Section 2

Central Bureau Report

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SECTION 2 - CENTRAL BUREAU REPORT

The Central Bureau (CB) is responsible for the daily coordination and management of ILRS activities. It facilitates communications and information transfer and promotes compliance with ILRS network standards. The CB monitors network operations and quality assurance of the data, maintains ILRS documentation, provides scientific and technological databases, and organizes meetings and workshops. In order to strengthen the ILRS interface with the scientific community, a Science Coordinator and Analysis Specialists within the CB take a proactive role to enhance dialogue, to promote Satellite Laser Ranging and Lunar Laser Ranging goals and capabilities, and to educate and advise the ILRS entities on current and future science requirements related to these measurement techniques. The Science Coordinator leads efforts to ensure that ILRS data products meet the needs of the scientific community and there is easy online access to all published material (via Abstracts) relevant to SLR science and technology.

2.1 STATUS AND ACTIVITIES OF THE CENTRAL BUREAU

Michael Pearlman, *Harvard-Smithsonian Center for Astrophysics*

John Bosworth, *National Aeronautics and Space Administration*

ORGANIZATION OF THE CENTRAL BUREAU

In response to the ILRS Call for Participation issued in January 1998, NASA submitted a proposal to operate the ILRS Central Bureau from GSFC. The proposal was accepted and the Central Bureau was organized in May 1998, shortly after the ILRS was endorsed by the IERS and the CSTG.

By drawing on available expertise from members of the GSFC SLR team and the Network coordinators, the Central Bureau provides the mix of talents necessary to support the technical and administrative services necessary for the ILRS. The Central Bureau staff includes the part-time services of people from NASA GSFC, the Harvard-Smithsonian Center for Astrophysics, Raytheon Information Technology and Scientific Services (RITSS), Honeywell Technology Solutions, Inc. (HTSI), and representatives from the three regional networks:

Name	Title	Institution
John Bosworth	Director	NASA GSFC
Michael Pearlman	Secretary	CfA
Steve Klosko	Science Coordinator	Raytheon ITSS
Van Husson	SLR Systems Specialist	Honeywell Technical Solutions, Inc.
Peter Dunn	Analysis Specialist	Raytheon ITSS
Mark Torrence	Analysis Specialist	Raytheon ITSS
Scott Wetzel	Operations Specialist	Honeywell Technical Solutions, Inc.
Carey Noll	Web Master	NASA GSFC
Erricos Pavlis	Analysis Specialist	NASA GSFC
Georg Kirchner	EUROLAS Net. Coordinator	Austrian Academy of Sciences
Hiroo Kunimori	WPLTN Net. Coordinator	CRL
David Carter	NASA Net. Coordinator	NASA GSFC

ACTIVITIES

Although the ILRS was not formally established until November 1998, the Central Bureau provided much of the early administrative, communications and coordination support during the ILRS organization and formulation stages. The Central Bureau supported the election process for Governing Board members, the selection of the ILRS logo, and the development of work plans for the Working Groups.

As one of its first tasks, the Central Bureau established the ILRS web site as a resource for information, communication and planning at:

http://ilrs.gsfc.nasa.gov/ilrs_home.html

The site provides current information on the ILRS organization, personnel, operations, missions planning, technology, data product and data product availability (see below). A communications center has been established at HTSI with parallel distribution to GSFC, CfA, and Raytheon ITSS with an established hierarchy for responses. Messages incoming to the Central Board are directed to cb@ilrs.gsfc.nasa.gov.

Outgoing mail to the general ILRS membership is routed through SLRMail at the EUROLAS Data Center (EDC). Specialized mail exploders have been provided through the CDDIS for intra-group communications to the Central Board, stations, analysis centers, data centers and the working groups.

From its beginning, the Central Bureau worked with the other emerging ILRS entities and their members to identify the key services and procedures that were deemed necessary to make the organization a success. Many were formulated as joint action items between one or more Working Groups and the Central Bureau. Some of the key items that have been accomplished so far include the establishment of:

- the ILRS web site;
- station performance standards;
- station performance and compliance reporting;
- report and documentation lists and libraries;
- documented data flow and prediction procedures; and
- formalized process for establishing tracking priorities, requesting mission support, and organizing campaigns.

Others still in process include the implementation of:

- a standardized site description data base;
- a weekly on-line assessment of station operations status;
- “intelligent” on-line forms for data base entries and updates;
- improved pointing predictions for “very” low earth orbiting satellites; and
- subdaily data submissions to the Data Centers.

Since the inception of the Central Bureau, its members with support from their home organizations have addressed these issues. A core group from the Central Bureau meets monthly to monitor progress on its actions items, to assess its interactions with the field stations and the other operational entities, and to monitor progress on Working Groups action items.

Figure 2.1-1 Central Bureau Core Group. In order: Mark Torrence, Scott Wetzel, Mike Pearlman, Van Husson, Peter Dunn, Julie Horvath, John Bosworth, Carey Noll. Not shown: Erricos Pavlis.

MEETINGS

The Central Bureau helped arrange the organizational meeting in Nice, France in April 1998 and organized the ILRS General Assembly Meetings in Deggendorf, Germany in September 1998, The Hague, the Netherlands in April 1999 and Florence, Italy in September 1999 and prepared the meeting reports for general distribution. Presentations on the ILRS have been presented at the Gemstone Meeting in Tokyo, Japan in January 1999, the IUGG Meeting in Birmingham, UK in July 1999 and the International Symposium on GPS in Tsukuba, Japan in October 1999.

CURRENT CHALLENGES

Although much has been accomplished through the end of 1999, current challenges over the next year for the Central Bureau include:

- strengthening the science liaison activity;
- encouraging and helping tracking stations and analysis centers to meet their minimum performance criteria;
- continuing the development of the ILRS website and data bases, in the areas of technology, science and applications, and operations, and formalize the process by which updates are approved;
- continuing the process of documenting configuration and standardizing processes/procedures.

2.2 MISSION PRIORITIES

Michael Pearlman, *Harvard-Smithsonian Center for Astrophysics*

The ILRS designates satellite priorities in an attempt to maximize data yield on the full satellite complex while at the same time placing greatest stress on the most immediate data needs. Priorities provide guidelines for the network stations, but stations may occasionally deviate from the priorities to support regional activities and to expand tracking coverage in regions with multiple stations. Tracking priorities are set by the Governing Board, based on application to the Central Bureau and recommendation of the Missions Working Group. The ILRS satellite priorities as of December 31, 1999 are given in Table 2.2-1.

Priority	Satellite	Sponsor	Altitude (Km)	Inclination	Campaign Ends
1	ERS-1	ESA	800	98.5	31 December 2000
2	GFO-1	US Navy	790	108.0	31 March 2000
3	ERS-2	ESA	800	98.6	
4	TOPEX/Poseidon	NASA/CNES	1,350	66.0	
5	Sunsat	Stellenbosch Univ	400	93.0	17 March 2000
6	Starlette	CNES	815 - 1,100	49.8	
7	WESTPAC	WPLTN	835	98	
8	Stella	CNES	815	98.6	
9	Beacon-C	NASA	950 - 1,300	41	13 July 2000
10	Ajisai	NASDA	1,485	50	
11	LAGEOS-2	ASI/NASA	5,625	52.6	
12	LAGEOS-1	NASA	5,850	109.8	
13	GLONASS 80	RSA	19,100	65	
14	GLONASS 72	RSA	19,100	65	
15	GLONASS 79	RSA	19,100	65	
16	GPS 35	US Air Force	20,100	54.2	
17	GPS 36	US Air Force	20,100	55.0	
18	Etalon 1	RSA	19,100	65.3	
19	Etalon 2	RSA	19,100	65.2	

Priority	Lunar Targets	Sponsor
1	Apollo 15	NASA
2	Apollo 11	NASA
3	Apollo 14	NASA
4	Luna 21	RSA

Table 2.2-1 ILRS Tracking Priorities as of 31 December 1999

Priorities typically decrease with increasing orbital altitude and orbital inclination (at a given altitude). Priorities may then be increased on some satellites to intensify support for (1) active missions (such as altimetry), (2) special campaigns (such as IGEX 98), (3) post-launch intensive tracking phases, and (4) missions of greatest importance to the scientific and analysis communities.

Tracking priorities are formally reviewed semiannually at the ILRS General Assembly Meetings. Updates are made as necessary at the discretion of the Governing Board.

2.3 Network Campaigns

Scott Wetzel, *Honeywell Technology Solutions, Inc.*

Michael Pearlman, *Harvard-Smithsonian Center for Astrophysics*

Introduction

The ILRS is responsible for the tasking and coordinating of special SLR tracking campaigns that are requested by users, supported by the Missions Working Group, and approved by the ILRS Governing Board. Campaigns are typically scheduled for periods from a few months up to a year and may be renewed if warranted. Campaigns are requested to support:

1. satellites in orbit that are having technical problems with onboard systems;
2. new experiments using satellites whose main mission has already been completed; and
3. special combinations of satellites for synergistic experiments.

A user can request a tracking campaign though the ILRS Central Bureau by first completing an on-line SLR Mission Support Request Form accessible through the ILRS web site at:

http://ilrs.gsfc.nasa.gov/ilrssup.html

The form provides the ILRS with a description of the mission objectives; mission requirements; responsible individuals, organizations, and contact information; timeline; satellite subsystems; and details of the retroreflector array and its placement on the satellite. Once the Central Bureau receives the completed form, the form is submitted to the Missions Working Group for review, iteration with the user, if necessary, and development of a recommendation on ILRS support. This recommendation takes into consideration the realism of the program, interest of others in the results, and the overall tracking load on the ILRS network. During the campaign, the Central Bureau will assign the campaign satellites a position within the ILRS tracking priority schedule.

Campaign reports with network tracking statistics and operational comments are issued weekly by the Central Bureau through SLR Mail. The Central Bureau monitors campaign progress to determine if adequate support is being provided. Campaign sponsors (users) are requested to report at the ILRS General Assembly Meetings on the status of ongoing campaigns, including the responsiveness of the ILRS to their needs and on progress toward results. They are also expected to report at the meetings on their results and experience from completed campaigns.

The following sections describe both the campaigns that occurred and have been concluded in the past year and current campaigns supported by the ILRS. Additional information can be found on the ILRS web site under the Missions and Campaigns section.

CAMPAIGNS COMPLETED IN 1999

Three campaigns were completed in 1999 (see Table 2.3-1).

Campaign	Initiated by	Start Date	End Date	Purpose	No. Passes
Geos-3	NASA - Frank Lemoine	Oct. 15, 1998	Apr. 20, 1999	Gravity Field Modeling	2241
IGEX 98	IGEX - Werner Gurtner	Oct. 19, 1998	Apr. 19, 1999*	GLONASS Complex Evaluation	9012 seg.
Etalon	WPLTN - Hiroo Kunimori	Oct. 30, 1999	Nov. 30, 1999	Geodetic Modeling in the WPLTN Region	297 seg.

** Note: The Official IGEX campaign on eleven GLONASS Satellites was completed on April 19, 1999 but ILRS continues to track three GLONASS satellites on a routine basis.*

Table 2.3-1 ILRS Campaigns Completed in 1999

GEOS-3

Launched in 1975, the Geodetic Earth Orbiting Satellite 3 (GEOS-3) was the first operational radar altimeter to measure the topography of the ocean surface. It also hosted an array of tracking systems for intercomparison of techniques. GEOS-3, at 115 degrees inclination, is in a fairly unique orbit. Its SLR contribution to the present gravity field models was based on ranging data of decimeter quality taken in the latter part of the 1970's and early 1980's. The present availability of sub-cm quality SLR data promised considerable improvement in orbit sensitive terms in the gravity field model. Originally requested for three months, the tracking campaign was extended for an additional three months to enrich the data set.

More information can be found on the ILRS web site at

http://ilrs.gsfc.nasa.gov/geos.html

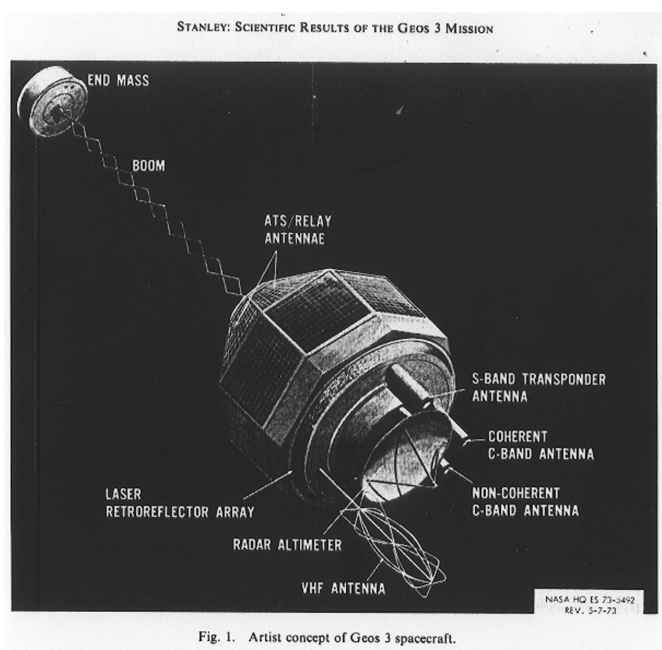

Figure 2.3-1 Artist's conception of GEOS-3

IGEX98

The International GLONASS EXperiment 1998 (IGEX 98) Campaign was organized by the IAG Commission VIII, the CSTG, IGS, and ION to provide independent SLR orbits to:

- evaluate the GLONASS-receivers as geodetic and navigation tools;
- help develop GLONASS radiation pressure models; and
- test combined SLR/microwave processing techniques.

The long-term goals of the campaign are to:

- establish the role of SLR for calibrating GPS and GLONASS;
- separate "gravitational and non-gravitational effects" in the trajectory of high orbiting satellites (using GLONASS, GPS, and Etalon data),
- stabilize the effect of SLR observations on GPS/GLONASS microwave-derived length of day (and integrated LoD=UT) and possibly nutation estimates, and
- combine SLR/GPS/GLONASS analysis for these high-orbiting satellites to conduct the first Global GLONASS Observation Campaign for geodetic and geodynamics applications.

Eleven GLONASS satellites were tracked in support of the campaign, which lasted from October 19, 1998, through mid-January, 1999. The campaign was extended for an additional three months to support the newly launched GLONAS 80, 81, and 82. The network continues to support GLONAS 70, 72, and 79 on a continued routine basis.

More information can be found on the ILRS web site at

http://ilrs.gsfc.nasa.gov/glonass.html

Figure 2.3-2 Artist's Conception of GLONASS

Etalon

The SLR passive geodetic satellites, Etalon-1 and 2, were launched by the Russian Federation to improve the accuracy of the terrestrial reference frame and to support measurements of Earth rotation parameters and the gravity field.

The one-month Etalon Campaign in November 1999, sponsored by the WPLTN, included intensive Etalon and Lagoes tracking to help develop a geophysical information system in the Asia Pacific region. The campaign also included GPS, DORIS, and VLBI measurements in the region.

More information can be found on the ILRS web site at

http://ilrs.gsfc.nasa.gov/etalon.html

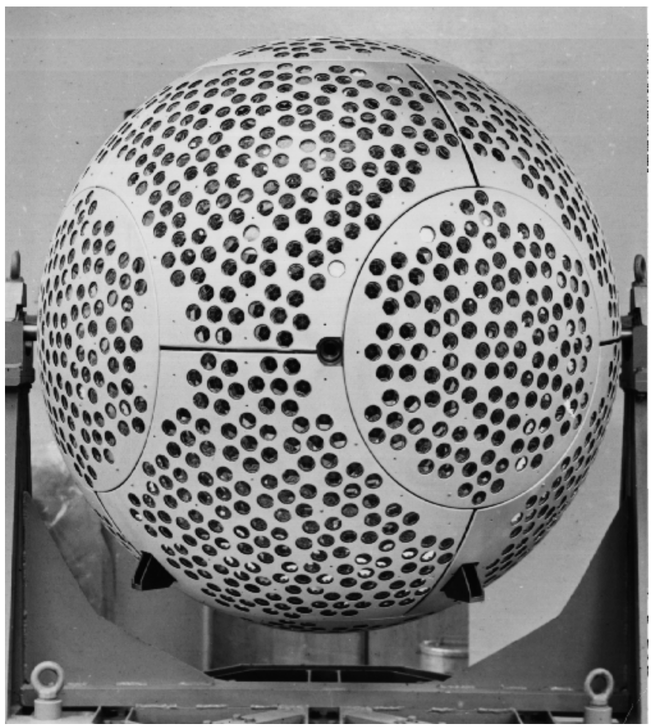

Figure 2.3-3 Etalon Satellite

ONGOING CAMPAIGNS

Four campaigns initiated prior to the year 2000 are still underway (Table 2.3-1 provides a brief summary.

Campaign	Initiated by	Start Date	Planned End Date	Purpose	No. Passes
BE-C	Univ. of Texas Minkang Cheng	July 15, 1999	October 31, 2000	Gravity field modeling	2557
ERS-1	D-PAF Franz-Heinrich Massman	July 20 1998	December 31, 2000	POD for ocean surface studies	5994
SUNSAT	NASA Erricos Pavlis	May 7, 1999	October 17, 2000	GPS/SLR intercompari-son	1066
GFO-1	NASA Frank Lemoine	Apr. 22, 1998	October 31, 2000	POD for ocean surface studies	4461

Table 2.3-1 Ongoing ILRS Campaigns

Beacon Explorer-C

Beacon-C (BE-C) was launched in 1965 as part of the US National Geodetic Satellite Program

It was the second retroreflector equipped Earth satellite to be launched to support measurement technique intercomparason, determination of station positions, and modeling of the gravity field.

Tracking on BE-C was reactivated after many years at the request of the University of Texas to augment the current complex of satellites used to study the secular and long period tidal variations in the Earth's gravity field. These studies are providing a critical global constraint on our understanding of the rheology of Earth, including the mantle viscosity and elasticity, and post-glacial rebound. The requirement for both the long-term temporal and spatial distribution of the SLR tracking data (i.e., from the satellites at various inclinations and altitudes) is critical for separating the variations at different degrees and orders. Since all all of the current geodetic satellites are orbiting at inclinations ranging from 50 to 110 degrees, BE-C satellite is the only useful target with a relatively low inclination (41 degrees). With SLR tracking capability having improved dramatically since the intensive Beacon-C tracking of the 1960's and 70's, the campaign is making a very beneficial to the modeling activity.

A six month campaign was initiated in July 1999. An extension was authorized through October 2000, based on the success to date.

Additional information can be found on the ILRS web site at:

http://ilrs.gsfc.nasa.gov/beaconC.html

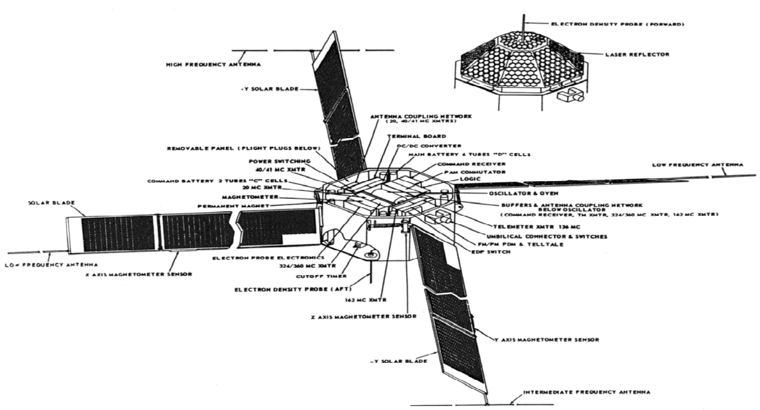

Figure 2.3-4 Beacon-C

ERS-1

European Remote Sensing satellite (ERS-1) is the first in a family of multi-disciplinary Earth Observation Satellites with a radar altimeter and a synthetic aperture radar (SAR) to study the topography of the ocean surface. Shortly after launch in 1992 the primary tracking system PRARE failed, and SLR became the only tracking technique to support the altimeter and the SAR. When ERS-2 was launched in 1997, its predecessor was placed in a dormant mode. In 1998 the European Space Agency reactivated ERS-1 so that the pair of satellites could work in a tandem SAR mode to map details of the ocean surface. SLR continues to support ERS-1 tracking in campaigns of 3 - 6 months at a time as the on-board systems continued to function for periods far beyond expectation. ERS-2 has been routinely tracked by the network since launch.

Additional information can be found on the ILRS web site at:

http://ilrs.gsfc.nasa.gov/ers1.html

Figure 2.3-5a ERS-1 Satellite

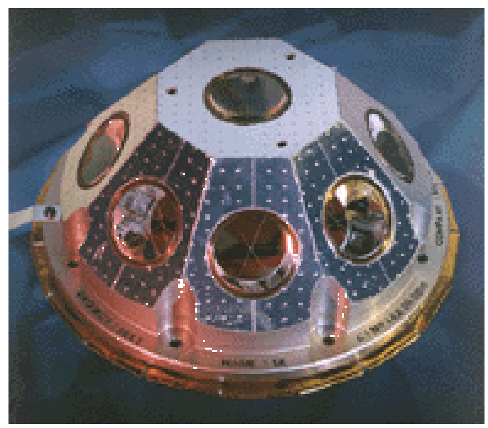

Figure 2.3-5b ERS-1 SLR Array

Sunsat

Stellenbosch UNiversity SATellite (SUNSAT) is a micro-satellite designed and built by electrical engineering students at the Stellenbosch University in South Africa. As an engineering project, the mission objectives are optical imaging of Earth surface conditions, email communications, studies of the Earth's magnetic field, gravity field, atmosphere and ionosphere, and evaluation of the on-board GPS system.

SLR is providing accurate orbits with which to evaluate the GPS. The GPS receiver is working and data is being evaluated at JPL. Several problems were encountered early in the mission which are now being overcome. The GPS L2 signal-to-noise ratio was very low due to shortcomings in the software. Spacecraft power limitations severely constrained GPS hours of operation. The S-band downlink failed, limiting data transmission to 9600 baud. The power limitation has been somewhat relieved by the orbital precession that has increased solar illumination. Software modifications are underway to alleviate the data congestion problem. Once the software is in place, the project expects that GPS usage will increase to as much as 60 hours per month.

SLR tracking started in May 1999 and is scheduled to run through mid-March 2000. In all likelihood an extension will be requested.

Additional information can be found on the ILRS web site at:

http://ilrs.gsfc.nasa.gov/sunsat.html

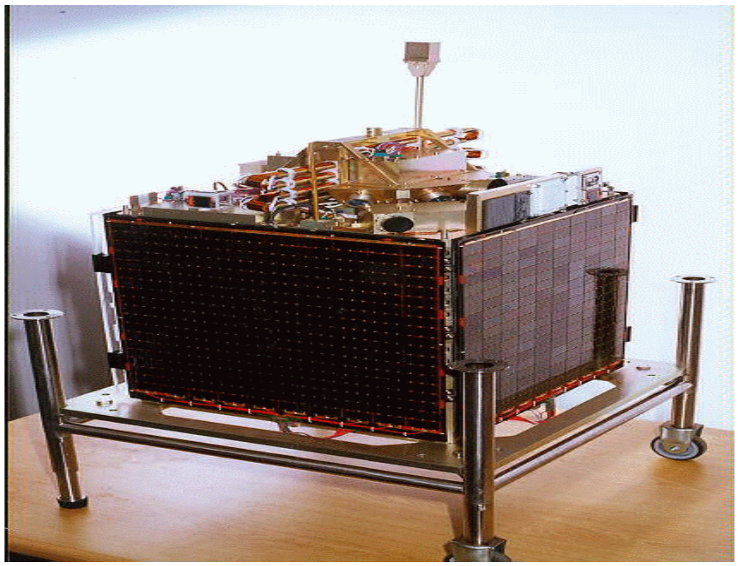

Figure 2.3-6 SUNSAT

GFO-1

The GEOSAT Follow-On 1 (GFO-1) program is the U.S. Navy's initiative to develop an operational family of radar altimeter satellites to maintain continuous ocean observation, including precise measurement of both mesoscale and basin-scale oceanography. The length and time scales of these processes are too large for conventional in-the-water oceanographic instrumentation configurations to measure. Satellite altimetry is the only known method by which oceanographers can precisely measure sea surface topography. The shape of the sea surface is the only physical variable directly measurable from space that is directly and simply connected to the large-scale movement of water and the total mass and volume of the ocean.

GFO-1 was launched on 10 February 1998 and ILRS tracking support commenced on 22 April 1998. The satellite had several problems including spontaneous resets that placed the spacecraft in stow mode and failure of the control system for the four GPS receivers. The reset and stow problem has been alleviated and routine SLR and Doppler tracking have provided the orbit determination for the altimeter. The initial six month tracking campaign has been extended through October 2000 to support the project in its efforts to overcome its difficulties. The altimeter is now going through calibration and validation. Once the altimeter performance is verified and operations can be sustained, the satellite will become a candidate for placement on the routine ILRS tracking roaster.

Additional information can be found on the ILRS web site at:

http://ilrs.gsfc.nasa.gov/gfo.html

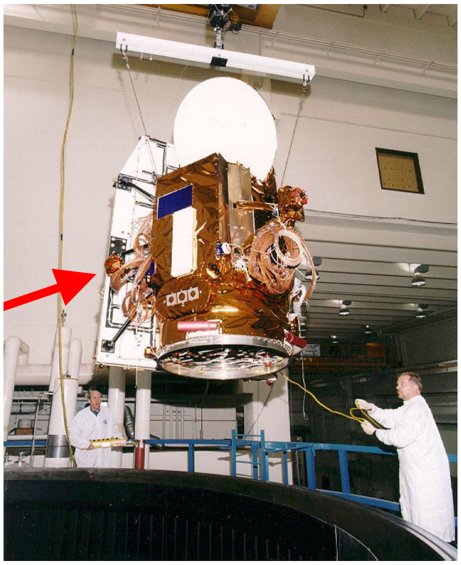

Figure 2.3-7a GFO-1 Satellite

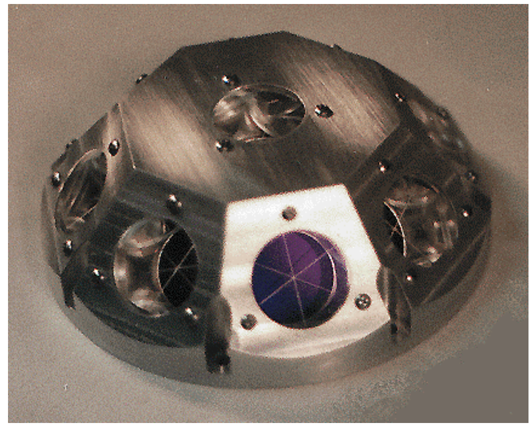

Figure 2.3-7b GFO-1 SLR Array

CONCLUSION

The campaign structure has been easy to implement and has allowed the ILRS to provide quick response to user needs. The ILRS has supported a number of campaigns over the past year. In particular, being able to bring back 20- and 30-year-old satellites has been very helpful to the scientific community.

2.4 Upcoming Missions

Scott Wetzel, *Honeywell Technology Solutions, Inc.*

Michael Pearlman, *Harvard-Smithsonian Center for Astrophysics*

Introduction

Request for tracking support for new missions must be submitted to the Central Bureau, reviewed by the Missions Working Group and approved by the Governing Board. New missions request tracking support by first completing an on-line SLR Missions Support Request Form accessible through the ILRS web site at:

http://ilrs.gsfc.gov/ilrsup.html

The form provides the ILRS with a description of the mission objectives; mission requirements; responsible individuals, organizations, and contact information; timeline; satellite subsystems; and details of the retroreflector array and its placement on the satellite. This form also outlines the early stages of intensive support that may be required during the initial orbital acquisition and stabilization and instrument checkout phases. Once the Central Bureau receives the completed form, the form is submitted to the Missions Working Group for review, iteration with the user, if necessary, and development of a recommendation on ILRS support including tracking priorities. This recommendation takes into consideration the realism of the program, interest of others in the results, and the overall tracking load on the ILRS network. The Central Bureau then submits the request to the Governing Board for approval.

Once tracking support is approved, the Central Bureau works with the new missions to develop a Mission Support Plan detailing the level of tracking, the schedule, the points of contact, and the channels of communication. New missions normally receive very high priority during the acquisition and checkout phases and are then placed at a routine priority based on the satellite category and orbital parameters.

After launch, New Mission Reports with network tracking statistics and operational comments are issued weekly by the Central Bureau through SLReports. The Central Bureau monitors progress to determine if adequate support is being provided. New mission sponsors (users) are requested to report at the ILRS Plenary meetings on the status of ongoing campaigns, including the responsiveness of the ILRS to their needs and on progress toward results. They are also expected to report at the meetings on their results and experience from the tracking support.

New Missions Planned for 2000 – 2001

Seven new missions are anticipated during 2000 – 2001 (See Table 2.4-1)

Mission Name	*Support Requester*	*Planned/Actual Launch Date*	*Mission Duration*	*Altitude (km)*	*Inclination (Deg)*	*Received Mission Request Form*	*Application*
CHAMP	GFZ Germany	July 2000	5 yrs	470	83	Yes	gravity and magnetic field mapping
JASON-1	CNES/NASA France/USA	Nov. 2000	5 yrs	1336	66	Yes	Environmental change
Vegetation Canopy Lidar *(VCL)*	NASA USA	April 2001	18 mos	390-410	65	Yes	Vegetation and land topography
Envisat-1	ESA Europe	Nov. 2001	5 yrs	800	98.5	No	Environmental change
IceSat (GLAS)	NASA USA	July 2001	3-5 yrs	600	94	No	ice level and ocean surface topography
Gravity Probe B *(GP-B)*	NASA-JPL USA	Sept. 2001	1-2 yrs	400	90	Yes	Relativity
ADEOS-II	NASDA Japan	Nov. 2001	3 yrs	803	98.6	No	Ocean circulation; atmosphere-ocean interaction

Table 2.4-1 New Missions Planned for 2000-2001

CHAMP

The CHAllenging Mini-Satellite Payload (CHAMP) will measure long-term temporal variations in the magnetic field, the gravity field and the atmosphere. Satellite laser ranging data will be used for precise orbit determination in connection with GPS for gravity field recovery; calibration of the on-board microwave orbit determination system (GPS); and two-color ranging experiments. CHAMP will have the following instrumentation onboard:

1. dual-frequency GPS receiver,
2. three-axes accelerometer,
3. magnetometer instrument package,
4. digital ion drift meter, and
5. a retroreflector array.

The laser retroreflector consists of four prisms to reflect short laser pulses back to the transmitting ground station. This enables the measurement of the direct two-way range between ground station and satellite with an accuracy of 1 to 2 cm.

More details on the CHAMP Mission are available at:

http://ilrs.gsfc.nasa.gov/champ.html

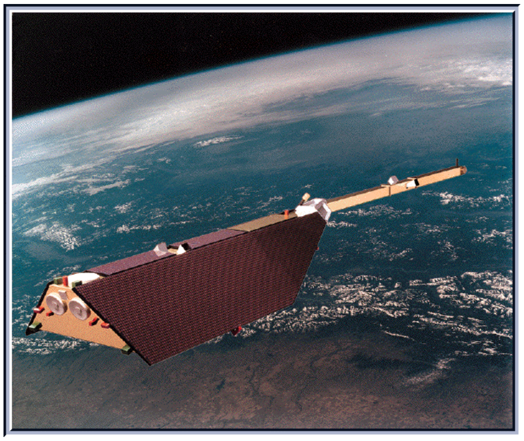

Figure 2.4-1a Champ satellite

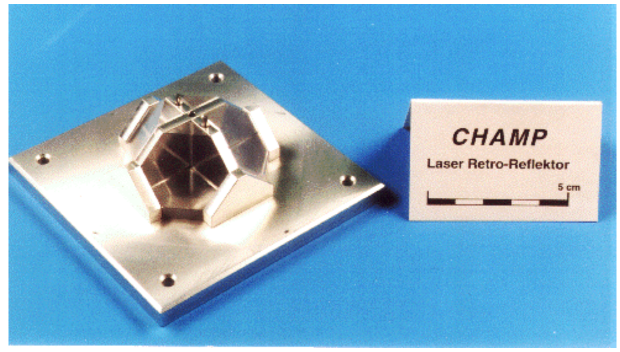

Figure 2.4-1b CHAMP SLR Array

Jason-1

Jason-1 is an oceanography mission to monitor global ocean circulation, discover the tie between the oceans and atmosphere, improve global climate predictions, and monitor events such as El Niño conditions and ocean eddies. The Jason-1 satellite, a joint France/USA mission, is a follow-on to the highly successful Topex/Poseidon altimeter mission. Precision orbit determination will be provided by GPS and SLR. Jason-1 will have the following instrumentation onboard:

1. Microwave radiometer
2. DORIS dual frequency system receiver
3. Dual-frequency solid-state altimeter
4. GPS receiver
5. Retroreflector array

The corner cubes are symmetrically mounted on a hemispherical surface with one nadir-looking corner cube in the center, surrounded by an angled ring of eight corner cubes. This will allow laser ranging in the field of view angles of 360 degrees in azimuth and 60 degrees elevation around the perpendicular to the satellite's -Zs earth panel. The design is identical to the array to be used on ADEOS-2 and GFO-1.

Additional information on the Jason-1 Mission can be found at

http://ilrs.gsfc.nasa.gov/jason1.html

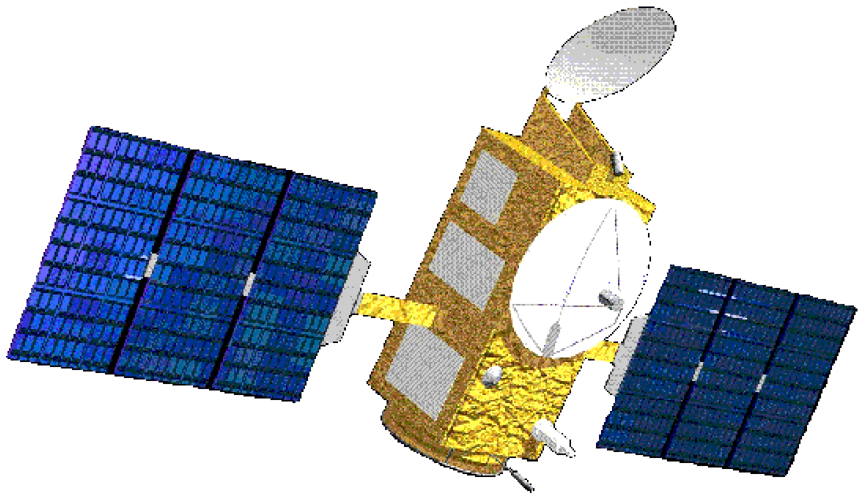

Figure 2.4-2a Jason Satellite

ADEOS-II

The ADvanced Earth Observing Satellite 2 (ADEOS-2) Mission is a joint international program like its successor, ADEOS-1. The mission will support the monitoring of global environmental changes while continuing and furthering the broad-ranging observation technology created by ADEOS-1. ADEOS-2 will carry the following instrumentation:

1. Advanced microwave scanning radiometer
2. Global imager
3. Improved limb atmospheric spectrometer
4. Seawinds
5. Polarization and directionality of earth reflectance
6. Retroreflector array

The corner cubes are symmetrically mounted on a hemispherical surface with one nadir-looking corner cube in the center, surrounded by an angled ring of eight corner cubes. This will allow laser ranging in the field of view angles of 360 degrees in azimuth and 60 degrees elevation around the perpendicular to the satellite's -Zs earth panel. The array design is identical to that of GFO-1 and ADEOS-II.

Additional information on ADEOS-II can be found at:

http://ilrs.gsfc.nasa.gov/adeos2.html

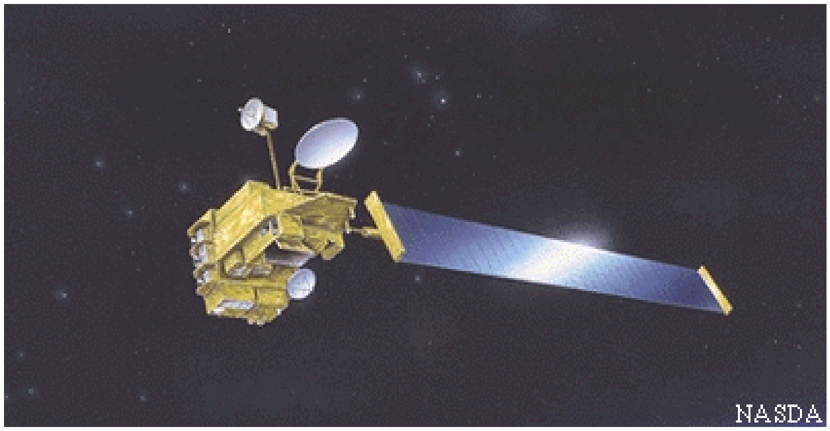

Figure 2.4-3a ADEOS-II Satellite

Vegetation Canopy Lidar (VCL)

The VCL mission will provide a characterization of the three-dimensional structure of the Earth including (1) landcover for modeling, monitoring and making predictions about the terrestrial ecosystem and climate modeling and (2) a global reference data set of topographic spot heights and transects. The mission will measure:

1. vegetation canopy top height to less than 1 m,
2. vertical distribution of intercepted surfaces,
3. ground surface topographic elevations to less than 1m

Measurements will be used to create a variety of gridded and ungridded data products. High resolution grid will be 2 km x 2 km; low resolution grid will be 1° x 1°.

Additional information on the VCL Mission can be found at:

http://essp.gsfc.nasa.gov/vcl/

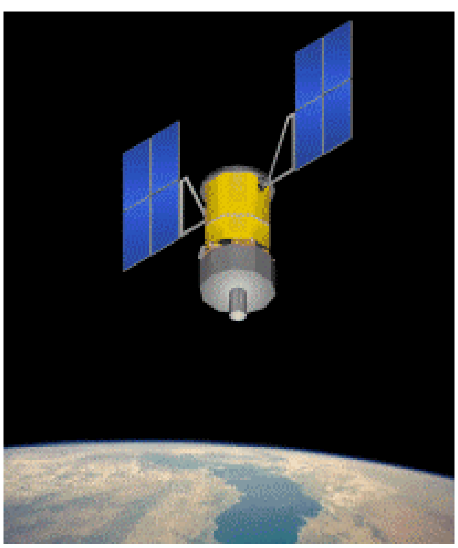

Figure 2.4-4a VCL Satellite

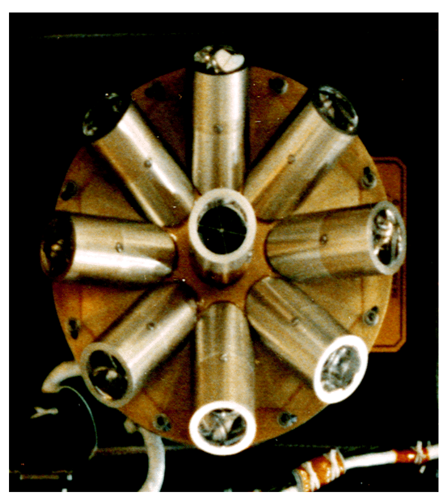

Figure 2.4-4b VCL SLR Retroreflector Array

Envisat

ENVIronmental SATellite (EnviSat) -1 is the successor to the European Space Agency (ESA) Remote Sensing Satellites ERS-1 and ERS-2. It will provide continuity with most of the ERS-1, 2 altimeter and SAR measurements and adds significant new capabilities. The mission will provide long term data sets for both climatological and environmental research. EnviSat-1 mission will monitor and support studies of the Earth's environment and climate changes; the management and monitoring of the Earth's resources, both renewable and non-renewable; and the development of a better understanding of the structure and dynamics of the Earth's crust and interior.

SLR will be used to calibrate the radar altimeter through precision orbit for ocean height data for monitor global ocean circulation, regional ocean current systems, and the study the marine gravity field.

Envisat will carry the following instrumentation:

1. Michelson Interferometer for Passive Atmospheric Sounding (MIPAS);
2. Global Ozone Monitoring by Occultation of Stars (GOMOS);
3. SCanning Imaging Absorption spectrometer for AtMospheric CartograpHY (SCIAMACHY);
4. MEdium Resolution Imaging Spectrometer (MERIS);
5. Advanced Along Track Scanning Radiometer (AATSR);
6. Advanced Synthetic Aperture Radar (ASAR);
7. Radar Altimeter 2 (RA-2);
8. MicroWave Radiometer (MWV);
9. Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS);
10. RetroReflector Array (RRA);

The corner cubes are mounted symmetrically on a hemispherical surface with one nadir-looking corner cube in the center, surrounded by an angled ring of eight corner cubes. This will allow laser ranging in the field of view angles of 360 degrees in azimuth and 60 degrees elevation around the perpendicular to the satellite's -Zs earth panel. The design is identical to the ERS-1 and ERS-2 reflectors.

Additional information on Envisat can be found at:

http://ilrs.gsfc.nasa.gov/envisat.html

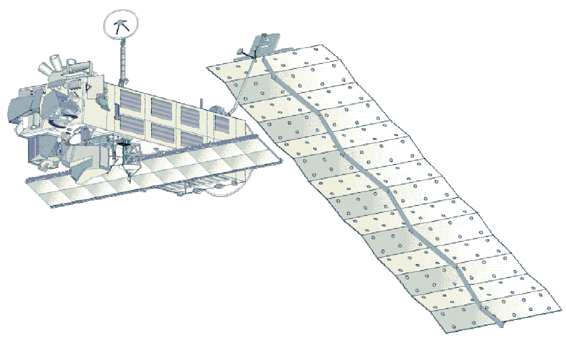

Figure 2.4-5a Envisat Satellite

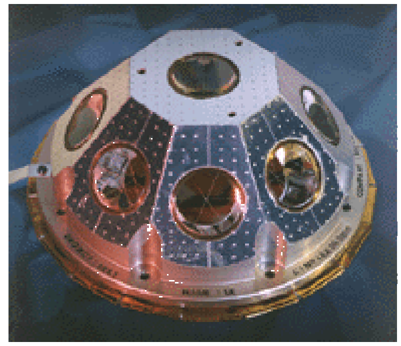

Figure 2.4-5b Envisat SLR Retroreflector Array

ICESat (GLAS)

The Ice Cloud and land Elevation Satellite (ICESat) begins with a launch on a Delta II (Model 7320) Expendable Launch Vehicle (ELV) in July 2001, into a near polar Low Earth Orbit (LEO) at an altitude of 600 km with an inclination of 94 degrees. The spacecraft accommodates the GLAS instrument which is currently estimated at a mass not to exceed 300kg and power of 330 W (each including 20% contingency), to fully achieve the EOS requirements.

The Geoscience Laser Altimeter System (GLAS) is an integral part of the NASA Earth Science Enterprise (ESE). GLAS is a facility instrument designed to measure ice-sheet topography and associated temporal changes, as well as cloud and atmospheric properties. In addition, operation of GLAS over land and water will provide along-track topography. GLAS will be carried on the Ice, Cloud and land Elevation Satellite (ICESat), scheduled for launch in July 2001.

The laser altimeter measures the time required for a laser pulse of 5 nanosecond duration to complete the round trip from the instrument to the Earth's surface and back to the instrument. This time interval can be converted into a distance by multiplying with the speed of light, and the one-way distance can be obtained as half the round trip distance. With the position of the instrument in space determined from a high accuracy Global Positioning System (GPS) receiver and from star camera and gyroscopes carried on the instrument/ spacecraft, the laser direction in space will be determined. From the GPS-determined position, the altimeter measurement and the laser pointing direction, the location on the surface of Earth illuminated by the laser pulse can be determined. The series of such laser spot, or footprint, locations provides a profile of the surface. Analysis of the sequence of laser spots over time enables the determination of temporal change in topography.

For more information on ICESat refer to:

http://ilrs.gsfc.nasa.gov/icesat.html

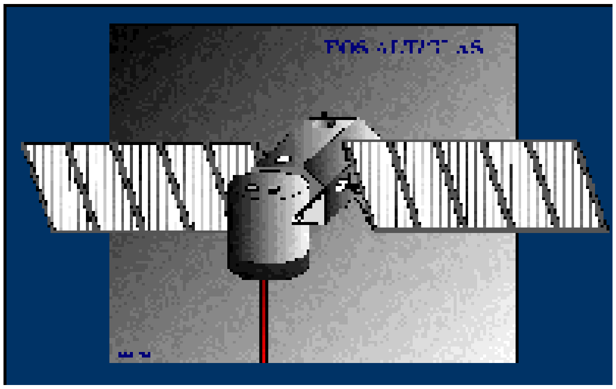

Figure 2.4-6a ICESat Satellite

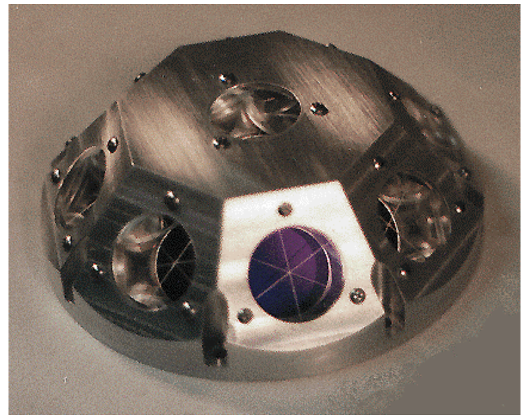

Figure 2.4-6b ICESat SLR Retroreflector Array

Gravity Probe B (GP-B)

Gravity Probe B will carry the relativity gyroscope experiment being developed by NASA and Stanford University to test two extraordinary, unverified predictions of Einstein's general theory of relativity. The experiment will check, very precisely, tiny changes in the direction of spin of four gyroscopes contained in an Earth satellite orbiting at 400-mile altitude directly over the poles. So free are the gyroscopes from disturbance that they will provide an almost perfect space-time reference system. They will measure how space and time are warped by the presence of the Earth, and how the Earth's rotation drags space-time around with it. These effects, though small for the Earth, have far-reaching implications for the nature of matter and the structure of the Universe. SLR and GPS will be used for precision orbit determination.

Gravity Probe B will carry the following instrumentation:

1. Four gyroscopes
2. Quartz telescope
3. GPS receiver
4. Retroreflector array

The retroreflector array is yet to be determined.

Additional information on Gravity Probe-B can be found at:

http://ilrs.gsfc.nasa.gov/gravity_probe_b.html

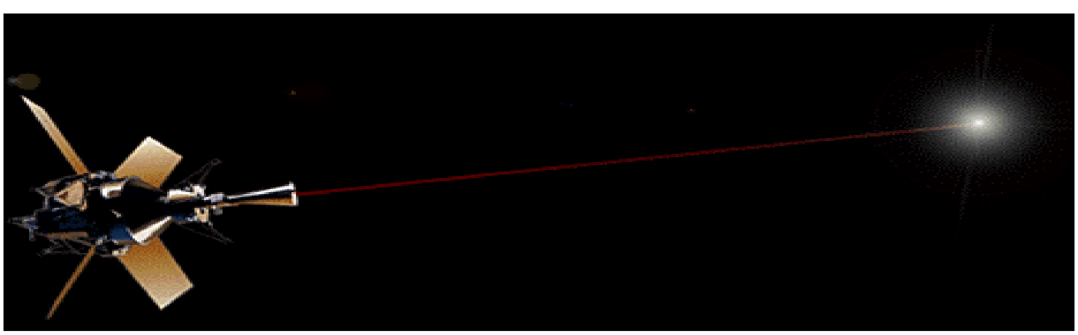

Figure 2.4-7a Gravity Probe-B

2.5 ILRS Web Site

Van Husson, *Honeywell Technology Solutions, Inc.*

Background

The ILRS Web Site was developed to provide communication and coordination for the ILRS. The site is physically hosted on the NASA CDDIS computer at GSFC at:

URL: http://cddisa.gsfc.nasa.gov/ilrs/ilrs_home.html or http://ilrs.gsfc.nasa.gov/

Node: cddisa.gsfc.nasa.gov

IP Address: 128.183.102.102

For convenience, redundancy, and ease of traffic, the site is mirrored at the Communication Research Laboratory (CRL) in Japan at:

http://galileo.crl.go.jp/ilrs/ilrs_home.html

and the EUROLAS Data Center in Germany at:

http://www.dgfi.badw–muenchen.de/edc/ilrs/ilrs_home.html

Shortly after the establishment of the ILRS Central Bureau (CB) in May 1998, the CB formed a web team to begin providing cohesions. Fast access and easy navigation were the primary web site design considerations.

The web site hierarchical structure includes up to five levels. The top level (level 0) contains the home page, the web site search and the site map. The next level down (level 1) contains the main site categories:

- About the ILRS, Working Groups,
- Satellite Missions,
- Station/Sub-Networks,
- Data Products,
- Science/Analysis,
- Reports,
- Frequently Asked Questions (FAQ),
- Contact Information,
- Links, and
- What's New.

The lower levels (i.e., levels 2, 3, and 4) contain more detailed information about their respective parent categories.

The ILRS web site went on-line in early September 1998 and was demonstrated, a week later, at the 1st ILRS meeting held in Deggendorf, Germany in conjunction with the 11th International Workshop on Laser Ranging.

CURRENT STATUS

The site has been under continuous development based on user feedback to better facilitate information exchange and to minimize site maintenance. To date three types of features (cosmetic, functional, and science presence) have been added to the site which include:

- web-based forms (join the ILRS, mission support request, change ILRS associate directory information)
- interactive database queries (station tracking statistics by year and satellite)
- ILRS e-mail exploders
- the ILRS Quick Reference Card (see Section 8.2)
- cross-referenced tables containing station, satellite, and prediction information
- the ILRS Library (see Section 2.7)
- the ILRS bibliography
- the ILRS science brochure (see Section 2.8)
- expanded external related science links.

FUTURE DEVELOPMENTAL ACTIVITIES

Future development activities of the web site include:

- a knowledge base (i.e., symptoms and causes of poor performance)
- dynamic content created automatically when information databases are updated
- consistent web page format
- station site information logs
- station status updates
- mission support requests and mission support plans
- improved search capability
- improved and standard navigation scheme
- near real time updates of both mirrored sites
- spacecraft center-of-mass algorithms

- a history of satellite priorities and maneuvers
- final campaign station performance statistics
- expanded and more current WG and CB activities
- annual reports

The web site team members are listed below:

Carey Noll, *NASA CDDIS*

Mark Torrence, *Raytheon ITSS*

Peter Dunn, *Raytheon ITSS*

Jennifer Beall, *Raytheon ITSS*

Van Husson, *Honeywell Technical Solutions, Inc.*

Michael Pearlman, *Harvard-Smithsonian Ctr. for Astrophysics*

Paul Stevens, *Honeywell Technical Solutions, Inc.*

2.6 NETWORK PERFORMANCE EVALUATION

Van Husson, *Honeywell Technology Solutions, Inc.*

CURRENT ACTIVITIES

The ILRS Central Bureau (CB) is responsible for network performance evaluation and coordination of data problem resolution. The data team at HTSI, part of the CB, has developed diagnostic tools (i.e., range bias, time bias, data format, and data integrity checks) using the weekly orbital solutions from the analysis centers and key station processing parameters contained in the normal point data. These quality assessment tools have evolved from earlier work of the NASA Data Engineering Team established under the Crustal Dynamics Project.

When the diagnostic procedures indicate a potential problem, an investigation is initiated. The investigation involves close coordination with the analysis centers, station operations, engineering, and sometimes the broader CB team. If the data problem is recoverable, it is documented and communicated to the community. The data correction algorithm is published on the ILRS web site and added to the historical data problem listing.

The CB generates the quarterly global performance report card, which is available from the ILRS web site at:

http://ilrs.gsfc.nasa.gov/performance.html

The report card contains metrics for each station, which are evaluated by their comparison to established ILRS performance standards. The performance goals are divided into three categories (data quantity, data quality, and operational compliance) and have evolved from the performance guidelines presented at the Shanghai 10th International Workshop on Laser Ranging in November 1996. The last report card in 1999 appears in Section 8.4.

FUTURE ACTIVITIES:

The CB continues to enhance its performance assessment tools for more sensitive diagnostics. These enhancements include:

- aggregated station LAGEOS range and time biases to identify temporal trends
- comparisons of analysis centers aggregated LAGEOS range and time bias estimates and station coordinates
- refined station meteorological data integrity checks based on historical data
- a knowledge base of performance problem symptoms and their causes

The major goal of the CB engineering team is to continue to push data quality assessment responsibility to the stations (operations and engineering). The CB will continue its ongoing training in this area to assist stations by providing performance evaluation algorithms and by giving presentations at ILRS meetings and workshops.

2.7 ILRS LIBRARY

Mark Torrence, *Raytheon Information Technology and Scientific Services*

The ILRS maintains a library of information in hardcopy form and an online bibliography of references to articles and presentations that are of interest to the scientific, analytical, and engineering SLR commentates.

The library's hardcopy documents, which are located in Boston at the SAO, fall into the following categories:

- ILRS documents (2 volumes)
- SLR Subcommission reports (14)
- CSTG Bulletins (4)
- CSTG SLR/LLR Subcommission reports (2)
- Laser ranging workshop reports (2^{nd} through 9^{th})
- program planning and review documents (16)
- SLR site information catalogue, retroreflector array transfer function (10)
- atmospheric refraction (1)
- mission support plans (8)
- SLR instrumentation information not from workshops (3)
- WEGENER documents (15)
- Asia-Pacific Space Geodynamics Program (APSG) documents (2)
- project reports (2)
- collocation reports (3)
- meeting reports (1)
- "Proceedings of the International Workshop on Geodetic Measurements by Collocation of Space Techniques on Earth", Communication Research Laboratory, Koganei, Japan, January 1999.

A complete citation list of the aforementioned hardcopy documents can be found at:

http://ilrs.gsfc.nasa.gov/science.html

on the ILRS web site.

The ILRS online bibliography currently has 2644 citations and is organized both alphabetically and by year of the citation. References are from the years 1966, 1971, 1975, and 1977 through the present. The bibliography can be found at:

http://ilrs.gsfc.nasa.gov/science.html

2.8 SCIENCE COORDINATOR REPORT

Mark Torrence, *Raytheon Information Technology and Scientific Services*

As established by the ILRS governing board, the science coordination activity of the ILRS is to:

- enhance science dialogue
- promote SLR goals and capabilities
- enhance the program/mission coordination and response
- promote multi-disciplinary dialogue
- help define and focus SLR science and technology goals
- help evaluate and plan for new technologies
- operate proactively to stimulate new or improved science products.

During the first year of the ILRS, a web page for science was made

http://ilrs.gsfc.nasa.gov/science.html

and a brochure describing SLR and its contributions to Earth science

http://ilrs.gsfc.nasa.gov/slrover.pdf

was updated. Also, an online bibliography of SLR related publications of SLR related geophysical, orbit determination, oceanographic and technology developments has been constructed (*see previous section*).

Brief presentations were made at each ILRS general meetings concerning how SLR contributes to scientific knowledge about the solid Earth and its' surface, about Lunar science, and to tests of relativity. SLR is and can continue to make unique contributions to knowledge of the temporal variations in the geopotential, to the maintenance of Earth scale, to the determination of Earth center of figure, and reference frame.

Additionally, SLR enhances the determination of Earth Love numbers and their frequency dependence, the refinement of low and intermediate harmonics of the static geopotential, the determination of the Earth's total mass, and vertical processes. Understanding the temporal changes in the Earth's gravitational field provides global constraints on the mass movements and exchanges occurring within the Earth-hydrosphere-atmosphere systems. SLR has made unique contributions to and can still enhance the resolution of the determination of the long wavelength non-tidal component of the temporal variations of the geopotential.

The static and dynamic Earth gravity model is used not only to perform precise orbit calculations, but also to act as a boundary condition on the mass distribution within the Earth, and for ocean dynamics. The variation of the ocean's surface from an equipotential surface requires removal of the geoid signal to yield a direct estimate of ocean circulation and isolation of the dynamic ocean topography.

Analysis of SLR data contributes to the estimation of the anelastic response of the solid Earth at tidal frequencies. The engineering community of the ILRS was encouraged to continue to improve the measurement accuracy to the few millimeter level allowing SLR to continue to contribute to scientific research.

Future science coordination activities will focus on the promotion of the unique contributions of SLR to science, and to the assessment of the evolving needs of the science community. This activity will participate in the formulation of a methodology to quality control science products and to provide standard test data sets for the analysis centers.