SECTION 3
MISSIONS AND CAMPAIGNS

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Current Missions

During 2007-2008, the ILRS supported 35 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 3-1). Seven missions were added to the roster during that period (see Table 3-1). The stations with lunar capability also tracked the lunar reflectors.

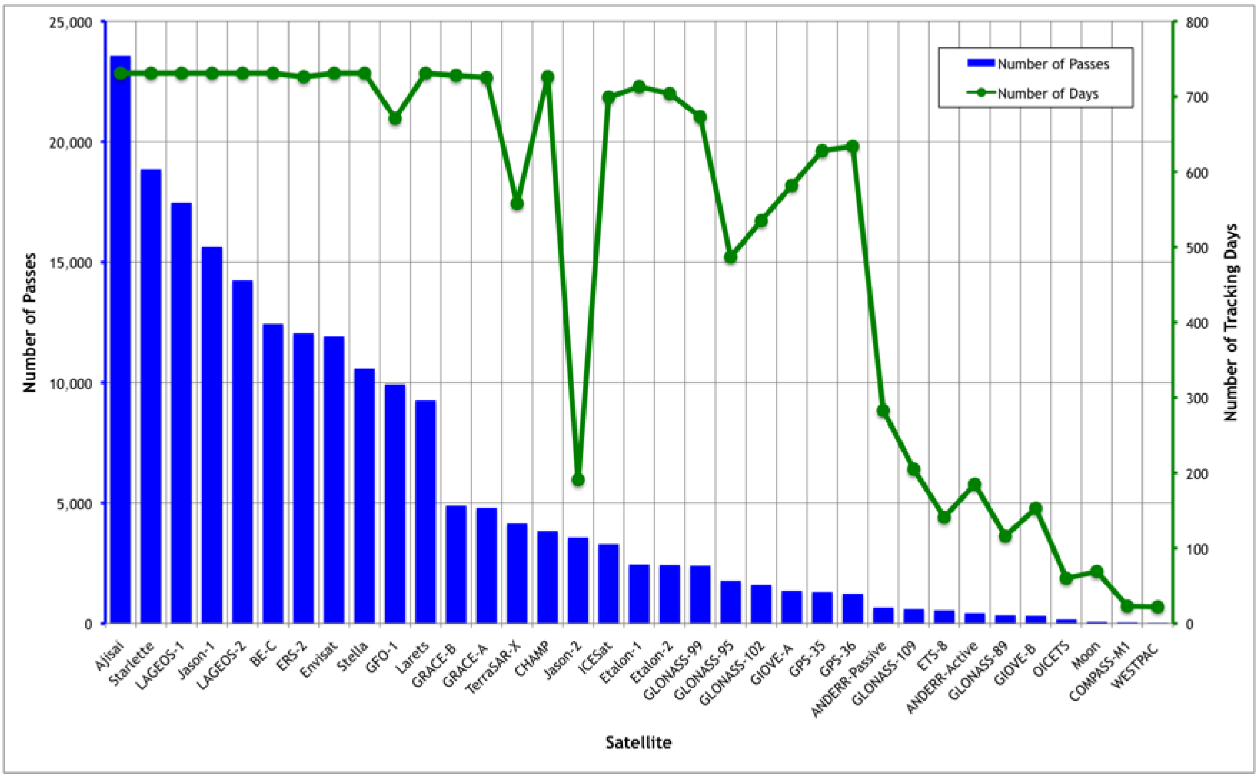

Figure 3-1. SLR tracking totals for 2007-2008.

The network continued to support the GLONASS constellation; GLONASS-102 replaced GLONASS-89 in May 2007. GLONASS-109 replaced GLONASS-95 in March 2008.

In March 2007, tracking began on ETS-8, the first ILRS target in a geostationary orbit. This is the first target above LAGEOS (except for the moon) that had uncoated cubecorners, which worked quite well. Several stations in the Pacific area have been able to range routinely.

The ANDE-RR satellites reentered in late 2007 and early 2008. The network was successful tracking these satellites down to 300 km and in some cases even below, a good indication of future success with GOCE. The GFO-1 mission ceased operating in November 2008. The radio systems aboard had failed at the beginning of the mission and SLR was the only means of POD for the altimeter.

Table 3-1. New Missions in 2007-2008

Mission	Date of First Pass	Sponsor	Application	ILRS Mission Support Requirement
ETS-8	March 2007	JAXA (Japan)	Technology Development	POD
TerraSAR-X	June 2007	Infoterra, DLR, GFZ (Germany)	X-band SAR	POD
GLONASS-102	July 2007	Russian Space Agency	Navigation	POD
GIOVE-B	April 2008	ESA (Europe)	Navigation	POD
GLONASS-109	May 2008	Russian Space Agency	Navigation	POD
Jason-2	June 2008	CNES/EUMETSAT / NASA/NOAA	Ocean Dynamics, Climate	POD, instrument validation
Compass-M1	December 2008	Chinese Defense Ministry, Shanghai Astronomical Obs.	Navigation	POD

Engineering Test Satellite 8 (ETS-8)

ETS-8, shown in Figure 3-2, was launched into a geostationary orbit to support development, experimentation and confirmation of large satellite bus technology, large-scale deployable antenna technology, mobile satellite communications system technology, mobile satellite digital multimedia broadcasting system technology and basic positioning technology using high-accuracy time standard devices. ETS-8, the largest geosynchronous satellite ever placed in orbit, was launched on December 16, 2006. JAXA plans to conduct a time synchronization experiment for future satellite positioning technology, including time management using an atomic clock onboard the satellite. SLR is providing POD for the mission. Of great interest initially was the use of uncoated retroreflectors (array shown in Figure 3-3) designed specifically to compensate for the velocity aberration.

More information can be found at the JAXA Web site: *http://www.jaxa.jp/projects/sat/ets8/index_e.html.*

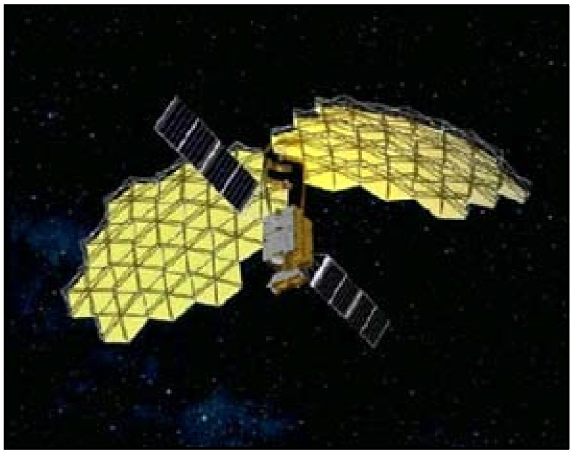

Figure 3-2. ETS-8 satellite (courtesy of JAXA)

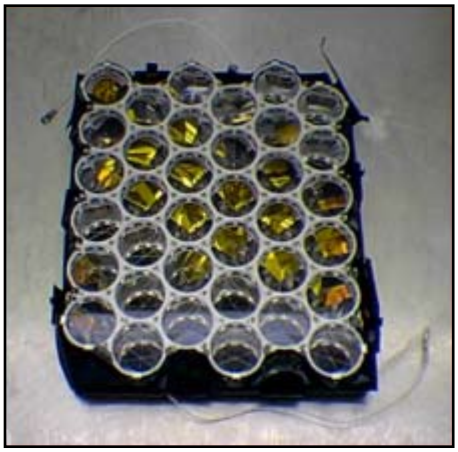

Figure 3-3. ETS-8 LRA (courtesy of HTSI)

TerraSAR-X

TerraSAR-X (Figure 3-4) is a mission with an active matrix, X-band Synthetic Aperture Radar (SAR), capable of mapping ground topography with a resolution of one meter for terrestrial research and applications. The SAR operates in all weather conditions during the daytime and at night. The satellite also has the experimental Tracking, Occultation and Ranging (TOR) package provided by GFZ and CSR, which consists of a two-frequency CHAMP type GPS receiver and a CHAMP Laser Retro-Reflector (LRR, Figure 3-5)). Data products include ortho-images, mosaics, coherence change detection, and topographical and thematic maps.

The satellite is the first to be built in a public/private partnership in Germany with Infoterra, DLR, GFZ and CSR in the U.S. The mission is also intended to establish a commercial Earth-Observation-market to develop a sustainable service business based on TerraSAR-X derived information products. Satellite laser ranging data provides precise orbit determination and validation and is complementary to the onboard TOR GPS.

More information is available from the GFZ Web site: *http://www.gfz-potsdam.de/portal/-?$part=CmsPart&$event=display&docId=1495914&cP=sec12.content.detail*.

Figure 3-4. TerraSAR-X (courtesy of DLR).

Figure 3-5. TerraSAR-X LRA (courtesy of GFZ)

GLONASS

The Global Navigation Satellite System (GLObal'naya Navigatsionnay Sputnikovaya Sistema, GLONASS), is based on a constellation of active GNSS satellites, sponsored by the Russian Federation Ministry of Defense. The satellites continuously transmit coded signals in two frequency bands, which can be received by users anywhere on the Earth's surface to identify their position and velocity in real time. The primary application of GLONASS is positioning and time transfer. The satellites (shown in Figure 3-6) are in GNSS orbits at approximately 19,000 km.

Figure 3-6. GLONASS satellite (courtesy JSC Information Satellite Systems–Reshetnev Company)

The system is a counterpart to the United States Global Positioning System (GPS) and both systems share the same principles in the data transmission and positioning methods. On October 12, 1982, the first GLONASS satellites were placed into orbit, and the experimental work with GLONASS began. Since that time, the system was tested, and different aspects were improved, including the satellites themselves.

The Etalon-1 satellite was launched with GLONASS-40 and -41 and Etalon-2 was launched with GLONASS-42 and -43.

The GLONASS space segment is designed to consist of 24 satellites located on three orbital planes. Each satellite is identified by its slot number, which defines the orbital plane (1-8, 9-16,17-24) and the location within the plane. The three orbital planes are separated 120 degrees. The eight satellites are separated by 45 degrees within three orbital planes. The current constellation consists of 18 or 19 operational satellites, with plane 3 fully occupied and plane 1 currently half-full. Additional satellites are currently being launched at a rate of six per year as required both to gradually fully-populate the constellation and as replacements for existing satellites. For more information see: *http://www.glonass-ianc.rsa.ru/pls/htmldb/f?p=202:20:16262908603374223037::NO*.

GIOVE-B

The Galileo constellation, a GNSS satellite radio navigation system initiative by the European Union and the European Space Agency, will consist of thirty satellites and ground stations providing position information to users in many sectors (transportation, social services, justice system, custom services, public works, search and rescue, etc.). Two experimental spacecraft, GIOVE-A and -B (formerly known as GSTB-V2/A and GSTB-V2/B), are in orbit and being tracked by the ILRS as a part of the Galileo System Test Bed to (1) secure the Galileo frequency allocations by providing a signal in space, (2) develop procedures for on-board clock characterization, (3) better understand the radiation environment, and (4) conduct related experiments.

GIOVE-A and GIOVE-B (shown in Figure 3-7) have different retroreflector arrays; both have flat arrays with solid back-coated cubes. The array for GIOVE-A (GSTB-V2/A) was built by Surrey Satellite Technology Ltd in the UK and has 76 cubes; the array for GIOVE-B (GSTB-V2/B) has been manufactured by Galileo Industries and has 67 cubes (see Figure 3-8). The signal link for both satellites is comparable to that of the GPS satellites. Arrays on the future Galileo satellites will have uncoated cubes that satisfy the ILRS standard for GNSS satellites.

For more information on the GIOVE aspects of the Galileo mission, refer to the ESA Web site *http://www.giove.esa.int/*.

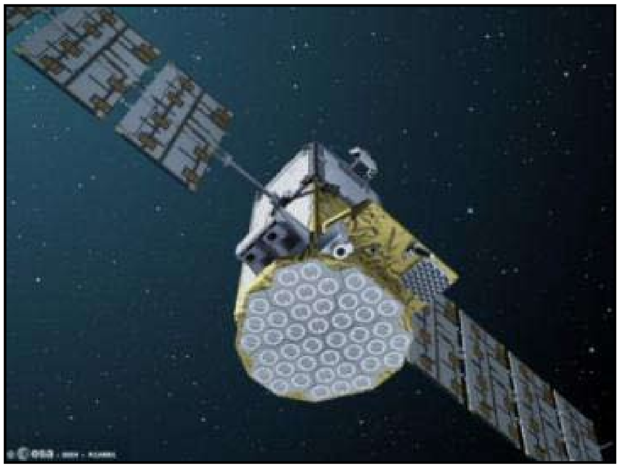

Figure 3-7. GIOVE-B satellite (courtesy of ESA)

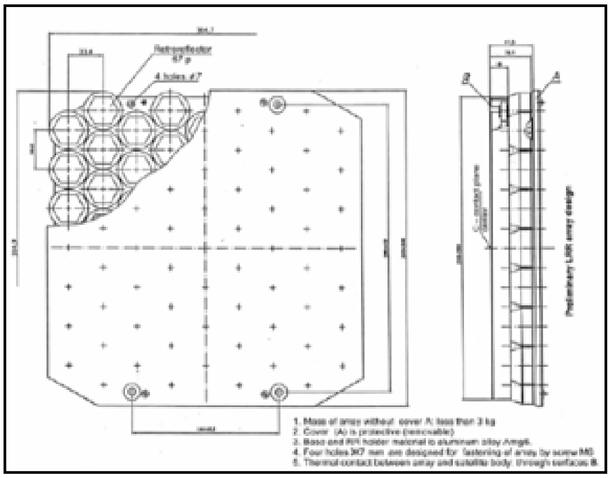

Figure 3-8. GIOVE-B array (courtesy of ESA)

Jason-2

Jason-2 (Figure 3-9), also known as the Ocean Surface Topography Mission (OSTM), continues the oceanography program begun by the earlier TOPEX/Poseidon and Jason-1 missions. Data products from Jason-2 are being used to monitor global ocean circulation, study the tie between the oceans and atmosphere, improve global climate predictions, and monitor events such as El Nino conditions and ocean eddies. The CNES, Eumetsat, NASA, and NOAA cooperative mission has nearly the same payload as Jason-1, including the next generation Poseidon altimeter, with a measurement accuracy of about 1 cm.

The Time Transfer by Laser Link (T2L2) payload (see *http://www-g.oca.eu/heberges/t2l2/home.htm*), is also part of the Jason-2 satellite. T2L2 is now taking data for precise characterization of the ultra-stable oscillator used by the DORIS positioning system. Relying on this clock, T2L2 may also be able to perform some orbit improvements on Jason-2 using one-way laser ranging. Jason-2, at its high altitude and with its very long integration times, in common view mode, provides an excellent opportunity for time transfer over intercontinental links.

Precision orbit determination is a fundamental requirement for achieving the goal of Jason-2. Jason-2 also has GPS receivers, DORIS, and SLR for POD. The SLR data provides the crucial centering of the orbit relative to the Earth's center of mass and the absolute calibration of the radial orbit error. The array on Jason-2 is shown in Figure 3-10.

More information about the Jason-2 mission is available at the CNES Web site *http://www.cnes.fr/web/CNES-en/1441-jason.php*.

Figure 3-9. Jason-2 satellite (courtesy of CNES)

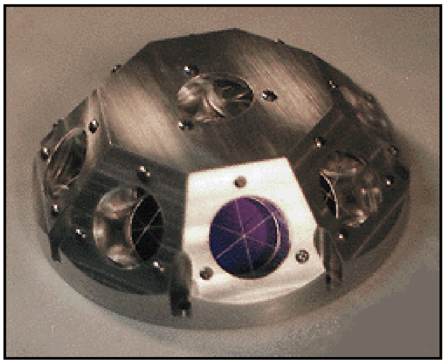

Figure 3-10. Jason-2 Array (courtesy of HTSI)

Compass-M1

The Compass Navigation Satellite Experimental System is a satellite constellation developed by the Chinese Defense Ministry; a diagram of Compass-M1 is shown in Figure 3-11. The system, also known as BeiDou, is the first space-based regional navigation and positioning network developed by China. Compass will provide all weather, two-dimensional positioning data for both military and civilian users. The system has both navigation and communication capabilities and spans most areas of the East Asia region. The satellite network consists of four BeiDou 1 satellites launched in 2000, 2003, and 2007 in geostationary orbit; a fifth satellite, Compass-M1, was launched in MEO in April 2007 with the first retroreflector array with uncoated cornercubes in GNSS orbit (see Figure 3-12).

For more information on Compass-M1 see: *http://www.oca.eu/gemini/ecoles_colloq/colloques/ilrs2007PresentationsPdf/10_Session.pdf/10.1_Fumin_LRA_Compass.pdf.*

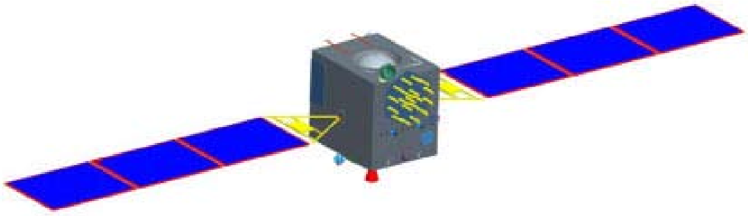

Figure 3-11. Compass-M1 satellite (courtesy of Shanghai Astronomical Observatory)

Figure 3-12. Compass-M1 Array (courtesy of Chinese Academy of Sciences)

Future Missions

A number of new missions, shown in Table 3-2, requiring SLR support for POD and instrument calibration and validation, are scheduled for launch over the next year.

Table 3-2. Upcoming Missions in 2009-2010.

Mission	Launch	Altitude (km)	Sponsor	Application	ILRS Mission Support Requirement
SOHLA-1	January 2009	666	JAXA (Japan)	Technology Development	POD
GOCE	March 2009	295	ESA (Europe)	Gravity field and Ocean circulation	POD and instrument calibration
ANDE	June 2009	350	NRL (US)	Atmospheric Modeling	POD
BLITS	June 2009	832	IPIE (Russia)	Test of retroreflector technology	Retroreflector in Space
LRO	June 2009	Lunar orbit	NASA	Lunar studies	POD in lunar orbit
PROBA-2	Second Quarter 2009	700 - 800	ESA (Europe)	Technology Development, solar studies	POD
QZS-1	Mid-2009	32,000 – 40,000	JAXA (Japan)	Navigation, position, timing	POD
STSAT-1	Mid-2009	390 - 1500	KIAST (Korea)	Technology development and Earth brightness	POD
TanDEM-X	Mid-2009	514	DLR, GFZ, EADS-Astrium, Infoterra	Digital elevation model	POD

Requests for new mission support by the ILRS should be submitted via the online request form on the ILRS Web site at *http://ilrs.gsfc.nasa.gov/satellite_missions/mission_support.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.

GOCE

The GOCE (Gravity field and steady-state Ocean Circulation Explorer) 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. The satellite (shown in Figure 3-13) 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 laser retroreflector array (Figure 3-14).

For additional information see: *http://www.esa.int/esaLP/LPgoce.html.*

Figure 3-13. GOCE satellite (courtesy of ESA)

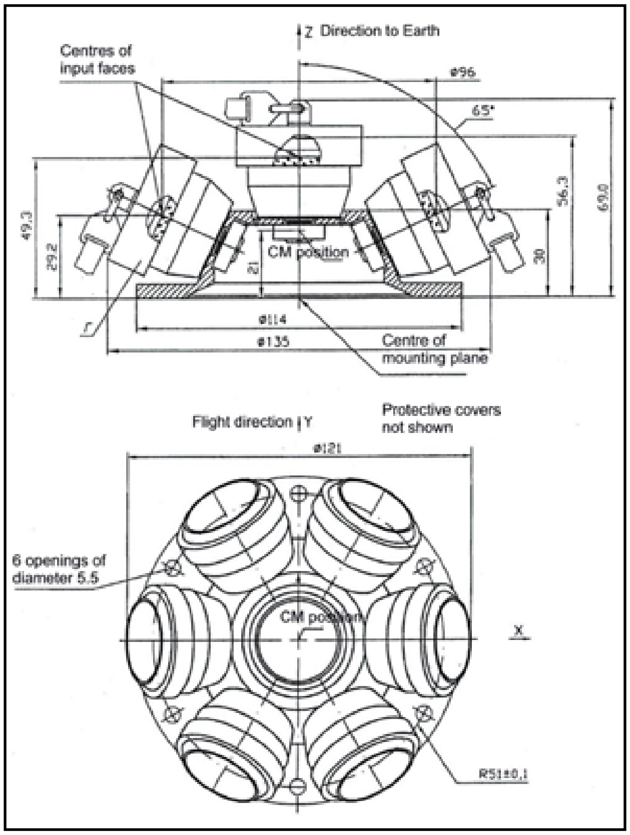

Figure 3-14. GOCE array (courtesy of ESA)

SOHLA-1

SOHLA-1 (Figure 3-15) 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 will be used for the calibration of GPS-based satellite positioning (array shown in Figure 3-16). The micro GPS receiver used in this mission has been developed by JAXA based on COTS automobile navigation technology. Launch is planned for January 2009. SLR tracking will be scheduled for short campaigns of several weeks at a time as required.

For more information see: *http://god.tksc.jaxa.jp/sohla/sohla.html.*

Figure 3-15. SOHLA-1 satellite (courtesy of JAXA)

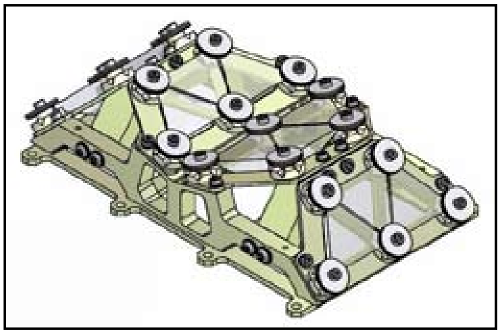

Figure 3-16. SOHLA-1 array (courtesy of JAXA)

PROBA-2

The Project for On-Board Autonomy (PROBA) is a series of technology demonstration missions of the European Space Agency. The first satellite in the series, PROBA-1, shown in Figure 3-17, was successfully launched on 22 October 2001, initially for a two-year mission and has now been operational for five years. PROBA-2, planned for launch in the second quarter of 2009, will continue 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 (Figure 3-18). SLR and GPS will provide POD.

For further information see: *http://www.esa.int/esaTQM/1134728792936_index_0.html.*

Figure 3-17. PROBA satellite (courtesy of ESA)

Figure 3-18. PROBA array (courtesy of ESA)

QZS-1

The Quasi-Zenith Satellite System (QZSS) is a Japanese regional satellite navigation program planned East Asia and Oceania. A two-stage system deployment is planned. As a first step, QZS-1, shown in Figure 3-19, will be launched in 2010 for technical validation and demonstration of several applications. The second step involves the launch of the second and third satellites several years later to demonstrate full system operation. JAXA and related research institutes are in charge of technology development and demonstration of the GPS complement and augmentation from QZSS.

QZSS is a three satellites constellation where each satellite is placed in the different orbital planes with inclined, geo-synchronous period and slight eccentricity. Each satellite is placed in an orbit so as to pass over the same ground track at constant intervals with at least one satellite in place near zenith over Japan at all times.

The QZSS has complete interoperability with GPS and will be worked as a GPS satellite with better geometrical position. QZS will improve availability and DOP compared with use of GPS only, especially in urban canyon and mountainous terrain. The satellite system is also a good platform for WDGPS (Wide-area Differential Global Positioning System). High elevation angle characteristics can be applied to the WDGPS platform for stable link. The target accuracy is several tens of centimeters. SLR tracking on QZS-1 is necessary to estimate navigation data biases and evaluate orbit determination accuracy; the array on QZSS is shown in Figure 3-20.

For additional information see: *http://www.jaxa.jp/projects/sat/qzss/index_e.html.*

Figure 3-19. QZSS satellite (courtesy of JAXA)

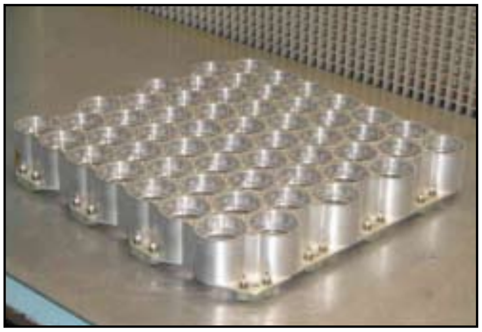

Figure 3-20. QZSS array (courtesy of HTSI)

STSAT-2

Science and Technology SATellite-2, being built by the Korea Advanced Institute of Science and Technology (KAIST) for development of a low earth orbit 100kg satellites, which can be launched by KSLV-1 (Korea Space Launch Vehicle-1) from the domestic space center (NARO Space Center). The mission supports the development of advanced technology for small spacecraft, and the development and operation of world-class space science payloads. STSAT-2, shown in Figure 3-21, has two payloads, a Dual-channel Radiometer for Earth and Atmosphere Monitoring system (DREAM) and a Laser Retroreflector Array). DREAM will measure brightness temperature of the Earth at 23.8 GHz and 37 GHz, for processing to obtain physical parameters such as cold liquid water and water vapor. The spacecraft technology mission objective is to develop a thermally, mechanically, electrically stable and radial resistant spacecraft system having high-precision attitude determination and control capability in a high eccentric ellipsoidal orbit.

Figure 3-21. STSAT-2 satellite and integrated array (courtesy of KAIST)

For more information see: *http://www.globalsecurity.org/space/world/rok/stsat.htm.*

ANDE

The Atmospheric Neutral Density Experiment (ANDE) flight is a mission flown by the Naval Research Laboratory to monitor the thermospheric neutral density at an altitude of 350km. The mission is scheduled to be launched from the Space Shuttle on June 16, 2009 and will measure 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.

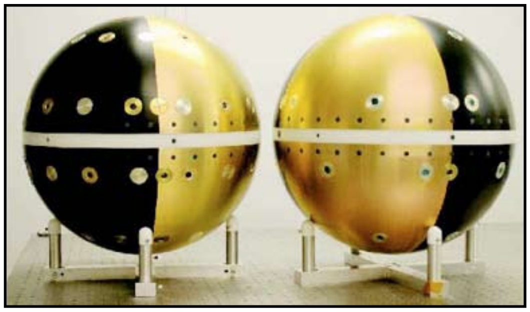

Figure 3-22. ANDE spheres (courtesy of NRL)

The ANDE mission consists of two spherical microsatellites (shown in Figure 3-22) fitted with retroreflectors: ANDE Active spacecraft (Castor) and the ANDE Passive spacecraft (Pollux). The satellites are identical in dimension (diameter of 19 inches), but have different masses, and will be tracked by the ILRS network as well as the Space Surveillance Network (SSN). The spheres will be in a lead-trail 400 km, 51 degree inclination orbit. Because of the difference in mass, the satellites will drift apart over time. The position observations of the satellites will permit studies on spatial and temporal variations in atmospheric drag associated with geomagnetic activity. 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.

For additional information see: *http://cddis.gsfc.nasa.gov/lw16/docs/presentations/ops_14_Thomas.pdf.*

BLITS

The BLITS (Ball Lens In The Space) retroreflector satellite (Figure 3-23) has been developed and manufactured by the Science Research Institute for Precision Instrument Engineering (IPIE) in accordance with the Federal Space Program of Russia and by an agreement between the Federal Space Agency of Russia and the International Laser Ranging Service dated January 10, 2006. 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 submillimeter accuracy SLR measurements. 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.

Figure 3-23. BLITS satellite (courtesy of IPIE)

The BLITS nanosatellite consists of two outer hemispheres made of a low-refraction-index glass (ЛК6 type) and an inner ball lens made of a high-refraction-index glass (ТФ105 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. A small spherical retroreflector of the same type (6cm in diameter) was fastened to the Meteor-3M spacecraft and tested during its space flight (2001-2006).

For further information see: *http://space.skyrocket.de/index_frame.htm?http://www.skyrocket.de/space/doc_sdat/blits.htm.*

TanDEM-X

An additional SAR satellite (TanDEM-X) flying in tandem with TerraSAR-X will provide interferometric data for a high-accuracy global Digital Elevation Model (DEM); the tandem configuration is shown in Figure 3-24. Like TerraSAR-X, the satellite also carries the experimental Tracking, Occultation and Ranging (TOR) package provided by GFZ, which consists of a two-frequency CHAMP type GPS receiver and a CHAMP Laser Retro-Reflector (LRR, Figure 3-5). 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)

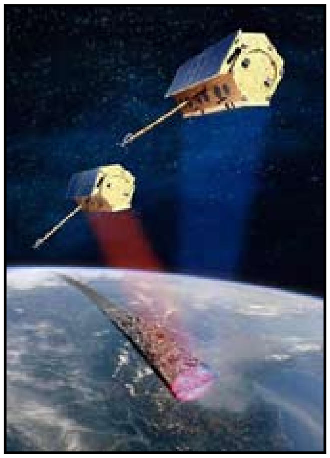

Figure 3-24. Picture of TerraSAR-X and TanDEM-X (courtesy of DLR)

High-precision orbit determination and interferometric baseline vector information of the tandem configuration will be accomplished through the TOR instrument.

For additional information see: *http://www.dlr.de/hr/en/desktopdefault.aspx/tabid-2317/3669_read-5488/ .*

LRO

The Lunar Reconnaissance Orbiter (LRO, Figure 3-25) is the first mission of the 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. This mission is currently scheduled to launch in June 2009 and is planned to take measurements of the Moon for at least one year. The measurement investigations are:

- Characterization of deep space radiation in Lunar orbit
- Geodetic global topography
- High spatial resolution hydrogen mapping
- Temperature mapping in polar shadowed regions
- Imaging of surface in permanently shadowed regions
- Identification of near-surface water ice in polar cold traps
- Assessment of features for landing sites
- Characterization of polar region lighting environment

Figure 3-25. LRO spacecraft (courtesy of NASA)

The LRO Laser Ranging (LR) system will use 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.

For more information see: *http://lunar.gsfc.nasa.gov.*