Space Geodesy Satellite Laser Ranging External Interface Control Document (ICD)

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SGSLR Software Development Plan

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Approved by:

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Preface

This document is under the configuration management of the Space Geodesy Project (SGP) Configuration Control Board (CCB). Configuration Change Requests (CCRs) to this document shall be submitted to the SGP CCB, along with supportive material justifying the proposed change.

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Change Information Page

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Contents

1 Introduction

The Space Geodesy Project (SGP) encompasses the development, operation, and maintenance of a Global Network of Space Geodetic technique instruments, a data transport and collection system, analysis and the public disseminations of data products required to maintain a stable terrestrial reference system. This includes the management, operations and development of NASA's Space Geodetic Network that is comprised of the four major space geodetic observing systems: Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR), Global Navigation Satellite System (GNSS), and the Doppler Orbitography and Radio-positioning by Integrated Satellite (DORIS) system.

The SGSLR network is being built to replace the aging existing NASA SLR network with newer and more sustainable, automated technology and that will satisfy the performance requirements needed for today's ITRF. The system is intended to provide continuous 24 hour tracking coverage of artificial satellites up to GNSS altitudes with nighttime ranging capability up to geosynchronous. NGSLR demonstrated much of its new technology and performance capability. Some developmental work remains to be completed in the next systems, so that a new network of future automated SLR systems will be integrated into a realizable system that meets the required performance criteria (*McGarry, et al. 2014), (Merkowitz, et al. 2014).*

1.1 Purpose

The purpose of the SGSLR External Interface Control Document (ICD) is to specify the interfaces between SGSLR and the external instruments and facilities that it interacts with.

These external instruments and facilities include the other SGP systems (VLBI, GNSS, site survey), the Crustal Dynamics Data Information System (CDDIS), the International Laser Ranging Service (ILRS), Mission Facilities for restricted satellite tracking, and the Integrated Geodetic Site Operations Center (IGSOC) which is the central entity for communication with all of the SGP systems.

1.2 Scope

The SGSLR External ICD lists and details all of the external interfaces to SGSLR. For internal SGSLR subsystem interfaces refer to the SGSLR Internal ICD (SGP-SLR-ICD-0002).

1.3 Overview of External Interfaces

SGSLR interfaces with the ILRS supported satellites using predictions received from the Data Centers or directly from the mission while ensuring that all tracking restrictions are satisfied for each satellite. In addition SGSLR's interface at the satellite consists of either a retro-reflector array (normal) or a laser transponder (currently time transfer or experimental ranging).

To ensure that SGSLR is safe, the Project interfaces with Goddard code 360 and the FAA. While this is not a system level interface, it is an important one. Details can be found in the SGSLR Laser Safety Handbook (SGP-SLR-HDBK-0001).

SGSLR interfaces with the International Laser Ranging Service in its procedures, data formats, satellite support, and satellite restrictions, as NASA is part of the ILRS. The ILRS website (http://ilrs.gsfc.nasa.gov) gives requirements on station performance and procedures, and on data formats and algorithms.

SGSLR gets schedules for tracking from the Space Geodesy Project which are generated from the ILRS priority list and the Project's requirements. Status and housekeeping information, as well as any alert messages, are sent at regular intervals to the IGSOC which provides monitoring of system status and performance. Alert message are also be texted to key personnel. The science data (satellite ranging normal point data and, if desired, full rate data) is sent to the Data Operations Center (part of the IGSOC) every 2 hours.

To coexist with VLBI's new broadband data collection, the aircraft avoidance radar cannot point directly to the VLBI signal detector. Currently, masking at both the VLBI antenna and the SLR gimbal prevent the systems from pointing at each other. Real-time communication of pointing angles is used to keep the systems from looking directly at each other.

The GNSS receivers do not interface with SGSLR, however, it is expected that some of the receivers will host corner cubes that SGSLR can range to, thus allowing for a direct measurement of the distance between the two. This may also be done with VLBI, but with the SGSLR aircraft avoidance radar turned off.

The Survey System is responsible for determining the system origin of the various SGP techniques to ~ 1 mm accuracy. To do this requires the SGSLR system have a stable reference point on the gimbal that the Survey System can use to do the measurement. This reference point must be accessible from many angles and its location relative to the system origin must be known and stable to the accuracy needed for the survey. In addition the Robotic Total Station (RTS) may have a cube mounted on its pier to support ground ranging from SGSLR.

1.4 Reference Documents

1.5 Reference Documents

The following documents are references to this CONOPS Document. In general, revision numbers and issue dates are not shown. The most recent version of these documents is applicable.

a. SGP-PG-0001, Space Geodesy Information and Configuration Management Plan

b. SGP Systems Engineering Management Plan (SEMP)

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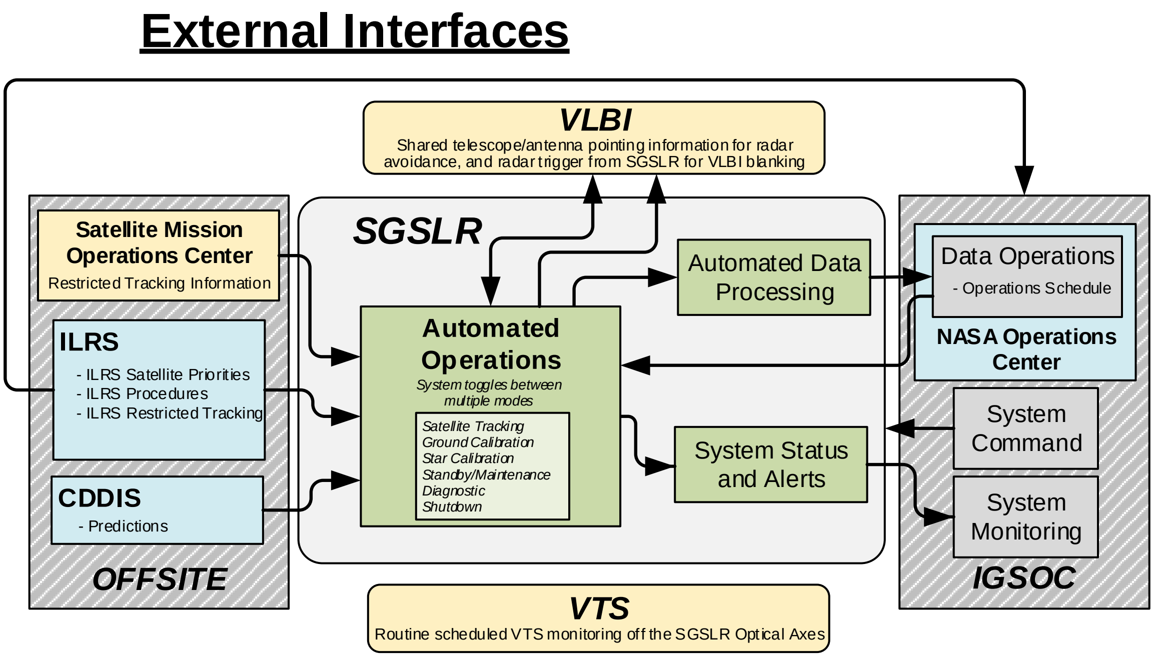

Figure 1 External Interfaces

2 IGSOC

The Integrated Geodetic Science Operations Center (IGSOC) is the Project's virtual central monitoring and command facility. This virtual facility consists of the Data Operations Center, a System Monitoring capability (virtual facility), and a location that can be virtually anywhere there is a laptop connected to the internet, to monitor and command the SGP systems around the world.

2.1 NASA Data Operations Center (DOC)

The DOC receives the Science Data products through a secure protocol interface, performs some quality checks and data analysis, concatenates them, and puts them on CDDIS. Data coming to the DOC must be in the ILRS specified Consolidated Ranging Data (CRD) format. See http://ilrs.gsfc.nasa.gov/data_and_products/formats/crd.html

2.2 Schedule and Predictions

SGSLR schedules are generated by the IGSOC on a daily or subdaily basis, and picked up by each SGSLR station when it is able to do so. Schedules should not be pushed on a regular basis to the stations but should rather be pulled by each SGSLR system at times when they are ready to take it. Should the IGSOC wish to push a schedule, they will need to do so by command which will override the normal activity on the station.

2.3 System Commanding & Monitoring

The System Commanding and Monitoring Facility (SCMF) receives status, housekeeping and performance information from the stations. This information can be monitored in real-time from anywhere in the world. The system allows trending of data so that performance monitoring can be easily done. In addition this facility will send out alerts via email and text if data that it is automatically monitoring crosses a specified threshold.

The SCMF can also command the stations, in a similar fashion to commanding for a spacecraft. The commands will be sent to one or more stations. Each station will look at the command, determining if the command is valid and the situation is safe to execute it, and then respond back to the SCMF with the action it is taking. If the command is executed, the station will send the SCMF back the result of the command execution and the system status.

The format of the data given to the SCMF is specific to each Technique. Our formats will be given are given in Appendix A.

3 ILRS, CDDIS and Mission Interface

NASA SLR is leader and major contributor of the International Laser Ranging Service (ILRS). This service coordinates the activities of Global SLR stations to support geodetic and geophysical research activities as well as IERS products important to the maintenance of an accurate International Terrestrial Reference Frame (ITRF).

3.1 The ILRS prescribes data format, system operating procedures, tracking priorities, and specified restricted tracking procedures, as well as, specifies prediction data format for mission generated predictions. The ILRS also provides performance guidelines and standards for all ILRS stations. CDDIS archives ILRS data, hosts the ILRS website, and provides access to SLR stations for satellite predictions.CDDIS

The Crustal Dyanmics Data Information System (CDDIS) archives SLR, VLBI, GNSS and DORIS data. In addition CDDIS hosts SLR predictions from multiple prediction providers. This information is available to anyone via anonymous ftp download and is used as the server for SGSLR routine prediction retrieval.

The SLR Network schedules are hosted on CDDIS as a backup for the individual stations to pick up on a daily (or sub-daily) basis.

In addition, for NASA missions, CDDIS may also host the restricted tracking Go/NoGo flag (give ILRS website). This was the case for the Lunar Reconnaissance Orbiter mission.

The European Data Center (EDC) can also be used as a backup for predictions and it is anticipated that CRD science data will be sent in parallel to both EDC and the NASA's DOC.

3.2 Mission Interface

If the Satellite Mission requires restricted tracking, the Mission may directly interface with each station. For some missions where only certain stations are allowed to track, the predictions will be hosted on a Mission computer. The Go/NoGo flag may also be hosted on a Mission computer. Lastly, for a segmented pass where there are restricted times when SLR stations cannot lase, the pass segment file will be available on the Mission computer.

4 VLBI

Very Long Baseline Interferometry (VLBI) is one of the geodetic techniques that are part of the Space Geodesy Project.

4.1 SLR Radar Interference

The new VGOS design utilizes signal over a broadband frequency. This differs from the original VLBI systems which use a narrow frequency band. Because of this the new NASA VLBI station's signal frequency now includes the 9.4 GHz frequency that has been in use by the SLR systems for their aircraft avoidance radar since 1995. To mitigate the interference at sites where VLBI and SLR coexist (and where SLR utilizes the radar), and to avoid damage to the signal detector on VLBI, the systems must avoid pointing directly at each other. This will be accomplished using a two-phased approach. A point-to-point communication will exist between each VLBI and SLR station at a site. The systems will continuously communicate their pointing location to each other in real-time. A sky pointing mask is utilized at both the VLBI antenna and the SGSLR gimbal around the area that needs to be avoided. If one of the systems is in the mask area or is going into the mask area, the other system cannot enter. The VLBI system will have priority over the SLR system if they both wish to enter the mask area at the same time. Alerts will be sent to the IGSOC if one system stays in the mask area for too long. If communication is lost between the systems, both systems will revert to avoiding the mask region.

In addition to the communication between systems, the SGSLR system will send a signal to the VLBI system every time the radar triggers. The VLBI system will use this information to blank its detector.

4.2 Inter-system distance

To support the Site Survey, the inter-system distance from VLBI to SGSLR may be measured directly by placing a corner cube reflector on the VLBI antenna, thus allowing SGSLR to range to the antenna. To do this would require the mask to be removed and the aircraft avoidance radar to be turned off at those systems where the radar is in use

4.3 Timing connections

When the VLBI system is close enough to the SGSLR system, the maser 10 MHz and 1pps signals will be sent to the SGSLR system to allow the two systems to remain time synchronized.

5 GNSS

The Global Navigational Satellite System (GNSS) receivers are a passive measurement system that receives signal from multiple different Navigational satellites to accurately determine location. Navigational satellites supported include the US GPS, the Russian GLONASS, and the European GALILEO.

5.1 Inter-system distance

To support the Site Survey, the inter-system distance from various GNSS receivers to SGSLR will be measured directly (where physically possible) by placing a corner cube reflector on the GNSS receiver mount, thus allowing SGSLR to range to the GNSS mount. For this measurement to be made the GNSS receiver's elevation angle from SGSLR must be above -5 degrees and the SGSLR system must have line of sight viewing of the GNSS cube.

6 Site Survey

The SGSLR system origin must be surveyed and referenced to the local survey system at each location. The system origin is nominally the point where the theoretical azimuth and elevation axes intersect. Since this point is not usually accessible once the system is operational, the site survey must be performed to a reference point on the gimbal that is outside the telescope.

6.1 SGSLR Reference Point

Survey measurements will be taken periodically by the Vector Tie System (VTS) using a Robotic Total Station (RTS). The RTS schedule will be developed by the Survey group and will be an input into the generation of the SGSLR Network schedule. At scheduled time the RTS will automatically survey the SGSLR mount at different azimuth and elevation positions. In order to support these measurements, the SGSLR system will have to know from the RTS schedule what pointing angles are required at given times. SGSLR will open the dome shutter, move the telescope to the right position at the right time, and move the dome into position. Because of the size of the dome shutter opening and the large angular movements required, SGSLR will need to offset point the dome to ensure line of sight from the RTS to the desired cube.

6.2 Inter-system distance

To support the Site Survey, the inter-system distance from the RTS to SGSLR will be measured directly by placing a corner cube reflector on the RTS monument, thus allowing SGSLR to range to the RTS. For this measurement to be made the RTS's elevation angle from SGSLR must be above -5 degrees.

7 References

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http://space-geodesy.gsfc.nasa.gov/

8 Appendix A

Data formats. (To be filled in.)

Abbreviations and Acronyms

Acronym	**Definition**
CDDIS	Crustal Dynamics Data Information System
CI	Configured Item
CM	Configuration Management
CONOPS	Concept of Operations
CONUS	Continental United States
CRF	Celestial Reference Frame
DAM	Device Access Manager
DOC	Data Operations Center
DITL	Day-in-the-life
FAA	Federal Aviation Administration
GPS	Global Positioning System
GUI	Graphical User Interface
ICC	Interface Control Computer
ICD	Interface Control Document
IGSOC	Integrated Geodetic Site Operations Center
ILRS	International Laser Ranging Service
IT	Information Technology
LOR	Laser Operations Report
M&C	Monitor and Control
MET	Meteorological
MLRS	McDonalds Laser Ranging Station
MTBF	Mean Time Between Failures
MTTR	Mean Time to Repair
NGSLR	Next Generation Satellite Laser Ranging
NMA	Norwegian Mapping Agency
NPT	Normal Point
POP	Pseudo Operator Computer
R/T	Real-Time
RAT	Remote Access Terminal
RCE	Range Control Electronics
RTS	Robotic Total Station
SGP	Space Geodesy Project
SGSLR	Space Geodesy Satellite Laser Ranging
SCMF	System Command and Monitoring Facility
SLR	Satellite Laser Ranging
TBAD	Transponder Based Aircraft Detection
TBH	Temperature, Barometric Pressure and Humidity
VLBI	Very Long Baseline Interferometry
VTS	Vector Tie System