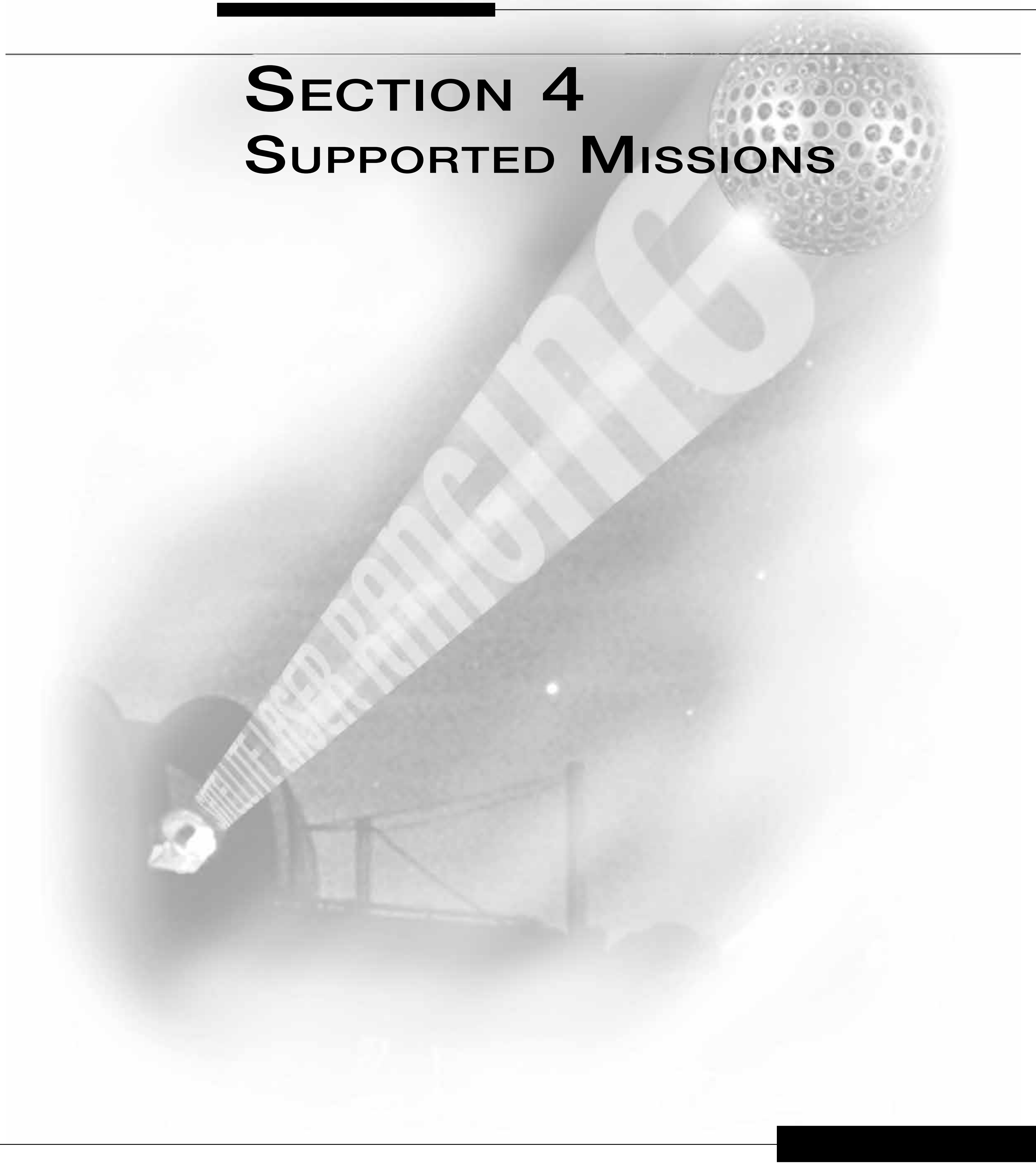
SECTION 4
SUPPORTED MISSIONS



SECTION 4

SUPPORTED MISSIONS

Graham Appleby/SGF, Scott Wettzell/HTSI/

CURRENT MISSIONS

The During 2009-2010, the ILRS supported 44 artificial satellite missions including passive geodetic (geodynamics) satellites, Earth remote sensing satellites, navigation satellites, and engineering missions. Missions were added to the ILRS tracking roster as new satellites were launched and as new requirements were adopted (see Figure 4-1). Ten missions were added to the roster during that period (see Table 4-1). The stations with lunar capability also tracked the lunar reflectors, one of which was rediscovered on the lunar surface after being lost for many years.

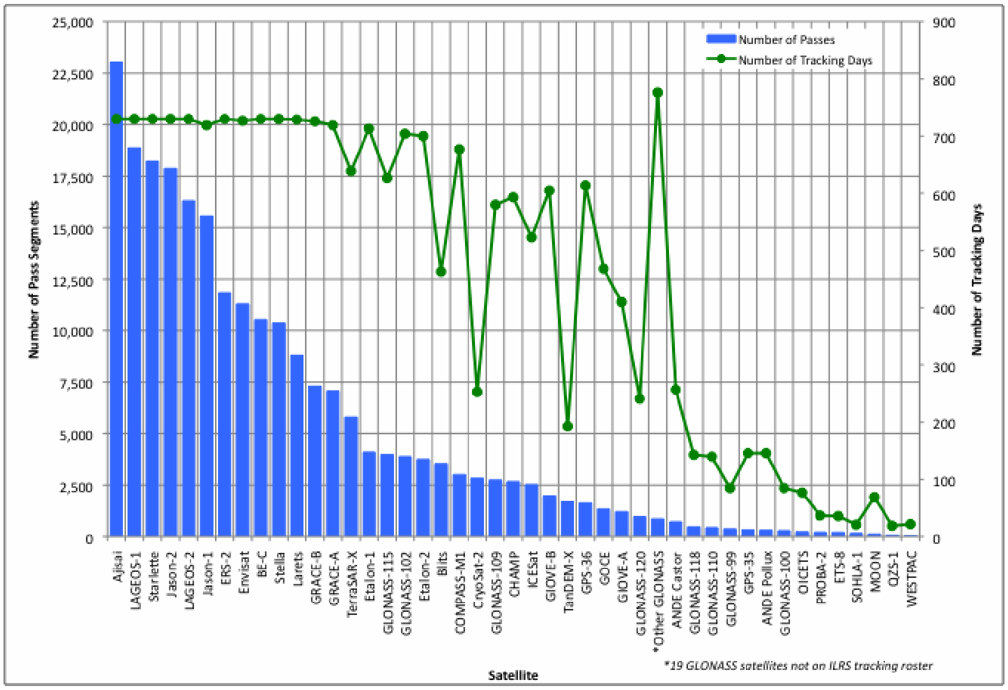


Figure 4-1. SLR tracking totals for 2009-2010.

The NASA Lunar Reconnaissance Orbiter (LRO) spacecraft and its laser altimeter brought one-way transponder ranging to a large subset of the ILRS network in support of precise orbit determination in lunar orbit. The network continued to support the GLONASS constellation; GLONASS-100 was added to the schedule in July 2009; GLONASS-115 replaced GLONASS-99 in March 2009; GLONASS-120 replaced GLONASS-109 in April 2010. During 2010 a few stations started experimental tracking of as many of the full GLONASS constellation as they could manage within their tracking schedules. It is likely that LR support for GNSS satellites will continue to increase, with the imminent launch of the first satellites that will ultimately constitute the European Galileo GNSS.

MISSIONS COMPLETED IN 2009-2010

The two satellites of the Atmospheric Neutral Density Experiment (ANDE) re-entered Earth's atmosphere during 2010 after a successful year-long mission.

The CHAllenging Mini-satellite Payload (CHAMP), launched on July 15, 2000, re-entered Earth's atmosphere on September 20, 2010. The dedicated low-orbit gravity field mission can be considered a pioneer for such missions, pre-dating GRACE and GOCE and leading the way to the development of very high precision gravity field models that are of value to many branches of geophysics.

During 2009, the Ice, Cloud and land Elevation Satellite (ICESat) came to the end of its mission to determine the mass balance of the polar ice sheets and their contributions to global sea level change. Since its launch in 2003, the mission provided multi-year elevation data as well as cloud property information, especially for stratospheric clouds common over polar areas. Some ten stations of the ILRS network whose procedures had been rigorously approved by the mission to avoid potential laser damage to its onboard detector tracked it on a regular basis.

After three years success, laser tracking support of the Engineering Test Satellite (ETS-8) from the WPLTN sub-network of the ILRS ceased during 2009. ETS-8 is in geosynchronous orbit and is a test of satellite-based positional augmentation of GPS navigation. The Australian SLR stations carried out some interesting return-rate experiments and polarization studies.

The JAXA Optical Inter-orbit Communications Engineering Test Satellite (OICETS) is a demonstration from LEO of optical communications with the ESA geostationary Advanced Relay and Technology MISsion (ARTEMIS). Laser tracking, the primary source of POD, ceased in September 2009 when the mission came to an end.

NEW MISSIONS IN 2009-2010

Table 4-1. New Missions Supported by the ILRS in 2009-2010

Mission	Launch	Altitude (km)	Sponsor	Application	ILRS Mission Support Requirement
SOHLA-1	Jan 23, 2009	666	JAXA (Japan)	Technology Development	POD, calibration of GPS
GOCE	March 17, 2009	295	ESA (Europe)	Gravity field and Ocean circulation	POD and instrument calibration
LRO	June 17, 2009	Lunar orbit	NASA (US)	Lunar studies	POD in lunar orbit
ANDE	July 30, 2009	350	NRL (US)	Atmospheric Modeling	POD
BLITS	Sept 17, 2009	832	IPIE (Russia)	Test of retroreflector technology	POD
PROBA-2	Nov 2, 2009	700 - 800	ESA (Europe)	Technology Development, solar studies	POD

CryoSat-2	April 8, 2010	720	ESA (Europe)	Sea-ice thickness and ice-sheet surface elevation	Altimeter calibration and satellite POD
TanDEM-X	June 21, 2010	514	DLR, GFZ, EADS-Astrium, Infoterra (Germany)	Global Digital Elevation Model	POD
QZS-1	Sept 11. 2010	32,000 – 40,000	JAXA (Japan)	Navigation, position, timing	POD

SOHLA-1

SOHLA-1 (Figure 4-2) is a technical demonstration satellite developed by local small and medium-sized enterprises in Japan with technical support from the Japan Aerospace Exploration Agency (JAXA) and Osaka Prefecture University. The main objective of SOHLA-1 is to develop and demonstrate a variety of technologies for small satellites. One example is a VHF lightning impulse system. SLR was used for the calibration of GPS-based satellite positioning. The micro GPS receiver used in this mission has been developed by JAXA based on COTS automobile navigation technology. SLR tracking was scheduled for short campaigns of several weeks at a time as required, from March 2009 until the end of the mission in February 2010. More information is available at *http://god.tksc.jaxa.jp/sohla/sohla.html*.

Figure 4-2 SOHLA-1 satellite (courtesy of JAXA)

Gravity field and steady-state Ocean Circulation Explorer (GOCE)

GOCE is an ESA mission dedicated to measuring the Earth's gravity field and modeling the geoid with extremely high accuracy and spatial resolution. It is the first Earth Explorer Core mission to be developed as part of ESA's Living Planet Program, and was launched into a very low orbit on March 17, 2009. The satellite (shown in Figure 4-3) consists of a single rigid octagonal spacecraft, approximately 5 m long and 1 m in diameter with fixed solar wings and no moving parts. The main objectives of the mission are to: (1) determine the gravity-field anomalies with an accuracy of 1 mGal (where 1 mGal = 10-5 m/s2), (2) determine the geoid with an accuracy of 1-2 cm, and (3) achieve the above at a spatial resolution better than 100 km. Mission instrumentation includes: a gravity radiometer, a 12-channel GPS receiver, and a standard compact laser retroreflector array. The mission, at an altitude of 250 km, is now mapping the Earth's gravity field with unprecedented precision, giving access to the most accurate model of the geoid ever produced (see for example *http://www.esa.int/esaCP/SEM1AK6UPLG_index_0.html*)

Figure 4-3. GOCE satellite (courtesy of ESA)

Lunar Reconnaissance Orbiter (LRO)

Figure 4-4. LRO spacecraft (courtesy of NASA)

The Lunar Reconnaissance Orbiter (Figure 4-4) is the first mission of NASA's Robotic Lunar Exploration Program (RLEP). The LRO mission objective is to conduct investigations that will be specifically targeted to prepare for and support future human exploration of the Moon. The mission was launched on June 17, 2009 and is planned to take measurements of the Moon for at least two years. The LRO Laser Ranging (LR) system uses one-way range measurements from laser ranging stations on the Earth to LRO to determine LRO position at sub-meter level with respect to Earth and the center of the Moon (on the lunar near-side or whenever possible). The LR aspect of the mission will allow for the determination of a more precise orbit than possible with S-band tracking data alone. The flight system consists of a receiver telescope, which captures the uplinked laser signal and a fiber optic cable, which routes it to the LOLA instrument. The LOLA instrument captures the time of the laser signal, records that information and provides it to the onboard LRO data system for storage and/or transmittal to the ground through the RF link. This process is used to drive a near-real time display via a web-link to the tracking station(s) in order to inform the operator on the level of ranging success throughout each pass, thus allowing pointing corrections, etc., to be made if required. Currently some ten ILRS stations regularly support this mission through being scheduled to cover specific passes. More information is available at *http://lrolr.gsfc.nasa.gov/index.html*.

The Atmospheric Neutral Density Experiment (ANDE)

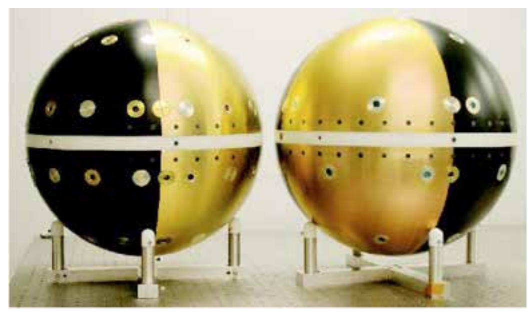


Figure 4-5. ANDE spheres (courtesy of NRL)

ANDE is a mission flown by the US Naval Research Laboratory to monitor the thermospheric neutral density at an altitude of 350km. The two satellites of the mission were launched from the Space Shuttle on July 20, 2009 and measured the density and composition of the low Earth orbit atmosphere while being tracked from the ground to better predict the movement and decay of objects in orbit.

The two spherical microsatellites, the ANDE Active spacecraft (Castor) and the ANDE Passive spacecraft (Pollux) (shown in Figure 4-5) are each fitted with retroreflectors. The satellites are identical in size (diameter of 19 inches), but have different masses, and were tracked by the ILRS network as well as the Space Surveillance Network (SSN). The spheres were in lead-trail 400 km, 51 degree inclination orbits. Scientific objectives include measurements of total atmospheric density for orbit determination and collision avoidance, validation of fundamental theories on air drag modeling, and establishing a method to validate neutral/ion density and composition derived from on-board sensors. ANDE Pollux re-entered the Earth's atmosphere shortly after its last observation by the SSN on March 28, 2010, and ANDE Castor re-entered on August 18, 2010.

Ball Lens in The Space (BLITS)

The BLITS retroreflector satellite (Figure 4-6) was developed and manufactured by the Science Research Institute for Precision Instrument Engineering (IPIE). BLITS was launched on September 17, 2009 and has been tracked by most of the ILRS network ever since. The purpose of the mission is experimental verification of the spherical glass retroreflector satellite concept as well as obtaining SLR data for solutions to scientific problems in geophysics, geodynamics, and relativity by millimeter and sub-millimeter accuracy SLR measurements.

The BLITS consists of two outer hemispheres made of a low-refraction-index glass (πκ6 type) and an inner ball lens made of a high-refraction-index glass (TΦ105 type). The ball lens radius is 53.52 mm; the total radius of the spherical retroreflector is 85.16 mm. The hemispheres are glued over the ball lens; the external surface of one hemisphere is covered with an aluminum coating protected by a varnish layer. All spherical surfaces are concentric. The satellite total mass is 7.53 kg. The "target error" (uncertainty of reflection center relative to the CoM position) is less than 0.1 mm, and the Earth's magnetic field does not affect the satellite orbit and spin parameters. SLR is the only source of POD information. This lack of target "signature" means that the single-shot range precision for most stations approaches that of their target-board ranging.

Figure 4-6. BLITS satellite (courtesy of IPIE)

The PRoject for OnBoard Autonomy-2 (PROBA-2)

Figure 4-7. PROBA-2 satellite (courtesy of ESA)

PROBA is a series of technology demonstration missions of the European Space Agency. PROBA-2, the second satellite in the series and shown in Figure 4-7, was successfully launched on November 2, 2009 from the Plesetsk Cosmodrome in Russia and continues ESA's validation of new spacecraft technologies while also carrying a scientific payload. The objectives of PROBA are in-orbit demonstration and evaluation of (1) new hardware and software spacecraft technologies, (2) systems for onboard operational autonomy, and (3) instruments for Earth observation and space environment measurements. PROBA-2 carries solar observation instruments, plasma measurement instruments, a GPS receiver, and an SLR retroreflector array. GPS provides POD, validated using SLR from a two-week ILRS campaign in March-April 2010. The spacecraft continues to provide solar science data. For further information see: *http://www.esa.int/esaMI/Proba/SEMJJ5ZVNUF_0.html.*

CryoSat-2

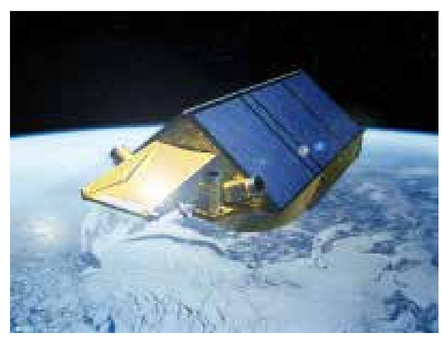


Figure 4-8. CryoSat-2 (courtesy of ESA)

A mission to measure change in the cryosphere, CryoSat-2 (Figure 4-8), was launched on April 8, 2010 into a non Sun-synchronous polar orbit 720km above the Earth. It is measuring the thickness of sea-ice and the surface elevation of ice sheets in both Northern and Southern hemispheres. For this, it uses an advanced radar altimeter combined with precise orbit determination. In addition, CryoSat-2's ocean measurements are being exploited by the French space agency CNES to provide global ocean observation products in near-real time. Understanding sea-surface currents is important for marine industries and protecting ocean environments. POD is carried out by the onboard DORIS system, with calibration of the altimeter and independent support for POD being supplied by ILRS SLR observations. More information is available at: *http://www.esa.int/esaLP/SEM54JVX7YG_LPcryosat_0.html.*

TerraSAR-X add-on for Digital Elevation Measurement (TanDEM-X)

TanDEM-X was launched on June 21, 2010. The goal of the TanDEM-X mission is to generate a high-accuracy global Digital Elevation Model (DEM). This goal is being achieved through TanDEM-X flying in a close (separation 250-500m) tandem orbit configuration with TerraSAR-X (Figure 4-9). Like TerraSAR-X, the satellite also carries the experimental Tracking, Occultation and Ranging (TOR) package provided by GFZ. TOR consists of a two-frequency CHAMP-type GPS receiver and a CHAMP Laser Retro-Reflector (LRR), giving access to high-precision orbit determination and inter-satellite interferometric baseline vector information. The mission's objectives are generation of DEM (e.g., for hydrology), along-track interferometry (e.g., for measurement of ocean currents), and bi-static applications (e.g., polarmetric SAR interferometry). More information is available at: *http://www.dlr.de/hr/en/desktopdefault.aspx/tabid-2317/3669_read-5488/.*

Figure 4-9. TanDEM-X and TerraSAR-X in close formation (DLR)

Quasi-Zenith-Satellite-1 (QZS-1)

The Quasi-Zenith Satellite System (QZSS) is a Japanese regional satellite navigation program planned to serve East Asia and Oceania. The first satellite of a two-stage deployment, QZS-1 (shown in Figure 4-10), was launched from the Tanegashima Space Center into a slightly elliptical geosynchronous orbit on September 11, 2010 for technical validation and demonstration of several applications.

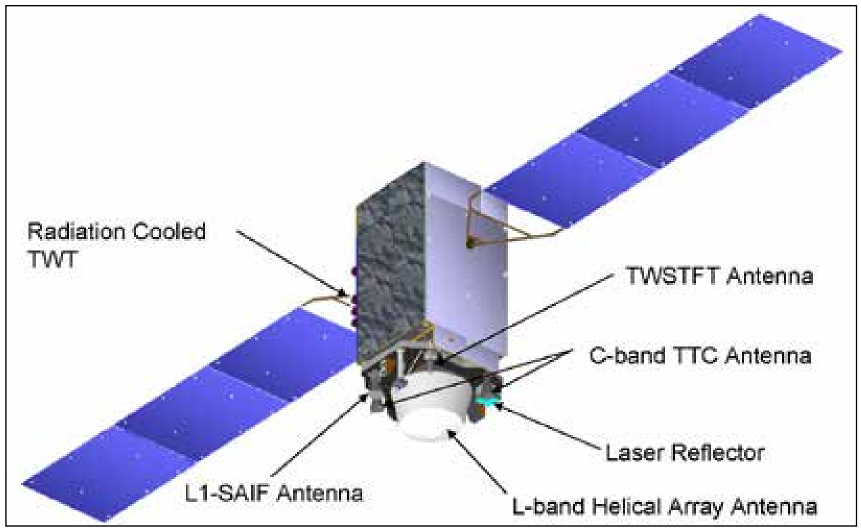


Figure 4-10. QZS-1 (courtesy of JAXA)

Ultimately, QZSS will be a three-satellite constellation where each satellite orbits in a different orbital plane such that at least one satellite is in place near the zenith over Japan at all times. The system will have complete interoperability with GPS, with JAXA and related research institutes managing the technology development and augmentation from QZSS. SLR tracking on QZS-1 is necessary in order to estimate navigation data biases and to evaluate the accuracy of orbit determination, which has a goal of several tens of centimeters. ILRS stations in the Western Pacific Laser Tracking Network routinely track QZS-1, mostly during the night. For additional information see: *http://www.jaxa.jp/projects/sat/qzss/index_e.html.*

FUTURE MISSIONS

A number of new missions requiring SLR support for POD and instrument calibration and validation are scheduled for launch over the next few years. All the satellites shown in Table 4-2 have sought and been granted tracking approval by the ILRS Governing Board.

Note: Requests for new mission support by the ILRS should be submitted via the online request form on the ILRS website at *http://ilrs.gsfc.nasa.gov/missions/mission_support/index.html*. Requests are reviewed by the ILRS Missions Working Group for suitability and then vetted by the ILRS Governing Board. Mission sponsors must supply precise details of the on-board characteristics of the retroreflector arrays as part of their Mission Support Request at the above link.

Table 4-2. Upcoming Missions Approved for ILRS SLR Support During 2009-10

Mission	Launch	Altitude (km)	Sponsor	Application	ILRS Mission Support Requirement
RadioAstron	Mid-2011	500-350,000	Lavochkin Association, Russia	Astrophysics	Episodic tracking sessions
KOMPSAT-5	2012	550	Korea Aerospace Research Institute (KARI)	SAR for Earth observation	Routine in support of GPS-based POD
SARAL	2012	800	CNES and Indian Space Research Organisation (ISRO)	Sea Surface	Routine for POD in support of DORIS

RadioAstron

The RadioAstron project (Figure 4-11, the Spectr-R project) is an international collaborative mission to launch a free flying satellite carrying a 10-meter radio telescope in high apogee (~350,000 km) orbit around the Earth. The aim of the mission is to use the space telescope to conduct interferometer observations in conjunction with the global ground radio telescope network in order to obtain images, coordinates, motions and evolution of angular structure of different radio emitting objects in the Universe with an extraordinary high angular resolution. Laser tracking to the 100-cube onboard array, most likely only possible from Lunar-capable SLR stations, will be important for the mission goals and be used to support the construction by RadioAstron of a high-precision celestial coordinate frame and a test of General Relativity by means of precision redshift measurements.

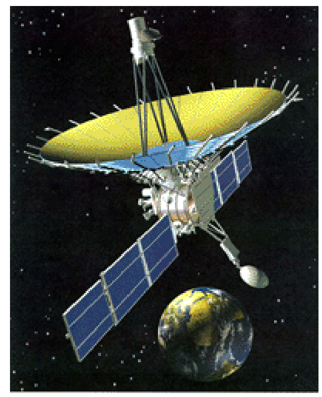


Figure 4-11. RadioAstron (courtesy Lebedev Physical Institute, Moscow, Russia)

KOMPSAT-5

The KOMPSAT-5 satellite (Figure 4-12) will carry out from low Earth orbit all-weather day/night monitoring of the Korean peninsula. The primary mission of the KOMPSAT-5 system is to provide high resolution mode SAR images of 1 meter resolution, standard mode SAR images of 3 meter resolution and wide swath mode SAR images of 20 meter resolution with viewing conditions of the incidence angle of 45 degrees using the COSI (COrea SAR Instrument) payload, for meeting GOLDEN mission objectives. GOLDEN stands for GIS, Ocean and Land management, Disaster and Environmental monitoring.
The secondary mission of KOMPSAT-5 is to generate atmospheric sounding profiles and support radio occultation science using AOPOD (atmospheric occultation and precision orbit determination). The secondary payload is composed of a dual frequency GPS receiver and a four-cube GFZ laser retroreflector array, identical to that flown on CHAMP and GRACE.

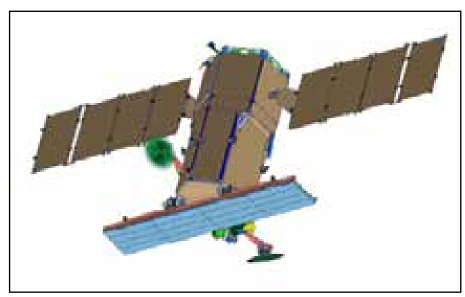


Figure 4-12. KOMPSAT-5 (courtesy of KARI)

SARAL

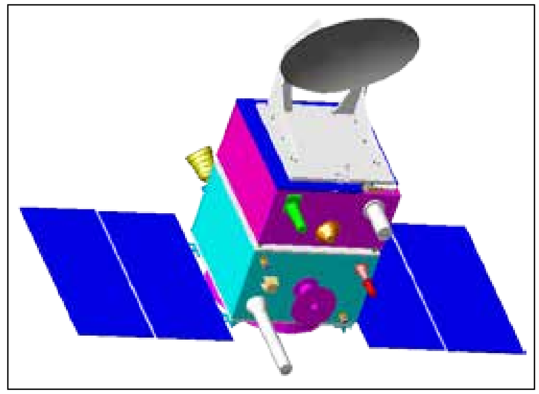


Figure 4-13. SARAL (courtesy of AVISO)

Satellite with ARgos and ALtika (SARAL) is a cooperative mission between CNES and the Indian Space Research Organization (ISRO) The mission (Figure 4-13) is complementary to Jason-2 and will provide observations of ice, rain, coastal zones, and wave heights. SARAL results from the common interests of CNES and ISRO in studying the oceans from space using altimetry and providing maximum use of ARGOS (Advanced Research and Global Observation Satellite), a joint NOAA CNES data collection system. The main mission objectives of SARAL are to create precise, repetitive global measurements of sea surface height, wave heights, and wind speed, ensure continuity of the altimetry service currently available from Envisat and Jason-1/-2 and to contribute to global ocean and climate studies to build a global ocean observing system. Instrumentation includes a CNES altimeter/radiometer (AltiKa), a DORIS system, a nine-cube laser reflector array built by CNESS and the ARGOS system. POD will be achieved by DORIS, with SLR providing strong tracking information to complement DORIS and by providing a unique and unambiguous verification of the absolute radial orbit accuracy.