SGP / SPACE GEODESY PROJECT

Space Geodesy Satellite Laser Ranging Operations Concept Document

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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.

Direct all comments, questions, or suggestions regarding this document to:

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Change Information Page

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1 Introduction

1.1 Purpose

The Concept of Operations (CONOPS), for the Space Geodesy Project (SGP) Space Geodesy Satellite Laser Ranging (SGSLR) System describes the operations, maintenance, configuration management, security, and other support functions (e.g., logistics and training) required in an operational environment. It describes how SGSLR will be operated and maintained to meet mission and system objectives. It also provides system characteristics from an operational perspective and helps facilitate an understanding of the system goals. It stimulates the development of the requirements and architecture related to the user elements of the system. It serves as the basis for subsequent definition documents and provides the foundation for the long-range operations and maintenance planning activities.

1.2 Scope

The scope of this document is to describe the design, development, and implementation of a new NASA SGSLR satellite laser ranging Network. This document covers the first three systems: two in the United States (Texas and Hawaii) and the third in Norway (Ny Alesund). The SGSLR design is largely a heritage-based design building upon the Next Generation SLR (NGSLR) Prototype implementation. In terms of SLR functionality, SGSLR and NGSLR are the same. Certain changes to the Prototype design are needed because of: lessons learned during NGSLR development and testing ease of maintenance or less costly maintenance, parts obsolescence at NGSLR, and new requirements for SGSLR. SGSLR is TRL 6 based upon the prototype demonstration, and because the changes do not affect the basic design of the SLR system. There are no new technology developments for the basic SLR system. Only new technology area is in automation: closed loop tracking.

1.3 Document Organization

The document is divided into four major sections, each containing multiple chapters and paragraphs defining the concepts for SGSLR. The sections are described as follows:

a. Section 1, Introduction. This section covers the Purpose, Scope, Reference Documents, and Assumptions.
b. Section 2, Facility Description and Layout. This section will cover the Location and Operational/Support Environment of SGSLR.
c. Section 3, SGSLR Overview. This section provides the System objectives and an overview of the SGSLR architecture, including descriptions of the system, its major subsystems, and the external interfaces.
d. Section 4, System/Site Operations. This section contains the Station Operations, Staffing, Training, Security, Maintenance and Logistics descriptions for SGSLR.

1.4 Concept Assumptions

The scope of this operations concept document is currently defined by baseline requirements referenced in the SGP-SLR-REQ-0001, SGSLR System Requirements Document. Updates to the baseline requirements will be addressed in subsequent revisions of this document or a separate document.

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

c. NPR 8715.3, NASA General Safety Program Requirements

d. GPR 1860.2, *Goddard Procedural Requirement: Laser Radiation Protection*.

e. GPR 1863.3, *Goddard Procedural Requirement: Radio Frequency Radiation Protection*

f. IEEE C95.1, *IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.*

g. IEEE C95.7, *Recommended Practice for Radio Frequency Safety Programs 3 kHz to 300 GHz*.

h. AC No: 70-1, Federal Aviation Administration Advisory Circular on Outdoor Laser Operations.

i. ANSI Z136.1-2007, *American National Standard for Safe Use of Lasers*.

j. ANSI Z136.6-2005, *American National Standard for Safe Use of Lasers Outdoors*.

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2 Facility Description and Layout

2.1 General

The SGSLR system is the design, development, and implementation of new satellite laser ranging station for NASA's SGP Network. The first three sites will be located at (1) McDonald Observatory in Texas, (2) Haleakala in Hawaii, and (3) Ny Alesund in Norway. Texas will be the first system, with either Hawaii or Ny Alesund as the second.

2.2 Location and Operational/Support Environment

The following figures show a generalized SGP Site Plan configuration.

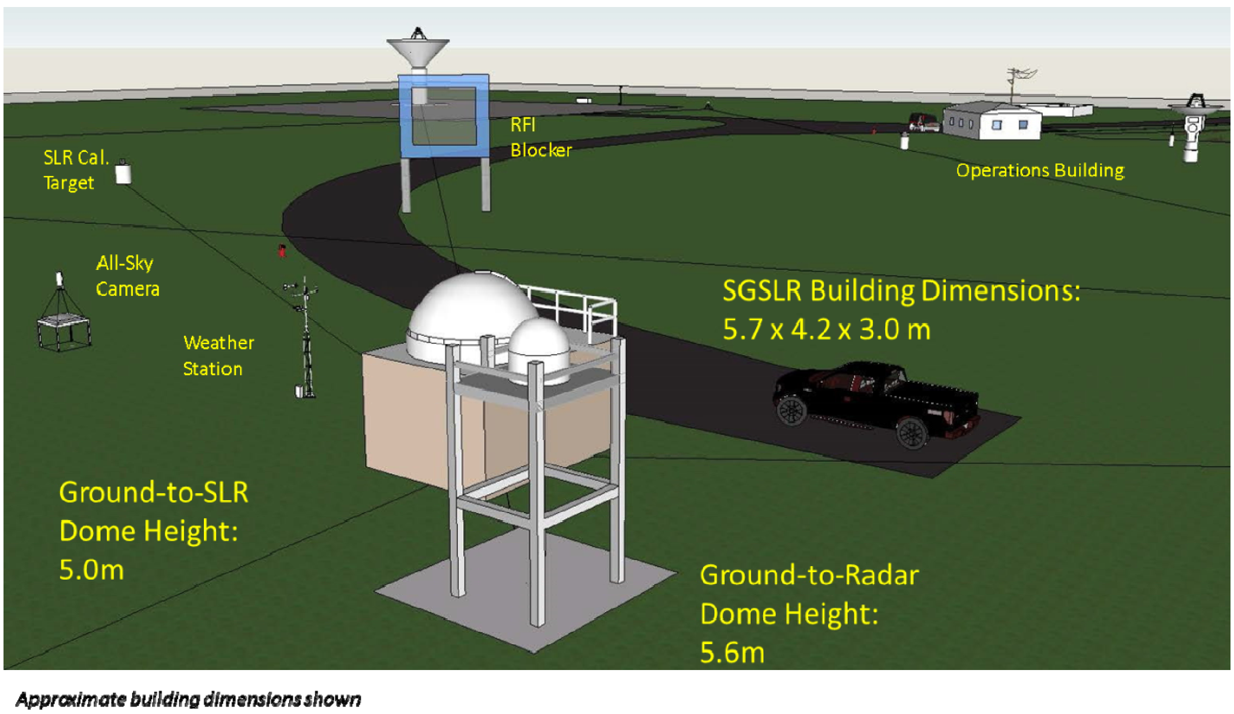


Figure 2-1. SGSLR Site Plan

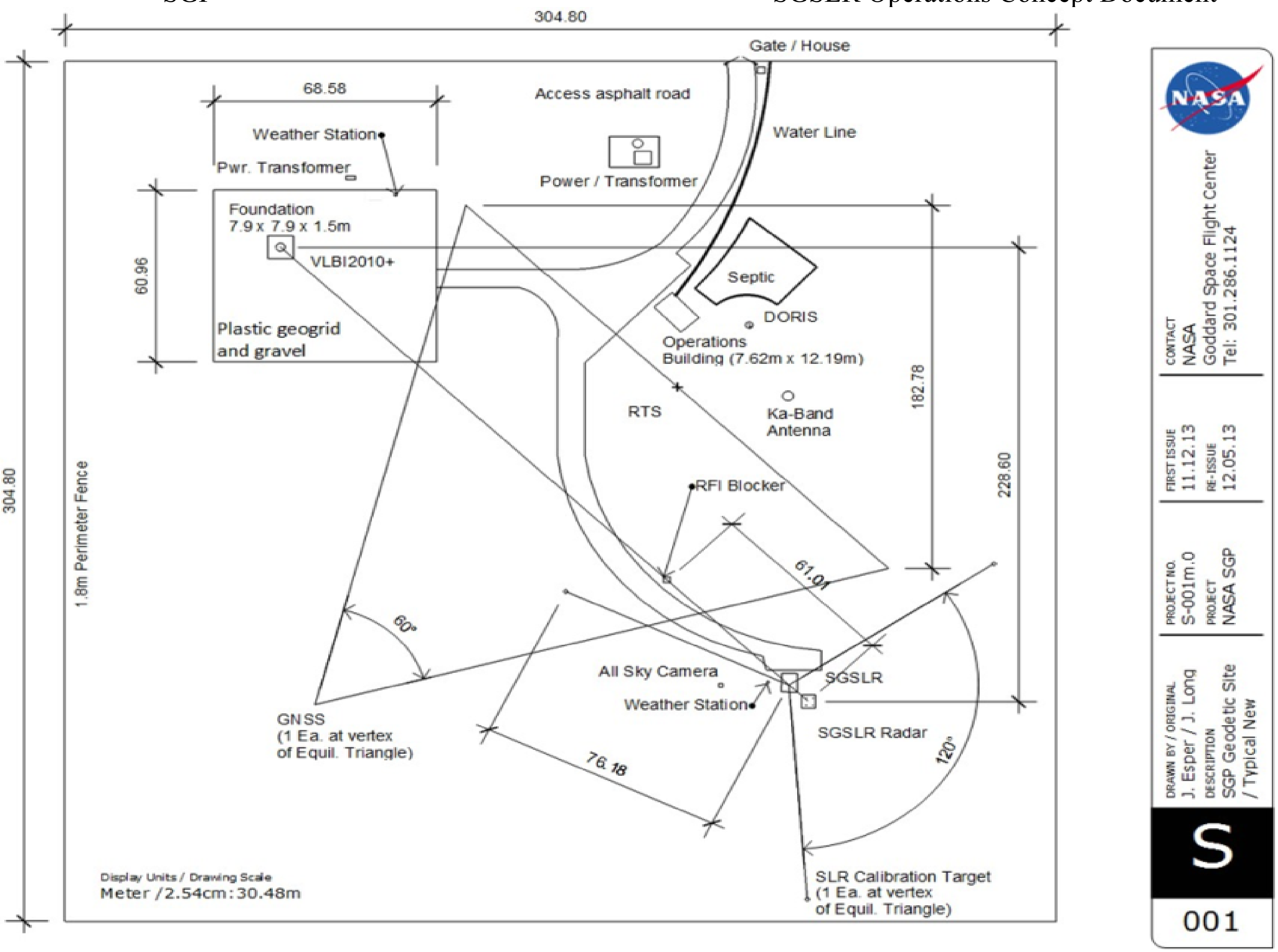
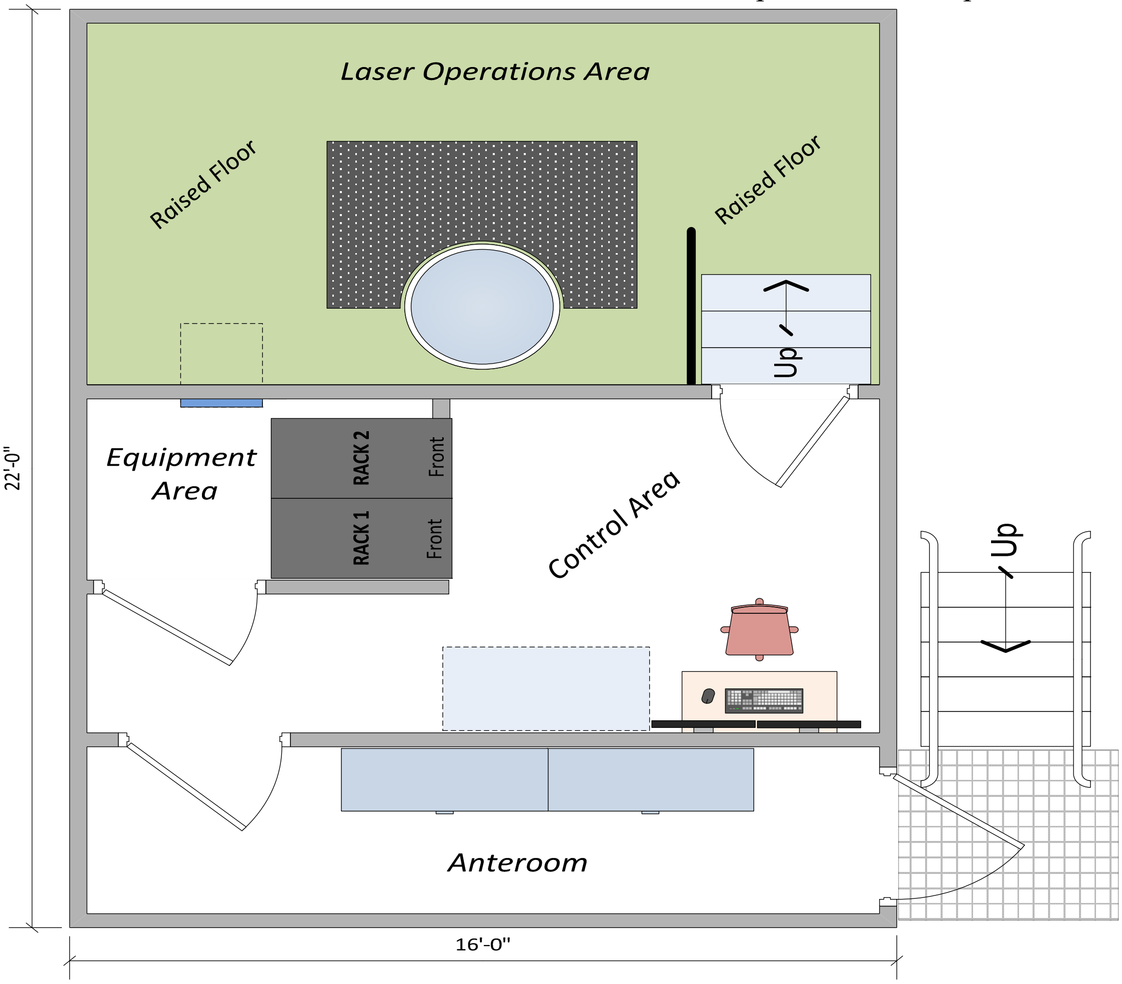


Figure 2-2. SGSLR Site Plan Drawing



- Compartmentalized to maintain clean environment and stable thermal conditions. Laser Operation Area environment is under positive pressure, with air HEPA filtered and temperature controlled to ±1 °C, humidity ~50%
- Chiller sends heated air directly into the return under the raised floor. Chiller on casters to allow the unit to be wheeled out of the room for drainage
- Warm air return under raised floor
- Compartmentalized for temperature stability with return air sent under the raised floor. Equipment area is temperature controlled to ±1 °C, humidity ~50%
- Control area is temperature controlled to
- ± 2 °C, humidity ~50%
- Workbench folds against wall when not in use
- Shelving units for documentation and spare parts
- Anteroom serves as a temperature, humidity, pressure, and particulate buffer between the inside and ambient
- Overhead platform for stairs serving as weather shield above entrance door to anteroom.

Figure 2-3. Planned SGSLR Shelter.

All of the first three sites differ from the generalized layout. At Texas the SGSLR station location will be almost a kilometer away from the VLBI station. The aircraft avoidance radar at Texas will be blocked by the landscape from damaging the VLBI detector. There will also be difficulty in running data signal and communication cables between the SGSLR and VLBI systems. Because of this the maser timing signal may not be available at the Texas SGSLR system. The operations building is likely to be near the VLBI system, a distance away from SGSLR. Initial operation at SGSLR will need to be in the SGSLR building, which implies the need for operations space there, as well as a requirement for bathroom facilities nearby. Figure 2-4 shows the Mc Donald station layout. In the figure, the SGSLR station will be located where the Mc Donald Laser Ranging Station (MLRS) is currently installed. The MLRS is a dual purpose installation designed to obtain observations from both artificial satellite and lunar targets. The V1 area is where the VGOS site will be located.

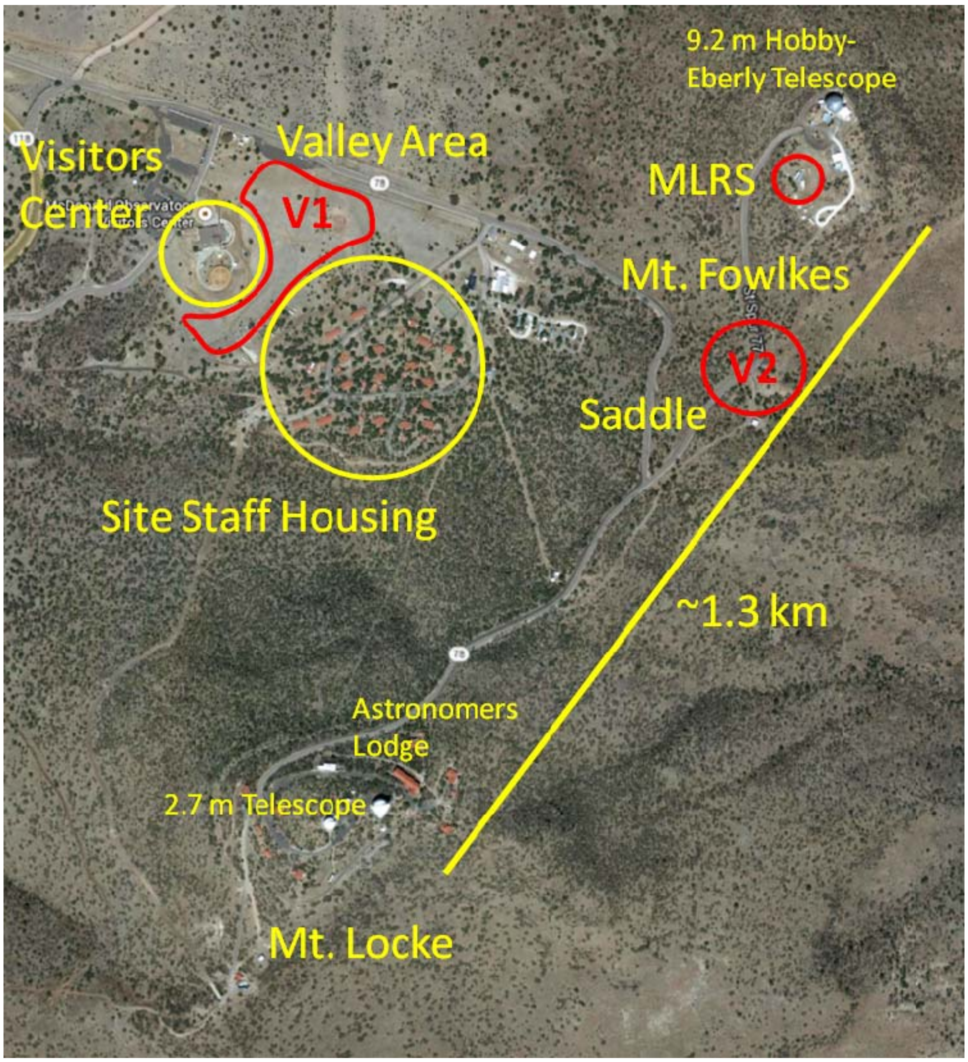


Figure 2-4. McDonald Site layout

At Hawaii the SGSLR system will be located on Maui while the VLBI system will be on the island of Kauai. There will be no interference between the VLBI and SGSLR systems, but no direct communication either. Haleakala does not want the radar's RFI on the mountain top. The current plan is to use the TBAD system for the Hawaiian SGSLR system. A final location for the Haleakala SGSLR system has been chosen but not finalized yet. The shelter layout for Hawaiian is planned to be similar to the one for Texas. Figure 2-5 shows the Haleakala Hawaii site layout.

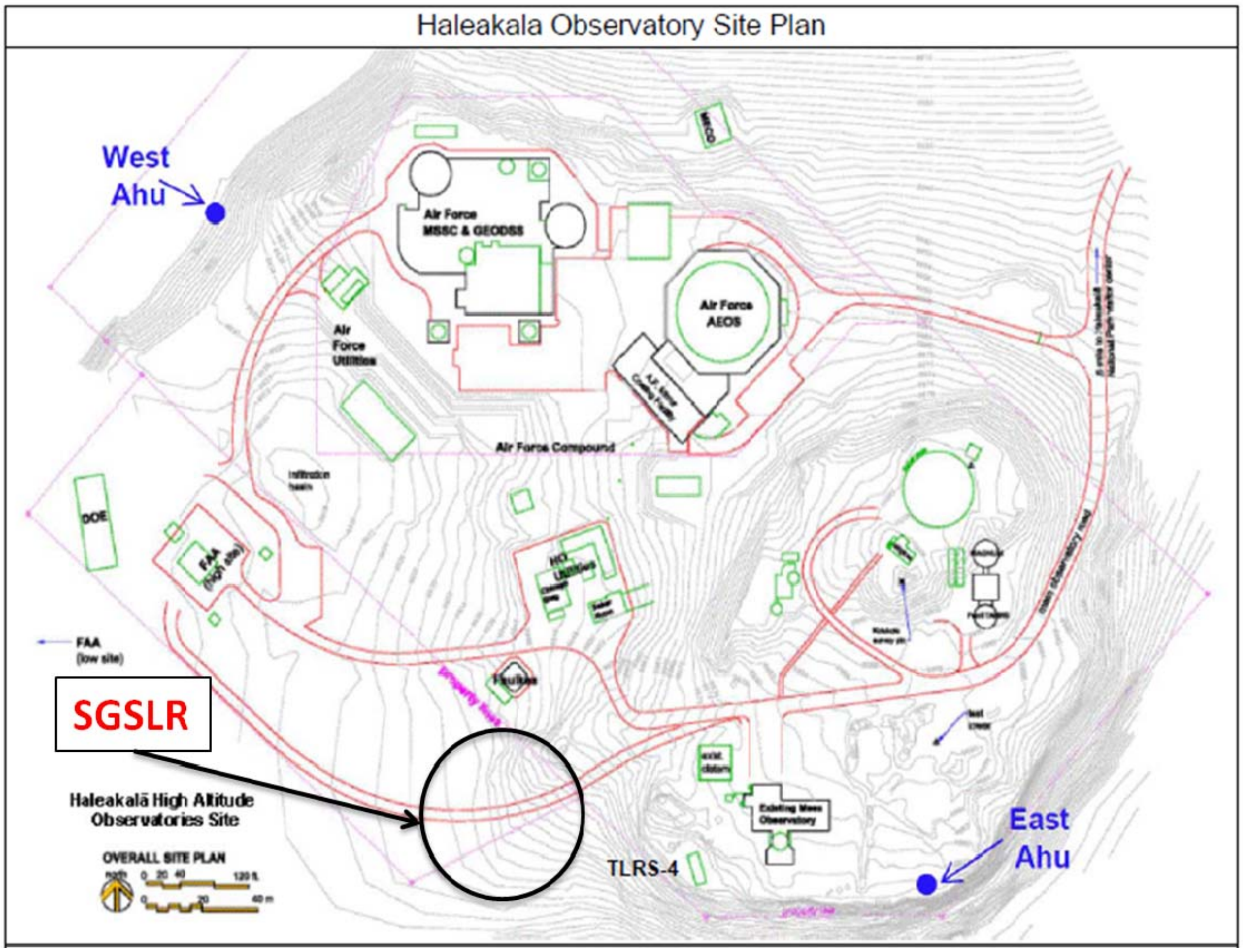


Figure 2-5. Haleakala Observatory Site layout

In Ny Alesund the site is owned and operated by the Norwegian Mapping Agency (NMA). The site will have two VGOS systems and an SGSLR system. NMA is purchasing the SGSLR system from NASA. NMA has built the SGSLR pad, pier and shelter. The shelter at Ny Alesund will not have the same layout as that at Texas or Hawaii. Ny Alesund does not allow RFI transmissions so the aircraft avoidance radar cannot be used there. Therefore there is no issue at this site with damage to VLBI from the SGSLR radar; however, there remains the issue of preventing aircraft from getting illuminated with the laser. The local aircraft control tower will have a laser disable button that can be used successfully for local aircraft, but international flights may also require protection. The team is looking into using the Transponder Based Aircraft Detection (TBAD) system for use at Ny Alesund. Direct communication between the VLBI systems and the SGSLR system will be possible. Figure 2-6 shows the NY Alesund station layout. This will be the first SLR system at the Ny Alesund facility.

Figure 2-6- Ny Alesund Site layout

3 SGSLR Overview

3.1 Architecture

There are ten subsystems that comprise the SGSLR. Each subsystem provides capabilities that are designed to meet the SGSLR requirements when integrated together. The subsystems are:

- Telescope
- Tracking
- Optical Bench
- Receiver
- Laser Subsystem
- Laser Safety
- Timing
- Weather
- Shelter and Dome
- Computers and Software

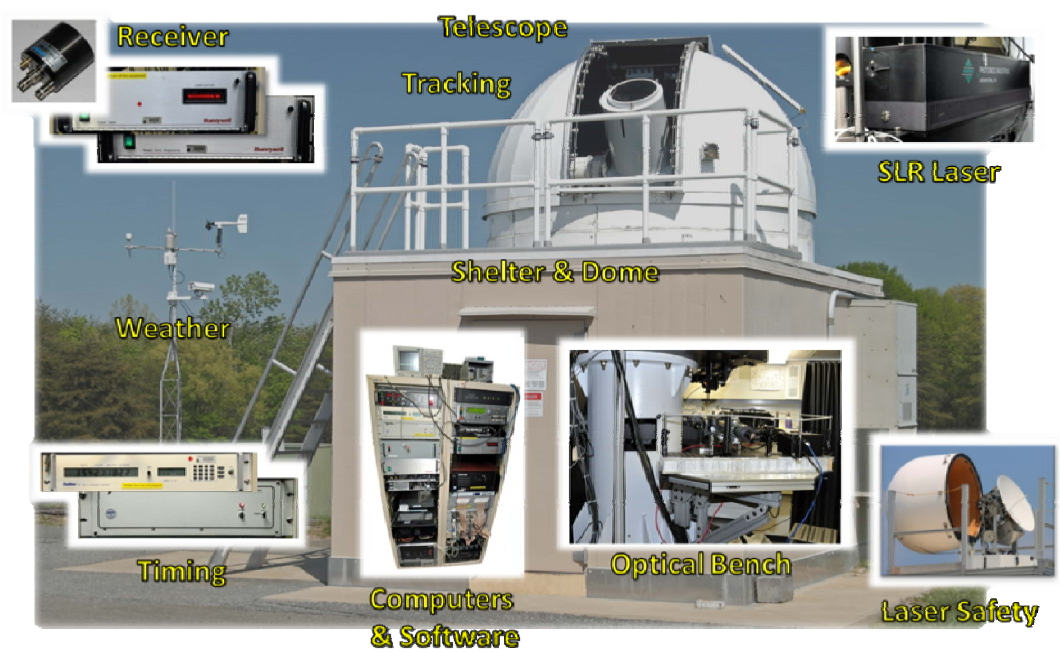


Figure 3-1. SGSLR Subsystems

A description of each of the SGSLR subsystems follows.

3.1.1 Telescope

The telescope is designed as a monostatic system to both transmit laser energy and to receive light from targeted objects through common optics and a common optical path. This subsystem includes the telescope and Coude path through the tracking subsystem, and all associated environmental monitoring and control devices such as temperature sensors, accelerometers, etc. This subsystem is contained within the dome and partially extends into the shelter.

3.1.2 Tracking Subsystem

The tracking subsystem drives the telescope to track Earth orbiting satellites, stars and fixed ground targets. The subsystem consists of the gimbal, encoders, servo electronics to calculate and output the servo drive control values and additional hardware/software to monitor/maintain environmental limits. The gimbal portion of the tracking subsystem is attached to a concrete pier which maintains vibrational isolation from other components of the shelter and domes to prevent disturbing the pointing and control of the gimbal and is covered in the Dome, Shelter and Pier subsystem. This subsystem has components in both the dome and the shelter.

3.1.3 Optical Bench

The optical bench subsystem is designed to allow the laser, receiver subsystem, and star camera to reside in an environmentally controlled environment, while supporting laser divergence changes for different satellites, point-ahead of the laser beam for satellites, beam blocking and beam attenuation for laser safety, system configuration changes for the various modes (star calibration, ground target ranging and satellite tracking), and reduction in the background light that the detector is exposed to (ND wheel, spatial and spectral filters). Laser light is directed along a path on the optical bench that is aligned to the telescope optical axis. The transmitted light goes from the laser to the pit mirror and eventually out through the telescope. Receive light captured by the telescope is directed to the receive path on the optical bench which is also aligned to the telescope optical axis. Finally, this subsystem includes diagnostic components to monitor the laser characteristics and to support alignment. The optical bench is contained within the shelter in a controlled thermal environment that is maintained to within +/- 2 degrees Celsius with an environment where dust and dirt are minimized as much as possible.

3.1.4 Range Receiver

The range receiver subsystem consists of the detector and associated electronics to detect and measure the start and stop event times, support the software's determination of the signal from the background noise and the range to the target, and provide angular offset information to allow for closed loop tracking. In addition, the range receiver subsystem includes the Range Control

Electronics (RCE) which provides the software with control of the laser fire frequency, provides the software range gate control for the detector during satellite tracking, and provides fixed ground target range gate control. Part of this subsystem sits on the optical bench; the rest is in the electronics rack. All are contained within the shelter. The electronics will be located in the electronics room which will be temperature controlled to +/- 5 degrees Celsius.

3.1.5 Laser Subsystem

The laser subsystem consists of the laser, associated control electronics, a chiller to maintain the lasers internal temperature and additional hardware/software to monitor/maintain environmental variables and control power output of the laser. The laser subsystem is contained within the shelter with the laser itself on the optical bench, the associated electronics in the electronics racks, and the chiller potentially on the floor in the optical bench area. The electronic racks will be located in a controlled thermal environment that is maintained to within +/- 5 degrees Celsius. The optical bench area will be thermally controlled to +/- 2 degrees Celsius with an environment where dust and dirt are minimized as much as possible. This is a class IV laser which isnot eye-safe. A kill switch will be located in the shelter, the dome and external to the shelter, for a human to use to stop the laser from firing.

3.1.6 Laser Safety Subsystem

The laser safety subsystem is designed to meet all NASA, ANSI, FAA, and local safety standards for outdoor laser use as well as to protect SGSLR and other ground personnel. It includes an instrument for aircraft detection which is co-aligned with the laser beam, support electronics, beam blocks and ND filters for eye-safety external to the system, and sensors to inhibit the laser should a subsystem fault occur or should someone access an area in the system where the laser light can cause damage, such as the roof of the shelter or the dome. The aircraft detection components reside on their own stand outside of the shelter, the beam blocks and ND filters are on the optical bench, and the support electronics and computer interface are in the electronics racks. Some of the sensors are outside of the shelter and some (such as the door to the optical bench room) are inside the shelter.

3.1.7 Time and Frequency

The Time and Frequency subsystem generates and regulates the various timing signals used by other subsystems as well as the time of day used by the software. It acquires a GPS time and ensures that the timing signal remains stable, outputs the acquired GPS 1pps and outputs 10 MHz signals that are synchronized to that 1pps. The system also includes a monitoring subsystem that uses a secondary GPS timing source to compare the GPS 1pps outputs and provide the data to the computer subsystem to assess the accuracy of the Timing and Frequency subsystem. SGSLR will have the capability to use the maser 10 MHz and its 1pps where these signals are available, for comparisons with the internal timing system, as a backup timing system, and for special missions such as planetary ranging. However, the primary source for the 1pps and 10 MHz will be the SGSLR timing system. Most of this system is contained within the shelter. The GPS antenna(s) are mounted outside of the shelter.

3.1.8 Meteorological

The Meteorological subsystem is designed to measure environmental conditions to provide information for precise ranging and health and safety of all subsystems. This subsystem consists of a variety of measurement devices all located roughly together outside the shelter and dome. The most important of these measurements for the ranging accuracy are the barometric pressure, temperature, and humidity. The system also includes stands and associated hardware/software for the system.

3.1.9 Dome and Shelter (and Pier)

This subsystem includes the components which enclose, protect and support the SLR operation. They are divided into three major components, the dome, the shelter and the pier with the riser. These are primarily the structure, but may also contain additional components as described below.

The dome is designed to contain and protect the telescope and the gimbal (part of the tracking subsystem) and associated hardware while allowing transmission and receiving of light while operating. This component includes the dome structure with an opening, the shutter over the opening, motors to open the shutter, motors to rotate the dome with the telescope, a structure to allow the rotation and any additional hardware needed to measure/maintain the environment within the dome. The dome must be large enough to allow a technician to work within while the shutter is fully closed. The gimbal and telescope will have full range of motion to perform testing with the dome completely closed.

The shelter is designed to contain and protect the optical bench, laser and all the electronics, as well as provide work space for support personal. In addition to the structure it includes HVAC, humidity control, lighting and all necessary additional hardware for monitoring the interior environment. The shelter provides the other subsystem with power, UPS, and surge protection, including protection from lightning. It also includes jacks for phone and telecommunications.

The pier provides physical support for the telescope and gimbal and vibrational isolation from the shelter. The riser is designed to mate the tracking subsystem to the pier and includes the mirror at the end of the telescope subsystem's Coude path (called the "pit" mirror) which delivers the light from the Coude path to the optical bench.

3.1.10 Computer and Software

The computer and software subsystem contain all the computers and the software that they run to control, calibrate and maintain the system as a whole, and to communicate with the control center. This subsystem links all other subsystems together, transfers and stores data, and communicates with the IGSOC. It is contained within the shelter.

3.1.11 Test Equipment

The SGSLR sites will include test equipment necessary to ensure that the stations are functional and ready for operations. This will include oscilloscopes, spectrum analyzers, signal generators, environmental monitors and emulators. Calibration of the test equipment will be conducted in accordance with NASA standards.

3.3 External Interfaces

External interfaces and data flow are shown in the figure below. Details of the external interfaces with the SGSLR system are defined in SGP-SLR-ICD-0001, SGSLR External Interface Control Document.

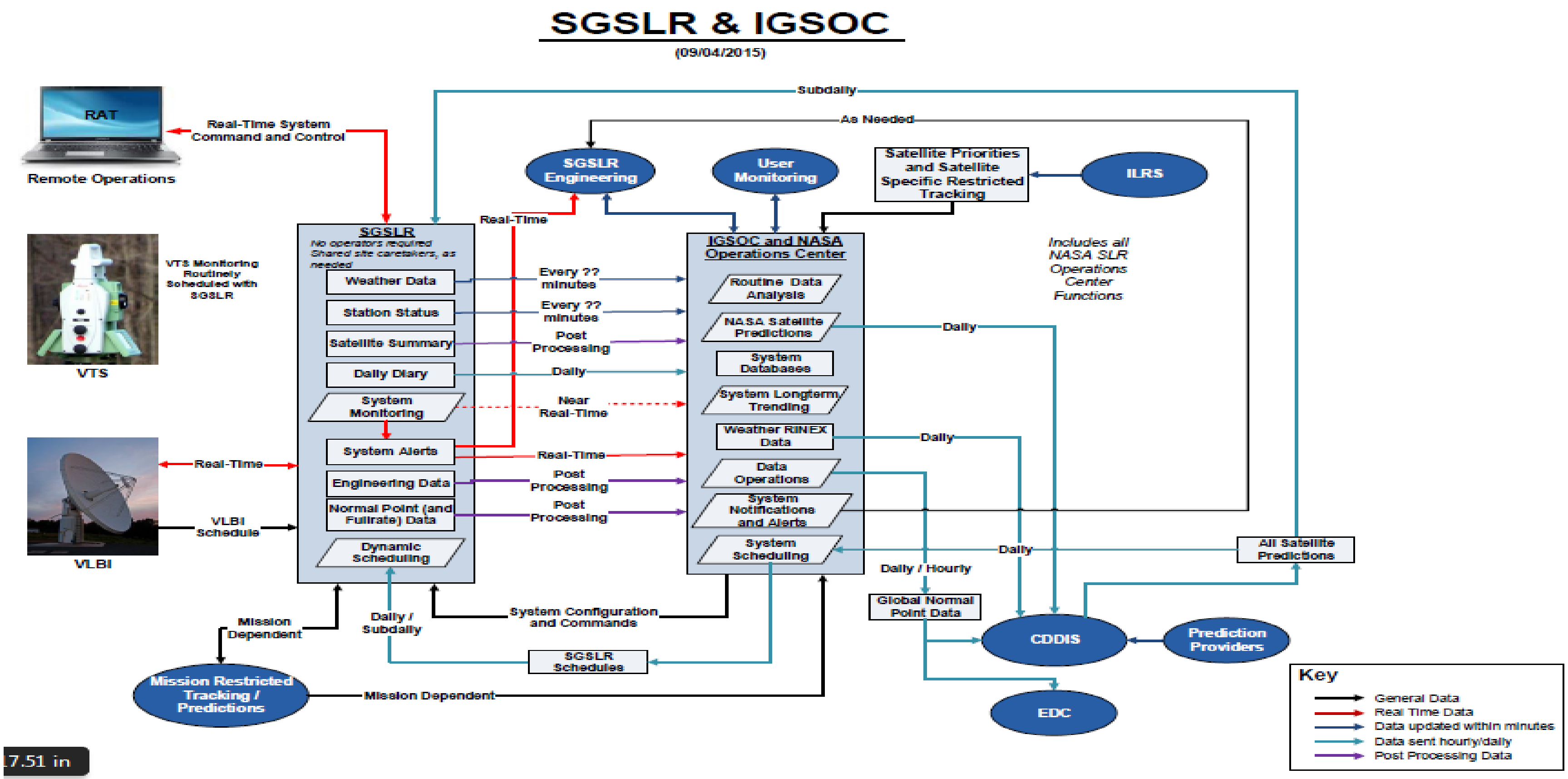


Figure 3-2. External Data Interfaces & Flow

3.4 Internal Interfaces

Internal interfaces are shown in the Figure 3-3. Details of the internal interfaces with the SGSLR system will be developed and defined in future Interface Control Documents (ICD*)*. This is a simplified internal data and signal flow diagram for SGSLR. Eight of the ten systems are shown in this figure (shelter and optical bench are not explicitly represented here). Blue lines represent data flow, black lines represent signals, and green lines represent light paths. Information on each subsystem is sent to the Control Computers for use in automated decision making and for sending to IGSOC. This part of the information flow is not explicitly shown here. The Remote Access Terminal (RAT) is also not shown in this figure as the system can run without it. RAT is shown in figure 3-4. TPH means Temperature, Pressure and Humidity. NPT stands for Normal Points.

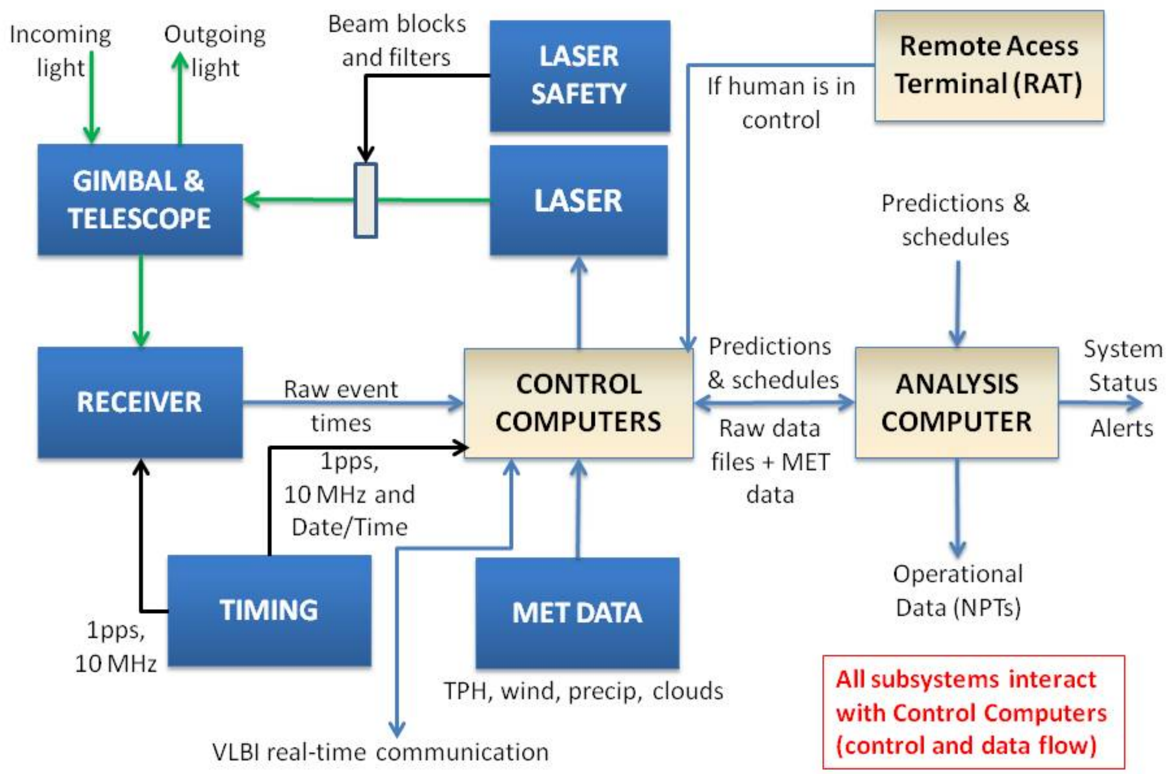


Figure 3-3. Internal Interfaces

3.5 Integrated Geodetic Site Operations Center (IGSOC)

IGSOC receives operational Normal Point (NPT) data (to the Data Operations Center) and generates station schedule and some satellite predictions, which will be available to SGSLR for pickup.. IGSOC also receives from the SGSLR stations information on safety, health and performance, plus decisions made and activities performed. Limit/Threshold violations can be defined at the IGSOC, and autonomic responses can be programmed. Limit violations can result in alert notifications. The station can also initiate alert notifications.

Users can remotely access long term trending and real-time status from anywhere. The legacy SLR Network sends information in the form of a Laser Operations Report LOR that is generated by the human operator per shift. At SGSLR the information will be sent in real-time, plus a daily diary with a summary of information from the day will be generated and sent to the IGSOC.

Human control of system must be through the Remote Access Terminal (RAT) which is part of the SGSLR system (and not part of the IGSOC, although it may be located anywhere). Separate from RAT, the IGSOC can command the SGSLR stations to perform certain functions but full human control can only be done through RAT. See Appendix A for a discussion on commanding SGSLR.

There will be various permission levels for SGSLR users. At the lowest permission level will be the operators. They can control SGSLR via RAT but cannot change databases or bring in any new files except through explicit menu selections on RAT. Supertechs can log into SGSLR and change databases and configuration files manually if needed. Software Developers can do all of the above but can also change the operational software. System Administrators have the highest level of permissions. The system should always be “operated” from the lowest permission level (operator).

The following figure shows the interfaces between SGSLR, IGOSC, and Remote Users.

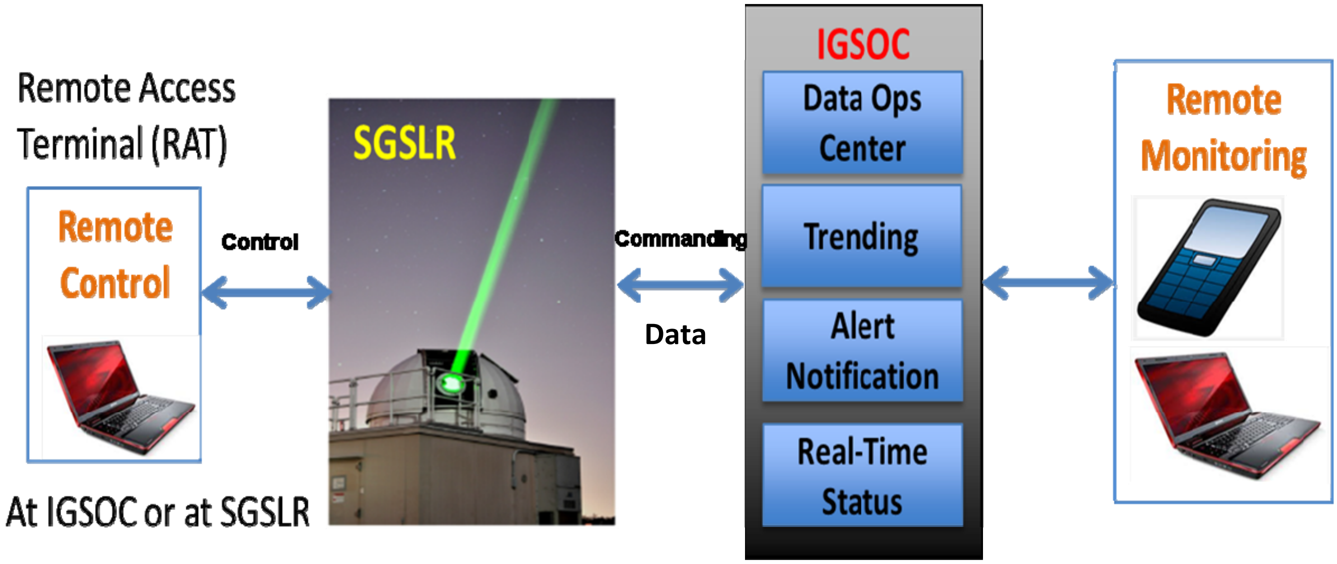


Figure 3-4. SGSLR/IGSOC Remote User Interface

4 System/Site Operations

4.1 Modes of Operations

SGSLR has the following Modes of Operation:

4.1.1 Satellite Ranging

This is the main operational mode of SGSLR. The system transmits its pulsed laser to the satellites and receives the return events, measuring both the outgoing and incoming light times. With this information the system forms ranges and time tags them. The data is corrected with calibration information, noise is filtered out, and the ranges are formed into normal points before being transmitted to the Data Operations Center (DOC). It is also planned to submit full rate data to the DOC. SGSLR will follow the ILRS guidelines for procedures and data formats including timeliness of data delivery and restricted tracking.

4.1.2 System calibration

To remove the delays caused by the system, SLR systems perform calibrations to targets whose distances are accurately known (nominally < 1.5 mm). SGSLR will perform both internal and external calibrations.

External calibrations are ranges to a cube that is external to the system. The optimum number of external targets is three, located 120 degrees apart. While this is not always possible, a minimum of one external target is required for SGSLR. The refraction correction must be calculated using the TBH in order to correct the path length. The surveyed range is then subtracted from the refraction corrected measured range to determine the system delay.

Internal calibrations are similar to external calibrations but here the target is internal to the system (within the dome). The distance is small enough that refraction corrections are not required. Internal calibrations are a good technique for measuring relative system changes over short periods of time. The combination of external and internal calibrations is a good way to determine an accurate system delay and monitor relative changes in between external ranging. External ground calibrations are planned to be performed about every 1.5 hours.

4.1.3 Star calibration

In order to determine the coefficients to the mount model errors and to situate the system in the Celestial Reference Frame (CRF), all SLR systems perform star calibrations. Depending upon the number of terms in the model a good star calibration can require 30+ stars (NGSLR requires 50). The process will be automated with the software pointing the telescope through the list of stars, and taking images from star camera to determine the pointing errors to each star. A post processed least squares fit of the pointing errors to the mount model is then performed to obtain the coefficients. SGSLR is expected to also be able to perform real-time Kalman Filtering to provide the capability of using just a few stars to do a mount model update.

Star assessments are performed at the start of every pass where the background light is low enough to allow star seeing. Similar to looking at a single star for a star calibration, the software will point the telescope to a star near the beginning of a satellite pass, get the centroid of the star image captured in the star camera, determine the pointing errors, and then use these as biases for the satellite acquisition. No update to the mount model is performed in this mode.

4.1.4 Vector Tie System support

To support the Vector Tie System (VTS) periodic survey monitoring of the SGSLR system, the station schedule will contain these VTS events:

- The VTS will need to take surveys monitoring SGSLR in various orientations, and so the schedule will have multiple orientations for SGSLR at given times (to match the VTS scheduled times).
- SGSLR will not range during these events but will need to orient the dome separately from the mount positioning, in order to give line of site to the reference cubes on the SGSLR mount from the VTS.

4.1.5 Standby/ Maintenance activities

Standby mode is used when the system cannot track due to weather conditions or system problems or when a human operator forces the system to Standby.

Maintenance activities, including software upgrades, backups, and other activities are performed from Standby mode as well.

4.1.6 Diagnostics / Simulation

To support hardware and software trouble-shooting, the system will be able to simulate many of the subsystems. Each subsystem that can be simulated can be done so independently of the others. The operator will be aware when simulation notification is active and the data generated during any simulations will be clearly marked as simulated data.

To support hardware trouble-shooting, the system will have diagnostic capability which will be available both locally and (eventually) remotely.

4.1.7 Shutdown

When there is a very severe problem with the system, such as loss of power, the software on the main SGSLR computer will report a RED condition to the IGSOC. It will then shut down all of the subsystems and all of the other computers, and then send a BLACK condition, along with a cell phone text alert to the Engineering team, before turning itself off. The only way to restart the system from this state is to be physically present at the station and manually repower the subsystems.

Regardless of the mode, operations will be the same whether an Operator is physically present, remotely controlling, or not participating (lights-out operation). The only difference will be who makes the decisions - not what functions are performed.

4.2 Day-in-the-life

The following table shows Day-in-the-Life (DITL) activities. The SGSLR system is designed to be automated and follow a schedule. The Operator, via RAT, can override the schedule at any time.

Event	Level of Automation	Time/Frequency
FAA Coordination (through NASA GSFC Code 350)	TBR	TBR
Ops log population	Automated, with Manual edit capabilities	Start of week
System Restart	Automated or Manual	Start of week and when necessary
Retrieve schedule and predictions	Automated	Once a day
Star Calibration	Automated or Manual with Automation	As needed
Ground Calibration	Automated or Manual with Automation	Every 1.5 hours
Satellite tracking	Automated or Manual with Automation	All other times
Laser stops when aircraft detected	Automated but Operator must re-enable	Aircraft detect
Post Processing	Automated	Every 20 minutes
CRD format data delivery	Automated	Every hour
Engineering Test, i.e Stability and MINICO tests	Manual	As needed
Data Backups	Automated	Daily
System Backups	(Minimal) Manual with Automation	Weekly
Vector Tie System (VTS) survey	Automated or Manual with Automation	As scheduled

Figure 4-1. DITL Activities

4.3 Steps to Remote Operations and Automation

Initially we plan to operate the first three SGSLR systems remotely (with a human operator nearby but not physically present at the station), although from function testing to commissioning the system will be operated locally.

As we gain experience with the automation of the system, and when the FAA allows the software to automatically re-enable the laser after an aircraft event, we will move the remote operation to anywhere in the world (note: FAA coordination currently occurs on a weekly basis).

Full automation is planned for the SGSLR systems that follow these three, with Texas, Hawaii, and Ny Alesund being retrofit for full automation 1-2 years after they become operational.

4.4 Command and Control

Through the operational lifecycle of SGSLR, manual Command and Control (C&C) will start at the site and will transition to Remote Operations

- At first, physically close to the site
- As Remote Operations matures, C&C will be transitioned to remote location(s).

C&C of SGSLR, regardless of location, will be performed utilizing the Remote Access Terminal (RAT).

The following figures are examples of the NGSLR RAT GUI. The SGSLR GUI will be similar.

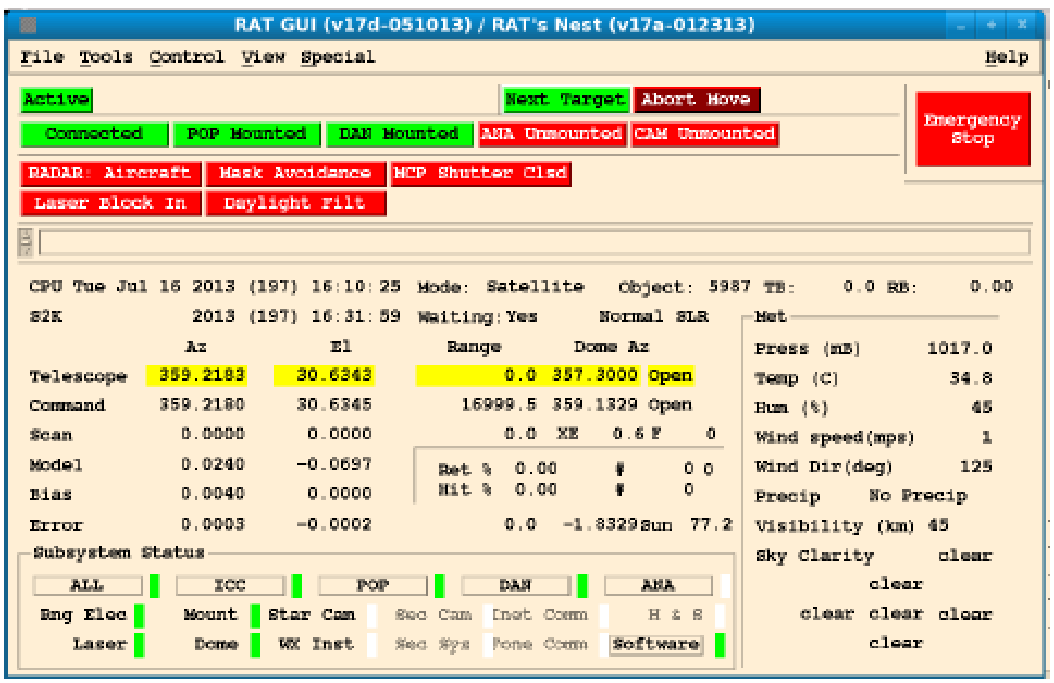


Figure 4-2. NGSLR RAT GUI Screen

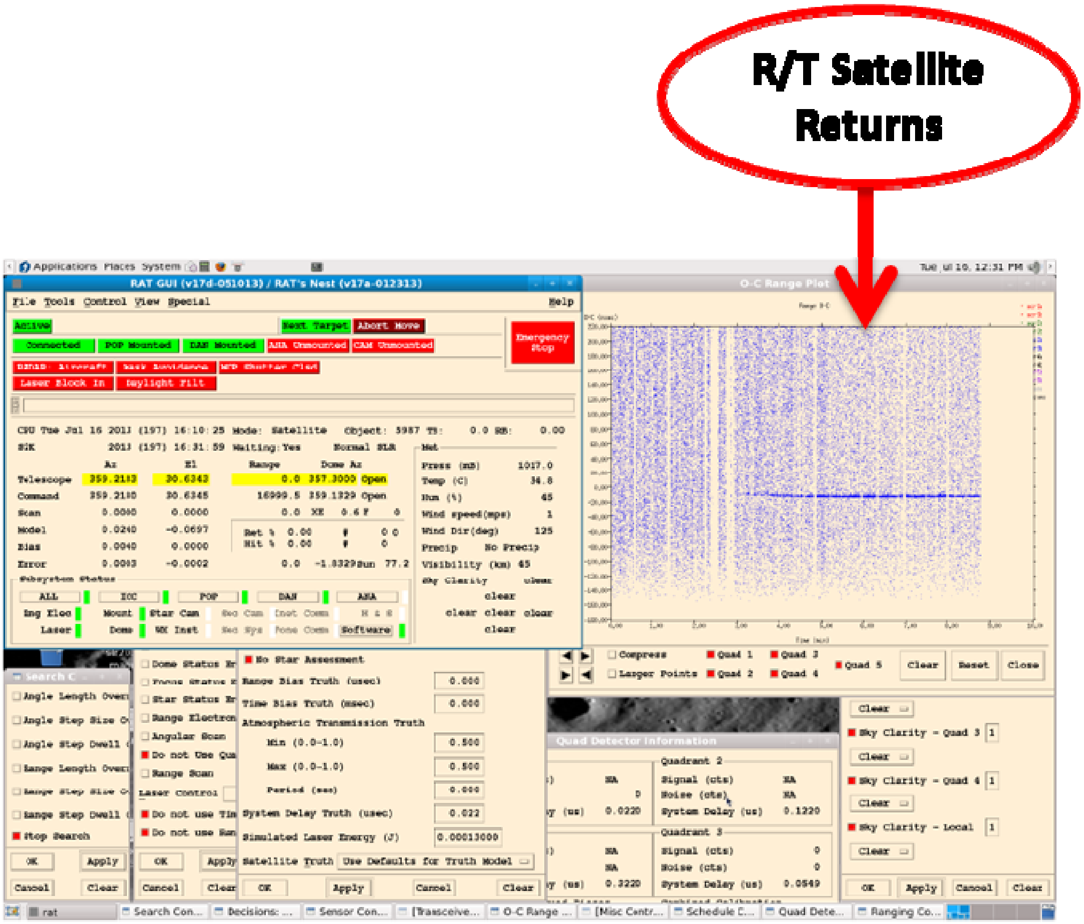


Figure 4-3. NGSLR RAT GUI Screen with Real-Time Satellite Returns

4.5 Local Operations

During Integration & Test, as well as Commissioning, Operations will be performed at the station.

Figure 4-4. Local Mode Operations at the Site

The system is designed to be automated and built with goal of being fully automated in the future. As the automation is implemented in the field, it will be vetted over time to increase confidence in automated operations.

Remote/Automated operations will first be performed locally to monitor performance/execution. GSFC Radiation Safety Office will need coordination with the FAA to acquire a letter of non-objection for Remote/Automated operations locally before conducting Remote/Automated operations from remote sites.

4.6 Future Remote Operations Concept

The SGSLR network of stations can be monitored and controlled (M&C) from an offsite SGSLR station.. The M&C functions will be accomplished through RAT and the IGSOC capabilities. Unique RAT instances will be needed for each SGSLR site (but all can reside on a single computer). A level of automation will be employed to routine background tasks. The remote operator only steers operations but is not intimately involved in the tracking tasks. If the remote connection is lost, the automation will manage and execute operations. Site technicians are at the SGSLR sites during nominal business hours, provide on-call support, and receive notifications for critical system alerts.

4.7 Future Automated Operations Concept

In the future, SGSLR will continue to increase the level of automated operations. The goal is the following:

- System operates without any human intervention
- Human can monitor remotely using IGSOC
- System and/or IGSOC will send alerts (via cell phone texting) when there are problems
- A local technician is on call at all times
- Normal operations for SGSLR, is to go back and forth between Lights-Out and Remote operation, as humans are available, and as needed
- The plan is to eventually operate longer and longer without any human intervention

4.8 Staffing and Training

4.8.1 McDonald

The McDonald SGSLR station is located in Texas. Facilities support is expected to be provided by the University of Texas. For the station, the following support staffing is needed for Human control of operations: preliminary planning indicates that four on-site technicians, shared with VLBI (for those sites where VLBI is close), should be able to handle the workload. They will work 8 hour shifts to provide 24 hour support, one must be on call anytime there is no one on site. Because of the close proximity to VLBI operations facility, VLBI operators can provide support to the SGSLR as needed.

4.8.2 Haleakala

The Haleakala SGSLR station is located in Maui, Hawaii. Facilities support is expected to be provided by the University of Hawaii. For the station, the following support staffing is needed for Human control of operations: preliminary planning indicates that four on-site technicians should be able to handle the workload. They will work 8 hour shifts to provide 24 hour support, one must be on call anytime there is no one on site. No VLBI operator support is expected at the SGSLR station because the VLBI station is located in Kauai, not at a close proximity.

4.8.3 Ny-Ålesund

The Ny Alesund SGSLR station is located in the research town of Spitsbergen, Norway. Facilities support is expected to be provided by the Ny Alesund facility personnel. For the station facility, it will have an NMA engineer on the mainland that interacts with both the on-site operators and the Goddard Sustaining Engineering group.

Onsite, Ny Alesund will need a technician who can follow technical directions both written and verbal in English to performer operations. The technician needs to have a good overview of the system and each subsystems function. The technician is expected to be able to troubleshoot the entire system at a moderate level and be able to run the Diagnostic software that will be available with each system.

Offsite support for Ny Alesund will consist of an engineer with SGSLR knowledge and who is Laser certified and can run the system. This person would be the first to answer questions and respond to any problems. The engineer would travel to Ny Alesund as needed and support troubleshooting of the SGSLR subsystems remotely. The engineer would provide the SLR long term continuity at Ny Alesund.

4.8.4 Training

The on-site operators will be required to be trained at Goddard as well as hands on training in the field. The training will be preliminarily developed during the build of the SGSLR Systems I and II and will include but not limited to:

- Station configuration, signal path and safety features
- Software operations
- Laser alignment procedures
- Station Interfaces procedures
- Satellite tracking procedures
- Laser Safety
- Laser Hazard Reduction System and Laser interlock verification procedures
- Preventive Maintenance procedures
- Ability to identify components on electrical drawings
- Lockout/Tagout training
- First Aid and CPR/AED training
- Electrical Safety-Related work practices
- Plan Spotter Training

- Ability to troubleshoot and operate the system

An operator and /or technician who is undergoing on-the-job training, or has obtained the qualified status, and who, in the course of such training, has demonstrated an ability to perform duties safely at their level of training and who is under the direct supervision of a qualified person shall be considered to be a qualified person for the performance of those duties. The operator and/or technician will need to be dedicated to SGSLR for the first year. All new technicians will need to be Laser Certified and have the training to remotely run the system. For the first year, we anticipate a shift per week of remote operations with non-optimized automated operation the rest of the time.

Training for the technician and the engineer will be at Goddard during the development and testing of SGSLR systems. It is expect all SGSLR systems to be very similar, so some training can occur during the build and testing of other SGSLR systems. In addition, we will have NASA engineers onsite at Ny Alesund for the delivery, setup and functional and system level testing of the system. It is also expect to have one or two engineers at Ny Alesund for multiple weeks of commissioning, after system level verification has completed, where more training will take place.

4.9 Maintenance

All ground station equipment will fall under a logistics plan that will follow *SGP Government Property Management.* A Logistics function centered at Goddard will oversee the storage and status of spare parts. All equipment will be tracked through NASA Property and all equipment and materials will be inventoried prior to operations by local personnel. An electronic inventory system will be used to manage spares and materials.

Facilities maintenance will be provided on a weekly basis by local personnel. Depending on the frequency of events, equipment maintenance will be provided on a scheduled and anomaly-driven basis by local or deployed personnel.

Equipment Preventive Maintenance (PM) activities will be a combination of remote and local actions and will include but not limited to:

- Inspect Laser Optics
- Clean Systems Panels
- PC Preventive Maintenance
- Verification of power supplies
- Inspect Laser Tables
- Cable Clearances
- Run Stability Tests
- Inspect Control Units
- Inspect Radome
- Check Radome Ventilation
- Lubricate system
- Lubricate Radar Antenna

- Calibration
- Dome Mechanism

Goddard will be responsible for a Sustaining Engineering group that will maintain and trouble-shoot the NASA SGSLR Network. This group will be located at Goddard but will be responsible for NASA (and associated partner) stations sustainment.. This will include travel to each SGSLR location periodically, remote support to the on-site technicians, repair and/or replacement of equipment, diagnosing problems with the system, anticipating problems and determining proper spares levels through review of the system performance, and trending, and determining what upgrades are needed and when. This group of engineers will also interface with the ILRS.

SGSLR sustainment includes receipt of some nominal level of spares from the procurement of the initial build hardware and to supplement spares within operations budget or over-guide in future years. Vendor support of spares repair, calibration, and replenishment will be used if most efficient but SGSLR sustaining engineering will be expected to take over depot level maintenance/repair or will develop replacements for items no longer supported by the vendor. Also, the equipment will be tracked for life expectancy at component level for sustainment and tracking Mean Time Between Failures (MTBF). The engineers will conduct diagnostics for non-PM activities to continually improving the life expectancy of the system and have an accurate inventory of essential spare parts for the system. On site calibration, refrigeration, etc. subcontractors will also be used as appropriate.

Nominal component level repair and testing will require lab space and testing equipment including laser lab space. Computer sustainment will require development environment and license(s). For some components rigorous test/validation will be required in operational (or simulated) conditions. Therefore the lab will provide for this level of testing or the GGAO SLR station will have the capability to test LRU's in parallel with operations or via patch panel or other near seamless switching scheme that provides least intrusion/impact to the operational station and its data quality. The lab/sustainment area should allow for multiple device test and comparison to standards for timing system and other components critical to data quality.

During the SGSLR operations lifecycle several phases will occur and the maintenance of the stations will follow in accordance to their status:

Phase I – Fully staffed Operational Station

During this phase a full time operator will be on site conducting and inspecting all systems and perform on site operations. Notifications of any maintenance issues will be available remotely and on site. Remote sustainment engineering will reside at Goddard.

Phase II – Partially staffed Operational Station

During this phase there is a combination of remote operations and part time staffed station on site. Notifications of any maintenance issues will be available remotely and on site. Remote sustainment engineering will reside at Goddard.

Phase III – Remotely staffed Operational Station

During this phase the station will be fully operated remotely with minimal onsite operator contact. Real-time video cameras will be on at all times recording the system to conduct remote inspections and evaluate any issues. Notifications of any maintenance issues will be available remotely and on site. Remote sustainment engineering will reside at Goddard. During critical events, mechanical and electrical maintenance personnel will be on-call as required to replace the failed or anomalous unit with a shelf spare. This response time should be more than adequate because of hot-sparing at each location even in the extremely unlikely event of a double site failure.

Phase IV – Fully Automated Operations

During this phase the station will be fully automated with minimal operator interaction. Real-time video cameras will be on at all times recording the system to conduct remote inspections and evaluate any issues during automated process. Remote sustainment engineering will reside at Goddard. During critical events, mechanical and electrical maintenance personnel will be on-call as required to replace the failed or anomalous unit with a shelf spare. This response time should be more than adequate because of hot-sparing at each location even in the extremely unlikely event of a double site failure.

4.10 Configuration Management

Configuration Management (CM) is the systematic process for establishing and maintaining control of all SGSLR baselines, its Configured Items (CI) and their associated product configuration information. CM includes processes for maintaining subsequent changes to the SGSLR network and documentation in response to approved requirements. The CM process includes planning, identification, change control, status accounting, and verification of all baselines and CIs throughout the product life cycle. CM is essential for the development, operations and maintenance of the SGSLR network. The SGSLR will follow the CM process described in SGP-PG-0001.

4.11 Security

The SGSLR Security Management Plan (located in the SGSLR Deployment Plan) will addresses the procedures for implementing requirements for information, physical, personnel, industrial, and counterintelligence / counterterrorism security, and for security awareness / education requirements in accordance with NASA Procedures and Requirements (NPR) 1600.1, Security Program Procedural Requirements; NPD 1600.2 NASA Security Policy; and GPR 1600.1 Goddard Security Requirements. This plan covers all of SGSLR stations.

4.11.1 Physical

Physical security consists of protocols implemented operationally via established procedures to secure the physical plant of each SGSLR site. Each site may implement physical security differently depending on the location of the stations but all sites will have security cameras inside and outside the buildings with night vision capability. The SGSLR stations located on NASA grounds and at other sites will utilize the host’s physical security. The physical security for SGSLR stations will be detailed in *SGSLR Security Management Plan*.

4.11.2 Information Technology

Information Technology (IT) for SGSLR will fall under the code 600 IT Security and IT Contingency Plans. The SGSLR specific information will be appendices to these Directorate Documents and will follow NASA IT Security Policy as given in NPR 2810.1A Security of Information Technology. IT security training is a yearly requirement for all personnel and SGSLR computers will undergo all required NASA security audits and scanning. If the host location has security requirements that are stricter than those of NASA, the higher restrictions will be followed.

4.12 Safety

The SGSLR project will be designed to meet the NPR 8715.3, NASA General Safety Program Requirements. Safety requirements for the SGSLR project will be developed by performing a Preliminary Hazard Assessment and tracking implementation of identified appropriate controls on the SGSLR Safety Verification Tracking Log.

All SGSLR operations must comply with the *Laser Radiation Protection* document. The SGSLR Laser Safety Plan is required to be submitted to the GSFC Radiation Safety Office after all non-administrative changes to the Plan or the Operations. If there are no changes to the document, the Laser Safety Plan is required to be submitted at least every 3-years. This is accomplished using the GSFC Form 23-6L Form.

The *Goddard Procedural Requirement: Laser Radiation Protection* also requires SGLSR operations to maintain current Letters of Non-Objection from the FAA. SGP completes FAA Form 7140-1 with the applicable Laser Control Systems Air Space Hazard Analysis and SGSLR Program Brief Description and submits to the GSFC Radiation Safety Office at least 60-days prior to expiration to request renewal of the FAA Letter of Non-Objection.

Appendix A: Commanding SGSLR from IGSOC

To be filled in later.

Abbreviations and Acronyms

Acronym	**Definition**
ANS	Alert Notification System
C&C	Command and Control
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
HEPA	High Efficiency Particulate Arrestance
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
MTBF	Mean Time Between Failure
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
SGP	Space Geodesy Project
SGSLR	Space Geodesy Satellite Laser Ranging System
SLR	Satellite Laser Ranging
TBAD	Transponder Based Aircraft Detection
TBH	Temperature, Barometric Pressure and Humidity
VLBI	Very Long Baseline Interferometry

Acronym	Definition
VTS	Vector Tie System