Section 5

Operations Center Reports

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SECTION 5 - OPERATIONS CENTER REPORTS

The Operational Centers are in direct contact with tracking sites organized in a subnetwork. Their tasks include the collection and merging of data from the subnetwork, initial quality checks, data reformatting into a uniform format, compression of data files, if requested, maintenance of a local archive of the tracking data and the electronic transmission of data to a designated ILRS Data Center. Operational Centers can perform limited services for the entire network. Individual tracking stations can also perform part or all of the tasks of an Operational Center themselves.

The ILRS has two SLR Operations Centers, the Mission Control Center in Moscow, Russia and the NASA Goddard Space Flight Center in Greenbelt, MD USA. The University of Texas also operates the LLR Operations Center in Austin, Texas USA.

5.1 MISSION CONTROL CENTER

Vladimir Glotov, *Russian Mission Control Center*

INTRODUCTION/FUNCTIONS PROVIDED; PREDICTIONS

The MCC's activity, as the Operation Center of Russian SLR network, began in 1990. Before that time most of the people involved had an active role in the MCC ballistic service for space missions supported by the MCC. Built in 1973, the Mission Control Center controls the Mir (early Salyut) orbital manned stations, the Soyuz space shuttles, the Progress space trucks, space science kits for orbital complexes, the reusable Buran space shuttle and the un-crewed space probes to Venus, Mars, Zond, Vega and Phobos. As a scientific body the Center also does its own research, solving specific spaceflight control.

Many experts in control systems, space technology, ballistics, telemetry, communications and tracking systems manage spaceflights, and officers from scientific institutions share the experiments and research. The mission program and the crew's safety depends on this group of people. Therefore the Mission Control Center is backed up with state-of-the-art technology. In particular, it has powerful message-transmitting equipment, facilities to gather information, etc. Tracking-telemetry/control (TTandC) stations implement all of the decisions in flight control operations. The TTandC stations communicate with the MCC by telegraph, telephone and television.

By the beginning of the 1990's the MCC ballistic service had accumulated more than 20 years of experience in the data gathering, storing and processing. The Russian SLR stations are part of different Russian networks, and therefore the MCC is responsible for coordinating the SLR activity. Stations transfer their data directly to the MCC.

In parallel with precise SLR data analysis (see Section 7.1.2.3.), MCC supports the collection of raw data from the Russian stations and provides the SLR community with corresponding normal points. In order to improve the quality of the data, limited mostly by equipment, the MCC has carried out upgrade work with the designers and operators of the equipment. As a result, the performance of Maidanak (1864) in 1995 and Komsomolsk (1868) in 1997 has been markedly improved.

Thus the Mission Control Center's next main tasks, as Operation Center of Russian SLR network, are:

- Permanent monitoring of SLR-stations data quality, cooperation with the station developers and staff in the analyses of station failures and developing approaches of station SLR-data improvement;
- Delivery of satellite predictions, tracking schedules and technical information to SLR-stations;
- Collection, quality check, failure detection of raw SLR data from tracking stations; NP generation for all stations and satellites;
- Transforming tracking data into international data formats (FR, QL, QL-NP), transferring SLR-data to International Global Data Centers (EDC, CDDIS)
- Cooperation with international services and Data Storage Centers in satellite tracking files and checking the quality of transfers of SLR-data;

- Cooperation with Russian SLR stations in the solving of technical problems during the station operation (in cooperation with RISDE - Head Russian SLR stations development and operation institution)

Starting in 1998 the MCC became the official processing center for the WPLTN. Currently the MCC supports Westpac satellite missions with IRVS predictions. Normally they are determined on a 1-2 week's basis with a slight tendency to reduce the time intervals in 1999 due to the increase in Solar activity. In 1999 Dr. Zhao You of the Chinese Academy of Science invited two MCC SLR Center experts (Dr. V. Glotov and Dr. V. Mitrikas) in the area of WPLTN station maintenance and development to visit China. They visited two Chinese SLR stations: Changchun and Beijing. Dr. Glotov and Dr. Mitrikas in the cooperation with Chinese experts from Changchun, Beijing and Shanghai SLR stations made the detailed long-term analyses of Chinese station SLR data quality and error sources leading to data quality degradation. Special recommendations concerning satellite tracking and calibration were developed.

STATIONS SUPPORTED

Since 1991 MCC, as the Operation Center of Russian SLR network, controlled the following SLR-stations:

- Maidanak-1 (1863)and Maidanak-2 (1864)
- Balkhash (1869)
- Evpatoria (1867)
- Komsomolsk (1868)
- Katzively (1893)
- Mendeleevo (1870 - station with old design)
- Sarapul (1871 - station with old design)

Unfortunately, at this time only the following stations are operational: Maidanak-2, Komsomolsk-na-Amure, Mendeleevo (old station) and Katziveli (operational only in summer). The Evpatoria station (1867) belongs to Ukraine, and the Balkchash station to Khazakstan. The MCC was able to make an agreement concerning the operation of the former USSR SLR stations in Uzbekistan (station Maidanak).

Thus, MCC controls 4 operational SLR stations now: Maidanak-2, Komsomolsk, Katziveli and Mendeleevo (1870, old design). MCC Operation Center also takes part in testing new SLR stations. The 1999 SLR tracking results for the Russian network for low satellites, high satellites and GLONASS is shown in Table 5.1-1.

RISDE, the developer of SLR stations, plans to create a new SLR station in the Altai region and to resume operation of Maidanak-1 station.

1999 Site Name	Sta	ER1	ER2	BEC	STR	STL	WES	GFO	TPX	AJI	Total
Komsomolsk	1868	69	62	5	43	46	13	0	113	113	459
Maidanak	1864	27	72	0	0	0	55	0	76	0	230
Mendeleevo	1870	91	85	0	35	44	46	36	55	41	433
Katzively	1893	0	0	1	0	0	0	0	5	0	6

Site Name	Sta	LA1	LA2	ET1	ET2	G35	G36	Total
Komsomolsk	1868	68	57	35	18	0	5	183
Maidanak	1864	129	96	30	30	24	18	327
Katzively	1893	17	15	0	0	0	0	32

Site Name	Sta	G62	G66	G68	G69	G70	G71	G72	G75	G79	G80	Total
Komsomolsk	1868	0	9	0	0	0	14	14	0	4	11	52
Maidanak	1864	1	6	8	14	20	11	33	1	35	6	135
Katzively	1893	0	4	0	0	0	0	3	1	8	1	17

Table 5.1-1 Number of Passes Tracked by the Russian Network in 1999

Facility/Current Status

There are two branches of the software used for routine service by the laser group of the MCC. The first is STARK, initially prepared as general software for usual missions with high accuracy. The other software, POLAR, is much more complicated and used now at the MCC for determination of highly accurate orbits, earth orientation parameters, sets of station coordinates, biases, station performance, etc. (see Section 7.1.2.3).

The first version of STARK was developed in 1993 to run under the DOS system for PC. It can adjust a maximum of 8 parameters (solar pressure and atmosphere drag in addition to state vector). STARK contains special dedicated database for state vectors, measurements, models, station coordinates, EOP, etc. The STARK software package has been designed to support satellite mission operations, orbit determination, “NP-QL” generation, orbit and complex tracking data analysis.

There are comprehensive graphics with many features in the software to compare orbits, to monitor measurement residuals. It is possible to calculate some general ballistic information such as visibility, shadow, etc. STARK has been tested for many actual missions, from reentering objects to satellites above geostationary. It is used to compute preliminary orbits and to build normal points for almost all missions supported by ILRS. Until 1998 STARK and POLAR were under permanent improvement of models and algorithms.

The STARK and POLAR SW packages run on Standard IBM compatible Pentium computers.

Key Points of Contact

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5.2 NASA GODDARD SPACE FLIGHT CENTER

David Carter, *National Aeronautics and Space Administration*

Scott Wetzel, *Honeywell Technology Solutions, Inc.*

INTRODUCTION

The NASA SLR Operational Center is responsible for:

- NASA SLR network control, sustaining engineering, and logistics
- ILRS mission operations
- ILRS and NASA SLR data operations

NASA SLR network control and sustaining engineering tasks include technical support, daily system performance monitoring, system scheduling, operator training, station status reporting, system relocation, logistics and support of the ILRS Networks and Engineering Working Group. These activities ensure the NASA SLR systems are meeting ILRS and NASA mission support requirements.

ILRS mission operations tasks include mission planning, mission analysis, mission coordination, development of mission support plans, and support of the ILRS Missions Working Group. These activities ensure than new mission and campaign requirements are coordinated with the ILRS.

Global Normal Points (NP) data, NASA SLR FullRate (FR) data, and satellite predictions are managed as part of data operations. Part of this operation includes supporting the ILRS Data Formats and Procedures Working Group.

Global NP data operations consist of receipt, format and data integrity verification, archiving and merging. This activity culminates in the daily electronic transmission of NP files to the CDDIS. Currently of all these functions are automated. However, to ensure the timely and accurate flow of data, regular monitoring and maintenance of the operational software systems, computer systems and computer networking are performed. Tracking statistics between the stations and the data centers are compared periodically to eliminate lost data. Future activities in this area include sub-daily (i.e., hourly) NP data management, more stringent data integrity tests, and automatic station notification of format and data integrity issues.

FR is not an ILRS required data product, but FR data from the NASA SLR network is automatically received, processed, and transmitted to the CDDIS in daily files.

Daily satellite predictions are generated and distributed to the stations and the ILRS data centers (i.e., the CDDIS and EDC) for every ILRS and NASA supported satellite. Daily predictions have eliminated the need of time bias functions and are required to support very low earth altitude satellite missions like CHAMP, ICESAT, and VCL.

The NASA SLR Operations Center is located at:

> Honeywell Technology Solutions Inc. (HTSI)/NASA SLR and VLBI
> Goddard Corporate Park
> 7515 Mission Drive
> Lanham, Md 20706, USA

HTSI (see Figure 5.2-1), formerly AlliedSignal Technical Services Inc. (ATSC), formerly Bendix Field Engineering Corp (BFEC), has been the NASA SLR operation center contractor since November 1983, the start date of the consolidated NASA SLR mission contract. Prior to this consolidation, NASA had three distributed SLR operation centers located at BFEC in Greenbelt, MD; at University of Texas (UT) in Austin, TX; and at Smithsonian Astrophysical Observatory (SAO) in Boston, MA. BFEC was the operations center for the NASA developed SLR systems (i.e., MOBLAS 1-8, STALAS, and TLRS-2). UT was the operations center for the UT developed systems (i.e., TLRS-1 and McDonald Laser Ranging System) and SAO was the operations center for the SAO developed systems (i.e., SAO 1-4).

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Figure 5.2-1 HTSI Group Photo

5.3 University of Texas LLR Center

Peter Shelus, *University of Texas*

The University of Texas McDonald Observatory houses the ILRS LLR Operations Center. The small size of the LLR observing network and the relatively small number of LLR analysis centers dictate the unique nature and operational procedures of this LLR Operations Center. Predicts are performed on-site at each station and data are automatically transferred from all observing sites to the Data Centers. Analysts secure their data directly from the Data Centers as needed. Feedback from the analysts often goes directly back to the observing stations. The responsibility of the LLR Operations Center has evolved to be one that assures the smooth flow of data, in a form and format that is useful for obtaining scientific results. The center also coordinates the observations and their scheduling in a manner to maximum the scientific gains. Consider the following.

During the early years of the LLR experiment, the main emphasis had always been upon securing the maximum amount of data possible. Getting signal photon returns back from the Moon was, and still is, a dauntingly technical challenge. However, in recent years, as the LLR data volume has risen to a reasonable level, the overall experiment has begun an effort to improve the quality of the data, i.e., to improve both the precision and the accuracy of the data products. This entails improving system calibration stability, reducing photon detection jitter, and improving the timing systems. It also entails the investigation into ways of obtaining more and better observations, nearer to the new moon and full moon phases. This is an important effort that should increase the scientific payback of the LLR experiment. In its way, the Operations Center tries to coordinate this activity, serving as the intermediary between the observing stations and the analysis centers.

For instance, the recognized LLR data deficits near the new and full moon phases are well documented. These deficits have the effect of reducing significantly the sensitivity of the Principal of Equivalence violation signal, i.e., c x cos (D), where c is a constant and D is the mean elongation of the Moon from the Sun. Roughly speaking, if one visualizes the $0° < D < 180°$ interval of synodic lunar phase between new and full moon, only the interval $40° < D < 160°$ is presently effectively being fitted. In this interval, the function, cos (D), is virtually linear, with its strongest signal strength being unused. This clearly calls for an concerted attempt to obtain much more data nearer to both the new moon and full moon phases, so long as the accuracy of the data is not affected too much.

Along those same lines, the present LLR data density also lacks symmetry around the first and third quarter lunar phases. More data is present on the full moon side of the monthly lunar cycle. This creates an overlap, or a projection, of the cos (D) signal onto two other of the partial derivative signals in the basic LLR model, i.e., -l and cos (2D), l being the mean anomaly of the Moon. If one solves for a hypothesized post-model signal, such as the Principle of Equivalence violation signal, any part of that signal that can be represented by partial derivatives, already in the model, get assimilated by any adjustments of that model. This is presently happening to a significant effect. It results in further reducing the sensitivity of a cos (D) fit to the data, which is a natural consequence of the asymmetry of data quantity about the quarter moon phases. Thus, LLR stations should attempt to favor observations that are on the new moon side of the lunar quarter phases. This should tend to de-couple the scientifically interesting cos (D) signal from the 1 and the cos (2D) signals.

There are other significantly negative effects of the data gaps at the new moon and the full moon phases, as well as the asymmetry about the quarter moon phases. These attributes couple the cos (D) signal to the cos (3D), cos (4D), etc. signals, and thereby bias the solutions for any cos (D) amplitude, in proportion to any of these higher Fourier signals from any synodically periodic systematic effect in LLR. Both theoretical and operational features of LLR are dominated by the synodic month cycle. So the present ability to separate an Principle of Equivalence violation signal from other synodic effects is degraded by the properties of the present data distribution.

It should also be noted that there is a deficit of LLR data with sidereal periodicity, i.e., there being fewer observations when the moon is in the southern hemisphere of the celestial sphere. This is because the window for quality observations is smaller, since both LLR-capable stations are located in the Northern Hemisphere. It is especially severe for the OCA station. This can potentially affect analytical fits for a cos (D) signal, if there are systematic effects in the residuals with annual period, where there presently seem to be. The full ramifications of this sidereal data density modulation are not yet fully understood, but it would suggest that, whenever possible, observations when the moon is in the Southern Hemisphere are favored, as long as observation quality is maintained.

Finally, at a low level, within the UT LLR Operations Center, there has been ongoing a small project to apply Bayesian statistics to better identify LLR data during times of low signal to noise ratio. Several studies have already been performed and a paper was presented at the International Workshop for Laser Ranging, that had been held in Deggendorf, Germany during September, 1998. That paper appears in the formal proceedings of the Workshop.

Progress has been accomplished in the LLR experiment within the UT LLR Operations Center. We are looking forward to another year of successful activity.

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