouble last year (see last year's report). They encountered a problem with a recalcitrant 15-year-old bolt on the old No. 2 camera that, if it had broken, might have prevented the replacement, but after an hour of work they managed to remove it and install the new No. 3 camera without incident.

On 15 May astronauts Mike Massimino and Michael Good conducted the most important and delicate space walk of the mission, replacing the six gyroscopes of the telescope's guidance system. It took much longer than expected, nearly eight hours. After struggling with one bulky set of gyroscopes, they finally had to settle on the installation of a refurbished set, along with five new instruments. The replacement of the gyros was the key upgrade for the repair mission.

On 16 May, in what was perhaps the most complex space walk ever, astronauts John Grunsfeld and Drew Feustal repaired the Hubble's broken Advanced Camera for Surveys and replaced a refrigerator-sized optics package with the new high-powered Cosmic Origins Spectrograph. They then replaced the Space Telescope Imaging Spectrograph during a fourth spacewalk. During their fifth and final 7-hour spacewalk on 18 May, Grunsfeld and Feustal changed some batteries, replaced a fine-guidance sensor, and added insulation plates on the outside of the Hubble.

In five days the astronauts spent 36 hours and 56 minutes space walking, replaced or fixed nine major components of the telescope, and extended the Hubble's useful life by five to ten years. The repair teams used a kit of 180 tools, 116 of which had been developed specifically for this mission. 316 bolts had to be loosened and refastened. The mission's cost of \$1.1 billion, including \$220 million for the new instruments, raised the investment in Hubble's 24 years of operation to \$10 billion.

The telescope was released on 19 May, and Atlantis promptly descended to an orbital altitude of 250 km, where the risk of collision with debris was much lower than at the Hubble's altitude of 575 km. Atlantis deorbited on 21 May, but was unable to land at the Kennedy Space Center due to bad weather. It landed instead at Edwards Air Force Base in California on 24 May. The first images from the refurbished telescope were released on 9 September, showing distant galaxies, a dense star cluster, a "pillar of creation," and a "butterfly" nebula.

The Planetary Society (USA) issued a space exploration plan on 13 November 2008, urging the new U.S. administration, NASA, and other spaceflight programmes worldwide to focus on putting people on Mars, not the Moon. The report stated that the Moon missions should be deferred until the costs of the interplanetary transportation system and shuttle replacement are largely paid, and that the spacefaring nations should embark on a step-by-step approach of new achievements, including a human mission to a near-Earth asteroid. Their plan, which builds on a February 2008 workshop at Stanford University (see last year's report), calls for international cooperation to minimize the costs to any one country and to increase public support, particularly in view of the current economic crisis. One potential candidate mission, a first flight to asteroids by humans, could be flown about 2025 according to the Society's plan, which would take all human lunar exploration out of the critical path toward an initial human Mars capability. The plan, which urged the incoming U.S. presidential team to adopt the alternative goals as a new Obama Vision for Space Exploration, was subsequently presented to Congress and the Obama Administration. Its title is "Beyond the Moon, A New Roadmap for Human Space Exploration in the 21st Century."

On 8 May U.S. President Obama chartered an expert outside panel, formally named the Review of U.S. Space Flight Plans Committee, to review and report on the U.S. future human space exploration programme, focusing particularly on the Ares-1 launcher and Orion crew capsule currently in development. Former Lockheed Martin chairman Norman R. Augustine was appointed chairman of the 10-member panel, which was directed to report back to Mr. Obama in three months to "identify and characterize a range of options that spans the reasonable possibilities for continuation of U.S. space flight activities beyond retirement of the Space Shuttle." Specific objectives for the panel's assessment were options for "(1) expediting a new U.S. capability to support utilization of the International Space Station; (2) supporting missions to the Moon and other destinations beyond low Earth orbit; (3) stimulating commercial space flight capabilities, and (4) fitting within the current budget profile for NASA exploration activities."

The panel's summary report, issued to President Obama on 8 September, stated that NASA's planned return to the Moon by 2020 could not be accomplished within the projected budget, and that NASA would need between \$3 billion and \$4



billion annually in additional funds to achieve that goal. The shortfall was due primarily to (1) the prior assumption that NASA would discontinue support of the International Space Station (ISS) after 2016, and (2) a reduction in funding for Project Constellation, the transportation segment of the U.S. human space exploration programme, to \$3.4 billion less than the original five-year budget. Also, NASA's latest overall budget for human space exploration through 2020 was \$28 billion lower than the \$80 billion originally approved when the Constellation architecture was selected four years ago. The Augustine report also concluded it was not likely that Constellation's vehicles, Ares-1 and Orion, would be ready to transport astronauts to and from the ISS before 2017, two years later than originally planned.

The panel report recommended to President Obama six options for human space exploration. There were two "budget constrained options," neither of which allowed for ventures beyond the international space station (ISS). One of these, which included development of the Ares-5 for heavy launch, called for human transportation to the ISS by Ares-1 and Orion and terminated the station mission in 2015; the other one extended the ISS mission to 2020 but reduced the heavy-lift vehicle development to a lower-capability "Ares-5 light" and would use commercial launchers to ferry crews to and from the ISS. Three "Moon first" options involved various mixes of Ares-5, Ares-5 Light, and a new Shuttle-derived launcher similar to the old "Shuttle-C" concept (see prior reports) but with refueling in orbit, plus a mix of Ares-1 plus Orion and commercial launchers to ferry ISS crews. Three "Flexible-Path Options" all extended ISS life to 2020, with a mix of Ares-5 Light, a Shuttle-derived launcher plus refueling, and a 75-tonne-payload concept using current evolved expendable launchers plus refueling. In these three options, all crew transport to the ISS would employ commercial launchers. All the "Moon first" and Flexible Path" options required significant budget increases for NASA – about \$22 billion by 2014 plus 2.4% annual increases thenceforth, plus ceasing ISS operations in 2015 and putting the diverted funds into the new infrastructure development.

The final report, issued on 22 October, recommended that NASA should make a major detour on their plans to return to the Moon, and should be focusing on bigger rockets and new places to explore, such as a nearby asteroid or one of the moons of Mars. And although the current NASA plans were well conceived in 2005 when they were first drawn up, when funding was diverted and launch dates delayed the Ares I rocket appeared have lost one of its major purposes: ferrying astronauts to the space station.

On 2 October Boeing (USA) and Russian Space Corporation Energia signed a memorandum of understanding to work together on a future common docking system for advanced space exploration vehicles. The two companies will develop a system based on Energia's existing Androgynous Peripheral Docking System, which has connected every space shuttle mission to the International Space Station for more than a decade.

XCOR Aerospace (USA) announced on 2 December 2008 that they were accepting \$20,000 deposits from space tourists for suborbital flights aboard the company's Lynx rocketplane (see prior reports). RocketShip Tours (USA) is the ticketing agency for the flights, which will cost \$95,000 per person. The Lynx missions using the Mark-1 vehicle are expected to begin in 2010. They will be piloted

by former Space Shuttle pilot Richard Searfoss and will each carry one passenger. The flights will reach a speed of Mach 2 and an apogee of 61 km, providing about two minutes of microgravity during a 30-minute total flight time. As of 2 December XCOR had received 20 deposits from customers, the first of whom is Danish investment banker Per Wimmer. XCOR plans a Mark-2 follow-on to begin operations in 2011, using an upgraded XR-5K18 13-kN thrust, pump-fed liquid oxygen-kerosene rocket engine (*vs* the Mark-1's XR-4K14, 7-kN thrust engine). It will be capable of reaching 110-km altitude.

On 3 March NASA issued a new \$9.6-million letter contract to Oceaneering International (USA) to begin work on next-generation spacesuits. The previous \$745-million contract to Oceaneering (see last year's report) had been rescinded due to a protest by losing contractor Exploration Systems and Technology (EST, USA). However, when EST and Oceaneering agreed in December 2008 to join forces, the protest became ineffective. The final contract, issued in August, was updated to recognize the revised schedule for project Constellation. The new Constellation Space Suit System (CSSS) will for the first time be a single modular spacesuit able to handle an astronaut's entire workload. The CSSS will have two primary configurations: one for launch, re-entry and emergency extra-vehicular activity (EVA); and a second for routine EVAs, walking on the Moon, and, eventually undertaking missions to Mars. The first system is scheduled for 2015, while the second is scheduled for 2020.

A training programme for prospective space tourists was inaugurated by Aurora Aerospace (USA) on 1 May at the Petersburg-Clearwater International Airport in Tampa Bay, Florida. The company is offering enhanced gravity and microgravity flights in the Czech Republic's L-39 trainer aircraft and a Rockwell propeller-driven aircraft, along with high-altitude breathing experience using a device that provides mixed ratios of oxygen and nitrogen. Aurora's full 2-day course is priced at \$8,000, with lower-price options ranging from \$1,500 to \$5,000.

The first weightless wedding took place aboard Zero Gravity Corporation's (USA) G-Force One aircraft on 20 June. A New York couple, Noah Fulmor and Erin Finnegan, were married by space tourist Richard Garriott during eight minutes of microgravity maneuvers following takeoff from Titusville Airport near Orlando, Florida.

A doctor and a fighter jet pilot, Jeremy Hansen and David St-Jacques, were selected as Canada's new astronauts on 13 May. The first new astronauts since 1992, they were chosen from among 5,351 applicants who underwent a year of intense evaluations. The two new astronauts began training at the Canadian Space Agency headquarters in Saint-Hubert, Quebec and at NASA's Johnson Space Center, and also supported the ISS missions of fellow Canadian astronauts Robert Thirsk and Julie Payette.

On 23 June NASA named six men and three women from a pool of more than 3,500 applicants to its 20th astronaut class since 1959. This class was noted as the first with no expectation of flying on the space shuttle. The nine astronaut recruits began training in August, along with new astronauts from Japan, Canada and Europe.

On 20 May ESA announced a roster of six new astronauts, selected after a year-long vetting process that began with 8,413 applicants who passed the medical examination. The men were Luca Parmitano (Italy), Timothy Peake (Britain), Andreas Mogensen (Denmark), Thomas Pesquet (France), and Alexander Gerst (Germany). The only female selected was Samantha Cristoforetti (Italy). They started 18 months of basic training in September at the European Astronaut Centre in Cologne, Germany, and then began individualized training for specific missions. Major Peake, a British national, was selected despite his government's longstanding refusal to take part in Europe's manned spaceflight activities, because he was among the best and his selection could provide an incentive to the British government to initiate participation in Europe's manned-spaceflight programme. Indeed, on 19 July Lord Drayson, UK Science Minister, announced that British astronauts will feature in the future of the UK's space ambitions, confirming the fact that Peake will be supported by the UK government and that the UK will once again be involved with human spaceflight.

The Japan Aerospace Exploration Agency (JAXA) announced on 8 September their selection of a Maritime Self-Defense Force doctor, Norishige Kanai, as an astronaut candidate for a long mission aboard the International Space Station. He went to the U.S. with two other Japanese astronaut candidates to undergo the two years of training required to qualify as a NASA astronaut.

On 27 February ESA named a Frenchman and a German to join four Russians in a 105-day isolation experiment at Russia's Institute of Medical and Biological Studies to test whether humans can survive on Mars. The "mission" began on 31 March and was completed on 14 July. It was followed by a 520-day experiment that was to last as long as a real mission to Mars. The participants had no television or Internet and their only links to the outside world were communications sessions with the mission control and an internal e-mail system. Communications with the mission controllers had 20-minute delays to simulate a real flight. As with a real mission, the supplies for the expedition were painstakingly worked out in advance and no additional goods were allowed to enter the capsule once the experiment started. A series of simulated emergencies were planned, and real-life emergencies would first fall to the crew to solve. Scientists scrutinized the six participants for stress, mood, hormone regulation, immune defenses, and sleep quality, as well as whether dietary supplements could sustain their health.

The Russian space agency Roskosmos announced on 10 March that for the first time in over ten years Russia will resume the recruiting and training of female cosmonauts. The decision was made shortly after control of the Gagarin Cosmonaut Training Center was transferred from the Russian Defense Ministry to Roskosmos, and was stated to be consistent with the Russian Constitution's guarantee of equal access to professions independent of gender.

Excalibur Almaz Ltd. (Isle of Man, UK) announced plans on 18 August at the Moscow Air Show to launch paying customers on weeklong orbital trips by 2013, aboard Russian Almaz ("Diamond") Reusable Return Vehicles (RRVs) that were used in the 1970s for travel to the secret Soviet Almaz space stations. The RRVs, now being overhauled and updated by Almaz and the original manufacturer NPO Mashinostroyeniya (Russia) to incorporate new technologies and customer needs, flew nine test flights to the Almaz stations, also called Salyuts 2, 3, and 5. Two of the

vehicles reached orbit repeatedly. Excalibur Almaz claims to be an international organization, with members in the U.S., Russia, Europe, and Japan and astronaut/cosmonaut advisers from the U.S. and Russia

India's Planning Commission, headed by the Prime Minister, approved on 23 February the Indian Space Research Organization's (ISRO's) \$2.5-billion proposal for a human space flight programme. The funds would be spent over six years and would include the construction of new facilities. The plan envisions launching two astronauts into space by 2015, to orbit at an altitude of 275 km and to return to Earth seven days later. ISRO began preliminary work on the programme on 1 April, using \$19 million of current-budget funding for human spaceflight while awaiting final programme approval by India's cabinet. On 6 October ISRO announced an opportunity for women to be a part of that first Indian human flight into space, but cautioned that there will be a long-drawn-out procedure to pick the best candidates and a rigorous training schedule to help survive grueling conditions in space. ISRO expects that process to take three years.

On 5 March China announced plans for launching a space station as soon as 2010. The 8.5-tonne small station Tiangong-1 ("Space Palace"), intended as a testbed for a subsequent larger station (see below), has a projected lifetime of only one or two years. It resembles ESA's automated transfer vehicle (ATV), with a docking port for arriving space vehicles and a service module with two flat rectangular solar arrays. To be launched by a Long March 2 or Long March 3 rocket, its first mission is planned to be a test docking with an unmanned Shenzhou-8 module in 2011, to be followed, if successful, by dockings with manned Shenzhou-9 and Shenzhou-10 modules.

Subsequent missions of a much larger (60-tonne) space station are planned for launch in 2020 by China's new Long March 5 rocket series, whose 1.18-kN liquid oxygen-liquid hydrogen engines passed initial testing last year. The station would be assembled in orbit from three modules, launched from China's new site on Hainan Island. At least one of the modules would weigh about 20 tonnes. The station, which is being designed for a crew of three, would be placed in an orbit at an altitude of 400 – 450 km and an inclination of 42 – 43 degrees. Its planned service life would be 10 years.

## **V. SPACE STUDIES AND EXPLORATION**

### **A. Astronomy and Astrophysics**

On 19 November 2008 NASA and the U.S. Department of Energy signed a memorandum of understanding for the Joint Dark Energy Mission (JDEM). It is the first mission designed specifically to advance the understanding of the nature of dark energy, which accounts for about 70% of the mass-energy content of the universe. It is the first of five Beyond Einstein cosmology missions that NASA has proposed to build and launch.

On 9 December 2008 observations using NASA's Spitzer space telescope (see last year's report) detected water in the atmosphere of exoplanet HD 189733b, 63 light-years away, where carbon dioxide had previously been identified by the Hubble

telescope's Near Infrared Camera and Multi-Object Spectrometer. The next day astronomers using Spitzer found what appear to be the galaxy's dimmest stars, two brown dwarfs known as 2M0939 that are each half as bright as the previous record holder. The object, 17 light-years away, was thought to be one brown dwarf until follow-up observations with Spitzer revealed that 2M0939 was fairly cool, only 325 degrees Celsius, and twice as bright as other brown dwarfs of its temperature. It is thought that the object is two brown dwarfs about the size of Jupiter but with 30 to 40 times the mass.

Then on 28 January *Nature* magazine (UK) reported the November 2008 discovery by Spitzer of what appeared to be extraordinary heating of exoplanet HD80606b. This planet, 200 light-years away and four times the size of Jupiter, heated up by about 700 degrees Celsius (from 527 degrees to 1,227 degrees) in just 6 hours. This is the first time "changing weather" has been observed on another planet outside the solar system. During its brief close pass to its sun from its 111-day orbit, the planet moves to within 0.03 astronomical unit of its star, one-tenth as far as Mercury is from our Sun. The temperature change creates fierce winds moving at 5 km/sec, producing large-scale storm systems that gradually peter out as temperatures cool.

Spitzer exhausted its last liquid helium coolant in mid-May, resulting in a telescope temperature rise from 2.2 Kelvins to about 31 Kelvins. As a consequence, Spitzer's two longer-wavelength instruments, the multiband imaging photometer and the infrared spectrograph, are no longer operable. However, the two shortest-wavelength detectors in the infrared array camera are still working, enabling Spitzer to refine the value of the Hubble constant, search for ancient galaxies red-shifted by the universe's expansion, and analyze the atmospheres of extrasolar planets.

On 10 August NASA's Jet Propulsion Laboratory announced that Spitzer observed plumes of vaporized rock and lava issuing from the collision of two planets circling a small young star still in the early stages of planet formation. They apparently smashed into each other at high speeds thousands of years ago. It is believed that there are some similarities between this impact and one that is thought to have created the Earth's moon.

NASA's Kepler space telescope was moved to its launch pad at Cape Canaveral Air Force Station on 19 February and was launched by a United Launch Alliance Delta-2 rocket on 6 March. It then moved itself into a 373-day orbit around the Sun, trailing in Earth's wake at a distance of about 15 million km (~ 0.1 astronomical unit). This unusual trajectory brings the field of view of Kepler's photometer out of the ecliptic plane and avoids the crossing of its line of sight by the Sun and the Moon. Over the course of its planned 42-month mission, Kepler will search up to 100,000 main sequence (Sun-like) stars in the Cygnus-Lyra region of the Milky Way for planets 30 to 600 times smaller than Jupiter. Distances to the target stars range from 30 to 1,000 light-years from Earth.

Kepler's 0.95-m diameter Schmidt telescope, with its 1.4-m primary mirror and 95-million-pixel photometer, is expected to be the first to find Earth-sized planets orbiting stars in the region where liquid water might exist. The photometer is so sensitive that it can detect variations in light of 20 parts per million. The potential

planets Kepler spots will later be examined by Earth-based telescopes to rule out false-positives and gather more observations. Following its launch, 20 students from the University of Colorado worked with 16 NASA controllers for 60 days to check out and power up the spacecraft, and the Planetary Society (USA) announced that they have created an exoplanet registry and will maintain it up to date. Originally a Discovery-class NASA mission, Kepler's cost rose over the last eight years to \$591 million. The 1.05-tonne spacecraft was built by Ball Aerospace (USA). It transmits its data via a high-gain antenna, the first to use Ka-band transmission, and carries enough station-keeping propellant for 6 years.

While still in its checkout period, Kepler transmitted its first image on 18 April, the day after its dustcover was jettisoned. That image included the star TrES-2, which has a known Jupiter-sized planet orbiting it every 2-1/2 days. Kepler achieved its fine-pointing mode on the very first try. Science data collection started on 12 May, and the first data were transmitted to Earth on 16 June. Then on 6 August, during the spacecraft's first ten days of operation, it spotted exoplanet HAT-P-7b. Although this planet was already known to exist, the ease and precision with which Kepler was able to discern its presence bodes well for the satellite's ability to find more hospitable Earth-like planets. In addition, Kepler made radical new discoveries about the hot Jupiter-class planet, by mapping its 2.2-day orbit and providing new details about its hazy, ozone-like atmosphere, where temperatures climb as high as 2,376 degrees Celsius. In the first 10 days of its calibration period, Kepler collected data on 52,496 stars, three of which were known to have transiting planets.

The first mirror segments of NASA's James Webb Space Telescope (JWST), Hubble's successor, completed their first series of cryogenic tests on 8 April. The first of 18 segments that make up the spacecraft's 6.5-m-diameter main mirror, the 1.5-m segments are being tested in batches of six by contractor Northrop Grumman in the 215 cubic-meter helium-cooled vacuum chamber at NASA's Marshall Space Flight Center. The segments, designed and built by Ball Aerospace and Technologies, are chilled to cryogenic temperatures four times over a six-week period. All mirror testing is expected to be completed by 2011, with launch of the \$5-billion spacecraft by an ESA-supplied Ariane-5 now planned for June 2014.

ESA's contributions to the JWST, which include two of its four instruments and the Ariane launch, total an additional \$740 million. On 14 October a full-scale engineering test model of the telescope's 200-kg Near Infrared Spectrograph (NIRSpec) was completed by ESA's European contractors and shipped by prime contractor Astrium GmbH (Germany) to NASA's Goddard Space Flight Center for testing in preparation for the JWST's Critical Design Review in April 2010. The NIRSpec has three telescopes, built by Sagem (France). It is unique in that its mirrors, mount, and optical base plate are all constructed of silicon carbide.

NASA announced on 19 June the selection of two Small Explorer mission proposals from among six finalists for the competition: the Sun-watching Interface Region Imaging Spacecraft (IRIS), proposed by Lockheed Martin Advanced Technology Center, and the Gravity and Extreme Magnetism Small Explorer (GEMS), proposed by NASA's Goddard Space Flight Center. The six finalists had been awarded \$750,000 mission feasibility study contracts in May 2008. The two selected missions could receive up to \$105 million each plus a NASA-supplied

launch, and are expected to launch no later than 2015. IRIS is a 3-m long spacecraft that will use a solar telescope and spectrograph to investigate the dynamics of the solar chromosphere and transition region. The 267-kg GEMS spacecraft will carry a specialized X-ray telescope to study neutron stars, black holes, and other unique stellar phenomena, especially the polarization of X-rays emitted from matter trapped near black holes. Spacecraft construction and operation of the GEMS mission will be conducted by Orbital Sciences Corporation.

On 3 February the Paris Observatory announced that the French Corot satellite (see prior reports) had discovered an Earth-like rocky exoplanet orbiting a distant star. Corot-7b is 1.8 times the size of Earth and about 5 times as dense, but boiling hot in places (up to 2,000 degrees Celsius) and covered with liquid lava or consisting of half water and half rock. It circles its parent star at high speed in a 20-hour orbit. Of the Earth-like planets detected to date, this is the first one spotted by the transit of its star, and it also the smallest. Its full characterization, including confirmation of its rocky nature, awaits determination of its mass, density, radius, and orbit parameters. On 28 May, Corot scientists announced that the spacecraft had detected phases of the first exoplanet it had discovered, Corot-1b (about 1,600 light-years distant). It was the first time an exoplanet's phases had been observed in the visible-light spectrum, revealing a dark nightside and a starside temperature of 2,000 degrees Celsius.

ESA's 3.3-tonne Herschel three-axis-stabilized Space Observatory (see prior reports) was shipped to the Kourou launch site on 12 February and launched by an Ariane 5 ECA rocket on 14 May, following a 4-week delay needed to verify flight-simulation software that monitors the spacecraft during launch and early operations. The \$1.7-billion infrared space telescope has a 3.5-m silicon carbide main mirror, 50% larger than NASA's Hubble telescope's but at 3 mm thick weighing only 320 kg, a third that of the Hubble mirror. Its advanced-technology cryostat and large refrigerant capacity, 2,250 liters of liquid helium, maintain its instruments at 1.7 Kelvins. The telescope was tested under cryogenic conditions at Centre Spatial de Liege (CSL, Belgium). Herschel was boosted to a large halo orbit around L2, the second Lagrange Sun-Earth libration point, about 1.5 million km from Earth. From there, it is studying the evolution of stars and galaxies in wavelengths ranging from submillimeter to far infrared, 60 – 670 microns, thereby making it possible to view relatively cool and diffuse matter such as interstellar and circumstellar gas and dust or hidden galaxies which have gone largely unseen to date. Its design lifetime is at least 3.5 years.

The same Ariane 5 rocket also launched ESA's smaller (1.8-tonne) Planck spacecraft, which underwent complete functional testing at Centre Spatial de Liège and was then shipped by air to Kourou on 18 February. Its telescope, with a 1.5-m primary mirror and cooled by a six-step cooling system that maintains it near absolute zero temperature (0.1 Kelvins), is measuring the temperature fluctuations of the cosmic microwave background radiation left over from the Big Bang with unprecedented resolution and sensitivity. A further objective is to observe the sky simultaneously in nine frequencies ranging from 30 to 900 GHz to derive the polarization state of the cosmic microwave background radiation, which has never been done before. It too was located at L2, but in a smaller Lissajous orbit, following its and Herschel's successful checkout on 21 May and midcourse correction maneuvers on 5 June and 2 July. Planck has a design lifetime of 18 months.

Planck began operations on 13 August, conducting a two-week trial, the “First Light Survey,” in which it made a map comprising strips of the sky in all of the energy frequencies covered by its two scanners. Planck’s routine observations, a 6-month all-sky survey, began on 27 August. On 14 September ESA reported that one of Herschel’s three instruments had stopped working, impairing the mission’s ability to conduct its observations. After being switched off for more than a month after an “unknown event” shut it down, it was unclear when the Heterodyne Instrument for the Far Infrared (HIFI) instrument will be turned on again. Herschel’s operations were to begin in October after completing performance verification. The problems with HIFI are not expected have an impact on the total mission except for the delay in making measurements.

ESA’s prime contractor for both spacecraft was Thales Alenia Space (France and Italy), but involved the combined efforts of 95 companies from a number of ESA’s governments. At \$2.46 billion for the spacecraft, their launch, and three years of operation, Herschel and Planck together constitute the largest space science contract ever signed in Europe, and the second most costly payload ever launched by an Ariane rocket, after Envisat’s \$3.14 billion.

An agreement to pursue a joint initiative between Russia and Germany for a high-energy space telescope mission was signed on 20 August. Spektrum Roentgen Gamma (SRG), formerly known as Spektrum-X-Gamma, was originally conceived in the late 1990s as a Russian-led mission featuring five telescopes covering the energy range from the far ultraviolet to hard X-rays. Now the mission will consist of two X-ray telescopes, Russia’s ART-XC and Germany’s eROSITA (Extended Roentgen Survey with Imaging Telescope Array). They will be launched from the Baikonur Cosmodrome by a Russian Soyuz Fregat rocket to the L2 Lagrange libration point, 1.5 million km from Earth. eROSITA, developed and built jointly by Germany’s Max Planck Institute for Extraterrestrial Physics (MPE) and the German space agency DLR, will consist of seven mirrors covering the 0.2 – 10 keV medium-energy range of the X-ray spectrum to investigate dark matter and energy. It will also study the evolution and growth of early black holes and gamma-ray bursts. The mirrors will be cooled to -80 degrees Celsius. Russia’s ART-XC will complement eROSITA in the 3 – 30 keV energy range, investigating black-hole accretion physics and census, particle acceleration mechanisms, and other aspects of high-energy physics.

## **B. Plasma and Atmospheric Physics**

On 30 January Russia launched the nation’s first science mission of its scale in more than four years. A Ukrainian Tsyklon 3 rocket lifted the Koronas-Foton spacecraft from the Plesetsk Cosmodrome into an 82.5-degree, 500-km circular orbit to analyze the causes of solar flares. Koronas-Foton was the third satellite in a series to study solar-terrestrial physics as part of the International Living With a Star Programme. The two previous missions were launched on 2 March 1994 and 31 July 2001. The Moscow Engineering Physics Institute (State University) was responsible for the scientific payload, which includes 11 instruments developed by scientific institutes in India, Poland, Russia, and Ukraine. The Research Institute for Electromechanics designed and built the 1,920-kg Koronas-Foton spacecraft. Its main goal is to investigate energy accumulation and its transformation into the energy of



accelerated particles during solar flares. The spacecraft will also determine the elemental abundance in the gamma-ray spectrum and the energy spectra of accelerated protons and nuclei, as well as the generation of light elements (deuterium, helium-3, lithium, and beryllium) during flares. Its design lifetime is three years.

On 19 March NASA selected three teams to design and subsequently to develop and build instruments for ESA's Solar Orbiter mission, one of five ESA Cosmic Vision M-class candidates. If committed by ESA, the Solar Orbiter is planned for launch in 2017 to a near-Sun orbit about a quarter of the distance to Earth. The three NASA instrument teams received \$1.7 million from NASA's Living with a Star heliophysics programme for Phase A design studies: a \$30-million Heliospheric Imager being designed by the U.S. Naval Research Laboratory; a \$34-million Spectral Imaging of the Coronal Environment imager to be developed by the Southwest Research Institute; and a \$17-million Suprathermal Ion Spectrograph to be designed by the Johns Hopkins University Applied Physics Laboratory. As announced on 20 March, seven more instruments are to be developed for ESA by Belgium, France, Germany, Italy, Spain, Switzerland, and the U.K.

NASA and ESA closed down operations of the Ulysses solar probe on 30 June after nearly 19 years of successfully observing the Sun's polar regions. It took the first measurements of interstellar dust particles and helium atoms, and discovered that the dispersal of solar particles is not solely a function of the latitude at which they are expelled from the Sun. The spacecraft, launched aboard Space Shuttle Discovery in 1990, was designed to last five years. It will continue to orbit the Sun indefinitely.

On 7 July NASA's Solar Dynamics Observatory (SDO) was shipped from builder Goddard Space Flight Center to the Kennedy Space Center in preparation for its November launch by a United Launch Alliance Atlas-V rocket. The first mission in NASA's "Living With a Star" programme, SDO is to image the Sun during its five-year mission in multiple wavelengths at a resolution ten times better than high-definition television: 4,096 x 4,096 pixels. It is expected to give in-depth, real-time information about changes in the Sun's magnetic field and the causes of the 11-year solar cycle. The 3.2-tonne spacecraft carries three primary instruments: the Atmospheric Imaging Assembly, built by Lockheed Martin; the Extreme Ultraviolet Variability Experiment, built by the University of Colorado, and the Helioseismic and Magnetic Imager, built by Stanford University and Lockheed Martin. The three instruments transmit about 1.5 terabytes of information daily at a rate of 150 MB/sec - - more data in 2 months than are stored in the entire U.S. Library of Congress - and SDO is therefore the first operational scientific satellite to employ Ka-band communications. Its total life-cycle cost is \$850 million.

### **C. Space Exploration**

On 24 November 2008 NASA approved development of the Juno mission to Jupiter, planned for launch in August 2011 and to reach Jupiter by 2016. The solar-powered spacecraft, the first outer-planet mission not to rely on a nuclear radioisotope power system, will study Jupiter's formation, composition, and structure. It will fly in an elliptical orbit, avoiding the highest-intensity regions of the planet's powerful magnetic field, in order to minimize damage to its solar cells. The \$1-billion+ project,

to be managed by the Jet Propulsion Laboratory, includes spacecraft construction by Lockheed Martin Space Systems, nine instruments to be developed and built by various teams in the U.S. and Europe, and launch by a United Launch Alliance Atlas-V. Juno is NASA's second New Frontiers mission; the first was the 2006 New Horizons mission to Pluto (see prior reports).

On 11 February NASA and ESA agreed to jointly pursue a new outer planets mission that would send separate U.S. and European spacecraft to visit the four largest moons of Jupiter, *circa* 2026. Meanwhile, the agencies also will work together on a less mature mission concept for visiting Saturn's moons Titan and Enceladus, which would include a NASA orbiter and an ESA lander and research balloon that would descend to Titan's cloud-shrouded surface.

The two spacecraft of the Europa Jupiter System Mission would launch on separate rockets from different locations in 2020, arriving at the Jupiter system six years later. NASA's orbiter, currently called Jupiter Europa, would have an estimated mass of 5 tonnes and would launch on an Atlas V. It would conduct four flybys of the Jovian moon Io and several of Callisto before settling into orbit around Europa. The spacecraft will produce global maps of Europa detailing the moon's topography, surface composition, and subsurface makeup via ground-penetrating radar. It will be able to transmit a tremendous amount of data back to Earth, which Galileo could not do because of its antenna problem. Total mission cost to NASA is estimated at \$2.5 billion to \$3 billion.

Meanwhile, ESA's spacecraft, initially named Jupiter Ganymede or LaPlace, would enter a "resonance" orbit between Ganymede and Callisto. Cost of this mission to ESA is estimated at \$1 billion; however a final commitment to proceed awaits ESA's 2011 decision *vis-a-vis* two other missions competing for ESA funding of \$836 million: the International X-Ray Observatory and the Laser Interferometer Space Antenna (Lisa; see prior reports). Both NASA and ESA spacecraft would spend nearly a year orbiting their respective targets.

India's Chandrayaan-1 entered lunar orbit on 8 November, 2008. Launched on 21 October 2008 and placed into a lunar transfer orbit (see last year's report), the spacecraft entered its final 100-km circular lunar orbit on 13 November 2008 after three more maneuvers. The Indian Space Research Organization (ISRO) reported that the spacecraft had begun remote sensing of the surface that day, and that all of its systems were functioning normally. It then released a 34-kg Moon Impact Probe to the surface of the Moon's southern polar region on 14 November, to relay imagery, altitude information, and spectral data back to Earth through the Chandrayaan-1 mother ship. The spacecraft's Lunar Laser Ranging Instrument, which measures the height of mountains and depth of craters, was activated on 16 November.

A temporary setback occurred on 25 November, when there was a sudden surge of temperature in Chandrayaan-1, to 49 degrees Celsius. Because the high temperature might have affected the performance of many of the orbiter's instruments, most of them were switched off and then turned on only one at a time, with all redundant instruments remaining off. This action was successful in reducing the temperature to 40 degrees Celsius. All instruments completed testing satisfactory

by the end of November, and Chandrayaan-1 began its planned 2-year operational mission.

On 29 August ISRO lost communications with Chandrayaan-1, apparently due to a computer malfunction. The abruptness of the failure was a surprise, as there were no prior indications that the spacecraft was under any stress. Efforts to restore communications during the next two days failed, and ISRO declared the spacecraft to have no further scientific value. The failure was subsequently traced to overheating of the satellite's electronics due to underestimating the temperature that would be encountered in its initial 100-km mapping orbit. ISRO contacted NASA to keep track of the orbiting spacecraft. Then on 2 September the American Institute of Aeronautics and Astronautics (AIAA) selected the Chandrayaan-1 mission as the recipient of an annual AIAA SPACE 2009 award, which recognizes key contributions to space science and technology. The AIAA is the U.S. representative to the International Astronautical Federation and the International Council on the Aeronautical Sciences.

On 24 September *Science* magazine's website published a report that data from three spacecraft indicate the widespread presence on the Moon's surface of water or hydroxyl. For decades, the Moon has been regarded as a completely dry place, with the possible exception of permanently shadowed craters near the Moon's poles, as announced earlier by NASA. If water is somehow more widespread, it could make future settlement of the Moon easier, especially if significant water could be extracted just by heating the soil. Oxygen is also essential for breathable air, and hydrogen and oxygen can also be used as a rocket propellant or for power generation.

Two days after having its orbit raised to 200 km on 19 May, Chandrayaan-1's Moon Mineralogy Mapper instrument, built by NASA, had found for the first time sure-fire clues of the presence of water and ice in the polar regions of the moon. The data on sunlight reflected off the Moon's surface indicated a dip at a wavelength where water and hydroxyl absorb infrared light. It was estimated that this represented a concentration of about one liter of water per cubic meter of lunar soil and rock. This observation was confirmed by re-examination of data from NASA's Cassini spacecraft when it passed the Moon in 1999 en route to Saturn, indicating signs of water or hydroxyl, mostly at the poles, but also at lower latitudes. Data from NASA's Deep Impact spacecraft (see prior reports) also found infrared absorption at the water and hydroxyl wavelengths, with the quantity of water varying with temperature. That suggests the water is being created when protons from the solar wind strike the lunar surface, freeing oxygen atoms in the regolith to combine with protons and electrons to form water. The nature of the data suggests that this reaction could only occur within a surface layer about 1 mm deep. More recent data collected on 8 September by the Russian Lunar Exploration Neutron Detector aboard NASA's Lunar Reconnaissance Orbiter further confirmed the presence of hydrogen, probably in lunar ice, in areas outside the permanently shadowed craters at the lunar south pole.

India announced on 4 December 2008 that they are seeking international partners for a 2015 sample-return mission to the Moon, to be designated Chandrayaan-3. Still in the concept phase, Chandrayaan-3 will not see any implementation work until the 2012 launch of Chandrayaan-2, a joint lunar lander and robotic rover mission with Russia (see last year's report).

On 6 December 2008 the ISRO and the Russian Space Agency Roskosmos signed a Memorandum of Understanding (MoU) to share critical equipment for an Indian Man Mission to the Moon. Both countries will jointly build the spacecraft for the mission, and an Indian astronaut will fly in a Russian spacecraft within the next five years. India will redesign the Russian space capsule Soyuz to send its astronaut on the joint manned space mission, which is expected to be a civilian flight without any military flavor. A scientist or engineer will participate in the mission.

Then on 3 January ISRO announced details of the mission. It will employ an India-built 3-tonne capsule orbiting Earth at 400 km for up to 7 days with a two-person crew. The capsule is being designed to carry a crew of three, and is planned to be upgraded to permit rendezvous and docking operations. Total programme cost is estimated at \$2 billion over the eight-year period from 2007 to 2015. Launch is planned for 2013 via ISRO's Mark 2 version of the agency's Geosynchronous Satellite Launch Vehicle (GSLV), which employs an indigenous cryogenic upper-stage engine in place of the Mark 1's Russian-built engine. The mission will require a new pad at the Satish Dhawan Space Centre and an astronaut training facility in Bangalore.

On 1 March China's lunar probe Chang'e-1 was guided to a controlled crash on the Moon after completing its 16-month mission, four months longer than originally planned (see prior reports). It had collected 1.4 terabytes of data, including images of the lunar surface and maps of its composition. The spacecraft was under remote control by two observation and control stations in east China's Qingdao and Kashgar.

Japan's Kaguya lunar orbiter (see prior reports) ended its 21-month mission when it was guided to a collision with the Moon on 10 June at a speed of 1.6 km/sec and an angle of 10 degrees, near the Gill Crater at 80.4 degrees east longitude and 65.5 degrees south latitude. The landing was precipitated from Kaguya's final 10 – 30 km orbit by a 140-second thruster burn over the north pole. Researchers studied its impact site to watch how radiation and micrometeoroids weather the newly exposed lunar soil over time. The impact was photographed by telescopes on Earth, and observers saw the plume of dust it raised.

NASA's Lunar Reconnaissance Orbiter (LRO) and Lunar Crater Observation and Sensing Satellite (Lcross) were launched by a United Launch Alliance Atlas 5-401 rocket from Cape Canaveral on 18 June. The 1.916-tonne LRO, built and managed by NASA's Goddard Space Flight Center, carries seven instruments to map the Moon areas that could be bases for future human exploration teams. Coordinating with data from India's Chandrayaan-1, China's Chang'e-1, and Sweden's Odin, they will also provide data on the Moon's origins and changes that have occurred in the 40 years since the Apollo missions. The \$600-million LRO was expected to have mapped the entire surface of the Moon from its 50-km orbit by the end of this year, with special emphasis on the polar regions.

LRO's experimental 13-kg synthetic-aperture radar (Mini-RF) is refining Chandrayaan-1's data on ice, water, and other hydrogen-bearing compounds. The Russian-built Lunar Exploration Neutron Detector (LEND) is producing high-resolution hydrogen maps based on neutrons emitted when cosmic rays strike the lunar surface. The Lyman-Alpha Mapping Project (LAMP), an imaging ultraviolet

spectrometer, is searching for water frost in the Moon's permanently dark regions. Detailed topographical maps of the surface are being generated by the Lunar Orbiter Laser Altimeter (LOLA) and the Lunar Reconnaissance Orbiter Camera (LROC). The Cosmic Ray Telescope for the Effects of Radiation (Crater) is mapping the radiation environment, and an infrared filter radiometer (Diviner) is mapping global day and night surface temperatures. LRO communicates with scientists back on Earth using a 33-cm Traveling Wave Tube Amplifier that can send information at a rate of up to 100 MB/sec and is the first high-speed data transmitter of its kind to fly on a NASA spacecraft.

On 20 August LRO teamed up with Chandrayaan-1 to perform a bi-static radar experiment searching for water ice in a permanently shadowed crater on the Moon's north pole. The two instruments looked at the same location from different angles, with Chandrayaan-1's radar transmitting a signal that was reflected off the interior of Erlanger crater, and then picked up by LRO. While this coordination sounds easy, the experiment was extremely challenging because both spacecraft were traveling at about 1.6 km per second and were looking at an area on the ground about 18 km across, requiring extensive tracking by ground stations of NASA's Deep Space Network, the Applied Physics Laboratory, and ISRO. However, it was reported on 2 September that programming problems on the U.S. Mini-SAR instrument aboard Chandrayaan-1 prevented the device from sending a radio pulse, and later analysis showed that even if Mini-SAR had released the pulse, the signal would not have reached its target because Chandrayaan-1's orientation was drifting more rapidly than anticipated. Mini-SAR operators had developed a fix for both issues, but not before the end of the Chandrayaan-1 mission (see above).

On 18 September, while LRO was making the first complete temperature map of the moon, it found that at the Moon's south pole, inside craters that are permanently shadowed, it is colder than far-away Pluto. Temperatures there were measured at -238 degrees Celsius (35 Kelvins). LRO also found many indications of hydrogen, which could indicate trapped ice below the Moon's surface.

The 901-kg Lcross spacecraft, attached to a ring on the booster rocket that remained attached to the Atlas's Centaur upper stage, was released when LRO reached its first 240-km x 25-km elliptical lunar orbit on 23 June. It then did a flyby of the Moon at a distance of 3,200 km and entered an elliptical Earth orbit, where it remained for over 60 days. On 22 August an anomaly in Lcross's inertial reference unit caused it to lose an estimated 140 kg of its propellant, almost half its full complement of 306 kg. However, NASA claimed that the spacecraft was carrying more propellant than it needed and still had enough left to complete its mission.

The Centaur stage was separated from Lcross on 9 October and set on a course to plunge into the Cabeus crater on the Moon (see below). The \$80-million Lcross spacecraft followed about 300 m behind it, and for the next hour had its instruments turned on, calibrated, and stabilized at a temperature of 21 degrees Celsius. Lcross's instruments consisted of five cameras (four infrared and one visible-light), three spectrometers, one photometer, and a data-handling unit.

The original Lcross target crater was Cabeus A, but on 28 September NASA changed it to the larger Cabeus crater. The decision was based on a continuing

analysis of recent data from Moon-orbiting spacecraft, which suggested that the new target Cabeus has the highest concentration of hydrogen of any other location at the lunar south pole. Cabeus is a large crater about 98 km in diameter located at the Moon's south pole, at 84.9 degrees south, 35.5 degrees west. It has two nearby satellite craters: 40-km Cabeus A, Lcross' original target, and Cabeus B, which is about 61 km in diameter.

Lcross observed the 2-tonne Centaur stage as it plunged into the Cabeus crater on 9 October at about 2.5 km/second, and analyzed the resulting 1.6-km-high lunar-debris plume, transmitting the data to Earth via LRO. Lcross then followed the Centaur into a crash landing, sending up its own plume of debris, which was analyzed by LRO's instruments and a number of Earth-based telescopes. LRO received the data about 90 seconds after Lcross's crash into the crater.

NASA signed a launch contract with Orbital Sciences Corporation (USA) on 14 September for the agency's Lunar Atmosphere and Dust Environment Explorer (LADEE). The spacecraft, which will measure the global density and composition of the lunar atmosphere from a lunar orbit, is scheduled to be launched in 2012 aboard a five-stage Minotaur-5 rocket. The Minotaur-5, a new configuration, uses excess U.S. military Peacekeeper missile hardware for its first three solid-propellant stages and commercial solid-propellant motors for its upper two stages. It can lift up to 650 kg into a geosynchronous transfer orbit or 400 kg to Earth escape. The LADEE mission will be its first launch.

On 13 November 2008, NASA scientists completed two weeks of testing at Mauna Kea, Hawaii, as part of NASA's lunar In Situ Utilization Project. The site, the University of Hawaii's Pacific International Center for Exploration Systems, was chosen for its lunar-like soil conditions. The system included three machines: a prospecting dune buggy robot called Scarab, equipped with a drill to sample soil, and two complementary production machines that can siphon off the oxygen and hydrogen elements. During the test the system produced oxygen at levels that would be required for a lunar outpost, indicating that lunar astronauts may be able to manufacture their own oxygen and water supplies from lunar rocks and soil.

On 26 May a team from the U.S. Geological Service (USGS) and Zybek Advanced Products (USA) created a synthetic regolith, virtually identical in composition to the Moon's surface. This version supersedes previous versions, since it is closer to the real material and can be produced at a much faster rate. NASA has contracted with USGS and Zybek to produce mass quantities, in order to stage and practice lunar exploration and studies on Earth before deployment of a human mission to the Moon. Four tonnes of the material were expected to have been made by the end of the summer.

Team "Part-Time Scientists" (Germany) on 24 June became the 19<sup>th</sup> team to compete for the Google Lunar X-Prize, and the first from Germany. And on 21 September a group of Russian engineers and managers known as "Team Selenokhod" announced that they too will compete for the prize, the first Russian team in the competition. Their vehicle, Selenokhod, consists of a lander with a communications system and two four-wheeled solar-powered rovers, each equipped with a high-definition camera and a low-gain antenna.

Goal of the international competition (see prior reports) is to land a robot on the Moon, travel 500 m on the surface, and transmit images and data back to Earth. The teams have until 31 December 2012 to claim the \$20-million grand prize, after which the prize drops to \$15 million until 31 December 2014. One of the competitors, Odyssey Moon, announced at a conference on 29 July that they had signed up five customers for payloads on their vehicle, called MoonOne. One of the members of The Next Giant Leap team, students at MIT's Space Systems Laboratory, unveiled in June a prototype robot designed to hop across the lunar surface. A third Google Lunar X-Prize team, Astrobic Technology, announced at the 29 July conference that they had already built three prototype rovers for their first mission, Tranquility Trek, scheduled to be launched in May 2011 to visit the Apollo 11 landing site and transmit imagery showing the effects of weather, radiation, and meteor bombardment on the equipment left there. A fourth team, Frednet, discussed their development of multiple Moon rovers, including a 72-gram ball based on a Lego Mindstorm model kit and a 4-kg rover.

On 12 September Armadillo Aerospace (USA) qualified to win the Level-2 \$1 million Northrop Grumman Lunar Lander Challenge prize by accomplishing a rocket-powered round trip modeled after a moon landing. The company completed all the qualifications for Level 2 of the Challenge, in which contestants' landers have to travel to and from two launch pads 50 m apart strewn with mock lunar rocks and reach an altitude of 50 m. Entries also had to hover for a minimum of three minutes during each leg and complete the course in 135 minutes, with at least 3 minutes of flying time to simulate the time required to go from lunar orbit to the surface. Masten Space Systems (USA) qualified for the \$150,000 Level-1 second prize on 7 October, with two 90-second flights of the company's 3.8-kN thrust Xombie rocket. The competition, which is funded by NASA, was to close on 31 October, with one other team, Unreasonable Rocket, planning to fly by then.

On 10 November 2008 NASA announced that the Phoenix Mars lander had shut down for good. The probe had lasted well past its planned 90-day lifetime, which ended in August, and met all its original objectives (see last year's report). Phoenix made its final radio contact on 2 November 2008, after which neither the Mars Reconnaissance Orbiter nor the Mars Odyssey spacecraft were able to make any further contact with it.

On 13 November 2008, after four days of no communications from Mars, NASA's Spirit rover radioed back to Earth that it had survived a nasty Martian dust storm that had obscured its solar panels and reduced its battery power to a level insufficient for operation of its communication system. The rover's batteries were indeed low, but were working. Then, in April, the rover suffered a number of behavioral problems – episodes of amnesia, computer resets, and failure to wake for communications sessions. These all seemed to work themselves out, but in early May Spirit bogged down in soft Martian soil at a site named Troy, sinking its five working wheels about halfway into the ground. On a positive note, wind had removed some of the dust from the rover's solar panels, making more power available to implement any fix that controllers could devise. But after months of devising and testing methods for freeing Spirit from the quagmire, and another dust storm in August that again reduced its power output, on 14 September NASA finally announced that they may never be able to succeed. Nevertheless, a last-ditch attempt was to be made in late October.

Until it bogged down, Spirit had operated successfully for over five years in a mission that was originally planned to last for three months.

On 28 July NASA's Mars rover Opportunity discovered the largest meteorite yet found on Mars. Named Block Island, the iron-nickel meteorite is about 60 cm high and 30 cm long, and is roughly ten times as massive as the previous record-holding iron-nickel meteorite, Heat Shield Rock, found in 2004.

NASA's Mars Reconnaissance Orbiter's (MRO's) radar discovered several dirt-covered water-ice glaciers in the southern hemisphere's Hellas Basin, according to a 20 November 2008 report. One of the glaciers is believed to be almost a km thick; another appears to be about three times the size of the U.S. city of Los Angeles. The radar readings showed no signs of significant rock debris within the glaciers, suggesting that they are relatively pure water ice. The rocky debris that covers the ice is probably what kept it in place and allowed it to survive below the surface for millions of years. It was concluded that these glaciers may represent the largest non-polar-cap reservoirs of water ice on Mars.

Then on 23 February MRO put itself into a protective "safe" mode due to a voltage "spike" that rebooted its computer, probably caused by a high-energy cosmic-ray burst. NASA engineers ordered MRO out of the safe mode on 28 February and then restored full science operations on 2 March.

On 24 September NASA's Jet Propulsion Laboratory (JPL) announced that MRO's radar instrument, looking below the surface of the Mars' north-polar ice cap, had found data that confirm theoretical models of Martian climate swings during the past few million years. The new three-dimensional map used 358 radar observations to provide a cross-sectional view of the north-polar layered deposits. These ice-rich layered deposits cover an area one-third larger than the U.S. state of Texas and form a stack up to 2 km thick atop a basal deposit with additional ice. Earlier radar observations had indicated that the Martian north-polar layered deposits are mostly ice. The new radar results show that high-reflectivity zones, with multiple contrasting layers, alternate with more homogenous zones of lower reflectivity. Patterns of how these two types of zones alternate can be correlated to models of how changes in Mars' tilt on its axis have produced changes in the planet's climate in the past 4 million years. These deposits on Mars, which appear to be almost pure water ice with only about 1% contamination by dust, hold about one-third as much water as Earth's Greenland ice sheet. In five mid-latitude sites MRO had found ice just below the surface, 50 cm to about 2.5-m deep.

Lockheed Martin (USA) unveiled the heat shield for the Mars Science Laboratory on 16 June. At 4.5 m diameter, it is the largest heat shield ever built for a Mars probe, and larger than the 4-m Apollo heat shield, which protected U.S. astronauts on their return to Earth from the Moon. It will protect the laboratory's rover vehicle, named Curiosity, from the Mars entry temperature, which could reach 2,100 C. Its protective surface is phenolic impregnated carbon ablator (PICA), which was flown on NASA's Stardust mission that returned to Earth in 2006 (see prior reports). Curiosity will use a new type of landing sequence on Mars. After the heat shield has done its job and has been jettisoned, a "sky crane" will conduct a powered descent



with thrusters. It will lower the Curiosity rover to the surface on cables, and then fly itself off to a crash landing. The launch of Curiosity is scheduled for the fall of 2011.

On 28 January the French space agency CNES proposed a redesign of ESA's 2016 ExoMars lander and rover mission, recommending a substantial downsizing to accommodate the budget constraints expected to be imposed at the late-year ESA governments meeting. The previous meeting, in November 2008, had rejected a \$1.55-billion ExoMars proposal. CNES said that downsizing now was preferable to risking later programme cuts that could prejudice the 2016 launch schedule.

CNES and Russia's space agency Roskosmos signed an agreement on 17 June to cooperate on Russia's Phobos-Grunt mission to land on Mars' moon Phobos and return soil samples to Earth. Under the agreement France will provide a gas chromatograph and a laser spectrometer as part of the Gas Analytic Package to be managed by Russia's Institute for Space Research (IKI). The mission includes a lander equipped with an Earth return module; it will conduct *in situ* soil analyses and collect the samples to be returned to Earth. The agreement "raises the possibility" that France will also receive soil samples. The mission will also carry a small 110-kg Chinese Mars orbiter called Yinghuo-1, which will study the Mars ionosphere, its plasma environment, and the atmosphere's ion escape mechanisms.

Phobos-Grunt was originally planned for launch on 6 October aboard a Zenit rocket from the Baikonur Cosmodrome. However, despite all efforts, the probe's flight control systems needed more tests before they could be considered reliable enough to survive a complex multi-year mission, so on 21 September the launch was postponed to the next Mars launch window, in 2011. And because the same personnel and facilities employed in the preparation of the Phobos-Grunt project will be needed for subsequent missions such as the Luna-Glob probe, these later missions may also be delayed.

ESA also signed an agreement with Roskosmos on 19 August to cooperate on two Mars exploration projects. ESA will use Russia's Proton rocket for the Exomars project to send a robotic rover to the Mars surface (see prior reports) and will buy Russian parts for the rover's power supply system, while the Phobos-Grunt spacecraft will use ESA's terrestrial communication facilities during its mission.

On 8 December 2008 NASA Associate Administrator Ed Weiler and ESA's David Southwood agreed to rework their individual Mars exploration programmes into a single programme, with launches that would flow from a commonly agreed set of priorities for each mission, and the two agencies would share the costs. They agreed that a joint exploration programme that looks to 2016 and beyond will still need input from existing groups, such as the International Mars Exploration Working Group. Subsequent developments of this cooperation are discussed below, in Section VIII of this report.

NASA's Dawn spacecraft received a gravity assist during a Mars flyby on 17 February, boosting its speed by 2.6 km/second and adjusting both its flight path angle and inclination with respect to the ecliptic plane. It was launched in September 2007 (see prior reports) on an eight-year mission to explore asteroids Vesta and Ceres. Its encounter with Vesta will occur in 2011.

On 17 August NASA discovered that glycine, the simplest amino acid and a vital compound necessary for life, had been identified in a sample from the coma of comet Wild 2, collected from the Stardust mission (see prior reports). The discovery strengthens the argument that life in the universe may be common, rather than rare, and that comets may have delivered amino acids to a young Earth. However, since glycine is used by terrestrial life, contamination from Earth sources might have been the source. Nevertheless, the analysis for different carbon isotopes revealed that the Stardust samples had more of the heavier Carbon 13 atoms than glycine from Earth, which is typical of glycine samples from space. Europe's Rosetta spacecraft should help shed more light on the issue when it lands on the nucleus of Comet 67P/Churyumov-Gerasimenko in 2014 (see prior reports).

On 4 May NASA announced their commitment to develop and fund two ESA planetary-mission instruments. The \$32-million Strofio mass spectrometer will probe the composition of Mercury's thin atmosphere aboard ESA's 2013 Bepi-Colombo mission, and \$6.6-million was allotted to use the agency's Deep Space Network to relay data transmitted by the ExoMars lander, for analysis of the structure of Mars' interior. The Strofio instrument is being developed by the Southwest Research Institute (USA), and the Deep Space Network project is being managed by NASA's Jet Propulsion Laboratory.

ESA decided on 4 February to extend the missions of Mars Express, Venus Express, and Cluster until 31 December 2009. Mars Express was launched in June 2003; Venus Express in November 2005, and the four-satellite Cluster constellation, which is studying the Earth's magnetosphere, was orbited in the summer of 2000.

On 3 March NASA's Jet Propulsion Laboratory announced the discovery by the Cassini spacecraft of a tiny (0.5-km) moonlet in Saturn's faint G-ring. Up to now, the G-ring was the only Saturnian ring not associated with a known moon. The discovery was based on the analysis of images taken by Cassini in August 2008, because the moonlet is too small to be directly observed by Cassini's cameras.

NASA's Messenger spacecraft, on its way to explore Mercury (see last year's report), conducted its third and final gravity-assist flyby of the planet on 29 September. Passing within 227 km of Mercury, the spacecraft's trajectory was adjusted to enable its insertion into Mercury orbit on 18 March 2011. During the flyby Messenger's controllers conducted extensive observations of the planet that built on the discoveries of the first two flybys (see prior reports). During the three flybys Messenger has now mapped 95% of Mercury's surface.

Controllers at the Japan Aerospace Exploration Agency JAXA restarted one of the ion engines on the agency's Hayabusa asteroid sample-return spacecraft on 4 February, following a coast period that has lasted since 18 October 2007 (see prior reports). There was enough xenon propellant aboard to provide the 400-m/sec velocity increment needed for an Earth return. Hayabusa's reaction wheel was also restarted, establishing 3-axis control of the spacecraft.

## **VI. TECHNOLOGY ADVANCEMENT**

### **A. Propulsion**

#### **(1) Earth to Orbit**

##### Solid-Propellant Rockets

The 2.25-MN rocket motor for the Launch Abort System to be used for rescuing astronauts aboard NASA's Orion crew exploration vehicle in the event of a launch accident (see last year's report) underwent its first test firing on 20 November 2008. The motor was built and tested by Alliant Techsystems (ATK) under subcontract to Orbital Sciences Corporation (OSC), both USA. The 5.1-m motor fired for 5.5 seconds, and its four nozzles generated a thrust of over 2.25 MN almost instantaneously upon ignition. But on 11 August Orion prime contractor Lockheed Martin assumed management control of the 31-kN Launch Abort System steering motor from Orbital Sciences.

Then on 4 December 2008 ATK test-fired a 4-segment space shuttle booster motor for a full Shuttle-equivalent launch duration of two minutes, to evaluate possible performance changes due to aging and to collect acoustic data for the five-segment Ares-1 launch vehicle. The test motor, at 7.5 years of age, was the oldest reusable solid-propellant rocket motor ever fired. Thirty-one microphones were used to collect the acoustic data for Ares-1.

A mechanical failure in the ground controller unit that sends power to the hydraulic system which moves the rocket's nozzle forced ATK on 27 August to call off the first test firing of the Ares-1's first-stage rocket motor, ending the test 20 seconds before the rocket fired. The failed component was replaced and a new test, the first of seven required to qualify the engine for flight, was conducted successfully on 10 September to evaluate 46 design objectives through 650 instrument channels. The motor developed 16 MN of thrust and burned 450 tonnes of propellant during the 123-second test firing.

The test firing also yielded data indicating that the rocket won't shake apart or endanger astronauts in flight. Early computer analysis had indicated that the rocket could produce severe vibrations that could affect the crew and the rocket (see last year's report). But based on the actual test data, it was concluded that the amount of mitigation needed, if any, will be small, and that the systems designed to mitigate the thrust oscillation are probably 10 times more than is needed. That "fix," called a "dual-plane isolator," consists of springs inserted between the Ares-1's first stage and upper stage and between the upper stage and the Orion crew capsule. NASA announced on 15 September that the springs were flight-proven technology, with the spring tension modeled to take care of 98% of the thrust oscillation. NASA also announced plans to use a backup fix that employs the mass of the vehicle's upper-stage liquid oxygen propellant to damp out vibrations. If this proves successful during tests late this year, it would eliminate the need for springs between the upper stage and the Orion capsule.

On 24 February Alliant Techsystems (ATK, USA) announced that hot-fire tests run in December 2008 marked the completion of an eight-year project to develop and produce a new solid-propellant rocket-motor design. Implemented under the U.S. Air Force Research Laboratory's (AFRL's) Integrated High Payoff Rocket Propulsion Technology (IHRPT) programme to improve U.S. solid-propellant rocket propulsion systems for multiple applications, the Phase-2 motor developed 79 kN thrust on its final 30-second test run. It had contained over 900 kg of high-energy solid propellant in its 94-cm diameter composite-material casing.

The U.S. Air Force Office of Scientific Research (AFOSR), NASA, Purdue University, and Pennsylvania State University announced on 21 August the successful trial launch of a small rocket using a new environmentally friendly propellant. Named Alice, the new propellant is composed of nanoscale aluminum powder and water ice. It is formed by cooling aluminum powder and water to a temperature of -30 degrees Celsius, reaching a consistency of toothpaste, 24 hours prior to flight. The test launch of a 3-m long rocket at Purdue University developed a thrust of 2.9 kN and achieved an altitude of 300 m. The new propellant is claimed to have higher performance than conventional propellants, and might be most useful on the Moon or Mars, where it could be manufactured using *in situ* materials.

### Liquid-Propellant Rockets

The first mission-duration test of Space Exploration Technologies Corporation's (Space-X's) Falcon-9 core-stage engines was conducted successfully at Space-X's McGregor Test Facility, Texas, on 22 November 2008. The 9-engine cluster ran for 178 seconds, developing a thrust of over 3.9 MN. Two engines were then shut down to simulate actual flight operations, leaving the remaining seven to continue firing for another 18 seconds. Final qualification test runs of the core-stage engines were conducted for 10 seconds on 12 October and for 30 seconds on 16 October, and they were then shipped to Cape Canaveral in November. The Falcon-9 vehicle has been contracted under NASA's Commercial Orbital Transportation System (COTS; see above and last year's report). The Falcon 9 launch vehicle was successfully raised to vertical in January at Space Launch Complex 40 (SLC-40) in Cape Canaveral, Florida.

On 17 June ESA signed a \$28 million contract rider with the Joint Propulsion Team consortium composed of Avio SpA (Italy), Astrium GmbH (Germany), and Groupe SAFRAN of Snecma (France), for the development of the future liquid-propellant engine demonstrator for the European Next Generation Launcher first stage, the High Thrust Engine Demonstrator. The project will include technologies for advanced subsystems to reduce cost and enhance reliability, along with integrated system demonstrator studies aimed at selecting the reference design by mid-2010 and conducting hot-fire tests of a mid-scale engine demonstrator around 2014.

Aerojet (USA) announced on 27 August the company's plans to re-start production of the Soviet-era NK-33 engine that is being modernized for use on Orbital Sciences Corporation's (USA) Taurus-2 rocket (see last year's report). Aerojet has 37 of the liquid oxygen-kerosene NK-33 engines on hand, plus a number still in Russia for which Aerojet has the rights, all to be modified and redesignated AJ26-62. The current stock would be sufficient for 10 – 12 years of Taurus-2 operations, but

potential demand growth, including possible use of the engine for the projected Soyuz-2 and -3, could motivate restarting their production in three to five years, either in Russia or in the U.S. The benefits of Russian production vs starting up a new line in the U.S. include lower cost and earlier availability.

On 1 October a test firing of the Universal Rocket Module (URM)-1 for Russia's Angara family of launch vehicles currently under development took place at the Rocket and Space Industry Research and Testing Center near Moscow. The test verified the engine performance at its maximum power level. The second in a series of firing tests planned for the URM-1, it lasted 203.4 seconds.

### Hybrid Rockets

On 22 January the Rocket Motor Two (RM2) propulsion system for Virgin Galactic's SpaceShipTwo [SS2] suborbital vehicle successfully completed hot firing tests. Runs were subsequently conducted on 20 April, 6 May, 20 May, and 28 May to evaluate several different fuels, igniters, injectors, insulators and nozzle configurations, as well as other components and parameters. Each of the tests was claimed to have met all of its objectives. The hybrid rocket, which uses nitrous oxide oxidizer and a solid fuel, was operated on the test series by Scaled Composites, builder of SpaceShipTwo, and engine subcontractor Sierra Nevada Corporation, which had acquired the original engine subcontractor, SpaceDev. Prior cold-flow testing of the engine had resulted in an explosion (see last year's report). SS2 flight tests are planned for the end of the year.

### Advanced Propulsion Technologies

On 8 May Pratt & Whitney Rocketdyne (PWR; USA) completed a series of 10 full-duration free-jet tests at Mach 4 on a baseline combined-cycle (ramjet/scramjet) engine. Sponsored by the U.S. Defense Advanced Research Projects Agency (DARPA) under their Falcon Combined-Cycle Engine Technology (Facet) programme, the successful tests pave the way for a future reusable Mach-6 space-vehicle launcher that could take off from and land on a conventional runway.

The University of Rome (Italy) reported in January a series of successful tests on supersonic combustion ramjets (scramjets) using lithium hydride (LiH) as fuel. Previous scramjet tests had used hydrogen and hydrocarbon (jet) fuels such as JP-7 (see prior reports). With 14.3% mass fraction of hydrogen, LiH represents a high-density fuel prospect, much more practical than the very low-density hydrogen itself. The research was conducted as part of the European Commission's Long-Term Advanced Propulsion Concepts and Technologies (Lapcat) hypersonic transport programme (see last year's report).

On 19 February Reaction Engines Limited (REL, UK) was awarded a \$1.6-million ESA contract for the Experimental Investigation of Key Technologies for a Turbine Based Combined-Cycle Airbreather Rocket Engine. The ESA contract is part of a total programme value of almost \$10 million.

NASA's Johnson Space Center and Ad Astra Rocket (Costa Rica) signed a Space Act Agreement on 8 December 2008 for the development of the Variable

Specific Impulse Magnetoplasma Rocket (VASIMR), leading to a test flight aboard the International Space Station with the goal of demonstrating its capability as a station reboost propulsor. The VASIMR, conceived and developed under the direction of former U.S. astronaut Franklin Chang-Diaz, consists of three linked magnetic cells: a plasma source cell to inject and ionize the propellant gas to form a plasma; a radio-frequency booster cell to amplify the plasma energy to the required temperature; and a magnetic nozzle cell to accelerate the plasma exhaust. This configuration has the ability, unique among electric rockets, to vary both the thrust and specific impulse. Following a series of development tests with ever-increasing power levels, the flight test version, designated VF-200-1, was designed to consume 200 kW of power. As of June, the experimental version of this configuration, the VX-200, had achieved a power level of over 149 kW, using a superconducting magnet operating at -268 degrees Celsius manufactured by Scientific Magnetics (UK), and on 30 September the VX-200 testbed reached a peak power of 201 kW, 1 kW over its design rating.

On 5 August NASA finished testing a new more powerful and fuel-efficient ion propulsion system for earth-orbiting and interplanetary spacecraft. It was built under the NASA Evolutionary Xenon Thruster (NEXT) programme led by the Glenn Research Center, who could start building a mission-ready version of the engine by January 2010, taking about 36 months to complete.

ESA released early test results on 18 March of a new ion thruster claimed to be the smallest, most controllable engine ever built for space use: three orders of magnitude smaller than current designs. The Field Emission Electric Propulsion (FEEP) engine, slated for ultra-accurate station-keeping of the ESA/NASA Laser Interferometer Space Antenna (Lisa) planned for launch next year, has a thrust range of 0.1 – 150  $\mu\text{N}$ , a thrust resolution better than 0.1  $\mu\text{N}$ , and a timer response faster than 190 msec. The 10-cm thruster's liquid cesium propellant is forced by capillary action between a pair of metal plates ending in a slit 1 micron wide, where the cesium is held until an electric field is generated. The field creates tiny cones in the liquid metal and drives positive ions from their tips to generate thrust.

## **(2) Upper Stages and Orbit Transfer**

NASA's Marshall Space Flight Center completed the critical design review for the J-2X on 13 November 2008. The upper-stage engine for the Ares-1 crew launch vehicle was the first element of NASA's Constellation Programme to pass the design review milestone, signaling the beginning of manufacturing and full-scale testing. That testing will begin in the fall of 2010.

On 8 December 2008, Aerojet completed testing of a new Advanced Materials Bipropellant Rocket (AMBR), a 670-N thrust engine that weighs the same as a 445-N-thrust configuration by using a new injector and pre-combustor design with an iridium-lined rhenium combustion chamber. It burns hydrazine and nitrogen tetroxide at pressures and mixture ratios typical of current flight engines, developing a specific impulse of 333.5 seconds during the 8 December test. Its development is being sponsored by NASA.

Aerojet also completed vibration and altitude hot-fire testing on 29 April of the MR-104G 700-N monopropellant rocket, 12 of which are planned for use on

NASA's Orion crew capsule. Besides subjecting the engine to the full vibration stresses expected during launch, the tests verified its ability to deliver an emergency-level thrust of 900 N.

SpaceX completed qualification testing on 23 April of the company's Draco thruster, 18 of which are to be used on the reusable Dragon capsule for cargo delivery to the ISS (see above). The tests involved 4,600 pulses of varying durations during 42 firings in a vacuum chamber, developing up to 400N thrust.

Early in January Pratt & Whitney Rocketdyne (USA) completed a series of 11 hot-fire tests on a modified RL-10 engine being developed under NASA's Common Extensible Cryogenic Engine (CECE) programme. The tests, aimed at demonstrating technology for the future Altair lunar lander vehicle, demonstrated combustion stability over a throttling range of 8 – 104% of the engine's rated 62 kN thrust. Total time accumulated on the 11 tests, which included simulation of a lunar landing, was 2,935 seconds.

In June Orion Propulsion, Inc. (USA) completed the qualification test programme of the Forward Propulsion System (FPS), which the company is building for Bigelow Aerospace's Sundancer space station, intended to support human presence on-orbit and serve as the cornerstone of a future Bigelow Aerospace orbital space complex (see prior reports). The innovative system runs on hydrogen and oxygen produced by the Sundancer's Environmental Control and Life Support System (ECLSS), extracting hydrogen and oxygen from waste water, sweat, and urine, so that dangerous propellants such as hydrazine are not needed.

A final two-minute test firing of the Zefiro 9A solid-fueled third-stage motor of Europe's future Vega small-satellite launcher (see prior reports) was successfully completed in Sardinia, Italy on 30 April.

The Indian Space Research Organization (ISRO) on 18 December 2008 successfully conducted the flight-acceptance test of ISRO's indigenous cryogenic upper-stage engine for the Geosynchronous Launch Vehicle GSLV- D3. Test duration was 20 seconds, during which the engine operated at 13% above its thrust rating. All engine parameters were satisfactory and closely matched the predicted performance.

## **B. Power**

After years of fruitless efforts to interest the terrestrial electric-power industry in space solar power systems, the Pacific Gas and Electric Company (PG&E), which is the largest provider of power to the U.S. state of California, asked its state regulatory agency on 18 April for permission to contract with the Solaren Company (USA) for a 200-MW satellite power constellation. Solaren's constellation of two to four satellites, planned to be operational in the geostationary orbit by 1 June 2016, are expected to use concentrators about 1 km in diameter; space-proven triple-junction gallium arsenide solar cells, which have demonstrated efficiencies of 42%; and microwave beams for power transmission to Earth. Neither the specific system design nor the satellite configuration have been released, nor have any financial terms of the contract.

Solaren was incorporated in 2001, and expects to employ existing spacecraft manufacturers to build the satellites. Baseline launch vehicles are likely to be Atlas-V and Delta-IV, and Solaren currently plans two or three launches to test their hardware plus four or five to launch the operational spacecraft. The 15-year contract with PG&E requires Solaren to obtain all necessary federal, state, and local permits and approvals, conduct the required environmental review, demonstrate system safety, and bear all the risk. PG&E's motivation for taking this action is the California requirement to produce 20% of the company's power from renewable sources by 2010, and the probable increase in that requirement to 33% by 2020. U.S. President Barack Obama's proposal for a \$150-billion U.S. green-energy programme was another incentive.

On 7 May the U.S. Department of Energy announced plans to restart the manufacture of plutonium-238 radioactive fuel for NASA's deep space missions, following a warning by the National Research Council that the nation was running out of the fuel. The agency requested \$30 million in its fiscal-year 2010 budget proposal to restart the fuel-making process, which is expected to cost about \$150 million. Requirements for the radioisotope fuel were estimated at 105 – 110 kg over the next 20 years, assuming that all future radioisotope power systems after the Jupiter flagship mission in 2017 employ the efficient Stirling engine-based designs currently under development. This would require Pu-238 production to be resumed by 2018 and provide 5.3 to 5.5 kg per year thereafter. Unfortunately, however, on 15 October the U.S. Senate deleted the \$30-million budget allocation that would have begun the process of resuming production of the isotope.

Boeing Satellite Systems International (USA) received a \$13.8-million Phase-2 contract from the U.S. Defense Advanced Projects Agency's (DARPA's) Fast Access Spacecraft Testbed programme on 2 July to ground-demonstrate a solar-concentrator power generation system. With the goal of enabling high-power, highly mobile spacecraft when used to power electric thrusters, the system is expected to generate 50 – 80 kW at specific power levels as high as 130 W/kg or more.

### **C. Spacecraft Design, Technology, and Development**

During December 2008 Northrop Grumman (USA) completed testing on a cryocooler that demonstrated the achievement of 4.4 degrees K. The device was similar to one being developed by the company for the James Webb Space Telescope, whose Mid-Infrared Instrument requires temperatures no higher than 6 Kelvins. Although ground-based cryocoolers have reached lower temperatures, 4.4 Kelvins is the lowest temperature demonstrated by a pulse tube Joule-Thomson design. This is the only cryocooler technology that has been proven to operate successfully in space, where it must meet specifications of perfect operation with no maintenance over periods up to ten years. The company is in the process of combining its cryocooler technology with an Adiabatic Demagnetization Refrigerator, a heat pump design that is claimed to be able to cool sensors down to 0.05 Kelvins. This level of cooling will be required for future space instruments such as the projected ESA/NASA/JAXA International X-Ray Observatory and NASA's planned Terrestrial Planet Finder.



On 11 March Northrop Grumman (USA) received a \$4.1-million contract to develop a wireless databus interface for satellites based on commercial technology. Goal of the 21-month Phase-1 effort, funded by the U.S. Air Force Research Laboratory, is to demonstrate a space-qualified design with a bus dry-mass reduction of 5 – 8%, half the fraction currently devoted to hard-wired harnesses. In addition to the extra payload mass that would allow, a wireless system could cut integration and testing time by half.

Advanced satellite technologies announced early in April that offer substantial mass reduction, higher power, and increased antenna apertures are stimulating the availability of new commercial communications and imagery capabilities. These include higher-resolution cameras; e.g., the 25-cm ability planned for GeoEye-2 in 2012; sharply reduced costs for broadband communications that make satellites competitive with terrestrial fiber networks; low-cost on-demand two-way-interactive media entertainment; and new personal digital assistants (PDAs) that provide personal situational awareness of the location of individuals and their family members, weather information, and geospatial imagery.

On 6 August the U.S. National Reconnaissance Office (NRO) announced that their new Colony Programme Office (CPO) is using 10-cm “cubesats” weighing 1 to 5 kg to demonstrate advanced technologies much more rapidly and at lower cost than larger satellites can. CPO has 12 cubesats in production this year and plans to purchase 20 to 50 more during the two years beginning in 2010 at a cost of about \$250,000 each. Technologies to be demonstrated include hyperspectral sensors, standardized attitude-control systems, radio-frequency modules, and structureless antenna arrays. The first cubesat launch is planned for 2010, and the NRO then plans to launch about 15 per year.

With the recent growth in interest in such small satellites, NASA’s Ames Research Center announced on the same date the initiation of their development of a new secondary payload adapter for launch vehicles that can carry up to 24 cubesats to orbit. Planned for use with small launchers such as Orbital Sciences Corporation’s Minotaur-1 and Space-X’s Falcon-1e, the 13-cm-tall disc would serve as the connector between the rocket’s upper stage and its primary payload. It is being designed to carry any combination of single or triple cubesats inside eight canisters. The U.S. Defense Department’s Operationally Responsive Space (ORS) Office has agreed to conduct testing of the device and the initial flight demonstrations.

#### **D. Materials and Structures**

Pursuing NASA’s \$4-million “grand challenge” research prize, a team at Cambridge University (UK) announced achievement of a cylindrical strand of ribbon using carbon nanotubes, for potential application to a space elevator. The team found a way of combining separate nanotubes into web-like structures that bind to form longer strands, essentially making long, thin carbon nanotubes into smoke particles that entangle and “hold hands.” In January the team was making about 1 gram of the material per day, enough to stretch about 30 km in length. The space elevator would require about 230,000 km, but the team acknowledges that there is a difference between what can be achieved in a laboratory and on an industrial level.

Arcjet testing of the phenolic impregnated carbon ablator (PICA-X) material for the heat shield of Space-X's Dragon space capsule (see above) was completed successfully at NASA's Ames Research Center late in February. Material temperatures up to 1850 degrees Celsius were reached during the tests. PICA-X will also be employed on the second stage of Space-X's Falcon-9 launcher, which is designed for return to Earth and reuse. PICA material was used on NASA's Stardust comet sample-return capsule, which returned to Earth on 15 January 2006 at a speed of 13 km/sec, the fastest human-made object ever to fly in the atmosphere (see prior reports).

Nevertheless, on 7 April NASA announced selection of a different material, Avcoat, for the Orion crew capsule's 5-m-diameter re-entry heat shield. Avcoat was used on the Apollo capsule's heat shield and on several sections of the Shuttle orbiter during its earliest flights. It had been put back into production three years ago to enable comparative testing with the PICA material. Avcoat is made of silica fibers with an epoxy-epoxy resin filled in a fiberglass-phenolic honeycomb. Unlike PICA, which is made in blocks and attached to the spacecraft after its construction, Avcoat will be fabricated directly onto the heat-shield substructure and attached as a unit to the crew module during spacecraft assembly. Production of Avcoat is now being continued by Lockheed Martin and subcontractor Textron Defense Systems.

NASA's Wallops Flight Facility launched a Black Brant 9 sounding-rocket on 17 August to test an inflatable ballute planetary reentry system. The NASA Langley Research Center/ILC Dover Inflatable Reentry Vehicle Experiment (IRVE) tested a system that could help future large spacecraft land on Mars -- spacecraft too big to survive with current systems. IRVE will help validate structural, aerothermal, and trajectory modeling and analysis techniques for the inflatable aeroshell system. The launch had originally been planned for 2006, but was delayed due to cost and technical factors. The IRVE heat shield, 3 m in diameter, was lifted to an altitude of 210 km and released at 198 km. Nitrogen was used to inflate the shield to a mushroom shape before landing in the Atlantic Ocean.

The Georgia Tech Research Institute and Raytheon (both USA) announced in August the development of a new highly conductive material for transferring heat away from high-power electronic equipment. It is a composite of diamond and copper, one of a number of materials being developed by the team under sponsorship of the U.S. Defense Advanced Research Projects Agency (DARPA) whose goal is to increase thermal conductivity 100-fold over that of current materials; i.e., 20 kW/m-oC vs copper's 200-300 W/m-oC.

## **E. Information Technology**

On 5 February NASA announced the availability of space mission information on the popular social networks Facebook and Twitter. Use of these social media Internet technologies gives NASA the ability to do deliver to the public nearly instantaneous access to information at no cost. The basis for the agency's decision was the great success achieved in 2008 with their posting on twitter.com of 600 updates on the Mars Phoenix mission, when over 38,000 people signed up to receive the updates, or "tweets." NASA now has its own Twitter website, twitter.com/nasa,

which provides up-to-the-minute updates on many current NASA programmes and a site for exchanging such information among engineers working on these projects, as well as informing and exchanging views with the general public to stimulate public enthusiasm for the agency's work.

The U.S. Center for Space Standards and Innovation (CSSI) on 23 March released a proposal for a prototype Internet-based space situational awareness (SSA) system. It would allow operators to submit data in different formats and have it converted automatically to a single standard reference set, running periodic proximity checks to verify the data supplied. The system would be used in a U.S.-operated global satellite data exchange effort called the Commercial and Foreign Entity (CFE) initiative to share satellite data on frequencies, contacts, orbital decay, projections, and near-term maneuvering plans. Future data prospects include spacecraft status and interference information. The CSSI system was tested last year by Inmarsat (UK) and several other operators, and is currently processing data for over 100 geostationary-orbit satellites.

BAE Systems (USA) announced on 24 April the beginning of qualification testing on a new radiation-hardened microchip for space applications. That testing is planned to be completed in February 2010. The chalcogenide random-access memory chip, C-RAM, provides 20 times the radiation tolerance of comparable commercial products. Its development was funded by the U.S. Air Force Research Laboratory (AFRL).

On 11 August Raytheon (USA) announced that it developed the world's largest infrared light-wave detector. With its 16 million pixels it is four times larger than infrared detectors currently in production, giving it a much greater ability to collect information from a much wider field of view with better sensitivity. Its 4,096 x 4,096-pixel array will for the first time permit full Earth hemisphere staring with a single focal-plane array, and eliminates the need for complex scanning mechanisms that were required to cover comparable fields with smaller detectors.

On 22 September ESA began testing SiREUS, the smallest solid-state gyro sensor ever to be flown in space. The size of a sugar cube, the gyro uses microelectromechanical systems (MEMS), with its moving parts incorporated into a single silicon chip. Its first application will be on the Sentinel-3 ocean, ice, and land vegetation spacecraft to be launched in 2013 for Europe's Global Monitoring for Environment and Security (GMES) network (see prior reports). Three of the 10 x 10-mm devices are being integrated into a 750-gram satellite unit. SiREUS is based on the SiRRS-01 device developed by Atlantic Inertial Systems (UK) and adapted for space by ESA. It will be manufactured by Selex Galileo (UK).

Ruag Space and AAC Microtec (Sweden) on 23 September announced their development of a 120-gram miniaturized package of control, computer, and mass memory components to demonstrate the feasibility of carrying advanced subsystems on nanosat-class spacecraft. It is the first use in space of three-dimensional wafer-level-packaged (3D-WLP) microsystem technology, using a plug-and-play architecture called Innovator. It was built for OHB System (Germany) and funded by the Swedish National Space Board. Its mass memory is based on an electrical design used on ESA's Herschel and Planck spacecraft (see above).

## **F. Automation and Robotics**

On 27 January the Canadian government released a budget increase of \$90 million over three years, beginning in April, for Canadian Space Agency research aimed at the development of terrestrial prototypes for space robotic vehicles. Specific vehicles identified as examples were a Mars lander and a lunar rover. Canada has been at the forefront of space robot development in a number of applications, most notably the International Space Station, but this was the first major increase in the CSA budget in many years. CSA's 2008 – 2009 budget is \$285 million.

## **G. Space Research Facilities**

On 2 December 2008 Space Exploration Technologies (SpaceX, USA) announced the availability of two DragonLab space stations, slated for launch in 2010 and 2011. To be launched by SpaceX's Falcon-9 rocket, DragonLab is claimed to be able to lift up to 6 tonnes of pressurized and unpressurized microgravity science payloads on flights lasting from a week to 2 years. The company has begun signing up customers, who were introduced to the concept during a workshop held on 6 November 2008, attended by representatives from six NASA field centers, NASA headquarters, the U.S. Department of Defense, universities, and several aerospace corporations.

Then on 19 January SpaceX and the Heinlein Prize Trust announced the Microgravity Research Competition for university and non-profit-company researchers. The award consists of a \$25,000 prize and a free launch aboard SpaceX's Dragon spacecraft for the selected microgravity experiment. Proposals were due on 20 March for innovative use of the microgravity environment to advance biotechnology, nanotechnology, combustion, metallurgy, and other fields.

On 5 March NASA and the U.S. Air Force Research Laboratory's Office of Scientific Research announced the selection of three national hypersonic science centers, who will each receive \$2 million per year for 5 years to advance research for flight at Mach 5 and beyond. The National Center for Hypersonic Combined-Cycle Propulsion at the University of Virginia will focus on air-breathing propulsion research, along with team members ATK GASL, Boeing, Cornell University, George Washington University, Michigan State University, National Institute of Standards and Technology (NIST), North Carolina State University, Stanford University, State University of New York at Buffalo, and University of Pittsburgh. The National Hypersonic Science Center for Hypersonic Materials and Structures at Teledyne Scientific and Imaging LLC includes team members Missouri University of Science and Technology, Princeton University, University of California at Berkeley, University of California at Santa Barbara, University of Colorado, University of Miami, and University of Texas. The National Center for Hypersonic Laminar-Turbulent Transition, focusing on boundary-layer control, will be at Texas A&M University, with team members California Institute of Technology, Case Western Reserve University, University of Arizona, and University of California at Los Angeles. These three teams were selected from over 60 proposals.

Then on 5 August a group of U.S. corporations created the Hypersonics Industry Team (HIT) to advocate a buildup of the current Mach-3+ programmes into practical applications and to support follow-on programmes after the current ones end. The team consists of Aerojet, ATK, Boeing, Lockheed Martin, McKinney Associates, Northrop Grumman, Pratt&Whitney Rocketdyne, Raytheon, Rolls Royce Liberty Works, and the University of Maryland. They plan to conduct system-level concept and mission-analysis studies, as well as ground- and flight-testing and demonstrator vehicles in an attempt to bridge the gulf between industry and the users of hypersonic technologies. Their targets include both military agencies and organizations requiring long-term space access.

On 7 August the National Research Council (USA) released a report recommending that NASA revive the NASA Institute for Advanced Concepts (NIAC), which had been terminated in 2007 after ten years of operations to release funds for the U.S. human space exploration programme. NIAC's funding of over \$4 million per year had been used to generate research studies of far-reaching advanced concepts in space and aeronautics with the potential of significant benefits to future NASA missions having time scales of ten to forty years. NIAC had been operated by the Universities Space Research Association, a consortium of over 100 universities. The 7 August Research Council report recommends that any new NIAC entity should report directly to the NASA Administrator and be managed separately from the agency's other mission-oriented divisions.

A new pilot plant in Barcelona, Spain was inaugurated on 4 June, to demonstrate and test regenerative life-support system technologies for use on the Moon and Mars. The Micro-Ecological Life-Support System Alternative (Melissa) plant, set up in the School of Engineering at Barcelona's Autonomous University, was derived from a first-generation facility that began operation in 2005 with some ESA funding. Melissa is expected to demonstrate an artificial ecosystem able to recover enough food, water, and oxygen from human waste, carbon dioxide, and minerals to sustain 40 rats (equivalent in oxygen consumption to one human) for two years, beginning in 2014 after a test and preparation phase.

ESA inaugurated a new science facility in Harwell, England on 22 July. Comparable to ESA technical facilities in Germany, Italy, the Netherlands, and Spain, the new laboratory will focus on planetary exploration and climate change, and especially development of a European source for the radioisotope power generators needed for distant-planet missions. It will help ESA draw on the expertise and creativity of the Harwell Science and Creativity Campus, where it will be located.

On 21 July Thales Alenia Space (Italy) released \$42 million as the first increment in rebuilding the satellite-component plant that was destroyed in the 6 April 6.3-magnitude earthquake in L'Aquila, Italy.

## **H. Environmental Effects of Space Flight**

### **(1) Space Debris**

The French Parasol satellite, flying in formation with NASA's Aqua and Aura Earth-observing spacecraft, had to be repositioned on 6 November 2008 to avoid debris from the Fengyun satellite China destroyed in an anti-missile test during January 2007 (see prior reports). It was the latest of three satellites that had to be repositioned to avoid debris from the January 2007 test.

On 20 January Russia's Space Forces chief of staff Gen. Alexander Yakushin said that an old Soviet-built nuclear-powered satellite had partly disintegrated on 4 July 2008, but that its 30 small fragments did not threaten the international space station or people on Earth. The Cosmos-1818 satellite's fragments remained in a high orbit (800 km) far above that of the ISS, and Yakushin added that the fragmentation, which he described as being "minor," did not pose any threat of radioactive contamination on Earth. Cosmos 1818 and a similar satellite, Cosmos 1867 (which remains intact), were test satellites launched in 1987 to demonstrate a new kind of nuclear power.

A low-Earth-orbit 690-kg Iridium-33 communications satellite collided with an inactive 800-kg Russian satellite on 10 February. The Russian spacecraft, Cosmos 2251, which was launched 16 years ago as a Stela-M communications satellite but had been non-operational for over 10 years, drifted down into the Iridium orbit. The collision, which took place over Siberia at an altitude of 790 km, created over 600 observable pieces of debris, estimated at 194 from the Iridium satellite and 505 from the Cosmos spacecraft. With a closing velocity of about 11 km/sec, it was the most severe spacecraft collision ever recorded. Although most of the resulting debris is expected to burn up in the atmosphere, the debris cloud could pose some threat to all low-orbit operational satellites, especially Iridium's remaining constellation of 66 satellites plus spares, a lot of weather satellites at 800 to 850 km, the NOAA-N Prime spacecraft just launched into an 854-km orbit (see above), and the "A-train" of civil Earth-observing satellites following one another in a 705-km orbit (see prior reports).

NASA concluded in April that one of the satellites probably did not hit the other's massive body directly but only rammed into a protruding solar panel or antenna, because the observed number of fragments were well below the number expected from the collision. The Iridium spacecraft was under-represented in the debris, so it's possible that something projecting from the Iridium smashed into the Cosmos. By April most of the fragments were still near the elevation at which the collision occurred, with few reaching the lower orbits occupied by the International Space Station and the space shuttle. Indeed, risk of a debris impact during the Hubble telescope repair mission in May was judged no greater than it had been a year earlier.

Iridium Satellite LLC replaced the lost satellite on 4 March with an on-orbit spare, Iridium 91. In June Iridium ordered their next-generation constellation and announced that it will be placed in the same orbit as the current one, after concluding that the orbit in which the collision occurred is only marginally more risky than the alternatives.

The remains of a European Ariane 5 rocket passed within 1.3 km of the Space Shuttle Discovery and international space station on 4 September, but did not come close enough to pose a risk to the spacecraft or their astronaut crews. The fragment came from a rocket that launched two satellites into orbit in 2006. It was relatively large by space debris standards, about 19 sq. m, and was flying in an extremely elliptical orbit with an apogee of nearly 32,000 kilometers.

In preparing for the first open international conference solely dedicated to addressing the removal of human-made orbital debris from Earth orbit, co-hosts NASA and the U.S. Defense Advanced Research Projects Agency (DARPA) issued a formal request for information on 27 September, with responses due on 30 October. The conference is planned for 8 – 10 December. The pre-conference request for information solicited ideas for clearing away human-made space debris ranging in size from as small as a millimeter to as large as spent rocket bodies and defunct satellites.

The current proliferation of tiny satellites, such as cubesats, is adding to the space debris problem. The point is approaching at which there will be so many collisions between space junk that incidents grow exponentially, a phenomenon referred to as collisional cascading. Some experts believe that the crossing point was 10 years ago; others say it's 20 years away. In either case, collisional cascading — where one collision has the potential to produce many others — is now unavoidable. Current space debris mitigation measures will delay, but not prevent, collisional cascading from happening in low Earth orbit, even if all launch activities stop right now, because once the cascading process has started there is no way of controlling it again.

Although space debris remediation will be a technically demanding and expensive undertaking, such costs must be viewed in relation to the value of space assets. Nevertheless, the solutions must be innovative and inexpensive if they are to stand a chance of being embraced. Various orbital debris-removal ideas have been suggested in the past, such as destroying debris with lasers, capturing it with foam spheres or nets, and retrieving spent spacecraft with space tugs. Some believe that orbital debris mitigation presents a commercial opportunity for enterprising firms offering satellite repositioning or debris removal services.

The challenges associated with removal are not only technical, but also political. For example, differentiating between a debris removal system and an anti-satellite weapon could be a critical issue, especially if a debris removal system operated by one country destroys or removes an object that is owned by another. To avoid this issue, the system operator would have to request permission from the owner of the object, which would present a formidable operational problem because of the number of debris objects that have to be eliminated.

## **(2) Near-Earth Objects**

The number of near-Earth objects (NEOs) discovered by September exceeded 6300, of which around 790 have diameters of 1 km or more. The number of potentially hazardous objects (PHOs), defined as objects with absolute visual

magnitudes of 22 or brighter (diameters of around 150 m or more) that come close to crossing the Earth's orbit, exceeded 1060 by September. Some 150 PHOs have diameters larger than 1 km. By far the main contributors to NEO discoveries remain the search programmes funded by the US.

The International Panel on Asteroid Threat Mitigation issued a report to the UN on 25 November 2008 that calls for an international decision-making programme to decide on actions to counter Near Earth Objects in advance of a potential catastrophe. It also urges the creation of a warning system that would operate telescopes worldwide to detect and track possibly harmful objects.

A dramatic event in the field of NEO detection occurred late in 2008, when the Catalina Sky Survey discovered a small NEO from Mount Lemmon, Arizona that, according to subsequent orbit calculations, would impact the Earth within 21 hours. As more data from professional and amateur observers around the world flowed in, the trajectory of the asteroid, named 2008 TC3, was updated by the NASA/JPL Near-Earth Object Programme Office and details were passed on to NASA Headquarters. NASA issued a press release at about 21:30 announcing the predicted impact later that night over northern Sudan; observations by U.S. government satellites, images from Meteosat 8, and a sighting by an airline pilot confirmed the predicted time and location. The relative velocity of the asteroid as it entered the atmosphere was 12.4 km/s and it was estimated to have a diameter of 2 - 5 m, which corresponded to a kinetic energy of roughly 1 kiloton of TNT depending on the object's density.

A scientifically valuable and unique follow-on from the impact of 2008 TC3 was the discovery of meteorites; i.e., fragments of the asteroid, as reported in the journal *Nature* on 26 March. In total 47 meteorites with a combined mass of 3.95 kg were recovered. Asteroid and meteorite reflectance spectra identified the asteroid as F-class, indicative of a dark carbon-rich object.

The importance of this unique sequence of events lies in the ability of existing NEO search programmes and an international network of observers to detect and track an incoming NEO on a very short timescale, enabling accurate predictions of the impact location less than 24 hours after discovery; this amounted to the first predicted impact of an NEO. The recovery of fragments of the asteroid provided scientists with the first opportunity to examine material from an impactor that was detected and observed as an asteroid with a known orbit. The meteorite and asteroid communities have realized the potential of such events for improving our understanding of the connection between meteorites and asteroids of different spectral and dynamic types. Understanding the composition, structure, and mechanical strength of NEOs is key to the development of effective mitigation strategies that might involve space missions which interact with a threatening object; e.g., mechanically or by means of some explosive device that causes ejection of material from the surface to modify its orbit.

Discoveries of small objects such as 2008 TC3, which proceed to impact the Earth, are likely to increase in the future as larger, more sensitive search telescopes come into operation. Besides their scientific value, such discoveries provide excellent tests of our NEO detection, tracking, orbit calculation, and impact prediction capabilities, enabling weaknesses in these areas to be identified and improvements made.



## **VII. EDUCATION**

### **A. Teaching Programmes**

On 25 March the Conrad Foundation (USA) announced that the American Institute of Aeronautics and Astronautics (AIAA) has become the newest partner to support the Pete Conrad Spirit of Innovation Awards. In the contest, teams of high-school students create innovative products for use in various fields of science and technology, including lunar exploration, personal spaceflight, and renewable energy through a mentor-based collaborative approach. With the new partnership, student teams in the space area will receive counsel and support from AIAA members, some of whom will serve as judges in the lunar exploration and personal spaceflight categories. Team finalists will have the opportunity to present their product concepts at AIAA events, and the top three teams in the aerospace competition categories will receive AIAA memberships.

The AIAA offered its “Education Alley: The Ultimate Field Trip” at the AIAA SPACE 2009 Conference and Exposition on 14–17 September. The programme highlighted the world of aerospace to over two thousand Pasadena-area students in grades K–6, with its theme: “Discover What’s Out There!,” through exhibits, lectures and demonstrations. It was sponsored by the Aerospace Corporation, the Boeing Company, the National Institute of Aerospace, Raytheon, SpaceX, Wyle, and the X PRIZE Foundation (all U.S.A.).

On 8 April NASA awarded the Alameda County Office of Education (USA) a \$1.4 million grant to implement the Learning Inspires Fundamental Transformation by Opening Future Frontiers for High School Science, Technology, Engineering and Mathematics Science (LIFTOFF) project. It will allow teachers to create classrooms in which they and their students are regularly engaged in cutting-edge NASA mission research with real scientists and science faculty, and will especially benefit under-represented minority students. It is also claimed that future science teachers throughout the 23-campus California State University system will benefit from the “best practices” in science and technology education LIFTOFF will showcase.

NASA’s Ames Research Center issued a \$10-million grant to the Universities Space Research Association (USRA, USA) on 27 March to design and manage a five-year programme that will match up students in science, mathematics, technology, and engineering with NASA scientists and engineers. The cooperative work-force development project, called the Education Associates Programme, is aimed at addressing the shortage of U.S. high-school students seeking university degrees in these fields.

A UP Aerospace SpaceLoft XL solid-propellant suborbital rocket carrying student experiments and cremated human remains was launched from New Mexico’s Spaceport America on 2 May, but failed about 10 seconds after liftoff when the vehicle’s payload section unexpectedly separated. The rocket had been intended to reach an altitude of 110 km. The mission was developed by the New Mexico Space Grant Consortium and the NASA Experimental Programme to Stimulate Competitive Research (EPSCoR), and the cremated remains were a memorial service provided to several prominent individuals by Celestis, Inc. (USA). The student payload was

recovered for examination, and the failure was subsequently traced to an incorrect flight parameter uploaded to the vehicle prior to launch.

From 3 May to 30 June NASA's Interdisciplinary National Science Programme Incorporating Research Experience (INSPIRE) accepted applications from high school students. NASA selected students in September to participate in an online learning community in which students and parents have the opportunity to interact with their peers and NASA engineers and scientists. Students were also able to apply for experiences during the summer of 2010 at NASA facilities and participating universities throughout the nation. INSPIRE is designed to encourage ninth through 12th grade students to pursue careers in science, technology, engineering, and mathematics.

Raytheon (USA) awarded \$20,000 MathMoveU bonus award scholarships to 30 high-school seniors and college undergraduates on 20 May, in recognition of their major studies in science, technology, engineering, and mathematics (STEM) subjects. The winners were chosen from among 900 students who had previously received Raytheon-sponsored middle-school scholarships.

The finals of the third UK Aerospace Youth Rocketry Challenge were held in Surrey, England on 2 April. The winning team in the competition, which was open to student teams aged 11 – 18 years, was from the Royal Liberty School in Romford, Essex. The goal of the competition was to design, build, and fly a rocket to an altitude of 230 m and then land, in a total flight time of 45 seconds, without breaking a raw egg carried as the payload. Sponsors of the 2009 Challenge were Lockheed Martin UK, Raytheon Systems Ltd, the Society of British Aerospace Companies, Selex Galileo, Inmarsat, Chemring Group PLC, Yorkshire Forward, and Aerospace and Defence KTN. The winners received a prize of \$1,500 for their school and a trip to the Paris Air Show in June.

On 16 May a four-student team from Madison West High School in Wisconsin, USA, won the Seventh Annual Team America Rocketry Challenge, besting a field of 100 teams. Goal of the competition was the same as that for the UK Rocketry Challenge (see above). However, the U.S. winner then lost the Second Annual Transatlantic Rocket Fly-Off to the winning UK team from the Royal Liberty School of Romford, Essex, who had also won the previous year's international fly-off. The competition was sponsored by the Aerospace Industries Association and the National Association of Rocketry (both USA).

The International Space University (ISU; France) inaugurated the first executive space-oriented Master of Business Administration (MBA) programme in June, providing financial, accounting, legal and other managerial training. The 18-month programme allows participants to continue in their careers, by limiting time spent away from their place of employment. The intention is to start a new group of participants each year. In January the ISU partnered with the Manx government on the Isle of Man to open the International Institute for Space Commerce (IISC), which will act as an international, non-profit, non-partisan “think tank” involving experts from academia, government, the media, business, and non-governmental organizations.

From 27 June to 28 August NASA's Ames Research Center was host to the ISU's 2009 Space Summer Programme, which included 120 students and 45 faculty, staff, and special lecturers. NASA Goddard Space Flight Center was also host this summer to more than 150 summer interns (high-school to graduate level) in over 15 different programmes covering robotics, astrobiology, Earth sciences, and space sciences.

On 11 June NASA announced a new \$8-million funding opportunity for projects designed to educate students, teachers and lifelong learners about global climate change. The "Global Climate Change Education: Research Experiences, Teaching and Learning" programme is expected to leverage NASA's unique contributions in climate and Earth-system science to enhance students' academic experiences and improve educators' abilities to engage and stimulate their students. A particular emphasis is placed on providing opportunities for students to investigate the climate system using NASA Earth observation data and NASA Earth system models.

Notices of Intent were filed by 2 July, and full proposals were due on 3 August. Proposals were to have offered innovative approaches for using NASA resources in support of elementary, secondary, undergraduate, and lifelong teaching and learning. Sources for the proposals were higher education institutions; state agencies, local agencies, or federally recognized tribal government agencies; public school districts; nonprofit organizations; NASA centers; federal agencies, federally funded research and development centers; and education-related companies.

NASA launched the NASA Student Ambassador Virtual Community this year, with the first group of interns from 35 states and 64 different universities in the United States.

On 15 March the space shuttle mission launched to the International Space Station (see above) carried Mission Specialists Joe Acaba and Richard Arnold, who besides being trained NASA astronauts are science teachers. During the mission, NASA conducted a variety of activities that leveraged the excitement of the flight, showcased the agency's education resources, and provided direct opportunities to get involved with the mission.

NASA's Office of Education held four pre-launch forums this year which supported space shuttle missions. These forums featured key stakeholders and groups of STEM advocates and educators, who provided input that supported efforts to educate, recruit, retain, and inspire the next generation of explorers.

University faculty and students participated in a "Rock On" Student Launch Workshop at NASA's Wallops Flight Facility on 22- 27 June. They learned the basics of building experiments for flight on suborbital rockets. The workshop culminated with the launching of the experiments aboard a NASA Orion sounding rocket.

NASA made available reduced-gravity flight opportunities that allowed teams of undergraduate science and engineering students to propose, design, and fly reduced-gravity experiments. In 2009, there were 79 proposals, of which 21 were accepted.

An evaluation of NASA's Science, Engineering, and Mathematics Aerospace Academy (SEMAA) was conducted this year. It included (1) a multi-site randomized control trial to study short-term impacts on K-12 students and their families; and (2) an implementation study to investigate variation in how sites implement the three project components: curricula enhancements, an Aerospace Education Laboratory, and a Family Café. This evaluation will help enable NASA to improve the quantity and quality of the data and evidence used to measure the degree to which NASA's education portfolio is meeting its goals.

On 24 April ESA's Education Office issued a call for proposals to European students for the "Fly your Thesis! –An Astronaut Experience" programme. Twenty teams will be selected to elaborate on their microgravity proposals for hyperbolic flights on an Airbus A300 Zero-G aircraft in the fall of 2010. Later this year, ESA's Education Office intends to launch a complementary call for opportunities on other microgravity research platforms, such as drop towers and centrifuges.

Finals of the Mission Virgin Galactic competition were held at the UK's Royal International Air Tattoo on 17 July. Entrants aged 11 – 14 years had to devise inventive ideas based on one or more of the unique scientific or engineering principles of the Virgin Galactic space ships (see above). Preliminary heats were held at Royal Air Force (RAF) bases, giving students opportunities for an exclusive "behind the scenes" look at a working RAF station.

The U.S. crew of the space shuttle Discovery embarked 5 July on an educational mission to inspire the UK's budding astronauts. The astronauts made their first stop on a UK tour, sponsored by the International Space School Educational Trust, at the Museum of Science & Industry in Manchester. They met with around 800 schoolchildren from across Greater Manchester to speak about their space experiences, from eating and sleeping to walking. The aim of the tour was to encourage young people from inner city areas to fulfill their ambitions and to promote the study of science, engineering and mathematics.

On 8 October the U.S. White House set up 20 telescopes, an inflatable dome with a three-dimensional video tour of the universe, and displays of Moon rocks and meteorites as President Barack Obama hosted a lawn star party for about 150 middle schoolers, the largest school group hosted to date by President Obama. A first for the White House, the event, which featured first U.S. female astronaut Sally Ride, was part of a worldwide emphasis on astronomy celebrating the 400th year since Galileo used a telescope. Its purpose was to emphasize science, math and technology education.

Master's degree students at Imperial College London and the Royal College of Art (UK) completed in August a segment of the Space Hotel Project, in which they created a robot concierge, a redesigned showerhead, and a full-sensory exercise wall. The concept could theoretically attach to the International Space Station. It could be built tomorrow with today's existing structures and technologies. Although the current shortfall in manned spacecraft capability affects the feasibility of a space hotel for tourists, space architect Daniele Bedini hopes to pitch the space hotel concept to private companies and space agencies.

Twenty quality video entries were selected in May to move to the second round of the International Astronautical Federation's (IAF's) Youth Grants Programme 2009. The programme is open to individuals who were between the ages of 21 and 33 on 1 January. 130 students and young professionals from 36 countries applied; 35% were women. Three-minute videos were submitted for the second and final round on 20 May. Ten people were chosen on 14 July to attend and present papers at the 60<sup>th</sup> International Astronautical Congress (IAC) in Daejeon, Korea, 12 – 16 October. Five were young professionals and five were students. The applicants were from a variety of countries and included a good distribution of students and young professionals, men and women. Two Canadians were also sponsored by their country to attend the IAC.

The Subcommittee on Global Space Workforce Development of the IAF Space Education and Outreach Committee was established in 2009 to prepare students in science, technology, engineering, and mathematics (STEM) disciplines and to motivate them for careers in space endeavors.

The winning experiment proposed by a school teacher in "Take your Classroom into Space" was done onboard the ISS by ESA astronaut Frank De Winne on 21 September. On the same day, school children located in four European museums (Greece, Belgium, Spain and Italy) conducted the same experiment simultaneously with De Winne using specially developed educational kits. The ESA/UNICEF Water Quiz is an online quiz developed by ESA in cooperation with UNICEF about the importance of water on Earth and in space. De Winne announced winners of the quiz on 6 October. The Drawing competition is a competition for primary school children in the context of the ISS mission with de Winne. Winners talked with De Winne onboard the ISS through amateur radio (ARISS).

During an ISS Day live event on 6 October, about 300 school children from all over Belgium participated in a day of space activities at the Free University in Brussels based on a day in the life of an astronaut. The event was highlighted by a live contact with De Winne on the ISS, where he performed demonstrations on properties of water showing the differences between what happens on Earth and in space. "Feeding the Future - Nutrition on Earth & in Space" is a DVD-based educational programme about nutrition for secondary school teachers and students to be released late in 2009. SUCCESS was a student competition to run an experiment onboard the ISS, whose winner, on the influence of space radiation on genes, was announced in May.

Between November 2008 and November 2009 the Canadian Space Agency (CSA) reached 3,334,340 students through the following programmes:

(1) The distribution of pedagogical resources, including Robomath, a 3-dimensional math immersive learning resource developed in support of CSA astronaut Julie Payette's participation in a space shuttle mission, as well as four resources covering topics such as air pollution and quality, extremophiles, and colloids developed in support of CSA astronaut Robert Thirsk's participation as the first Canadian ISS crewmember.

(2) Participation in the Tomatosphere project, where students learned about life support requirements for long-duration space missions while studying the germination rates of tomato seeds exposed to a variety of environments.

Tomatosphere is a collaborative initiative among the CSA, the University of Guelph, Heinz Canada, Agriculture and Agri-Food Canada, the Ontario Centres of Excellence, and Stokes Seeds.

(3) Participation in the Get Fit for Space Challenge (GFFS), developed in support of Robert Thirsk's ISS mission. GFFS focuses on encouraging Canadians to maintain a healthy and physically active lifestyle, challenging people to exercise by running the equivalent of 340 km in order to reach the ISS, where Dr. Thirsk awaited them to provide a virtual tour of his home of six months.

During the same timeframe, the CSA reached approximately 1,000 educators through Professional Development opportunities, including their annual three-day Space Educator Conference and CSA participation at provincial Science Teacher Association conferences and school-board professional development days.

During the summer, Youth Space Camp was conducted in Russia at the Gagarin Cosmonauts Training Center in Star City. This event was organized by the Government of Moscow, the Gagarin Cosmonaut Training Center, and the Andromeda Center for Space Cooperation. More than 200 high-school students visited the Camp. Its aim was to promote the history of space flight and cosmonautics among high-school students and to offer them the possibility of training as real cosmonauts on real space simulators.

The 16<sup>th</sup> International Aviation and Space Airshow MAKS-2009 was held in Zhukovsky, Russia from 18 – 23 August. The University Science and Aviation-and-Technical Art of Youth section was organized within the framework of the air show to demonstrate scientific and technical developments of young scientists and university specialists. Leading Russian technical universities participating included Bauman Moscow State Technical University, Moscow Aviation Institute, Moscow Institute of Physics and Technology, Moscow State Aviation and Technological University, Siberian State Aerospace University, and a number of other universities.

## **B. Public Awareness**

In February Google (USA) added a Mars category, Google Mars, to the website Google Earth, which combines satellite imagery, aerial photographs, and other geographic information. Then on 13 March Google added a new “Live from Mars” update, which includes such features as real-time tracking of Mars orbiters, access to raw data, historical globe maps of Mars, and guided fly-around tours of the Red Planet. One of the goals of the new feature is to have users contribute information to the website programme.

On 7 May Microsoft Live Laboratories (USA) began integrating a new programme, Photosynth, into its Virtual Earth software. Photosynth allows NASA to offer the public virtual three-dimensional tours of the International Space Station and close-up views of the Mars Science Laboratory rover model. Photosynth is accessible on the Internet using web browsers on laptop and desktop computers.

NASA's Ames Research Center and Microsoft Corporation (USA) signed a Space Act Agreement on 24 March to bring high-resolution images of the Moon and

Mars to Internet users via Microsoft's free World Wide Telescope Internet portal introduced in May. Ames is providing 100 terabytes of data, including imagery from the Mars Reconnaissance Orbiter (MRO) and the Lunar Reconnaissance Orbiter (LRO). Beginning this fall, Microsoft software will enable users to pan or zoom in on planetary surfaces, including the polar regions, with high definition in three dimensions and without image distortion.

The IAF and the UN Office for Outer Space Affairs (UNOOSA) organized a briefing on 3 June to African Permanent Missions in Vienna entitled "Fostering Space for Africa". It was held as part of the fifty-second session of the Committee on the Peaceful Uses of Outer Space (COPUOS). The briefing was moderated by IAF President Berndt Feuerbacher and Ciro Arevalo Yepes, Chairman of COPUOS. UNOOSA Director Mazlan Othman presented the Africa Report of the United Nations Inter-Agency Meeting on Outer Space Activities and Peter Martinez, representative of the South African delegation, introduced "Opportunities offered by Space to Africa". IAF Executive Director Philippe Willekens outlined opportunities to be offered by the 62nd International Astronautical Congress to be held in Cape Town, South Africa in October 2011.

## **VIII. GLOBAL SPACE MARKET ISSUES AND OPPORTUNITIES**

### **A. Government Programmes**

On 2 March the U.S. Navy solicited bids for a Commercial Broadband Satellite Programme (CBSP), a massive 5-year procurement of commercial satellite bandwidth and related services that is aimed at achieving a tenfold increase in capacity over its existing Inmarsat-based infrastructure and lease arrangements. Responses received by 2 April are seeking a single end-to-end service contract that covers C-band, Ku-band, and X-band satellite capacity, ground-station services, terrestrial connectivity, operations, and maintenance. The one-year contract with four one-year options will be for a maximum of \$600 million.

Replacing the Navy's current commercial L-band service from Inmarsat, the new programme requires 449 MHz of Ku-band capacity and 329 MHz of C-band capacity, both covering 95% of the globe outside the polar regions beyond 65 degrees north and south latitude. It also requires 118 MHz of X-band capacity which excludes the Pacific region, where no commercial X-band capacity exists and there is coverage by the U.S. military satellite system. The new system will mandate replacement of the Navy's L-band shipboard terminals with the new terminals capable of at least 0.88 MB/sec for small ships, at least 3.6 MB/sec for ships like cruisers and destroyers, and at least 21.4 MB/sec for force-level ships such as aircraft carriers. The shipboard terminals are being contracted separately from the CBSP, with their total cost estimated at about \$175 million.

The U.S. General Services Administration and Defense Information Systems Agency announced early in August a new "common marketplace," the Future Comsatcom Services Acquisition, which will procure commercial satellite communication services for the entire U.S. government. Beginning in September

2010, the new agency will award contracts expected to amount to over \$5 billion in the next decade.

On 11 August the U.S. National Geospatial-Intelligence Agency (NGA) announced that they are seeking radar data from commercial synthetic aperture radar satellites that collect data in the X-band, C-band, or other commercially available bands. The NGA will award firm fixed-price indefinite-delivery, indefinite-quantity contracts worth up to \$85 million each over five years to as many as four commercial firms. Responses were due by 15 September, but the NGA did not announce an award date. Then on 23 September the NGA announced plans to issue a new round of commercial satellite imaging contracts with resolutions ranging down to 0.25 m. The EnhancedView contracting vehicle will be patterned after NGA's previous NextView programme, whose up-front payments helped underwrite DigitalGlobe's (USA) and GeoEye's (USA) new-generation imaging satellites WorldView-2 and GeoEye-1. NGA plans to issue a request for proposals late this year and sign contracts in the spring of 2010.

The 2009 ESA Investment Forum, held in Brussels in April, attracted over 150 participants. The Forum brings together the finance and investment communities with startup companies using space technology, applications, or services in a non-space environment, to highlight the commercial benefits of satellite and space technology in applications on Earth. The 2009 Forum addressed satellite downstream applications such as navigation, communication, Earth observation, and location-based services. Out of a field of 36 business-plan presenters seeking funding, investor panels selected the six best companies and also provided valuable individual feedback.

On 15 October newly re-elected European Commission (EC) President José Manuel Barroso, in his first speech on space policy, said "We need more security in space and from space. Our space assets and infrastructure are indispensable for our economy and security and we need to protect them. The European Union (EU) should develop an independent capacity to monitor satellites and debris orbiting the Earth and the space environment, and tackle possible hazards." The EC has been spending an average of \$1 billion per year on space projects during the seven-year budget period that ends in 2013, but is likely to spend several times that amount during the seven-year budget starting in 2013. Up to now the Commission's main space interest has been in programmes that have direct economic benefit and affect policies already pursued by the EU, such as environmental monitoring, safety of hazardous transport, and maritime surveillance, but the EC now expects to broaden its space interest to include space exploration. Issues to be addressed include assuring independent access to space; independent human spaceflight activity in the context of an international partnership; and how to support the international space station.

India released its interim 2009 space budget on 16 February, citing a 27% increase over 2008, which in turn had provided a 24% increase over 2007. The interim \$924-million Indian Space Research Organization (ISRO) allocation for the fiscal year 1 April 2009 through 31 March 2010 was adopted by India's Parliament on 28 February. New elements in the budget included development of a new kerosene-oxygen rocket engine and an advanced-technology communications satellite, funding for an Institute of Space Science and Technology, six space launches, and four new Earth-observation missions. Then on 6 July, following national elections in May, the



final budget was issued, with a 40% increase over 2008 for ISRO, to \$1.04 billion. The largest increment went for launch vehicle development, followed by satellite technology and space applications.

On 25 June the UK's Science Minister, Lord Drayson, inaugurated a study to seek ways of stimulating the space sector and contributing to the British economy. The Innovative Growth Team for Space (Space IGT) will examine Britain's regulatory environment for the space sector, assess the organizational setup for space in Britain, and explore ways to maintain public awareness and support for space technology.

On 6 March South Africa's Trade and Industry minister announced a National Space Policy, whose primary goal is to acquire the appropriate space-based systems for wider socio-economic benefits, along with independent access to space. One of the major thrusts of the policy is to ensure the necessary capacity and resources need to implement that goal. The policy also recognizes that cooperation and collaboration with other countries is of great importance to ensure the success of South Africa's space industry. On 13 May the Department of Science and Technology (DST) initiated the final step in the formal establishment of the South African National Space Agency (Sansa) by starting the search for board members for the agency, to serve over the next four years. The agency was expected to be in place before the start of the country's next fiscal year on 1 April 2010.

The Japanese government's Basic Space Plan, published in June, shifted policy emphasis from research and technology development to space utilization and commercial activities. Entrepreneurial activities include non-space companies' efforts to serve an anticipated long-duration human space flight market for food, sleeping bags, apparel, medical equipment, and biotechnology products. New Medican Tech Corporation developed a water recycle system, and Sato Sports Plaza began to provide astronaut training. System engineering companies such as WEL Research Co., Ltd. and Space Systems Development Corporation were established as "spinoffs" from major aerospace companies. Axel Space was formed to commercialize university space R&D efforts. The Institute for Q-shu Pioneers of Space and Sho Engineering Corporation were also established by distinguished engineers. Regional entrepreneurs, universities, and experienced retirees have been facilitating entrepreneurship while pursuing spaceport development. Examples include Hokkaido New Satellite Technology and the non-profit Hokkaido Aerospace and Science Technology Incubation Center (HASTIC).

## **B. Commercial Enterprises**

Despite the global economic downturn, the commercial satellite industry reported glowing results during the first quarter, which ended 31 March, compared to the same period in 2008. Eutelsat (France) reported a 5.6% increase in revenue, with a backlog growth since 31 December 2008 of 8.6%. Intelsat's (Bermuda) first-quarter revenue grew by 10% and its earnings by 4%; second-quarter revenue growth was 9.8%. Telesat's (Canada) revenue was up by 25% and its earnings by 16%. The Astrium division of EADS (Europe) reported a 20% increase in revenue and a 9% growth in pretax profit. Astrotech's (USA) revenue grew by 47%, and profit increased

by 170%. Orbcomm (USA) reported a 25% growth in both number of subscribers and revenue, but lost \$8 million in earnings before taxes due to loss of a satellite (see above). OHB System (Germany) reported a 29% increase in revenue, a 15.5% increase in pretax profit, and a 100% growth in backlog. Revenues of Satmex (Mexico) increased by 15%, and the company's earnings were eight times higher than the comparable period last year. Countering the general trend, Gilat's (Israel) revenue dropped by 14% and its profit by 91%, and EchoStar's (USA) loss increased by 13.5%.

Eutelsat also reported a sharp growth in revenue of 7.2% during the second quarter, ending 30 June, exceeding estimates made 6 months earlier. SES, too, reported a 7% increase in revenue and a 10.3% increase in earnings for the first half, ending 30 June, and Telenor (Norway) reported 25% growth in the second quarter compared with 2008. MacDonald, Dettwiler & Associates (Canada) reported 9.7% revenue growth for the first half, and EADS Astrium (Europe) registered a whopping 29% first-half growth over the same period in 2008. Hispasat (Spain) also reported a 10.7% growth in revenue and a 55% increase in profit for the first half of 2009 over the same period in 2008.

Nevertheless, on 22 June Sea Launch (USA) filed for bankruptcy court protection under U.S. Chapter 11, citing as reasons for the filing their recurring losses from operations due to lower demand for lifting commercial satellites and inability to secure financing to pay \$245 million due 22 June on a total debt of \$2 billion, plus a \$52-million arbitration ruling against them in favor of Hughes Communications (USA). On 1 July Boeing (USA), the principal shareholder in Sea Launch, paid \$448 million to Sea Launch creditors, and on 22 July announced their intent to recover \$269 million from the other Sea Launch partners, plus another \$209 million guaranteed by the partners against Sea Launch's \$1.46 billion debt to Boeing. Sea Launch intends to maintain all normal business operations while in bankruptcy. The company then had a backlog of 10 launches, but on 25 August the bankruptcy court agreed to allow Intelsat to bypass Sea Launch for three launch contracts and deal directly with the company's Russian partner, Space International Services (SIS), which represents the Russian and Ukrainian partners involved in the operations of Land Launch.

However, both Intelsat (Bermuda) and SES (Luxembourg), the world's two biggest commercial satellite fleet operators, said on 11 September that they were willing to provide written promises of future launch contracts to aid Sea Launch in its effort to exit bankruptcy under new ownership, because they view the return of Sea Launch as critical to the smooth functioning of the global satellite telecommunications industry. A few days later they were joined by satellite operators DirecTV (USA), Eutelsat (France), SkyPerfect (Japan), and Telesat (Canada), all of whom also sent letters of support.

Then on 16 September, because of concerns about the now-limited availability of large-satellite launch-service providers, four of the largest satellite operators formed a lobbying group, Coalition for Competitive Launches, to enhance worldwide competition in the provision of commercial satellite launches. Its mission is to persuade the U.S. Administration to expedite the reform of current export license controls (see above) so as to permit the launching of commercial spacecraft

containing U.S.-made components on Chinese rockets, and to urge United Launch Alliance (ULA, USA), which has been limited to the launching of U.S. government spacecraft, to broaden their production so as to appeal to the commercial market. ULA has been reluctant to do so because they claim that the current launch-market price range is 10% - 20% too low for them to operate profitably. The Coalition have hired former U.S. senator John Warner to intercede for them with the U.S. Administration, although he is not permitted to do so with Congress because of standing rules of ethics.

Satellite insurance data released on 2 April at the International Space Insurance Conference in Venice, Italy cited positive results for 2008: underwriters booked premiums of \$930 million and paid out only \$320 million in claims. Coupled with positive margins for six of the past seven years, this encouraged more underwriters to enter the market. As a consequence, the available insurance for a launch increased from 2008's \$530 million to \$560 million in 2009, and there was no growth in satellite insurance premium rates. Indeed, premiums have decreased slightly: despite the rise in on-orbit failures and the current financial-market recession, annual on-orbit insurance rates in recent years have dropped from 2.5% to less than 2%, and launch premiums have remained steady at 10 – 12%.

Euroconsult's 12<sup>th</sup> World Market Survey of satellite construction and launch trends during the decade from 2008 to 2018, released on 10 June, predicted a drop in average satellite mass of 5% compared to the previous decade, to 1.89 tonnes; an increase of 47% in the number of satellites launched, to 1,185; an increase of \$2 million in average satellite price, to \$99 million; no change in average satellite launch price, at \$51 million; an increase of 15% in the number of communications satellites launched into the geostationary orbit, to 234, and an increase of 28% in their total market value.

Euroconsult also published on 3 September a report, "Satellite-Based Earth Observation: Market Prospects to 2018," predicting that global sales of satellite-based Earth observation data will top \$1 billion for 2009, and that Earth observation data sales are expected to grow at a 16 % annual rate through 2018. According to the report, the 128 Earth observation satellites launched in the last decade have generated about \$20.4 billion in revenue, while the approximately 260 satellites that will launch over the next decade should generate \$27.4 billion.

The sixth Space Investment Summit Coalition (SISC) was held in Orlando, Florida in May and the seventh in Boston, Massachusetts in September, with each forum attracting about 100 participants. The SISC encourages funding of space-related startups by private seed-money and early stage investors. These conferences stimulate theme-based dialogue regarding emerging space markets and host investor-oriented business-plan presentations. SISC-6 explored opportunities in the tourism, entertainment, and hospitality industries, and SISC-7 exposed investors to nine startup business plans in numerous fields.

On 8 October the Tauri Group (USA) released their annual report on the commercial space flight industry, commissioned by the Commercial Spaceflight Federation (USA). U.S. firms seeking to open space to private citizens saw a modest 6% growth in 2008, with \$261 million in total collected revenue last year. Investment

in the emerging personal spaceflight industry rose more than 20% since January 2008. To date, cumulative investment has grown to \$1.46 billion, a 20% increase over the period ending in December 2007, with almost half of the investment funds already spent and some \$830 million available. The industry employed 1,186 workers in 2008. The report focused only on companies seeking to develop or support commercial human spaceflight activities.

The U.S. Federal Communications Commission (FCC) approved the purchase of Iridium Satellite LLC by GHL Acquisition Corporation on 14 August. Stockholders in both companies approved the acquisition on 23 September.

On 1 October ViaSat Inc. purchased WildBlue Communications (both USA) for \$568 million plus another \$27 million in transaction expenses. The acquisition provides ViaSat with distribution, billing, and customer service networks and eliminates their need to find a partner for ViaSat-1, currently under construction by Space Systems/Loral (USA). ViaSat-1, due for launch in 2011, will provide more bandwidth than all other Ka-band satellites combined, having received a licensing modification from the U.S. Federal Communications Commission (FCC) that permits a throughput of 125 GB/sec. ViaSat projects WildBlue subscribers to grow from 400,000 to about 2 million by 2012, as a consequence of their offering a tenfold increase in bandwidth and 20 times more capacity in those areas of the U.S. where WildBlue has seen its highest demand.

Intelsat announced their purchase of Israel Aircraft Industries' Amos-1 satellite on 12 August. Although in an inclined orbit, requiring users to employ a more complex antenna than those needed for geostationary-orbit satellites, Intelsat claims that Amos-1, with its nine Ku-band transponders, will still be useful to certain of their customers for its three remaining years of life. It has been moved from Spacecom (Israel)'s slot at 4 degrees west longitude to an Intelsat slot over the Indian Ocean and has been renamed Intelsat-24.

Ruag (Switzerland) announced their purchase of Oerlikon Space (Switzerland) on 3 June for an estimated price of \$141 – \$188 million. Oerlikon makes payload fairings for the Ariane 5, Atlas V, and Vega launchers, as well as other ultra-lightweight, high-stability structures, precision mechanical components, and communications equipment. Ruag had purchased Saab's (Sweden) space business last year for \$47 million.

The Italian Earth observation company e-Geos was created on 1 July to market Cosmo-SkyMed radar satellite imagery, especially to customers in the middle east. Telespazio (Italy) owns 80% of the new company; the Italian space agency ASI owns the remaining 20%. Telespazio, which itself is owned by Italy's Finmeccanica (67%) and Thales Group of France (33%), transferred their Earth observation division to e-Geos. ASI transferred to the new company the rights to commercialize imagery from the four Cosmo-SkyMed satellites, three of which are already in orbit (see last year's report), with the fourth planned for launch in 2010.

On 3 November 2008 Pytheas Cyprus Ltd. announced its purchase of a majority share in Addvalue Technologies Ltd. (Singapore) for \$64 million. Addvalue builds mobile satellite terminals for Thuraya (UAE) and for Inmarsat's (UK) BGAN

broadband service (see prior reports). The investment consists of an initial 30% stake in Addvalue, to be followed in 12 months by the exercising of a call option increasing Pytheas's ownership to 51.5%. Pytheas's motivation for the purchase is their belief that satellite communications is a safe investment in this time of global financial upheaval.

On 18 January the Center for Space Entrepreneurship (eSpace) was established in the U.S. state of Colorado to stimulate the creation of new entrepreneurial space companies and to commercialize the technologies they generate. Initial capitalization was \$1 million, invested by a local Colorado initiative called the Workforce Innovation in Regional Economic Development (WIRED), who provided \$500,000, and by eSpace partners University of Colorado, the state of Colorado, the U.S. Air Force Research Laboratory's Phillips Research Institute, and SpaceDev Inc. SpaceDev provided a 7,000-sq-m design, testing, and manufacturing facility to house the startup companies that use the new Center. eSpace has committed \$90,000 to a Venture Design programme at the University of Colorado to fund graduate-student team projects on aerospace technologies with commercial applications that could transition to eSpace's facility, and "Straight to Space" programme grants to attract non-college students into aerospace. eSpace resources include grants, mentorship by proven aerospace chief executives, physical space, manufacturing and test infrastructure, and access to U.S. government Small Business Innovative Research (SBIR) grants. During its first year, eSpace selected the first four incubator ventures and founded a new facility at the Air Force Research Laboratory's Phillips Research Institute in New Mexico.

The 8th Continent Project (8C) was founded this year at the Colorado School of Mines. It is a comprehensive international initiative to integrate space-derived technology and resources into the global economy. 8C's mission is to accelerate the emergence of investment opportunities in traditional aerospace areas as well as in non-aerospace ventures such as location-based applications, traditional and renewable energy, biotechnology, information technology, materials sciences, and robotics. 8C is securing sponsorship and programme commitments from research and education grants, private sponsors, philanthropic organizations, and programme income revenue streams. Current programmes include education and training, an international student business plan competition, a "virtual" aerospace business incubator, career resources, and an investor network. New 8C initiatives include a Moon rock exhibit, a university student network, European expansion, and a Denver airport research park.

Sirius XM Radio (USA; see prior reports) received a commitment of \$530 million in loans on 17 February from Liberty Media Corporation (USA) in exchange for a 40% stake in the company and seats on the Sirius XM board of directors. The transaction allowed Sirius XM to avoid defaulting on a debt payment of \$172 million due that day.

Satellite radio pioneer Worldspace, which had filed for bankruptcy in 2008 (see last year's report), announced on 27 August that its creditors had terminated an agreement to sell its assets to Yenura Pte. Ltd. Yenura had agreed in March to acquire Worldspace Systems and Afrispace (both USA) for \$28 million, but defaulted on payments, precipitating the 27 August termination. At the time, Worldspace had sufficient cash to keep operating for two more months.

On 28 July Virgin Galactic (USA) sold a 32 percent share to Aabar Investments (Abu Dhabi, UAE) for \$280 million to help fund a test-flight programme that began late this year. The money helped complete the building of the Virgin Galactic spacecraft and financed the testing of the system. Aabar has also committed \$100 million to fund a satellite launch capability and plans to build a spaceport in Abu Dhabi. The deal, which still requires approval by U.S. regulatory agencies, will guarantee the UAE exclusive regional rights to host tourist and scientific flights from its spaceport. Aabar's biggest shareholder is the International Petroleum Investment Company, which is wholly owned by the UAE government. The Virgin Group (UK) had invested \$130 million in Virgin Galactic as of the date of Aabar's purchase, and had received deposits of \$40 million from 300 prospective space tourists for \$60 million worth of ticket sales at \$200,000 per seat.

Swedish Space Corporation (SSC) purchased its joint-venture partner Universal Space Network (USA) on 21 January. The purchase price was not disclosed, but 2008 revenues for SSC were \$43.2 million and about \$15 million for Universal, about half of which were from U.S. government agencies. U.S. regulatory agencies subsequently approved the transaction.

On 20 April SES Astra (Luxembourg) and Yahsat (UAE) created a new joint-venture company, YahLive. YahLive will lease 23 Ku-band transponders on the Yahsat-1A satellite, scheduled for launch late in 2010, to market satellite direct-to-home television broadcast services to over 24 countries in the middle east, north Africa, and southwest Asia. SES invested \$50 million in cash for 35% equity in YahLive, and will also have management control of the company. Further, SES will settle frequency coordination issues between its existing Ku-band reservations for the geostationary-orbit slot at 51 degrees east longitude and Yahsat-1A, to be placed in a slot at 52.5 degrees. Yahsat's Yahsat-1B, which will be a Ka-band spacecraft for regional government and military use and is now under construction for launch in late 2011, will not be included in the YahLive venture. On 8 October Yahsat signed a \$46-million contract with ViaSat, Inc. (USA) to use their SurfBeam 2 technology for its YahClick satellite consumer-broadband service. The contract includes four ground gateways, a network control center, and an initial batch of user terminals.

On 17 September a new company, BB Sat (USA), secured the rights to offer two-way consumer broadband service in Japan, using the Ka-band capacity of Sky Perfect JSat's Superbird-B2 satellite located at 162 degrees east longitude. BB Sat has ordered its first 500 Surfbeam two-way satellite terminals from partner ViaSat Inc. (USA), and plans to grow the service from an initial 30,000-subscriber trial programme to 250,000 subscribers. The company concluded agreements with Japanese Internet service providers in mid-October. The basic service is a downlink of 2.5 MB/sec, with uplink at 512 kB/sec. BB Sat's initial service is priced at an initial fee of \$334, a service fee of \$5.50 per month, and a terminal-rental charge of \$15 per month. Japan's Internet service providers handle sales, billing and customer service; BB Sat is responsible for terminal installation. BB Sat's owners and financiers have invested \$1 million in the new company, much of which was needed for the three-year process of securing their blanket network-operations license from Japan.

## **IX. INTERNATIONAL COOPERATION AND SPACE LAW**

Following up earlier discussions in December 2008 (see above), on 8 July NASA and ESA announced the creation of a Mars Exploration Joint Initiative (MEJI) to design missions for 2016, 2018, and 2020. The missions will include landers and orbiters conducting astrobiological, geological, geophysical, and other high-priority investigations, and will lead to the return of Mars samples in the 2020s. Cooperation on ESA's ExoMars project (see last year's report), which had been discussed informally at prior meetings, was not included in the MEJI agreement.

As the next step, NASA signed a cooperative framework agreement with ESA on 11 September to advance work on space exploration, including human spaceflight. NASA also signed a similar agreement with Canada on 9 September. The agreement with Canada covers cooperation between government agencies, scientists, and industry contractors on human space flight, exploration, space science, and Earth science, including transferring data and goods as well as intellectual property rights. The memorandum of understanding with ESA will allow the two agencies to work together on new space transportation systems, drawing on data generated in the development and operations of Europe's Ariane 5 launch vehicle. NASA Administrator Charles Bolden said that as NASA continues to enhance the scientific observation of our planet and the solar system, he is looking to Canada and other international partners to play key roles in future U.S. exploration plans.

The broad ESA/NASA memorandum should result in greater compatibility and interoperability in orbital hardware and launch vehicles. Specific subject areas covered include composite materials, development of payload shrouds, and the management of propellants in spacecraft traveling to and from lunar orbit. The agreement is unprecedented in that it permits both agencies to work on developing common elements for rocket and orbital hardware systems without undue burdens from each side's technology transfer regulations. In the longer term, NASA and ESA could decide to launch gear on each other's rockets with assurance that the launcher-payload interfaces are common and require no new development. In that sense, the agreement is a breakthrough in the field of launchers. As the first concrete result of the newly signed cooperation accord, ESA began design work in October on an International Berthing and Docking Mechanism (IBDM) for the ISS. A contract valued at about \$14.6 million for IBDM design was approved by ESA delegations in September and was signed in October with prime contractor Verhaert Design and Development (Belgium).

Then, on 8 October, the ESA governments gave tentative approval for ESA to join with NASA in a two-step Mars exploration programme that retains Europe's goal of perfecting atmospheric entry, descent and landing technology, as well as developing a Mars lander and rover. The agreement with NASA was expected to be finalized by mid-November, by which time ESA should have a clearer idea of whether the new Mars-exploration scenario can be kept within the currently approved ESA budget limits on the ExoMars mission. According to ESA Director-General Jean-Jacques Dordain, these two cooperative missions with NASA permit retaining all the goals for the ExoMars mission while at the same time reducing the risk. The two missions would be launched by NASA-provided Atlas 5 rockets in 2016 and 2018,

thereby reducing ESA's mission cost to within the approved ExoMars budget (see below).

The new program includes a 2016 launch of a 600-kg ESA lander that will include exobiology experiments and also permit ESA to test powered atmospheric descent and landing on the Mars surface. The lander will not include nuclear batteries, which would have added to mission cost and complexity. Instead, it will be powered by conventional batteries that will limit the lander's operational life to days, or perhaps a few weeks, but certainly not months. ESA also will provide a Mars telecommunications orbiter for the 2016 mission, with NASA supplying the electronics payload for the satellite.

The 2018 mission will feature ESA's rover deployed to the Mars surface by the same Sky Crane system that NASA plans to use for the large Mars Science Laboratory rover to be launched in 2011 (see above). This system has the rover, attached by a cord to the descent module, gently lowered to the surface.

With this plan, ESA's ExoMars mission combines three challenging elements — descent and landing, the lander package and the rover — all ESA's responsibility. The new programme separates the lander from the rover and thereby reduces overall programme risk. It has the support of ESA's major contributors — France, Germany, Italy and Britain — and the agency expects to make sure the Mars mission contracts are distributed to each nation in accordance with that nation's contribution to the programme, hewing to ESA's established policy of "geographic return." Italy will probably remain the biggest single contributor to the redesigned Mars effort, so that ESA will not need to abandon the three years of design work on the rover and lander that were conducted under the earlier ExoMars programme.

Then on 23 October, at the EU-ESA International Conference on Space Exploration, most of the 27 European governments expressed support for a major (although as yet undefined) financial investment in space exploration, which they now consider as something more than a source of new technologies or other practical spinoffs. They announced plans to make an initial decision in 2010 on a space exploration roadmap for robotic and human missions in collaboration with the U.S., Russia, Japan, China, India, and other nations.

On 17 September the French space agency CNES and NASA signed an agreement to cooperate on four different space-based research projects. A mission to Mars in 2013, called "Mars Atmosphere and Volatile Evolution," will carry out a new analysis of the planet's atmosphere. The mission will provide the first direct measurement data to answer key questions about the past and current evolution of Mars. NASA will have operational control of the probe; CNES will supply their new version of a "Solar Wind Electron Analyzer," which will be used to measure the characteristics of Mars' solar winds and their ionospheric electrons.

The second mission, "Magnetic Multisphere Mission," will launch four satellites in 2014 which will evaluate different aspects of the Earth's magnetosphere, particularly the acceleration of its particles and turbulent zones. Again, NASA will oversee the satellites and CNES will supply several of the instruments.



The agreement also permits the participation of American researchers in the analysis of the data and other observations from a 2006 CNES/ESA mission which is studying planetary transit phenomena. In return NASA will grant CNES access to its Keck Observatory near the summit of Mauna Kea in Hawaii. The agreement also covers a space-based study of Earth's ocean topography and soft-water sources, "Surface Water and Ocean Topography," which will provide scientists with an extensive and previously unseen view of the quantity of Earth's soft-water resources as well as a much more detailed measurement of the size of seas and oceans than has been possible up to now. This mission is designed to improve the management of Earth's water resources and will also provide more accurate predictions on climate trends.

The Czech Republic became the 18th full member of ESA on 14 November 2008, and began a six-year transition period to evaluate how best to adapt Czech industry and technology capacity to ESA's requirements. The republic also signed an agreement on 22 June to become a full member of Eumetsat in 2010. The Czech Republic had been a Cooperating State in Eumetsat since 2005, which permitted unlimited access to Eumetsat data.

Latvia also signed a cooperation agreement with ESA in July, the second Baltic nation to do so (Estonia had signed a comparable agreement in 2007). Facilities expected to benefit from the agreement are the Ventspils International Radio Astronomy Center, the Brubaker Baltic company, which makes semiconductor detectors, the University of Latvia's Institute of Physics, and the Latvian State Institute of Wood Chemistry, in the area of cryogenic insulation.

A resolution adopted by the European Parliament on 20 November 2008 calls on the European Union to encourage synergies between civilian and security developments in the field of space. The motivation for the resolution appeared to be the past and current controversy over the prospective use by European defense forces of the Galileo and EGNOS positioning and navigation systems and the broad-based Earth-observation programme known as Global Monitoring for Environment and Security (GMES). Then on 26 November the ESA governments gave initial approval to both programmes, but did not endorse either the European Data Relay Satellite System (EDRS) or the Space Situational Awareness (SSA) programmes.

However, ESA noted that both these programmes had received enough early backing to make it likely they would soon become fully funded. Germany had committed 50% of the \$302-million cost of building three sets of identical sensor packages for EDRS, each with a laser communications terminal and a Ka-band transmission payload. Two of the packages would be placed on commercial telecommunications satellites as piggyback passengers under a commercial arrangement; the third would be placed on a small, dedicated data-relay satellite. The ESA governments approved only \$62 million of the \$378 million cost of the SSA programme, for studying the effects of solar flares and other space weather conditions on satellites and how ground-based sensors could be used to track potentially dangerous near-Earth asteroids.

ESA also has signed a security agreement with the European Union's top security agency and created direct links with the European Defense Agency; has

established mechanisms to produce, store and transfer classified data; has added staff with "confidential" and "top secret" security clearances at its centers in Italy and the Netherlands and created office corridors that are off-limits to those without security clearances; has conducted tests with the NATO alliance of mobile and maritime satellite communications technologies; and has begun trials with the German Defense Ministry of the ESA-developed AmerHis interactive and broadband communications technology. ESA Director-General Jean-Jacques Dordain has said that nothing prevents ESA from working in the defense sector, but up to now there was no real demand to do so.

Then on 2 December 2008 France, Germany and Italy agreed for the first time to give the EU's Satellite Center at Torrejon, Spain, both free and paid access to their military observation satellites: the French Helios 2 optical imagery spacecraft with 35-cm resolution, Italy's Cosmo-Skymed radar satellites, and Germany's SAR-Lupe constellation.

On 26 November 2008 the ESA governments approved about \$12.6 billion in new financing for the coming years, with major new funding for Earth observation and meteorological satellites, early work on a more powerful version of the Ariane 5 rocket, and an increase in annual spending on space science. They also committed the money needed for Europe to maintain its right of access to the ISS, mainly by providing four more unmanned Automated Transfer Vehicle (ATV) cargo carriers. Specific allocations included an increase in space science budgets by 3.5% per year for at least three years, vs the December 2007 increase of only 2.5%; \$25 million on preliminary designs to modify the Automated Transfer Vehicle (ATV) to enable it to return to Earth with cargo; \$450 million more than ESA had asked to pursue development of a new Ariane 5 upper-stage engine, called Vinci, to enable an Ariane payload of two telecommunications satellites weighing a combined 12,000 kg, vs the current version's capacity of about 9,000 kg.; \$1.05 billion for three duplicate versions of the Sentinel Earth observation satellites for GMES/Kopernikus, to be launched after 2013 (see last year's report); \$1.12 billion for a third-generation Meteosat programme; and \$1.07 billion as initial, but not yet final, backing for the 2016 Mars rover and lander mission Enhanced ExoMars, toward the mission's total cost of \$1.5 billion (the balance to be sought by ESA from Russia, the United States and perhaps elsewhere; see above).

On 6 May the United Nations' International Telecommunications Union (ITU) initiated measures to stiffen requirements and reduce the abuse of the geostationary-orbit registration system for communication satellites and asked its 191 member governments to propose solutions to the current issues. These include "virtual satellites," i.e., satellites registered but never launched; satellites which have expired but are still registered; using a single satellite to claim several orbital slots; and registering excessive power levels and enormous coverage areas, effectively denying other operators' subsequent registrations.

JSC Kazakhstan Gharysh Sapary, representing the government of Kazakhstan's space agency Kazcosmos, signed a memorandum of understanding with Europe's Astrium company on 19 May. The memorandum outlined a broad partnership covering the creation of a joint-venture company to build and oversee a new satellite integration center in Astana, Kazakhstan; the training by Astrium of over

100 Kazakh engineers in France and Kazakhstan; the purchase by Kazakhstan of two Astrium-built optical Earth observation satellites; and the delivery by Astrium of satellite Earth stations in Kazakhstan to receive optical images from Spot Image (France) and radar imagery from Infoterra (Germany).

The \$330-million contract was signed on 6 October. One of the two satellites will be built by Astrium Satellites (France) and will carry an optical imager with 1-m resolution. It will be similar to the Theos and Formosat-2 satellites built by Astrium for Thailand and Taiwan (Province of China), and will be launched in early 2014. The second satellite, with 7-m resolution, is to be launched in late 2014. It will be built by Astrium-owned Surrey Satellite Technology Ltd. (SSTL, UK) on the company's SSTL-150 platform, which was used for the RapidEye constellation (Germany); the UK's TopSat demonstration satellite; and China's Beijing-1. TopSat and Beijing-1 are part of the SSTL-coordinated Disaster Monitoring Constellation, which includes SSTL-built spacecraft for Algeria, Nigeria and Turkey (see prior reports). The contract includes the launch of both satellites, which Kazakhstan plans to use for a wide range of civil applications, including surveillance of natural resources and agriculture, mapping, and support for natural-disaster response. The new joint venture also will oversee the space programme of the Kazakh government, which is budgeted at \$259 million per year.

Eight officials from the China National Space Administration visited NASA on 2-3 December 2008 to conduct meetings of the Earth and space science working groups that were created at the previous summer's initial meetings in Beijing (see last year's report). Following the convening of a special review of U.S. human space flight by President Obama (see above), a U.S. team headed by former NASA Deputy Administrator and Shuttle astronaut Fred Gregory visited China on 22 September to discuss cooperation in human space flight. The U.S. delegation, organized by the U.S. Space Foundation, visited Beijing Space City to brief five Chinese astronauts, including Yang Liwei and Zhai Zhigang, on their spaceflight experiences and to answer questions about U.S. practices. They were invited to inspect the assembly of Shenzhou-8, the 8.5-tonne Tiangong orbital target with which Shenzhou-8 will rendezvous and dock next year (see above), and the Chang'e 2 robotic lunar orbiter, due for launch in October 2010. The U.S. team also visited the China Academy of Space Technology (CAST), the China Astronaut Research and Training Center, and the Beijing Aerospace Control Center (BACC). Discussions of future cooperation in human space flight were conducted by the U.S. delegation with Wang Wenbao, director of the China Manned Space Engineering Office, and Zhou Jianping, chief designer of the China Manned Space Engineering Programme. Invited visits to China's space facilities are also planned later this year by NASA Administrator Charles Bolden and U.S. President Barack Obama.

Then on 15 October, at the 60th International Astronautical Congress in Daejeon, Korea Dong Nengli of China's Manned Space Engineering Programme announced that in addition to the 60-tonne Chinese space station launch in 2020 (see above), China is planning to conduct a human lunar-mission concept study. However, he also said that they would welcome a chance to join an international mission. To prepare for the human mission, China will launch a second robotic mission, Chang'e 2, in October 2010, to orbit the Moon at an altitude of 100 km and carry a camera with a resolution of better than 10 m. Next will come the 3.75-tonne Chang'e 3, to be

launched in 2012 directly to the Moon, where it will place a lander carrying a rover. Its mission will be to study the Moon's geological structure, its material composition, and internal structure; as well as to seek usable materials and build up an observatory based on the Moon. Nengli also cited China's planning for a lunar sample-return mission "before 2017."

On 2 March the Los Angeles Superior Court granted a final judgment of \$603.23 million to ICO Global Communications in its lawsuit against Boeing Satellite Systems International (BSSI) claiming breach of contract in completing and delivering the last 10 satellites of ICO's original 12-satellite order (see prior reports). BSSI is appealing the decision, a process that could take several years. Then on 3 March Great Britain's Office of Communications (Ofcom) notified ICO that because ICO's single satellite cannot be construed as an "operational system," Ofcom would instruct the United Nations' International Telecommunications Union (ITU) to cancel ICO's registration in the ITU Master International Frequency Register. ICO claimed that the delays in completing and deploying its constellation were due to the lawsuit against Boeing, and that ICO would continue to defend its international legal rights. However, on 15 May ICO Global's subsidiary, ICO North America, filed for Chapter 11 bankruptcy protection due to their inability to meet an August payment on their \$750 million debt, but continued to operate during the re-organization process. ICO Global itself was not affected by the bankruptcy filing.

On 13 August U.S. President Obama ordered a review of U.S. export controls governing dual-use technology transfers, which cover the export of U.S. commercial communication satellites and components, with the goal of accommodating U.S. national security needs without inhibiting the competitiveness of U.S. companies. On 9 September the U.S. Department of State (DOS) confirmed their intent to reform the export-licensing regime known as the International Traffic in Arms Regulation (ITAR). The review process for an export-license application has already been streamlined to two weeks from its duration of 43 days in 2006, and the DOS plans to cut that in half by the end of the year.

Then on 7 October the U.S. relaxed licensing restrictions on commercial radar satellites, permitting US companies to distribute higher quality data and potentially opening the door for a domestic market. The first license under the new regulations was granted to Northrop Grumman Aerospace Systems (USA) for a synthetic aperture radar (SAR) satellite called Trinidad, which is based on the currently flying TecSAR spacecraft built by Israel Aerospace Industries.

In February Bigelow Aerospace (USA) received approval from U.S. government export control authorities for a Commodity Jurisdiction request. The company can therefore train foreign nationals in how to live and work in its commercial habitats, and have such foreign nationals operate on their space complexes, all without filing any paperwork or seeking further Government approval. This legal milestone establishes a vital precedent for other firms, with Virgin Galactic and Space-X already outlining publicly their plans to file such requests. Bigelow has two privately-financed Genesis inflatable space stations in orbit (see last year's report).

On 20 July India and the U.S signed a Technology Safeguards Agreement that permits India to launch civil and noncommercial satellites containing U.S. components, but the launch by India of third-party commercial satellite containing U.S. components is still being negotiated.

Croatia started a national space programme on 1 May. As a planned science-exploration and educational project in the area of space technologies, its stated goal is to create, launch into orbit, and maintain a picosatellite, and to create similar craft intended for upper-atmosphere exploration. Demonstration missions to the Moon and planets of the Solar System are also planned, along with the creation of robotic systems.

The Israel Space Agency and the Italian Space Agency signed a bilateral agreement 16 June at the Paris Air Show to promote cooperation in the peaceful exploration of space. This agreement, which will cover the next five years, targets five key areas for cooperation: space research, including the exchange of professors and researchers; space science and exploration; Earth observation research and applications; space communications; and the use of ground equipment and ground segment infrastructure.

On 6 October Belgium and Brazil signed a four-year agreement to cooperate on Earth observations and satellite technologies and to seek the elimination of import taxes on equipment covered by the agreement. Belgium is the sixth-largest financial contributor to ESA.

## **A. Global Developments and Organizations**

### **(1) Status of UN Treaties**

Since 1987, the International Institute of Space Law (IISL) compiles an annual report on the status of international agreements relating to activities in outer space. This report includes signature, ratification, as well as declaration of acceptance of rights and obligations that have taken place since January of the current year. It is published on the IISL website and in its Proceedings.

In March, the Democratic People's Republic of Korea (DPR) of Korea acceded to the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (the Outer Space Treaty). The Outer Space Treaty has thus reached an important milestone, having been ratified by 100 States.

The Democratic People's Republic of Korea also acceded to the 1975 Convention on Registration of Objects launched into Outer Space.

In July, Nigeria also acceded to the 1975 Convention on Registration of Objects launched into Outer Space.

## **(2) International Organizations**

### **COPUOS**

The 48th Session of the Legal Subcommittee of COPUOS took place on 23 March-3 April 2009 in Vienna, Austria. The 52nd Session of the plenary of COPUOS took place in June 2009 in Vienna, Austria.

The Asia & Pacific Space Cooperation Organization (APSCO), a regional intergovernmental organization, formally requested to become a permanent observer in COPUOS. The Committee decided to recommend to the General Assembly, at its sixty-fourth session, the granting of permanent observer status to APSCO.

### **UNOOSA**

The the United Nations Office for Outer Space Affairs, together with the Government of the Islamic Republic of Iran and the Iranian Space Agency and supported by APSCO, organized the 2009 U.N. workshop on Space law that was held in Teheran in November 2009 (see also below, under 'Iran').

### **International Astronautical Federation (IAF)**

The 60th International Astronautical Congress (IAC) took place from 12 to 16 October, in Daejeon, Korea. The IAC was organized by the International Astronautical Federation (IAF) and the Korea Aerospace Research Institute (KARI). The theme of this year's IAC was 'Space for Sustainable Peace and Progress'.

### **International Academy of Astronautics (IAA)**

The IAA organized in October 2008 the first international interdisciplinary congress on space tourism, held in Arcachon (France), where technical, economic and legal aspects were addressed. The IISL supported the congress, in view of the large interest from the legal community to present papers. A follow-up conference is being planned for 2010.

In February, the IAA issued a Study on 'Medical Safety and Liability Issues for Short-Duration Commercial Orbital Space Flights', in which legal aspects were addressed.

The IAA and IISL (see below) organized the 24th Scientific-Legal Roundtable at the IAC in Daejeon in October 2009, on private commercial spaceflight.

### **International Institute of Space Law (IISL)**

The IISL Board of Directors asked the General Assembly of members in Korea in October to vote on its Statutes and By-Laws as amended. The IISL Statutes had to be amended several years ago when the IISL was incorporated the Netherlands as an independent international non-governmental organization (NGO), but the By-Laws were not updated at that time. A committee of the Board worked on the amendments over the past few years and they were accepted by the Institute's

members. The current version of the Statutes and By-Laws are on the IISL website, [www.iislweb.org](http://www.iislweb.org).

The IISL held its 52nd International Colloquium on the Law of Outer Space during the 60th International Astronautical Congress, Daejeon, South Korea, between 12 and 16 October. The Colloquium opened with two new events: the first Nandasiri Jasentuliyana Keynote Lecture on Space Law, which was delivered by Prof. V. Vereshchetin, former member of the ICJ, dealing with ‘The Law of Outer Space in the General Legal Field (Commonality and Particularities)’. The second new event was the first Young Scholars Session, which was also held during the same session. The other sessions addressed the following topics:

- Peace in Space;
- Third Party Liability Issues in Commercial Space Activities and Legal Challenges to Earth Observation Programs with Particular Emphasis on Developing Countries;
- Legal Mechanisms for Encouraging Space Commerce;
- Recent Developments in Space Law.

#### *Manfred Lachs Space Law Moot Court Competition*

Since 1992, the IISL has organized the Manfred Lachs Space Law Moot Court Competition. The 18th Space Moot Court competition was held in Daejeon, Korea, during the IISL Colloquium. Three regions were represented: Europe (9 teams), Asia Pacific (26 teams), and North America (8 teams).

The winner of the 2009 world finals was the National Law School of India University (India). This team won the Lee Love Award, established in 2008 for members of the winning team. The runner-up was Georgetown University (USA), which won a special award given by the Korean Minister of Justice. The second runner-up was the University of Strathclyde (Scotland, UK). Ms. Raeesa Vakil from India won the Sterns and Tennen Best Oralist Award, whereas the Eilene Galloway Award for Best Brief was won by Georgetown University.

As has become traditional, three judges from the International Court of Justice presided over the finals, held at Solomon Law Park in Daejeon: H.E. Judge Abdul Koroma, H.E. Judge Peter Tomka, and H.E. Judge Leonid Skotnikov.

The Isabella H.Ph.Diederiks-Verschoor Award and Prize for Best Paper by a Young Author was awarded to Catherine Doldirina, a Ph.D. student at the Institute of Air and Space Law, McGill University, Montreal, Canada. The paper’s title is “A rightly balanced intellectual property rights regime as a mechanism to enhance commercial earth observation activities”.

#### *Eilene M. Galloway Symposium on Critical Issues in Space Law*

The 4th Eilene M. Galloway Symposium on “Critical Issues in Space Law”, will be held on December 10, 2009, at the Cosmos Club in Washington, DC. This symposium is organized, sponsored and coordinated by the National Center for Remote Sensing, Air and Space Law (University of Mississippi) in cooperation with

the IISL, and is held in honour of Dr. Galloway and her long-standing contribution to space law. This year's symposium topic is "Peace in Space", and was suggested by Dr. Galloway, who passed away on May 2, 2009. The symposium is dedicated to her memory.

#### *IISL Statement on private property rights on the Moon*

After having issued a first statement in 2004, the IISL Board of Directors issued a new statement on the issue of private property rights on the Moon. It was adopted by consensus at the IISL Board of Directors meeting in Vienna in March 2009. The statement was presented to the COPUOS Legal Sub-Committee on the first day of its session. See <http://www.iislweb.org/docs/Statement%20BoD.pdf>

#### IISL/ECSL Symposium for the Legal Subcommittee of COPUOS

The annual IISL/ECSL Symposium for delegates and staff of the COPUOS Legal Subcommittee took place at the 48th Session of the Legal Subcommittee, which met from 23 March-3 April 2009 in Vienna, Austria. The topic for this year's symposium was "The 30th Anniversary of the Moon Agreement." Chairpersons for this event were Tanja Masson-Zwaan, President IISL, and Sergio Marchisio, President ECSL. Papers addressed the following topics: "The negotiation of the Moon Agreement", by Judge Helmut Türk, Vice-President, International Tribunal for the Law of the Sea. "The Moon Agreement - Perspective from Developing Countries", by Jose Monserrat Filho, Brazilian Society of Space Law, Brazil; "Some Legal and Factual Considerations about the 1979 UN Moon Agreement", by Jean-François Mayence, Federal Science Policy Office, Belgium; "The Common Heritage of Mankind Principle: the Moon and Lunar Resources" by Juan Manuel de Faramiñán Gilbert, University of Jaén, Spain; "Is a New Look Necessary in the Age of Exploration and Exploitation?" by Susan Trepczynski, Finalist in the World Finals of the Manfred Lachs Space Law Moot Court Competition, USA; and "Protecting the Environment of Celestial Bodies by Dr. Mahulena Hofmann, University of Giessen, Germany/Charles University Prague, Czech Republic. Prof. Vladimír Kopal, Chairman of the Legal Subcommittee gave some concluding remarks.

#### European Centre for Space Law (ECSL)

##### *Summer Course*

The ECSL held its 18th Summer Course on Space Law and Policy at the University Nova of Lisbon, Portugal, from August 31st to September 11th, 2009. The Summer Course attracts participants from an increasing number of European universities.

##### *ECSL Practitioners' Forum*

A one-day Practitioner's Forum has been organised every year since 1992. The aim of the Forum is to provide those working in the space sector with a informal forum for the exchange of views, knowledge and information. On Monday 15 December 2008, the annual ECSL Practitioners' Forum took place at ESA Headquarters in Paris, on the subject of "National space legislation in Europe – Issues



of authorisation in the light of developments in European space cooperation.” The meeting was chaired by ECSL Chairman Prof. Marchisio, and began with a brief introduction by Prof. von der Dunk, Practitioners’ Forum Coordinator. More than fifty people attended. Among the speakers were Prof. Marboe, incoming Chairperson of the UNCOPUOS Legal Subcommittee’s Working Group, who spoke on national space legislation. Other speakers also addressed the issue of national authorization regimes.

The afternoon session was chaired by Dr. Hulsroj, Director Legal Affairs and External Relations of ESA. Topics addressed included authorization of space tourism: the case of the Netherlands; authorization of space activities after the entry into force of the EU Reform Treaty, as well as national authorisation and GATS-principles (MFN, national treatment).

#### International Law Association (ILA)

The International Law Association (ILA) Space Law Committee -which has permanent observer status in COPUOS and both its Subcommittees since 1996- took part in the COPUOS’ Legal Sub-Committee last March-April and submitted both a Report (published in written form in Doc. A/AC/C.2/L.275, pp.8-17) and made an oral presentation on the work of the ILA during 2008. It concerned the results and recommendations adopted at the ILA 73rd Conference in Rio (August 2008) and future work of the Space Law Committee for ILA’s 74th Conference (The Hague, 15-20 August 2010). The ILA’s work focused on remote sensing (with special reference to the use of satellite data in national and international litigation), national space legislation, registration, space debris (following the UNGA Resolution of 21 December 2007), and also introduced some basic questions on Near Earth Objects (NEOs) with a view to addressing the subject in its future work.

#### UNIDROIT

The International Institute for the Unification of Private Law (UNIDROIT) has been working on a Draft Protocol On Matters Specific To Space Assets for several years. In its most recent draft, the Protocol would apply only to the satellite itself, and not to more controversial items, such as licenses. In November 2007, UNIDROIT’s Assembly of Parties established a Steering Committee, with the aim of finalizing the Space Assets Protocol in a timely manner. At the 2009 Spring meeting of the UNCOPUOS Legal Sub-Committee, UNIDROIT presented a revised version of the Protocol, and plans to hold a meeting of governmental experts in December 2009 in Rome, at which time the final text should be presented and ready for approval by the Fall of 2010. In the meantime, various delegations to COPUOS suggested that this item remain on the agenda of the COPUOS Legal Subcommittee.

### **B. Europe**

#### **a. Draft Code of Conduct for Space Activities**

The Council of the European Union in December 2008 adopted a Draft Code of Conduct for Outer Space Activities (Council doc. 16560/08, 3 Dec. 2008). The aim of the Draft Code is for the subscribing countries to undertake certain measures in

space operations to minimize risk of collisions, to refrain from intentional actions which might directly or indirectly cause damage or destruction of objects in outer space, unless “such action is conducted to reduce the creation of space debris and/or justified by imperative safety considerations.” The EU is currently holding consultations to revise the text to make it more acceptable to more countries.

#### **b. European Union / European Commission (EC)**

The Treaty of Lisbon (initially known as the Reform Treaty) is an international agreement signed in Lisbon on 13 December 2007 designed to change the workings of the European Union (EU). Having been ratified by all EU member states, the treaty will enter into force on 1 December 2009. The treaty amended the Treaty on European Union (TEU, Maastricht; 1992) and the Treaty establishing the European Community (TEC, Rome; 1957). In the process, the TEC was renamed to Treaty on the Functioning of the European Union (TFEU).

Prominent changes include increased involvement of the European Parliament in the legislative process through extended co-decision with the Council of Ministers, and the creation of a President of the European Council with a term of two and a half years.

The stated aim of the treaty is "to complete the process started by the Treaty of Amsterdam [1997] and by the Treaty of Nice [2001] with a view to enhancing the efficiency and democratic legitimacy of the Union and to improving the coherence of its action."

The Lisbon Treaty, for the first time ever, will provide a formal competence for the European Union in the field of space (See article 4.3 TFEU: “In the areas of research, technological development and space, the Union shall have competence to carry out activities, in particular to define and implement programmes; however, the exercise of that competence shall not result in Member States being prevented from exercising theirs”).

The European Commission is of the opinion that the European Union needs its own space surveillance network to protect the investment it is making in satellite systems for climate monitoring, security, navigation and other purposes. Space policy is an area to be developed, and the Commission expects to broaden its space interest to include space exploration. According to press reports, the European Commission is expanding its reach in space and is likely to spend several times the \$1 billion per year it currently spends on space projects during the seven-year budget starting in 2013 that is now being crafted.

On May 14 the European Commission published its selection decision for the S-band process in Europe. The Commission selected two operators, Solaris Mobile Limited and Inmarsat Ventures Limited, each of which received 2 x 15 MHz of S-band spectrum, to provide European wide satellite TV and other mobile satellite services across Europe. This selection is being contested by several entities, alleging that the EC’s decision to award frequencies is beyond its scope of competence, and therefore, illegal; rather, it is the ITU’s role to do the frequency allocation and coordination. While the frequencies have been awarded on a pan-European level,

Solaris Mobile and Inmarsat will still have to obtain national licenses and pay any associated fees required by the individual countries. Depending on the outcome of these challenges, it may be a while yet before mobile satellite TV services are provided in Europe, utilizing the S-Band.

TerreStar Europe on May 25 announced that it had filed a lawsuit in a Luxembourg high court against the European Commission (EC) seeking the annulment of the EC's decision to select Inmarsat and Solaris Mobile as exclusive license holders to operate S-band pan-European mobile satellite services. TerreStar stated that the EC's review process was prompt and narrowly focused and that the EC excluded TerreStar Europe on a technicality at a preliminary stage of the selection procedure. TerreStar also claims that the EC misread its submission and failed to investigate what the commission claimed were inconsistencies in TerreStar's submission. TerreStar joins rival MSS provider, ICO Communications in protesting the May 13 decision by the EC.

### **c. European Space Agency (ESA)**

ESA astronaut Frank De Winne became the first European commander of the International Space Station in October 2009 with the departure of Russian cosmonaut Gennady Padalka who had filled this role since April. De Winne is the first non-American and non-Russian to take on this role. De Winne remains as ISS Commander until shortly before his return to Earth at the end of his six-month ISS Mission – currently set for 1 December 2009. During his time in command, De Winne will oversee the completion of the Japanese HTV mission and welcome a new module from Russia. The Mini-Research Module 2, or MRM 2, will act as an additional docking port and airlock at the Russian end of the station.

Europe may buy a Soyuz spacecraft to try to ensure at least one European astronaut heads to space each year, officials say. The director of human spaceflight for the European Space Agency has asked Moscow if it could increase production of Soyuz spacecrafts from four to five a year, to increase ESA-Russian cooperation and also take into account NASA's retirement of the Space Shuttle.

The European Space Agency hosted the 5th European Conference on Space Debris at ESA's Space Operations Centre (ESOC) in Darmstadt, Germany, from 30 March -2 April. The conference was the largest dedicated event on space debris issues, and was co-sponsored by the British, French, German and Italian space agencies (BNSC, CNES, DLR, ASI), the Committee on Space Research (COSPAR) and the International Academy of Astronautics (IAA).

Space debris has recently been attracting increasing attention not only due to the growing recognition of the long-term need to protect the commercially valuable low-Earth and geosynchronous orbital zones (LEO and GEO), but also due to the direct threat that existing debris poses to current and future missions. In February 2009, a Russian spent satellite collided with an operational Iridium satellite, causing a great deal of space debris, highlighting the hazards posed by space debris. While commercial and scientific uses of space have expanded across a wide range of activities, including telecommunications, weather, navigation, Earth observation and science, space debris has continued to accumulate, significantly threatening current

and future missions. ESA informed that, as of December 2008, the U.S. Surveillance Network had catalogued 12,500 objects as space debris.

## **EGNOS**

European Geostationary Navigation Overlay Service (EGNOS) is Europe's first venture into satellite navigation. It was developed by the European Space Agency (ESA) under a tripartite agreement between the European Commission (EC), the European Organisation for the Safety of Air Navigation (Eurocontrol) and ESA. EGNOS is comprised of transponders aboard three geostationary satellites and a ground network of about 40 positioning stations and four control centers, all interconnected.

In April 2009, the ownership of the EGNOS assets were transferred from the European Space Agency to the European Commission (EC) which now manages and finances the entry of EGNOS into the Service Provision phase. While the EC now owns and manages the EGNOS system, ESA is the design and procurement agent through a delegation agreement with the EC. The European Satellite Services Provider, ESSP SaS, based in Toulouse, France, manages EGNOS operations. A contract between the EC and ESSP SaS was signed on 30 September. The contract provides for the management of EGNOS operations and the maintenance of the system until the end of 2013.

EGNOS complements the GPS system. The EGNOS Service Area includes all European states and has the system-inherent capability to be extended to other regions, such as EU neighboring countries, North Africa and more generally, regions within the coverage of three geostationary satellites being used to transmit the EGNOS signal. This is a major milestone for the project: its primary service being available to all users equipped with EGNOS-compatible receivers. Most mass-market satellite navigation receivers being sold today are ready for EGNOS. The Open Service is provided free of charge.

## **Galileo**

The Second International Colloquium on Fundamental Aspects and Scientific Applications of Galileo was held in Padua, Italy, 14–16 October 2009. The Aula Magna of the University, the very place where Galileo Galilei gave some of his lectures, was the venue for this event. This event brought together leading members of the European scientific community and their international partners interested in the scientific use of Galileo and fundamental aspects of Global Navigation satellite Systems (GNSS).

In September, GIOVE-A, the first Galileo test satellite in orbit, was moved to a higher orbit to ensure that it does not cross the operational Galileo constellation's orbits for more than 100 years. Launched on 28 December 2005 from Baikonur, with an expected lifetime of two years, GIOVE-A is still in perfect condition after almost four years in space. During that time, it has achieved all of its objectives, validating key technologies.

GIOVE-A secured the Galileo frequency filings with the International Telecommunication Union (ITU), and facilitated the experimental reception of navigation signals from Medium Earth Orbit (MEO). GIOVE-A and GIOVE-B are fully operational, waiting for the launches of the four Galileo In-Orbit Validation satellites, scheduled for late 2010 or early 2011. The launches have suffered delays due to last-minute difficulties with the satellites, which are being built by a European consortium led by Astrium Satellites and Thales Alenia Space.

## **GMES**

GMES (Global Monitoring for Environment and Security) is an EU-led initiative. Following the recent Commission Communication and EU Competitiveness Council conclusions on GMES, the European Commission ensures the political coordination of GMES and the development and implementation of a programmatic, institutional, financial and regulatory framework and takes the lead in identifying and bringing together user needs for GMES. It also ensures the availability and continuity of operational services that support its policies. Technical implementation is entrusted to European entities.

In this context and in accordance with the 5th Space Council Resolution of September 2008, ESA's role within GMES is to be the development and procurement agency for the dedicated GMES Sentinel Missions, and the coordinator for the whole GMES Space Component, including contributions made available by Member States, EUMETSAT and further GMES partners.

In January, an amendment to the EC-ESA GMES agreement was signed by Mr. Jean-Jacques Dordain, the European Space Agency (ESA) Director General, and Mr. Heinz Zourek, Director General of the European Commission's Directorate General for Enterprise and Industry. This amendment extends the scope of the original Agreement (signed in February 2008) to activities of Segment 2 of the GMES Space Component Programme and paves the way to ordering the second units of the Sentinel 1, 2, 3 satellites as well as the atmospheric chemistry missions Sentinel-4 and -5 precursor. The amendment also adds a further contribution from the European Commission of €205 million to segment 2 of the GMES Space Component (GSC) programme.

### **d. Austria**

The first Austrian satellite, TUGSAT-1/BRJTE will be launched into outer space in the near future, making Austria a space-faring country for the first time.

During the Spring session of the COPUOS Legal Subcommittee, the Austrian delegation, which headed a working group on national legislation on space activities presented a comparative analysis on existing legislation on space activities in several of the European countries, and invited other countries that had not participated to date, to join the Working group, and so enhance its work.

## **e. Czech Republic**

The Czech Republic ratified the ESA Convention on 12 November 2008 and has thus become a full member of the European Space Agency.

Some 50 astronauts and cosmonauts from across the world met in Prague, for a "Planetary Congress" organized by the Association of Space Explorers (ASE) to review the member states' space programs and promote space exploration among the public. Yang Liwei, China's first astronaut was in attendance, and was treated with great deference by top Russian and US astronauts attending this year's congress. They seemed very impressed by China's space program.

## **f. Estonia**

In November, Estonia became the fifth European country to sign the European Cooperating State Agreement with ESA. The signed agreement strengthens Estonia's relations with ESA and defines the legal basis for developing a Plan for European Cooperating State (PECS) Charter, describing activities, projects and budget for Estonia's cooperation with ESA. ESA and Estonia will have to complete the list of projects that will be presented for approval to the relevant ESA Committees and Programme Boards. The PECS Charter should be signed before the end of November 2010.

## **g. France**

### *Arianespace*

Arianespace has had a very successful series of launches and launch contracts this year. Among them, on April 14 Arianespace announced that it was selected to launch the Intelsat New Dawn satellite for New Dawn Satellite Company Ltd., a joint venture between Intelsat, Ltd. and a South African investor group led by Convergence Partners. The satellite is being built by Orbital Sciences Corporation using its STAR-2™ platform and will be equipped with 28 C-band and 24 Ku-band transponders to provide new capacity to Africa for voice, wireless backhaul, Internet and media services. The launch will take place in 2010.

In July, Arianespace successfully launched TerreStar-1, the largest commercial satellite ever deployed to orbit, on an Ariane 5 ECA launcher, for TerreStar Networks Inc.

Weighing nearly 6,910 kg at launch, the SS/L-built satellite is designed to function with a terrestrial repeater network and provide Sband mobile voice, data and video services to support critical communication and business continuity services for government, emergency responder and enterprise customers.

On 1st October, Ariane 5 team flew its fifth rocket of the year, topped with a high performance Spanish broadcasting satellite and a secure German military communications craft. The rocket carried the Amazonas 2 communications satellite and the COMSATBw 1 spacecraft. The next Ariane 5 has been stacked atop a mobile launching platform in preparation to receive its dual communications satellite cargo --

the SES World Skies' NSS 12 for coverage across the Eastern Hemisphere and Telenor's Thor 6 to serve the Nordic countries. The seventh launch for the year has already arrived at the launch site.

According to Arianespace, commercial satellite launch prices have continued to rise in recent months despite the excess of launcher capacity worldwide and early signs that the global credit crunch is delaying some satellite programs. The current economy is affecting the launch market: as struggling satellite customers are seeking financial aid from export credit agencies and even healthy satellite operators are opting for smaller satellites rather than larger ones to save money.

### ***Eutelsat***

Eutelsat's W2A was successfully launched on April 3 by International Launch Services (ILS) from the Baikonur Cosmodrome in Kazakhstan on a Proton-M launcher. The satellite, built for Eutelsat Communications by Thales Alenia Space on its Spacebus 4000 C4 platform, is equipped with 46 Ku-band transponders, 10 C-band transponders and an S-band payload. The satellite's S-band payload will be used by Solaris Mobile, a joint venture between Eutelsat and SES Astra, to provide capacity to pan-European mobile video, radio and information systems service providers. (See European Commission section as to some controversy that has arisen as a result of Solaris' use of the S-band).

### **h. Ireland**

Ireland seems to be keen on space tourism. It held the "Unconscionability, Volenti and Space Tourists," a Law Student Colloquium, at Trinity College, Dublin, 4th April 2009. A few months later, the Society of Legal Scholars held its Centenary Conference on "Consumer Law and Space Tourism", at Keele, UK on 7th September 2009.

The 9th European Symposium on Light Pollution was held from the 17th-18th September 2009 in Armagh, Ireland.

Astronomy Ireland hosted the Dublin Telescope Nights, as part of the 100 Hours of Astronomy events. Hundreds of events were held across the country to celebrate the Bliain Idirnáisiúnta na Réalteolaíochta/ International Year of Astronomy, including the Astro-Art Fun workshop held at Omagh library, together with the Astronomy "From Earth to the Universe" exhibition held on Tuesday 6 October 2009. World Space Week was launched in Ireland with an astronomical theme for the Donegal Bay & Blue Stacks Festival 09.

Ireland had entered into an agreement with India, on Scientific and Technological Co-operation between the Government of Ireland and the Government of the Republic of India, done at New Delhi in January 2006, but it only entered into force at the end of 2008. The text of the Agreement is available at <http://www.dfa.ie/uploads/documents>.

## **i. The Netherlands**

In September 2009, the Minister of Economic Affairs launched the Netherlands Space Office (NSO) the new Dutch agency for space affairs. The NSO is a cooperative endeavour between the Ministry of Economic Affairs, the Ministry of Education, Culture and Science, the Ministry of Transport, Public Works and Water Management, and the Netherlands Organisation for Scientific Research (NWO). With the NSO, the Netherlands has its own space agency, commissioned by the government to develop and run the Netherlands Space Programme. Further, the NSO represents the Netherlands in its relations with other national and international space agencies like ESA, NASA, DLR and CNES.

## **j. Russian Federation**

Russia was planning to orbit three Glonass navigation satellites on October 29 following their launch cancellation in September, according to the Federal Space Agency Roscosmos. Another three satellites will be launched on December 4. The 18 satellites the system requires for continuous navigation services covering the entire territory of the Russian Federation are currently in orbit, and the six due to go up in two launches this year would bring numbers up to the 24 needed to provide services worldwide.

The press reported in September that a group of Russian engineers and managers known as Team Selenokhod will compete for the Google Lunar X Prize. Team Selenokhod was noted for being the first Russian team in the competition. The team's vehicle, Selenokhod, consists of a lander with a communications system and two four-wheeled, solar-powered rovers each equipped with a high-definition camera and a low-gain antenna, according to a press release posted on the X Prize Foundation's Web site.

Measat Satellite Systems, the Asian satellite operator, signed a deal with StarHub Cable Vision (StarHub) for the delivery of the Golf Channel to Singapore. StarHub's Golf Channel is a 24-hour channel featuring tournaments played around the world.

With 70 % of the content made up of live coverage of leading golf events, the channel features events such as the U.S. Professional Golfers' Association (PGA) Tour, European PGA Tour, Ladies Professional Golf Association Tour, Champions Tour and Nationwide Tour.

Satguard Asia announced the launch of its latest GPS-based vehicle security and tracking devices designed to bring the technology within the reach of the majority of vehicle owners. Based on the latest GPS, global information system (GIS), global system for mobile communications (GSM) and general packet radio service (GPRS) technologies, the devices can locate and track any moving asset in real time with an accuracy of less than a meter. The products are specially targeted for Asian markets including India.



## **k. Spain**

The Technical University of Madrid established in 2009 a new postgraduate programme of studies, the Master in Space Technology (MST), with the support of the Spanish authorities and ESA. The MST includes an introductory course on Space Law, which will cover the following topics: the five UN outer space treaties; legal regime of the ISS; the ITU regulations; and legal aspects of space insurance. The lectures are being conducted by IISL member Rafael Moro Aguilar (Madrid, Spain). The MST will run from January to December every year.

Hispasat's Amazonas 2 satellite was transported to the European Space Agency launch base in Kourou, French Guiana, from where it was launched on an Ariane 5 ECA at the end of September. The \$293 million satellite, built by EADS Astrium, was transported after it passed resistance and performance tests. Amazonas 2 aims to increase the operations capacity and flexibility of Hispasat's satellite system and consolidate it as the operator of reference in the Spanish and Portuguese speaking markets. Spanish satellite operator Hispasat is targeting a strong performance in its core markets in Europe and Latin America, and this launch is expected to help the operator.

## **l. Sweden**

Swedish Space Corp. (SSC) in May completed the acquisition of U.S.-based Universal Space Network (USN), a U.S.-based telemetry, tracking and control services provider, after receiving approval from the U.S. government. SSC said that under the terms of the acquisition, first announced in January, USN will operate as a U.S. corporation and subsidiary of SSC with no change to its operation or organization. USN aims to provide a larger set of global services to their customers while continuing to provide a high level of support to each customer locally. PriorNet, the trademarked name of their global satellite tracking service, is now positioned to better support civil, commercial and government missions worldwide.

Sweden has made a deal with Virgin Galactic about launching space tourism from a spaceport in Sweden, according to press reports.

## **m. Turkey**

The Turkish Defense Ministry awarded Telespazio a contract to provide its Gokturk optical reconnaissance Earth observation satellite system in December '08. The contract includes the launch of the Gokturk satellite and the installation of the satellite's ground installations. Also included is a satellite integration and test center to be built in Turkey, whose government has said it wants to develop a domestic satellite manufacturing industry.

## **n. United Kingdom**

Inmarsat selected Arianespace to launch the Alphasat I-XL communications satellite in 2012. The deal follows an agreement between Inmarsat and the European Space Agency (ESA) to cooperate on the commercialization of the first mission to use the new European platform, Alphasat. Alphasat I-XL will be built by Astrium using

an Alphasat platform, and will be positioned at 25 degrees East, joining Inmarsat's current fleet of 11 geostationary satellites providing mobile voice and data communications services across Europe, Africa and the Middle East.

## **C. Africa and the Middle East**

### **a. Iran**

The Iranian Space Agency (ISA) announced that the first domestically-built satellite of Iran called 'Omid' (Hope) was sent to orbit in February, on-board the nationally-developed launching rocket 'Safir-2', raising concerns in many countries in regard to Iran's aims and aspirations.

While the significance of the launch was debated by military and intelligence analysts and arms control experts, many agreed that Iran had achieved a milestone: Only 10 other countries have successfully launched satellites into orbit. It was also a reminder of Iran's progress in developing militarily useful technology. Iran claims that its satellite program has a 'peaceful nature' and will only be used to meet Iran's domestic needs.

The United Nations/Islamic Republic of Iran Workshop on Space Law on the "Role of International Space Law in the Development and Strengthening of International and Regional Cooperation in the Peaceful Exploration and Use of Outer Space" was held in Tehran, Iran, from 8-11 November 2009. This successful event was jointly organized with and hosted by the Iranian Space Agency (ISA) and supported by the Asia-Pacific Space Cooperation Organization (APSCO).

Dr. Ahmed Talebzadeh, the former President of the Iranian Space Agency (ISA) will be the Chairman of the COPUOS' Legal Subcommittee for the period of 2010-2011.

### **b. Nigeria**

Afcom Satellite Networks in June completed construction of its next-generation C-band satellite gateway ground station in Lagos, Nigeria. The C-band gateway, which is networked with Intelsat satellites, provides services suited for the banking, oil and gas industries as well as other multi-national companies throughout Nigeria and West Africa. Afcom will increase its capabilities, offering broadband Internet and VSAT services to its customers.

Nigeria's expanding economy, and a corresponding dependence on sophisticated wireless technology requires organizations to have exceptional reliability and high service levels from their VSAT providers in order to compete in the world, according to Afcom.

### **c. South Africa**

South Africa's Trade and Industry Ministry in December 2008 launched the country's National Space Policy, stating that it South Africa's primary goal is to acquire the appropriate space-based systems for wider socio-economic benefits, as

well as for the country's independent access to space. According to the Ministry, one of the most urgent areas of work with regards to the policy is to ensure that the country has the necessary capacity and resources to implement it. South Africa believes that cooperation and collaboration with other countries would be of great importance to ensure the success of the space industry in South Africa.

South Africa also passed in December 2008 a law establishing a National Space Agency, which entered into force in January 2009. The aim of this law is to coordinate the different space activities that are being conducted by South Africa, and to facilitate government investments in this sector.

#### **d. United Arab Emirates**

Aabar Investments of Abu Dhabi and Virgin Galactic have entered into a strategic partnership which involves Aabar's investing \$280m for a 32% (approximate) stake in Virgin Galactic's holding company. Aabar has additionally committed \$100m to fund a small satellite launch capability for the commercial spaceliner. The transaction is subject to regulatory clearances in the US.

Thuraya announced in March that it had launched a satellite-based Public Calling Office (PCO) service in Zambia and Cameroon. Thuraya's PCO is a telephone unit providing voice, data and fax communication for communities based in remote and rural areas that have no access to terrestrial networks. It enables users to call and send text messages nationally and internationally in multiple languages and without having to purchase a mobile satellite handset.

The launch in the two African markets has been through commercial partnership with Fort Info Technology, a Dubai-based long-standing service provider for Thuraya services across several countries. The initiative in both Zambia and Cameroon is being undertaken in partnership with local non-government organizations that are responsible for installing the PCO in remote areas.

Yahsat is investing \$100 million in YahLive, a direct-to-home service it plans to launch in the fourth quarter of 2009 with joint venture partner SES Astra, which is investing \$50 million in the project. YahLive is expected to generate revenues in its third year on growing regional demand for high definition and that a large portion of its capacity will be utilized between the third and fifth year. It estimates the market will grow 38 percent per annum with about 100-plus high definition channels to be added in the region by 2017. Yahsat's two satellites are being built by EADS Astrium and Thales Alenia Space and are scheduled for launch in the second half of 2010.

In August Mohamed Youssif was appointed CEO of YahLive, a partnership between SES Astra and Yahsat offering satellite capacity for DTH services to the Middle East, North Africa and South West Asia. Youssif previously served as CCO of Arabsat. YahLive will own and commercialise 23 BSS-transponders on the Yahsat 1A spacecraft to be positioned at the 52.5 degrees East orbital position and operating in the Ku-band frequency.

## **D. Asia and the Pacific**

### **a. APSCO**

The Asia Pacific Space Cooperation Organization (APSCO) began its operations in December 2008. APSCO evolved from Asia Pacific Multilateral Cooperation in Space Technology and Applications (AP-MCSTA), which came into being when an MoU was signed between China, Pakistan and Thailand in 1992. The objectives of APSCO are to focus on space science / technology and its applications, education / training and cooperative research to promote peaceful uses of outer space in the region. The APSCO Convention, according to Article-9, would enter into force when at least five States have signed it and deposited with the host Government (China) their instruments of ratification or acceptance. The APSCO Council was to be formally established after ratification of the convention.

The organization, headquartered in Beijing, has nine member-states: Bangladesh, Indonesia, Iran, Mongolia, Pakistan, Peru, Thailand, Turkey and China. It is the second regional space cooperation organization in the world after the European Space Agency.

### **b. Australia**

In April, the Australian military signed a \$167 million, 15-year contract with Intelsat to host a specialized UHF payload to provide communication services for Australia's defense forces. Intelsat is dedicating a portion of its Intelsat 22 satellite, which is being manufactured by Boeing. The payload is optimized to address high-growth service areas, supplying 48 C- and 24 Ku-band transponders to provide network services and media customers in Africa, Asia, Europe and the Middle East. Intelsat's satellite will provide market capacity for commercial and government applications.

The Australian Senate Standing Committee on Economics issued a Final Report on the current state of Australia's space science and industry sector, "Lost in Space? Setting a new direction for Australia's space science and industry sector." Issues addressed in the Report include Australia as a launch site; Australia as a base for space tourism; whether Australia needs more satellites; the role of Government and space research; and lastly, space policy and the government's role in setting space policy.

The committee believes it is not good enough for Australia to be lost in space. Rather, it is time to set some clear directions. The Australian government should have a space policy and, like most other comparable countries, an agency to implement it. The global space industry generates global revenues of around US\$250 billion per annum<sup>2</sup>, and Australia should be playing a larger role. Accordingly, the recommendations in the report's final chapter chart a course towards Australia regaining an important place in global space science and industry by gradually developing a dedicated space agency. The complete report may be found at <http://www.aph.gov.au/>

### **c. China**

The 2008 Annual Conference of the China Institute of Space Law was hosted by the Institute of Space Law of the Beijing Institute of Technology on the 20th of December, 2008. The topic of the conference was "Harmonious World and Rule of Law in Outer Space". 50 experts in space law participated in the conference, including Prof. Joanne Irene Gabrynowycz from the University of Mississippi (and IISL Board member). The experts discussed some legal issues resulting from the commercialization, and militarization of outer space. They provided some useful suggestions for the perfection of international legislation on space law and Chinese legislation on space law.

In April, the Chinese government announced that it had merged China Aerospace Science and Technology Corporation (CASC) with China Satellite Communications Corp. (China Satcom). China Satcom, with total assets worth 6.6 billion yuan (\$965 million), will operate as a wholly owned subsidiary of CASC. According to CASC, the merger was planned by the Chinese government in an effort to reform the country's telecommunications industry. The merger will extend CASC's research and manufacturing services to include operating satellite-based telecommunications. CASC plans to launch seven satellites for broadcast and mobile communications purposes in the next five years. Separately, China Satcom said its telecommunication operations will be taken over by China Telecom, a major telecom service in China, after the merger is completed with CASC. China Telecom is among three telecom services left in China, including China Mobile and China Unicom.

Chinese space officials are interested in sending their astronauts to the Moon on their own, although they say China would 'welcome' a chance to join the larger international exploration effort that has coalesced around the International Space Station. Officials from China's Manned Space Engineering Program at the October International Astronautical Congress (IAC) held in Korea, elaborated on plans to continue gaining spaceflight experience by building toward the 60-ton, three-person space station.

The AsiaSat 5 satellite entered into commercial service in September, a few weeks after International Launch Services (ILS) successfully launched the AsiaSat 5 satellite. AsiaSat 5, a Space Systems/Loral (SS/L) 1300 satellite, is located at 100.5 degrees East, where it will replace AsiaSat 2. Transfer of traffic from AsiaSat 2 to AsiaSat 5 will be completed over the next few weeks, according to AsiaSat. AsiaSat 5 has 26 C-band and 14 Ku-band transponders and will provide video and news distribution and contribution services as well as to governments and corporations for VSAT network services for private broadcasters.

The AsiaSat 5C satellite will also be built by Space Systems/Loral, according to an AsiaSat announcement in May 2009. AsiaSat, however, has scaled back expectations for this company's overall performance in 2009. The company now expects results similar to 2008, according to a statement in AsiaSat's first-half 2009.

#### **d. India**

The Indian Space Research Organisation (ISRO) announced on July 28 that India signed a technology safeguards agreement with the United States, to facilitate the launch of non-commercial U.S. satellites on Indian launch vehicles. The agreement also includes allowing satellites with U.S. components, previously prohibited on Indian spacecraft, to be launched on Indian rockets. ISRO estimates the total global market for non-commercial launches at about 40 satellites a year. India's contribution to that number has been minor. ISRO said it hopes the TSA agreement will enable India to claim a larger stake in the market. Despite the agreement, India is still prohibited from launching heavy commercial U.S. satellites or components.

In October, it was reported that India is scouting for 15-16 sq km of land on the moon. The land should have some specific characteristics, including a crater with ample water. The land should also have enough shadow regions that stay cool in the peak of summer. The location would be for a "lunar base," which one senior scientist with the ISRO program said would be built starting in 2020. India aims to share the lunar base with the global community through an international collaboration under the aegis of the International Lunar Network (ILN), a partnership of 10 space-faring nations, including India, set up last July.

India has sought a Russian spaceship for sending 'space tourists' into orbit, an official said. A Roskosmos spokesperson said the deal would be commercial, with two space travelers flying in the non-reusable 'Soyuz TMA' ship, to be piloted by a Russian cosmonaut. No details about the deal or the value of the contract were provided.

ISRO's long-term mission is to have a permanent research station on the Moon, upon the conclusion of the Chandrayaan project, according to Mylswamy Annadurai, ISRO Project Director for Chandrayaan I and II. At an exhibition, Annadurai called on the students to work for the country after achieving academic success.

All the three payloads on board India's Oceansat-2 have been switched on and are providing good quality images of India and oceans around the world, according to the Indian Space Research Organisation (ISRO).

Dr Madhavan Nair, Chairman of ISRO, was elected President of the IAA during the Korea IAC. Subsequently, Dr. Radhakrishnan became Chairman of ISRO.

#### **e. Japan**

In April, astronaut candidates Kimiya Yui and Takuya Onishi attended an induction ceremony held at the Japan Aerospace Exploration Agency, or JAXA. The two are noted as potential candidates for work on the International Space Station. The astronauts-to-be will seek to work eventually for an extended period of time on the International Space Station, with Japanese astronaut Koichi Wakata, a "veteran" Japanese worker on the ISS.

In April, Japan announced that it hopes to have a two-legged robot walk on the moon by around 2020, with a joint mission involving astronauts and robots to follow. The Strategic Headquarters for Space Development said a specific plan would come over the next two years. This plan is part of a broad framework outlined by the group, which is charged with plotting a new course for Japan's space strategy. The group also recommended promoting research into military satellites, such as an early warning system for detecting ballistic missile launches and systems to detect and analyze radio waves sent in space.

In July, the Japan Aerospace Exploration Agency (JAXA) completed the assembly of the Japanese Experiment Module "Kibo", Japan's first manned space facility. The assembly was completed as the Exposed Facility was attached to Kibo's Pressurized Module, and all functions were verified to be satisfactory. "Kibo" is now fully established as a permanent on-orbit laboratory that provides both pressurized and exposed experiment environments.

In early September, JAXA launched the HTV-1, using its brand-new H-2B rocket. Both spacecraft functioned perfectly during the spaceflight debut. The HTV-1 is the first in a new line of Japanese space freighters to haul tons of supplies for astronauts aboard the space station. The H-II Transfer Vehicle (HTV) Demonstration Flight departed from the International Space Station (ISS) on October 31, and re-entered the atmosphere on November 2, thus successfully completing its cargo transportation operations to the ISS, and accomplished all its missions in about 52 days following the re-entry.

#### **f. Kazakhstan**

The government of Kazakhstan has chosen Astrium to build and launch two Earth observation satellites, and provide a satellite integration and test center in Kazakhstan, in a contract concluded Oct. 6. One satellite will be built by Astrium Satellites and the other by Astrium-owned Surrey Satellite Technology Ltd. The contract includes the launch of both satellites, but launcher selection has not been made.

#### **g. Republic of Korea**

Korea was the host of the 60th International Astronautical Congress, held in Daejeon, 12-16 October. The Congress' theme was "Space for Sustainable Peace and Progress." One of the keynote speeches was given by Korea's first woman astronaut, Yi So-Yeon.

South Korea and Russia were to meet in late October for a formal review to determine why a jointly developed space rocket failed to place a satellite into orbit. The meeting is expected to shed light on why the KSLV-1 rocket failed to insert a satellite properly into orbit. "Both South Korean and Russian engineers are expected to conduct simulations this week that reflect actual launch conditions on a duplicate model of the nose fairing to see why the covers did not fall off.

## **h. Democratic People's Republic of Korea (DPRK)**

In April North Korea said that it had put a communications satellite into orbit and that it was transmitting patriotic music, including a celebratory tune, but the US and South Korea reported that the satellite had not reached orbit. The US military's Northern Command stated on its Web site that the payload itself landed in the Pacific Ocean. North Korea had ordered its armed forces on standby and warned it would retaliate against anyone seeking to block its planned satellite launch, a launch many feared was a disguised missile test.

In March, North Korea ratified both the 1967 Outer Space Treaty and the 1975 Registration Convention.

## **i. Malaysia**

RazakSAT, Malaysia's first remote sensing satellite was launched into space from Kwajalein Island on April 21 by SpaceX's Falcon 1 rocket. The satellite will provide high resolution images of Malaysia that can be applied to land management, resource development and conservation, forestry, fish migration and security. Together with RazakSAT, two other satellites meant for educational purposes CubeSAT and InnoSAT were also launched.

Space Exploration Technologies Corporation (SpaceX) announced on July 15 the successful launch of the RazakSAT satellite. The satellite which was designed and built by Astronautic Technology (M) Sdn Bhd of Malaysia, will provide imagery for land management, resource development, conservation, forestry and fish migration programs within Malaysia.

Malaysia, a country with around 25 million people, has seen its pay-TV landscape dominated by DTH operator Astro All Asia Networks (Astro). However, its dominance is likely to be challenged in the next year when Telekom Malaysia (TM), the country's biggest telco, launches its IPTV service. TM likely will enter the Indonesian IPTV and high-speed broadband services market in the 2010 first quarter year. However, TM will face challenges from Astro, which has been offering services via satellite for a number of years. Malaysian homes seem to have an extremely healthy appetite for TV entertainment ranging from premium English language movies to vernacular programs.

## **k. Solomon Islands**

In November 2009 Solomon Telekom signed an agreement with SES WORLD SKIES, a division of SES S.A. for satellite capacity to extend its broadband services across the Solomon Islands. The contract for half a transponder will enable Solomon Telekom to significantly increase Internet and wireless access throughout the Melanesian country of approximately 520,000 people.



## **E. The Americas**

### **a. Brazil**

Telespazio Brasil in September selected Gilat Satellite Networks to provide a 1,200-site Gilat SkyEdge 2 broadband satellite communications network, to be used by Sicredi Bank for both primary enterprise networking connectivity as well as back-up services.

Gilat's networks will connect Sicredi Bank branches in Brazil. A majority of the banks previously did not have access to high-speed connectivity. The satellite network will provide branches with backup connectivity in areas where terrestrial networks, such as DSL and wireless, are accessible and used as the main connectivity platform.

Telespazio said it chose Gilat for its service pricing. Careful evaluation of competing VSAT technologies revealed that Gilat's SkyEdge 2 network provides superior performance and the lowest total cost of ownership, according to Telespazio Brasil. Telespazio Brasil became a Gilat customer in 2001, when it began using Gilat VSAT networks to power Brazilian enterprise networking applications at nearly 1,000 sites nationwide.

The University of Sao Paolo in August held its first workshop on Space Law in August, an event coordinated by Dr. Paulo Borba Casella, Professor of Public International Law at the Faculty of Law, USP. The four featured speakers were José Monserrat Filho, Vice President of the Brazilian Society of Space Law, and IISL Board Member, Tanja Masson-Zwaan, IISL President and Deputy Director of the Institute of Air and Space Law, Leiden University (NL); Dr. Valnora Leister, the first Brazilian to hold a doctorate in Space Law, graduate of the Institute of Air and Space Law, McGill University, and Olavo Bittencourt Neto, of the Law Faculty of USP.

### **b. Canada**

The Canadian Radio and Television Telecommunications Commission (CRTC) issued a mandate in May that Canadian TV networks will have to make larger investments in local programming and Canadian content if they are compensated for the value of the signals they provide to cable and satellite carriers. The policy mandate was made during CRTC hearings to renew conventional TV licenses and hear arguments over "fee-for-carriage" issues from networks. Canadian broadcasters CTV and GlobalTV argued that cable and satellite companies, such as Rogers and Bell, should pay fees to the commission for the content provided by local broadcast stations. Cable and satellite providers complained to the CRTC that CTV violated the Canadian Broadcasting Act with a "Save Local TV" campaign. The CRTC said it is exploring other policy options but will arbitrate a deal between the two sides, if necessary, according to the commission's statement.

Telesat selected Space Systems/Loral (SS/L) to build the Telstar 14R satellite. The satellite will be equipped with 46 Ku-band transponders (27 fixed and 19 switchable) and has a design life of 15 years. Telstar 14R will be located at 63°W and will provide broadband and video services to customers in the Continental United

States (including the Gulf of Mexico, Central America and southern Caribbean), Brazil, the Southern Cone of South America and the Andean region.

Guy Laliberté, founder of Le Cirque du Soleil, became the first Canadian space tourist, and recently spent a few days at the ISS. He trained in Russia, and was taken to the ISS aboard a Soyuz spacecraft. He stated that he wanted to bring joy to outer space, the same as he has brought to so many people on Earth through the performances of Le Cirque du Soleil. According to the press, Laliberté mixed star power, science lectures, music and poetry with water, hosting a TV/Internet show from the International Space Station aimed at raising awareness for Laliberté's "One Drop Foundation", which seeks to draw attention to the growing shortage of clean water. A worldwide audience tuned in via TV and the Internet to watch the show that featured participants from 14 countries including former US Vice President Al Gore and rock group U2.

Institute of Air and Space Law, McGill University, Montreal

An International and Interdisciplinary Congress on Space Debris was convened at the Institute of Air and Space Law, Faculty of Law, McGill University, on 7-9 May 2009. The Congress was attended by experts in various disciplines (e.g. science, technology, policy, international relations and law) from several developed and developing countries, governmental space agencies, ministries of foreign affairs, armed forces, academic institutions, private companies, and consulting firms. This two-session event was organized to assess the value of the 2007 COPUOS Space Debris Mitigation Guidelines and to put forward specific and viable policy and regulatory steps (mechanisms) that may be considered by states and other stake holders to monitor and reduce the space debris risks. The Montreal session concentrated on comprehensive analysis and assessment of the causes, trends and implications of space debris in order to fully and precisely understand the seriousness of the problem; i.e. essentially covering the first four objectives mentioned above. The Bonn-Cologne session, to be convened on 29-30 April 2010, will thoroughly analyze the report of the Montreal Session in order to put forward viable and concrete policy and regulatory options (including draft policies and/or treaty), both at international and national levels.

This Congress was preceded by a high-level International and Interdisciplinary Roundtable on the study of space, its governance and its peaceful use was held at the Institute of Air and Space Law, Faculty of Law, McGill University, on 6 May 2009.

The 6th International and Interdisciplinary Space Security Index Workshop, was convened at the Institute of Air and Space Law, Faculty of Law, McGill University, on 5-6 May 2009. This is a joint project of McGill Institute Air and Space Law, Spacesecurity.org, Project Ploughshares, the Cypress Fund for Peace and Security, the Space Generation Foundation, the Simons Centre for Disarmament and Non-Proliferation Research at the Liu Institute for Global Issues, UBC, and the International Security Research and Outreach Programme at Foreign Affairs Canada. The objective of the Space Security Index is to support transparency and dialogue on space security challenges and potential cooperative responses by providing an annual assessment of space security based on background information and in-depth analysis

on key trends related to outer space. This annual assessment is developed through primary research in consultation with space security experts.

### **c. Colombia**

Colombia announced in March that it plans to launch a communication satellite that will be used nearly exclusively for domestic communications in areas where other means of communication are not cost-effective. The satellite would comprise 54 transponders, and utilize C, Ku, and Ka bands. More than 15 companies have responded to the preliminary request for proposals issued by the Colombian government. A final decision should be made by end-year. The launch of the satellite would be for 2012. This “Satcol” is the second version of a domestic satellite system that was proposed in the 1980s, also called “Satcol.”

Colombia, according to a press report, is also in talks with the Israeli government regarding the construction of 2 remote sensing satellites. No timetable as to construction or launch of these satellites has been offered.

In April, the Law School of the Universidad Sergio Arboleda in Bogota, held its first symposium on space law. Ciro Arevalo, current Chairman of COPUOS, was one of the principal speakers. A second symposium on space law is being planned for early 2010.

Union Temporal Conectando a Colombia awarded a contract to Bantel Telecom, a provider of satellite communications in the Caribbean, Central America, and Andean Region, to provide Ku-band satellite services utilizing the Hughes HN system, Hughes Network Services in September. The contract is part of the Compartel project, an initiative of the Colombian government to promote telecommunications in remote communities of the country with limited economic resources. This contract is key to Bantel and reflects its solid growth in the region. Its experience of more than 18 years, combined with powerful satellite coverage and the versatility of the Hughes HN7000S broadband satellite terminal, offers the best service quality in the region, according to Hughes.

### **d. Perú**

Telefónica del Perú signed a three-year deal with SES Americom-New Skies in June, for nearly a full transponder of capacity aboard the NSS-10 satellite. Telefonica will use 33 megahertz of NSS-10 capacity and GSM backhaul to deliver corporate voice and data solutions as well as broadband and mobile phone services to customers in Peru unable to access terrestrial networks. The deal also enables Telefonica to extend the capabilities of its metropolitan networks to remote locations. Telefonica del Peru offers seamless corporate, cellular and residential communications services between major cities like Lima and Puerto Maldonado in Peru. Increasingly, satellite-delivered voice and data, GSM backhaul, broadband, and mobile phone services are opening the door to newfound communications capabilities and business opportunities in rural mining and farming villages that were once out of touch. The financial details of the contract were not disclosed.

## **e. Uruguay**

A young woman electrical engineering student from Uruguay's Universidad de la República was selected by the IAF's Youth Grants Programme to participate in this year's IAC in South Korea. She was one of 130 candidates worldwide seeking this award. Information on the IAF's Youth Programmes was provided by the Centro de Investigación y Difusión Aeronáutico-Espacial (CIDA-E).

Uruguay convened the "World Space Week" between 4-10 October. This event was organized by Prof. Fernando Giménez, who was named coordinator by the World Space Week Association. Prof. Giménez is a member of the CIDA-E. Another CIDA-E member, Dr. Marta Gaggero, participated in this event, speaking on "Uruguay and Outer Space."

During the "Jornadas de la Asociación Latinoamericana de Derecho Aeronáutico y Espacial" (ALADA) which took place in Punta del Este in March, Dr. Juliàn Hermida, an Argentinean lawyer spoke on a "Legal Régime for the International Space Station." This was one of the principal topics of this event. At the conclusion of its Congress, ALADA formed a working group, whose aim is to research the legal framework of the ISS. Dr. Marta Gaggero of the CIDA-E is involved in this Working Group.

In November, the ALADA will convene the aerospace lawyers of the Rio de la Plata region at the San Isidro Law College, and CIDA-E will present a paper at this event, on the 30th anniversary of the Moon Treaty.

## **f. United States**

### **Government**

The Obama Administration is moving forward with plans to buy more satellite imagery from private companies while Congress grapples with developing a long-term strategy to ensure that US military and intelligence agencies have access to the images they need. The National Geospatial-Intelligence Agency issued a classified request in October, asking firms that operate remote-sensing or imaging satellites for information on how they could meet US government needs as part of its plans to award major contracts to commercial imagery providers next spring under its Enhanced View program. However, at the same time Congress is backing a plan under which the government would build new satellites that might ultimately compete with those of commercial providers, such as GeoEye and DigitalGlobe.

Obama Administration officials are moving to revitalize yet another faltering American industry: the communications satellites sector. According to press reports, the rescue could be virtually free, if export controls that classify satellite technology as weapons are lifted. The House Foreign Affairs trade subcommittee held hearings on the matter. While proponents of change are optimistic, conservatives still go for the national security arguments, believing that strict regulation is needed. Since the regulations were enacted in 1999, the legal complications involved in selling commercial communications satellites have contributed to a sharp decline in American companies' share of the market, from nearly 90 percent to about 50 percent.

## U. S. House of Representatives

The US House Passed the Commercial Space Indemnification Bill in October, allowing for indemnification for commercial launch providers in the unlikely event that a launch accident caused third-party damaged above the maximum probable loss that providers have to insure against. HR 3819 would extend the provision for three more years, with no other changes. Some commentators thought the bill is a mixed bag for the commercial space launch industry. While pleased to see the indemnification regime renewed, the private sector probably would like a longer term than three years.

## Federal Communications Commission (FCC)

President Obama nominated Julius Genachowski as Chairman of the FCC. Other new appointees are Mignon Clyburn and Meredith Attwell Baker. Michael J. Copps was Acting Chair until Genachowski's appointment. Robert M. McDowell was appointed by Pres. Obama to serve another term on the FCC. U.S. law permits up to three members of a single political party to serve on the board at the same time.

In April, the FCC adopted a Report and Order (R&O) and Further Notice of Proposed Rulemaking (FNPRM) which aims to expand and enhance first-responder 4.9 GHz nationwide broadband deployment. The new rules also give public safety better tools to share time-sensitive data and streaming video footage in emergencies or life-threatening incidents.

In its order, the FCC granted primary status to 4.9 GHz standalone, permanent fixed links used to deliver such broadband services as fixed video surveillance links used to monitor high-risk facilities or environments along with permanent fixed links that connect 4.9 GHz base and mobile stations used to deliver broadband service; these could be used to support broadband at hot spots and other fixed public-safety broadband networks as well as to connect other public-safety networks using broadband spectrum. In addition, the order retained the current requirement for individual site-based licensing for all permanent fixed stations, but it revised the output power measurement procedures for 4.9 GHz band devices to be the same as those required for devices using digital modulation techniques regulated by Part 15 of the Commission's rules. This rule change is intended to speed deployment of new technologies in the 4.9 GHz band for the benefit of public safety users, the order adds.

To further enhance public safety communications, the Commission preserved paging operations in the VHF public safety band, and clarified that cross-band repeaters are permitted for all public safety systems. One advantage to using the 4.9 GHz is that it will enable use of new broadband applications in support of public safety, such as high-speed digital technologies and wireless local area networks for incident scene management, to share crucial broadband data and thereby assist those in need, address emergency situations and disasters, and save lives.

## NASA

President Obama named Charles Bolden as NASA's Administrator, following some speculation as to who would take over from Mike Griffin, the former Bush-

appointed Administrator. A former astronaut, Charles Bolden was top in the list of potential replacements. Bolden flew on a shuttle flight with Senator Bill Nelson, who heads the committee that oversees NASA.

NASA's Administrator Charles Bolden gave a speech in October to the National Association of Investment Companies in which he strongly endorsed the idea of entrepreneurial space ventures as key to keeping people -- students in particular -- interested in space. In the speech, Bolden called companies like SpaceX, Blue Origin, Armadillo Aerospace, Virgin Galactic, Xcor, Bigelow Aerospace, Masten, Flag Suit, and Ad Astra "inspirational." Bolden added that NASA is devising ways to work with these companies and others who will come, and urged investors to take notice.

In October, NASA launched a rocket to the moon, with the hopes of establishing whether or not there is water on the moon. Its destination is one of the very wettest spots on the moon, according to scientists involved in the LCROSS project.

According to scientists involved, LCROSS is different from preceding "kamikaze" missions: it is bigger, more complex and -- perhaps -- more important than similar previous ventures, because it is purposefully searching for water. The mission was developed at high speed and low cost, offering hope to NASA of a faster, cheaper future for space exploration. The October 16 impact on the Moon was observed by thousands of people, live and on-line. Though the general public was disappointed, the scientists were elated with the results of NASA's "bombing" of the Moon, as the spacecraft hit the Cabeus crater, right on target.

TDRS 1, the pioneer of NASA's constellation of tracking and communications satellites, is being retired from service after more than 25 years in orbit. A failure on the TDRS 1 satellite led NASA officials to finally retire TDRS 1 after operating almost four times longer than designed. Officials can still command the satellite, but it is now useless to customers. The spacecraft will be moved out of its geosynchronous orbit for final decommissioning. Two new TDRSS craft are being developed for launch in 2012 and 2013.

The Augustine Committee's final report, "Review of U.S. Human Space Flight Plans," was released in late October. The report reflects the quality of the individuals who drafted it, and should serve well as a foundation for the necessary debate and analysis that will further shape the USA's human spaceflight and exploration programs. The American Institute of Aeronautics and Astronautics (AIAA) will examine the future of America's space programs in light of the Augustine Commission's findings, in a special presentation that will be held on November 2, 2009.

#### U.S. Air Force (USAF)

The U.S. Air Force took issue with a report released by the U.S. Government Accountability Office (GAO), which claimed that the U.S. military GPS system is experiencing serious degradation. This information is not accurate, according to a May 25 statement by the US Air Force. The issue is not whether GPS will stop working, but rather, if there is a risk that the GPS will not continue to exceed

performance standards. The May 7 GAO report, “Global Positioning System: Significant Challenges in Sustaining and Upgrading Widely Used Capabilities,” said there is only an 80 percent likelihood that the Air Force would be able to maintain its full 24-satellite constellation between 2010 and 2014, which could result in lower GPS performance. Currently, the USAF has 30-plus satellites on orbit.

## **Private Sector**

### **Boeing**

Boeing Co. in May accused NASA of altering the evaluation process between the company and its competitor, Lockheed Martin, in the battle for a \$1.1 billion contract to build up to four GOES-R weather satellites. NASA awarded Lockheed Martin with the contract in December. Boeing initially filed a protest to the U.S. Government Accountability Office (GAO) immediately after the deal was announced. The GAO opened a review on the issue, but never completed it due to NASA's agreement to re-evaluate the bids. Despite the agreement, NASA upheld its original award decision on May 6, prompting Boeing to request that the GAO reopen its review. Boeing stated that the complaint is warranted because of serious flaws and a lack of transparency in the selection process. Boeing alleges that its scores were higher, but NASA inexplicably changed them. These scores involved the mission suitability factors and switched the positions of Boeing and Lockheed Martin in the competition. Boeing believes its cost estimate is more believable because it built GOES N, O and P, which were used as the basis for GOES-R price. In a company statement, Lockheed Martin said it is confident the GAO ultimately will uphold NASA's recent decision to select Lockheed Martin.

### **Globalstar**

Globalstar in July completed its financing of \$738 million that will fund the company's next-generation satellite system. The total financing combines a \$586 million credit facility secured in March by Coface, France's export credit agency; a registered direct offering of convertible debt and warrants for \$55 million; and a \$60 million deposit by Thermo Funding, the majority shareholder of Globalstar. The \$738 million financing fully funds the manufacture, delivery and launch of Globalstar next-generation network and ground facilities by Thales Alenia Space as well as accelerated delivery of additional second-generation spare satellites. The financing also will facilitate the introduction of Globalstar's next-generation satellite interface chipsets being designed by Hughes Network Systems. The company will have the resources needed to deploy a new constellation of satellites designed to last beyond 2025 and to build the supporting ground infrastructure that will position it to be first to market with a host of advanced IP-based mobile satellite services years ahead of its competitors.

### **Iridium**

On 11 February, one of Iridium's operational satellites was accidentally destroyed when a spent Russian satellite collided with it, creating a fair amount of debris. NASA officials told the press that the ISS was not thought to be in significant danger from the space debris as it orbits at an altitude of 220 miles, well below that of

the satellite wreckage clouds. Although this event has minimal impact on Iridium's service, the company is taking immediate action to address the loss, which could result in limited service disruptions in the form of brief, occasional outages. Iridium has been working to determine solutions to avoid future collisions and endorses long-term investment to improve space situational awareness.

The accident was commented in the press, but no mention was made of the fact that the Russian satellite, launched in 1993, was no longer operational, and should have been de-orbited at the end of its useful life. The 1975 Registration Convention (Art. IV) requires its Signatories (Russia among them) to notify the UN Secretary-General of space objects which are no longer in Earth orbit.

Although the United Nations General Assembly endorsed the Space Debris Mitigation Guidelines in 2007, this collision has prompted some to call for more specific rules or laws governing decommissioning of satellites and prevention of additional space debris. The United Nations and the United States government have indicated the intent to take seriously the issue of space debris, and address the issue at the October 2009 Session of the United Nations General Assembly.

Iridium Satellite has partnered with mobile satellite industry companies and the emergency response community to form the Promotion of Two-way Emergency Communication and Tracking Systems (ProTECTS) alliance, Iridium announced in September. The alliance aims to foster the adoption of portable, two-way satellite-based location, tracking and messaging technologies and address issues affecting suppliers and users of these vital safety devices. The ProTECTS alliance membership includes Active Web Solutions, Blue Sky Network, DMC Worldwide, EMS Global Tracking, L-3 Communications, Paradigm Secure Communications and others.

While one-way emergency beacons can provide a valuable aid to life-saving services, they also can have a high incidence of false alerts triggered by accidental activation, placing a heavy burden on first responders who must try to verify the validity of the distress signal before deploying rescue resources.

Iridium also is launching an initiative to focus its internal engineering, research and development, product certification, activations, marketing and channel sales support resources to assist service partners in bringing personal safety products and services to market.

In preparation for hurricane season, Iridium Satellite in May commenced its third annual "Test Your Satellite Phone" initiative, in partnership with The Association of Public-Safety Communications Officials (APCO) International. Iridium said the goal of the initiative is to encourage emergency workers and first responders to prepare now to ensure that their satellite phone works properly for emergency situations. The "Test Your Satellite Phone" program is timed to coincide with the U.S. National Weather Service's "National Hurricane Preparedness Week," May 24-30. The satellite phone is only with reliable communications tools and training that public-safety personnel can focus on their first priority of helping the communities they have vowed to support," according to APCO International.



Iridium Satellite reported a 41.9 percent decline in net income to \$9.7 million in its 2009 first quarter financial report, released June 3. The company's equipment revenues declined to \$20.5 million during the first quarter, a 34.3 percent drop from the previous year. However, total revenue for the quarter was up 2 percent to \$75.8 million from \$74.3 million in 2008. The decrease in net income is primarily due to increased expenses related to Iridium Next, the company's next-generation satellite constellation. According to Iridium, net income dropped 83 percent in the fourth quarter of 2008, driven by Iridium Next development expenses. The report also revealed strengths in the company's performance. Iridium's subscriber base grew 31.2 percent from prior year quarter to 328,000. Iridium expects its operational EBITDA to grow in the range of 11 percent to 20 percent to produce between \$120 million and \$130 million on low single-digit revenue growth during 2009.

Iridium Satellite was granted approval by the Federal Communications Commission (FCC) to combine with GHL Acquisition, in August. This helps advance Iridium's plans to build its next-generation satellite constellation, Iridium Next. The combination, announced in September 2008, will result in Iridium becoming a publicly traded company. Under the terms of the agreement to combine, about 26.8 million warrants issued by GHL Acquisition will be repurchased or restructured upon closing of its Iridium acquisition —reducing the number of fully diluted GHL Acquisition shares that will be outstanding following completion of the Iridium acquisition. Stockholder approval of the transaction was obtained in September.

#### Protostar

ProtoStar and its five affiliates filed for Chapter 11 bankruptcy protection, the U.S. Bankruptcy Court of Delaware in July 2009. ProtoStar listed assets and liabilities between \$100 million to \$500 million and lists Philippine Long Distance Telephone Co. as its largest unsecured creditor. ProtoStar has two satellites, ProtoStar 1 and 2. ProtoStar 2, built by Boeing, was handed over to ProtoStar in June after completing in-orbit tests and confirming the satellite's readiness to enter service providing direct-to-home broadcasting and telecommunications services to the Asia-Pacific region.

#### Sea Launch

Sea Launch has identified several potential sources of financing to help the beleaguered launch provider recover from bankruptcy, assuming the company can follow a profitable business plan and hold on to its customer base. The company hopes to secure so-called debtor-in-possession financing in October '09. Officials have set an early goal to emerge from bankruptcy by the end of the first quarter of 2010. Launch operations from sea could resume by the end of next year, with the company working on a business plan that could be profitable with four missions per year.

#### SES Americom

SES AMERICOM-NEW SKIES Satellite Division re-branded itself as SES WORLD SKIES in September 2009, bringing together SES AMERICOM, the leading supplier of satellite services in the U.S., with the global satellite services of SES NEW SKIES. SES WORLD SKIES serves broadcasters, cable programmers,

telecommunications companies and networks, governments, aeronautical and maritime communications integrators, Internet service providers, and educational institutions with efficient communications and content distribution solutions. This division of SES operates a fleet of 25 satellites, capable of providing coverage and service throughout the world. SES WORLD SKIES also has six spacecraft under construction and access to global ground facilities.

SES Americom-New Skies announced June 3 that it had won a three-year capacity contract with BT for nearly three full transponders of C-band capacity on the NSS-10 satellite. BT will extend its IP network into remote regions of Brazil, expanding its SES-owned capacity from 92 to 104 megahertz of C-band in order to provide IP trunking services to link businesses based in Manaus and other rural stretches of Northern Brazil to its teleport and Internet access point in São Paulo. A portion of the purchased bandwidth will support single channel per carrier service and distance learning applications throughout Brazil. This is the second Latin American capacity contract won by SES for NSS-10. Telefonica del Peru secured capacity on the spacecraft, located at the 322.5 degrees East, to provide GSM backhaul services.

### Sirius XM Radio

On June 30, International Launch Services, Inc. (ILS) successfully launched the FM-5 satellite for Sirius XM Radio from the Baikonur Cosmodrome on a Proton Breeze M rocket. FM-5 was built by Space Systems/Loral based on its 1300 bus design and weighed 5,820 kg at launch. It also has a 9-meter reflector dish – technology intended to increase signal performance with smaller fixed and mobile digital user devices and will be positioned at the 96°WL orbital location. Sirius has three active satellites and plans on replacing one per year through 2012. In February, ILS won a contract to launch Sirius FM-6, under construction at Space Systems/Loral. Sirius-FM6 is scheduled to launch in the fourth quarter of 2010.

XM Satellite Radio, a wholly owned indirect subsidiary of Sirius XM Radio, is reorganizing following its bankruptcy filing, and is offering senior notes for sale. It will use the net proceeds from the offering to repay all amounts outstanding under its amended and restated credit agreement; to replace the \$150M second-lien credit agreement with Liberty Media Corporation, and to refinance or repay other corporate debt.

### Space tourism

Space tourism seems to be off to a slower start than had been anticipated when Space Ship One won the Ansari X Prize a few years ago. According to one commentator, spaceflight remains the realm of government astronauts and a handful of extraordinarily wealthy people who have paid millions for rides on Russian rockets to the international space station. Virgin Galactic has signed up many tourists willing to pay \$200 thousand for a sub-orbital flight, but no timetable for the start of commercial operations is being released. Other opinions are more positive: some people are certain there will be commercial spaceflights within this decade.

Virgin Galactic plans to launch satellites as well as tourists into space, according to a press report from the company issued at the International Astronautical

Congress in Daejeon, South Korea. The company has set up a division to both develop a launch rocket and seek satellite customers for it. Adam Baker, formerly of Surrey Satellite Technology (SSTL) in Guildford, UK will be in charge of Virgin's satellite venture. Virgin's stated aim is to reduce the cost of lofting small 50-kilogram satellites into low Earth orbit from about \$10 million today to about \$1 million.

## **Space Adventures**

In March, a Russian Soyuz rocket carried a Russian and US crew, and an American billionaire to the International Space Station. Along for the ride was Charles Simonyi, who made his fortune in computer software, and paid \$35 million for his second trip on the Soyuz. Although the press stated that Simonyi could be last space tourist for years, a few months later a Canadian became his country's first space tourist. However, the ISS's crew increase from 3 to six could mean that professional station astronauts will need every spare seat on the Russian Soyuz spacecraft, as well as on the up to eight remaining space shuttle flights that go to the ISS. Space Adventures remains confident that there might be a couple of seats for commercial purposes in 2010 or 2011. In 2011, Space Adventures plans to launch the first private mission to the International Space Station in partnership with the Russian Federation's Federal Space Agency. The mission will mark the first time that a Soyuz spacecraft has been given over entirely to private citizens.

Space Adventures announced that it will be able to send two space tourists into orbit on Soyuz spacecraft from 2012 onwards. Further, Space Adventures would pay for the construction of the spaceship, the launch services and the salary of a Russian cosmonaut as crew commander. It seems that the company already has a number of candidates who are willing to pay for trips into space, including Russian-born American billionaire and Google co-founder Sergey Brin.

Space transportation, tourism, communications and imagery, if developed by private parties could be a multibillion-dollar industry. In the lead is former astronaut Buzz Aldrin playing a central role. Aldrin has been a persistent advocate for commercial spaceflight, and adds much credibility to his many ventures. Aldrin is seen as the ideal iconic leader for these endeavours.

## **Non-profit Sector**

### Space Data Association

The Space Data Association is being spearheaded by Intelsat, SES and Inmarsat, some of the largest commercial satellite fleet operators, with other satellite-fleet operators expected to join in the coming months. They have agreed to create a non-profit organization headquartered in the Isle of Man to operate a voluntary satellite database, as part of a broader effort to combat satellite interference. The database will assemble information on satellite location, broadcast frequencies and power, signal polarization and coverage areas. If it works as intended, it will reduce the time between when a customer notifies a satellite operator of interference and when that interference is located, although identifying the source of interference solves only part of the problem. Most interference has one of two causes. The first is

antenna-pointing or other installation and operational missteps by ground station managers. The second major cause of interference is defective or obsolete hardware.

Selecting tax haven Isle of Man as the locale was done in part to ease the fears of some satellite operators that placing a database on U.S. territory would invite U.S. government review — a fear that would have kept several operators from taking part.

The Intelsat-SES initiative already has secured support from other satellite operators including Eutelsat, Telesat, SkyPerfect JSat, Hispasat, Satmex, Asiasat, Sat-GE, Amos-Spacecom, Telenor, Star One, and Arabsat.

### ESpace

The University of Colorado and SpaceDev announced in January the formation of a nonprofit organization to further entrepreneurship and work force development in the space industry. ESpace will serve as an incubator for startup aerospace businesses, funding new technology development on the university level and providing grants to high school graduates and community college students as a way to spur job growth. The foundation will give five companies \$20,000 in grants and access to SpaceDev facilities. ESpace also will give a \$90,000 grant to CU's aerospace engineering sciences department to fund an eSpace Venture Design program.

### Space Enterprise Council

The US Chamber of Commerce disbanded the Space Enterprise Council (SEC), an affiliate established in 2000 that lobbies US policymakers on behalf of the domestic space industry, effective May 1st, according to press reports, leaving the Council to face an uncertain future. The Space Enterprise Council was notified in mid-March by the US Chamber of Commerce of its intention. The Council will now work with its 35 member companies to determine the best way forward.

## **CONTRIBUTORS**

This publications was based on a report prepared by Jerry Grey, President Emeritus of the International Astronautical Federation (IAF) for Tetsuo Yasaka (Vice-President, Technical Activities, IAF) and Madhavan Nair (Vice-President, Scientific Activities, International Academy of Astronautics). It was approved by Berndt Feuerbacher, President of IAF. The International Institute of Space Law (IISL) contribution on international cooperation and space law was prepared by Sylvia Ospina, Member of the IISL Board of Directors. Information was compiled from submissions of IISL members and other sources. The IISL contribution is intended to highlight important events, and does not pretend to be all-inclusive. The IISL regrets any inconsistencies and/or omissions it may contain.





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