Space Geodesy Satellite Laser Ranging System Requirements Document Public Version

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Levels 3 & 4

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4. Subsystems

4.1. Telescope and Gimbal Subsystem

The telescope is designed as a monostatic system to both transmit laser energy and receive light from targeted objects through common optics and a common optical path. The gimbal drives the telescope to track Earth orbiting satellites, stars and fixed ground targets. This subsystem includes the telescope and Coudé path through the tracking subsystem, two cameras mounted on the telescope (one low light camera for viewing dim targets and one wide field of view camera for visual tracking), and all associated environmental monitoring and control devices such as temperature sensors, accelerometers, etc. It also includes the gimbal, encoders, servo electronics, and additional hardware/software to monitor/maintain environmental limits. The gimbal portion of the telescope and gimbal subsystem is attached to a riser which is mounted on a concrete pier and maintains vibrational isolation from other components of the shelter and dome to minimize disturbances to the gimbal pointing and tracking. This subsystem has components in both the dome and the shelter.

4.2. Optical Bench

The optical bench (OB) subsystem is designed to allow the laser subsystem, 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 (which is part of the OB subsystem), along the Coudé path, 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 star camera is part of the optical bench subsystem. The optical bench is contained within the shelter.

4.3. 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. The range receiver subsystem also includes the RCE (Range Control Electronics) 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. In addition the range receiver subsystem includes a wide field of view low light Acquisition Camera for use in acquiring targets with poor predictions. Part of this subsystem sits on the optical bench, the rest is in the electronics rack. All are contained within the shelter.

4.4. Laser Subsystem

The laser subsystem consists of the laser, associated control electronics, a chiller to maintain the laser's 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 rack mounted in the optical bench area.

4.5. 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.

4.6. 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, and outputs the 1 PPS from an oscillator disciplined by GPS and the 10 MHz signal that is synchronized to that 1 PPS. The system also includes a monitoring subsystem that uses a secondary GPS timing source to compare the GPS 1 PPS outputs and provide the data to the computer subsystem to assess the accuracy of the Timing and Frequency subsystem. Most of this system is contained within the shelter. The GPS antenna(s) are mounted outside of the shelter.

4.7. Meteorological

The Meteorological subsystem is designed to measure outside environmental conditions to provide information for precise ranging and health and safety of the system. 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 ranging accuracy are the barometric pressure, temperature, and humidity. The system also includes stands and associated hardware for the system.

4.8. Dome, Shelter, and Pier/Riser

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.

4.8.1. Dome

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 reception 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.

4.8.2. Shelter

The shelter is designed to contain and protect the optical bench, laser and all the electronics, as well as provide work space for support personnel. 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 subsystems with power, UPS, and surge protection, including protection from lightning. It also provides a pass-through for internet and telecommunications.

4.8.3. Pier and Riser

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.

4.9. Computer and Software

The computer and software subsystem contains all the computers and the software to control, calibrate, and maintain the system as a whole, and to communicate with the control center. The software is designed to support local, remote, and fully automated operations. This subsystem links all other subsystems together, transfers and stores data, processes the ranging data, and communicates with the IGSOC. It is contained within the shelter.

	SGSLR Level 3 Requirements		28-May-16	version 1.5x
		Verification Method		
SGSLR #	Description	Method	Level	Where verified
SLF	Functional requirements			
SLF 3.1	With a standard clear atmosphere or better, SGSLR stations shall be capable of 24 x 7 tracking of satellites whose arrays satisfy the ILRS retro-reflector guidelines, and whose altitudes are 300 km to 22,000 km.	T,A	System	Field
SLF 3.1.1	With a standard clear atmosphere or better, SGSLR stations shall be capable of tracking geosynchronous satellites whose arrays satisfy the ILRS retro-reflector guidelines.	T,A	System	Field
SLBP	Baseline performance requirements			
SLBP 3.1	Data precision for LAGEOS NPT shall be < 1.5 mm when averaged over a one month period.	T,A	System	Field
SLBP 3.2	The LAGEOS Normal Point range bias shall be stable to 1.5 mm over 1 hour.	T,A	System	Field
SLBP 3.3	Over one year the RMS of station's LAGEOS NPT range biases shall be < 2mm.	T,A	System	Field
SLBP 3.4	SLBP3.4: SGSLR Station shall be capable of producing an annual volume of 45,000 LEO, 7,000 LAGEOS and 10,000 GNSS NPTs.	T,A	System	Field
SLBP 3.5	Normal Point time of day shall be accurate to < 100 ns RMS.	T,A	System	Field
SLBP 3.6	Systems shall have a modular design supporting maintenance and upgrades.	A	System	Field
SLBP 3.7	Systems shall be capable of local and remote operation by an operator with a path to full automation.	T,A	System	Field
SLBP 3.7.1	Systems and operations shall satisfy local and NASA safety requirements.	T,A	System	Field
SLBP 3.7.2	Systems shall be capable of following ILRS procedures and formats and handle ILRS-defined restricted tracking.	T,A	System	Field
SLBP 3.8	SGSLR Stations shall not introduce any unquantified biases into the legacy SLR network.	T,A	System	Field

	Controlled by: Jan McGarry	SGSLR Level 4 Requirements	Developed by Mark Shappirio
		7-Aug-16	
		Version 2.0	
SGSLR #	Parent	Description	Rationale for requirement
4.1		**Telescope and Gimbal (GTA)**	
4.1.1		**Telescope**	
4.1.1.1	SLF 3.1 SLF 3.1.1	The telescope subsystem shall be designed to transmit from the optical bench subsystem and return receive light from the satellite to the optical bench subsystem	Overall description of subsystem purpose
4.1.1.2	SLBP 3.4	The telescope shall be capable of operation within -40oC to +50oC and wind speeds up to 18 m/s.	Telescope must be able to operate without issue in a wide range of environments.
4.1.1.3	SLBP 3.7 SLBP 3.4	The telescope shall be capable of survival at temperatures ranging from -50oC to +55oC.	The telescope must be robust enough to maintain stability of the optical components.
4.1.1.4	SLBP 3.4 SLBP 3.6	The telescope optical paths shall be sealed against dust and contamination.	A sealed telescope will keep the optical components clean longer, and require less maintenance.
4.1.1.5	SLP3.7 SLBP 3.7.1	The telescope shall support the mounting of system support equipment.	The telescope must be robust enough to hold additional payloads while maintaining stability of the optical components.
4.1.1.6	SLBP 3.4 SLBP 3.6	The telescope optical elements shall be designed to meet MIL-SPEC-C-675 sections 3.8.2, 3.8.3, and 3.8.4.1	Reduced downtime results in reduced operational costs, increased data volume and longer telescope life.
4.1.1.7	SLBP 3.4 SLBP 3.7	The telescope shall be capable of maintaining alignment.	Reduced downtime results in reduced operational costs, increased data volume and longer telescope life.
4.1.1.8	SLF 3.1 SLF 3.1.1	The rotation caused by the optical Coude path with respect to gimbal angular space shall be defined by a fixed model.	Coude path rotation must be known to convert angular measurements on the optical bench to the gimbal's angular space.

4.1.1.9	SLF 3.1 SLF 3.1.1 SLBP 3.4	The telescope optical elements shall optimize system performance and lose no more than 2% per surface at wavelengths of 532, 1064 and 1550 nm and not more than 4% (TBR) loss per surface in the broadband from 400 nm to 800 nm	Reducing the light losses for SLR wavelengths improves the number of returns for daylight operations and faint targets while maintaining throughput in the broadband for star calibrations
4.1.1.10	SLF 3.1 SLF 3.1.1 SLBP 3.4	The telescope optical elements shall be designed to allow alignment of the system in the field	Required for periodic maintenance and replacement of damaged/worn parts in the field
4.1.1.11	SLBP 3.4	The telescope shall be designed to have a 10^-6 reduction in stray light through the optical path even while pointing to within 10 degrees of the sun	To maximize the daytime tracking ability, stray light must be kept low
4.1.1.12	SLBP 3.4	The telescope shall be capable of having a FOV of 40 arc sec unvignetted, 60 arc sec with some vignetting for acquisition, and a total FOV of 2 arc minutes for star calibrations.	FOVs must be managed to support acquisition and maximize signal to noise.
4.1.1.13	SLBP 3.4	The telescope shall be designed to achieve the fundamental performance of the baseline prescription	To optimize performance.
4.1.2		**Gimbal**	
4.1.2.1	SLBP 3.4	The Gimbal shall be capable of a maximum slew velocity of at least 20 deg/s.	Max slew velocity should minimize the time required to transition from one target to the next. Time between passes, especially interleaved segments must be minimized to maximize data collected.
4.1.2.2	SLBP 3.4 SLF 3.1 SLF 3.1.1	The Gimbal shall be designed to follow the angular commands to within 1 arc second RMS while tracking satellites from 300 km altitude to geosync, as well as stars for star calibrations, from 7 to 90 degrees elevation for all azimuth angles.	To maximize the data collected the system must be able to precisely track passes that have both a high angular velocity and significant acceleration to passes that move at a sidereal rate.
4.1.2.3	SLBP 3.7	The Gimbal shall provide digital status information on critical parameters, like temperature and voltages, for monitoring.	Knowledge of the temperatures and voltages show health of the system and may be used in determining mount model corrections.
4.1.2.4	SLBP 3.4	The Gimbal shall be capable of operation over the temperature range of -40oC to +50oC.	System must be able to operate in cold high latitude climates as well as hot climates. We want to use the same gimbal across all of the SGSLR Network.

4.1.2.5	SLBP 3.7 SLBP 3.4	The Gimbal shall be capable of survival at the expected extremes of temperature form -50oC to +55oC(TBR).	The tracking subsystem must be robust enough to survive extreme environmental conditions.
4.1.2.6	SLBP 3.4 SLBP 3.6	The Telescope and Gimbal subsystem shall be designed to have a system downtime no greater than 0.75% (TBR), which consists of scheduled maintenance, MTBF and MTTR.	To maximize the data collected the system must remain operational for very long periods of time.
4.1.2.7	SLBP 3.7 SLBP 3.7.1 SLBP 3.4	The tracking subsystem shall be able to support a payload of the telescope and an additional 120 lbs.(TBR) of equipment necessary for operation and diagnostics.	The gimbal must support the telescope as well as cameras, potentially aircraft avoidance instrumentation, and other items.
4.1.2.8	SLBP 3.2 SLBP 3.3 SLBP 3.8	The location of the intersection of the axes for the gimbal shall be known to within 1mm in 3D space(TBR) and referenced to an external survey point on the gimbal.	The roundtrip time of flight is measured from the system origin (intersection of gimbal axes) so the knowledge of this location relative to the survey point is crucial to the accuracy of the measurement.
4.1.2.9	SLBP 3.4	The Gimbal interface shall be capable of transmitting position information from the GTA to the software at least a rate of 1 kHz to confirm accurate tracking of the target (satellite) trajectory based on the operational laser fire rate.	In order to determine the pointing accuracy at each laser fire the mount pointing location must be known at the laser fire rate.
4.1.2.10	SLBP 3.4	The Gimbal shall include an internal error model table that will map repeatable errors in pointing and tracking.	This internal table determines the GTA blind pointing capabilities.
4.1.2.11	SLF 3.1 SLF 3.1.1 SLBP 3.4	The Gimbal shall be designed to meet absolute open loop pointing requirements of <= 3 arcsec RMS through the use of a GTA mount model based on tracking stars (star calibration).	The accuracy requirement for GTA absolute (celestial) pointing requires a correction to the raw encoder values for various pointing errors.
4.1.2.12	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.8	The Gimbal shall be designed to allow for calibration of the system by pointing at ground targets.	Required to monitor changes in system delays and maintain 1mm precision in ranging
4.1.2.13	SLF 3.1 SLF 3.1.1	The Gimbal shall be capable of mechanically mating to the pier through the use of a riser.	Allows standardization of GTA design for a variety of piers and shelters

4.1.2.14	SLBP 3.6	The Gimbal shall be capable of being reshipped.	To allow for redeployment. In particular one of the GTA subsystems must be at GGAO in support of the collocations. It will then need to be redeployed.
4.1.2.15	SLBP 3.7.1	The Gimbal shall be designed to meet all of the NASA, GSFC and local safety standards.	required for safety
4.1.2.16	SLBP 3.4	The Tracking subsystem shall be capable of a tracking azimuth velocity of 0°– 10°/sec with an azimuth acceleration of 0°-2°/sec2; a tracking elevation velocity of 0°-2° deg/sec with an elevation acceleration of 0°-0.5°/sec^2	To maximize the data collected the system must minimize any keyhole area and must be able to precisely track passes that have both a high angular velocity and significant acceleration as well as passes that move at a sidereal rate.
4.1.2.17	SLBP 3.7	The Tracking Subsystem shall be capable of full control by the SGSLR system software, and provide all relevant data to the system software.	Required for remote/automated operations and for monitoring, decision making, and transfer to IGSOC.
4.1.2.18	SLBP 3.7	The Tracking Subsystem shall be designed to support local, remote, and fully automated operations	Required for remote/automated operations and for monitoring, decision making, and transfer to IGSOC.
4.2		**Optical Bench**	
4.2.1	SLF 3.1 SLF 3.1.1	The optical bench subsystem shall serve as the optical interface between the laser transmitter, receiver, GTA, and star camera.	Requirement on the functionality of the optical bench
4.2.2	SLBP 3.4 SLBP 3.6	The optical bench subsystem shall be designed to have a system downtime no greater than 1.65% (TBR), which consists of scheduled maintenance, MTBF and MTTR.	In order to ensure required data volume the system must minimize down time.
4.2.3	SLBP 3.7	The optical bench subsystem shall be capable of full control by the SGSLR system software, and provide all relevant data to the system software.	Control and knowledge of the settings required for health and safety of the system and for monitoring, decision making, support remote and automated operations, and transferring information.

4.2.4	SLBP 3.7	The optical bench subsystem shall be capable of being automatically placed into all operational configurations by the software.	Requirement for remote/autonomous operation of the system
4.2.5	SLBP 3.4 SLF 3.1 SLF 3.1.1	The components on the optical bench shall be compatible with all laser output characteristics.	The bench must be able to handle the output characteristics of the laser including divergence, wavelength and the energy density from the laser at full power.
4.2.6	SLBP 3.4 SLF 3.1 SLF 3.1.1	The optical bench subsystem design shall optimize system ranging performance at 532 nm, 1064 nm, and 1550 nm, and star imaging performance from 400 nm to 800 nm.	Light throughput needs to be optimized to maximize signal.
4.2.7	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.4	The optical bench subsystem shall be designed to minimize backscatter across all operational wavelengths.	To maximize signal to noise ratio.
4.2.8	SLBP 3.6 SLBP 3.7.1	The optical bench subsystem shall be capable of manual configuration for testing, troubleshooting, and special calibrations of the system.	Required for testing and diagnostics with engineer present.
4.2.9	SLF 3.1 SLF 3.1.1 SLBP 3.4	The optical bench subsystem shall be capable of directing the transmit laser beam along a path angularly different from the telescope optical axis for point ahead capability.	To increase signal to noise by minimizing laser divergence and telescope FOV

4.2.10	SLBP 3.7.1	The optical bench subsystem design shall provide space for the required optical attenuators and beam blocks to address laser safety.	Required for laser safety.
4.2.11	SLBP 3.4	The optical bench subsystem shall be isolated from vibrations from the shelter that are greater than the equivalent to Vibration Criterion Curve A (VC-A) 50 micrometers/sec RMS (TBR).	The optical bench must be isolated from the shelter and the system pad to maintain optical stability.
4.2.12	SLBP 3.4 SLF 3.1 SLF 3.1.1	The optical bench subsystem design shall support alignment to within 1 arc seconds (TBR) of the transmit, receive, and star camera optical paths to the telescope optical axis.	To ensure pointing accuracy.
4.2.13	SLBP 3.7 SLBP 3.7.1	The optical bench subsystem shall be capable of being placed into a "safe mode" in the event of an unexpected power failure.	Required for safety of the equipment.
4.2.14	SLBP 3.1 SLBP 3.2 SLBP 3.3SLBP 3.6 SLF 3.1 SLF 3.1.1	The optical bench subsystem design shall include sufficient space for the laser head of the laser subsystem.	To accommodate the laser on the optical bench.
4.2.15	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.6 SLF 3.1 SLF 3.1.1	The optical bench subsystem design shall include sufficient space for the receiver subsystem.	To accommodate the receiver on the optical bench.
4.2.16	SLRBP 3.7	The optical bench subsystem shall be designed to support local, remote, and fully automated operations.	Requirement for remote/autonomous operation of the system
4.2.17	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.8	The optical bench subsystem shall be designed and optimized to support the required range measurement precision and stability.	To support the system performance requirements.

4.2.18	SLF 3.1 SLF 3.1.1 SLBP 3.4	The optical bench subsystem shall capture usable nighttime images of stars down to magnitude 6 (TBR).	To provide enough stars for mount pointing calibration.
4.2.19	SLF 3.1 SLF 3.1.1 SLBP 3.7 SLBP 3.4	The optical bench subsystem shall be designed to support the 2 arcmin FOV for star imaging and 60 arcsec FOV for satellite acquisition.	The FOV must be wide enough to allow for the expected nominal errors in the system pointing to stars and satellites.
4.2.20	SLBP 3.4	The optical bench subsystem shall provide stray light protection for the detector and all cameras on the bench.	Required for the system performance and safety of the components.
4.2.21	SLBP 3.6 SLBP 3.4	The optical bench shall support local and remote diagnostic capability.	To allow for trouble-shooting in the field, either locally or remotely.
4.3		Range Receiver	
4.3.1	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.8	The range receiver subsystem shall make all timing measurements relative to the system base frequency with < 5 ps (TBR) precision and < 10 ps (TBR) stability over an hour.	To meet operational performance requirements
4.3.2	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.8	The components of the range receiver subsystem shall each have a known error which collectively do not exceed the subsystem's ranging error budget.	All errors contributing to system error must be controlled to maintain overall error budget
4.3.3	SLF 3.1 SLF 3.1.1	The range receiver subsystem shall be designed to detect photons from the laser pulse in the transmit optical path.	Functional performance requirement.
4.3.4	SLBP 3.1 SLBP 3.2 SLBP 3.3	The range receiver subsystem shall be designed to detect single photons from the receive optical path.	To meet science (ITRF) requirements for range measurements

4.3.5	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.8	The range receiver subsystem shall be designed to operate in three modes: internal calibration, external calibration, and satellite ranging.	Different time of flight ranges require different gating and protection for stray light into the detector. Calibrations are required to meet performance.
4.3.6	SLBP 3.4	The range receiver subsystem shall have a system dead time that is less than 10 ns (TBR).	Measurements cannot be made during detector or timer dead time. Minimizing this dead time means reduced data loss which maintains normal point data volumes.
4.3.7	SLBP 3.4	The range receiver subsystem shall be capable of avoiding > 90% (TBR) of collisions between the transmit and receive events.	Timing measurements of the return pulses from satellite cannot be made when the receive events occur around the same time as the fire.
4.3.8	SLBP 3.4	The range receiver subsystem shall be capable of blanking the detector during laser energy transmission.	Needed to protect the detector from scattered laser light
4.3.9	SLBP 3.4 SLBP 3.7 SLF 3.1 SLF 3.1.1	The range receiver shall provide timing and spatial information from transmit and receive events needed for closed loop tracking.	The system needs information from the receiver to calculate the biases needed for closed loop tracking and to form the science product.
4.3.10	SLBP 3.4 SLF 3.1 SLF 3.1.1	The range receiver subsystem shall be able to correctly distinguish and accurately process satellite range returns with (1) background noise rates up to 13 MHz (TBR) with a return signal rates of between 0.05 and 0.2 pes/fire (TBR), and (2) background noise rates up to 5 MHz (TBR) for return signal rates between 0.001 and 0.05 pes/fire (TBR)	The system must be able to make range measurements with daylight background noise rates, and with very low return rates from satellites.
4.3.11	SLBP 3.4 SLF 3.1 SLF 3.1.1	The range receiver system shall be able to survive and recover from 30 MHz (TBR) background rates.	The design of the detector, receiver optics and electronics must allow the system to recover from high background rates.
4.3.12	SLF 3.1 SLF 3.1.1 SLBP 3.1 SLBP 3.2 SLBP 3.4	The range receiver subsystem shall provide gating to the detector for internal and external calibrations, and satellite ranging.	The detector must be protected and the background noise reduced temporally.
4.3.13	SLBP 3.4 SLBP 3.7	The range receiver shall be capable of full control by the SGSLR system software, and provide all relevant data to the system software.	To support remote/automated operations and for monitoring, decision making, and transfer to IGSOC.

4.3.14	SLBP 3.4 SLBP 3.6	The range receiver subsystem shall be designed to have a system downtime no greater than 1.8% (TBR), which consists of scheduled maintenance, MTBF and MTTR.	To achieve the data volumes required the system can only be down for short periods.
4.3.15	SLBP 3.7 SLBP 3.7.1	The range receiver subsystem shall be capable of being placed into a "safe mode" in the event of an unexpected power failure.	Required for safety of the equipment
4.3.16	SLBP 3.7	The receiver subsystem shall be designed to support local, remote and fully automated operations.	Subsystem must function properly during all modes of operation.
4.3.17	SLBP 3.7 SLBP 3.4	The range receiver subsystem shall provide spatial information to =< 2 arc second accuracy (TBR).	Subsystem must function properly during automated operation. Spatial information is needed for closed loop tracking.
4.3.18	SLBP 3.7 SLBP 3.4	The range receiver subsystem shall provide signal processing information in the form of a spatial histogram across the tracking FOV to the system software at 20 Hz (TBR) rate.	Needed to support automated closed loop tracking for automated operation. Signal processing by the hardware allows the software to make faster decisions.
4.4		**Laser SUBSYSTEM**	
4.4.1	SLBP 3.4 SLF 3.1 SLF 3.1.1	The laser subsystem shall generate optical pulses for ranging with an adjustable power output and repetition rate for a set wavelength, pulse width and enough energy to successfully range to the highest required satellites.	To allow for adjustments in output for different configurations of the telescope from station to station and to allow for collision avoidance between outgoing and incoming laser pulses.
4.4.2	SLBP 3.4 SLBP 3.6	The laser subsystem shall be designed to have a system downtime no greater than 2.85% , which consists of scheduled maintenance, MTBF and MTTR.	To maintain the required annual normal point data volume.
4.4.3	SLBP 3.7	The laser subsystem shall be capable of full control by the SGSLR system software, and provide all relevant data to the system software.	Required for remote/automated operations and for monitoring, decision making, and transfer to IGSOC.
4.4.4	SLBP 3.2 SLBP 3.4	The laser output shall be stable over defined periods of time.	Stability of the laser is needed for millimeter level system performance.

4.4.5	SLBP 3.4	The laser subsystem shall be capable of firing continuously for one month between scheduled maintenance periods.	Operational parameters will require firing continuously for hours.
4.4.6	SLBP 3.4	The laser subsystem shall be able to resume firing at nominal output parameters after defined periods of interruption.	To maintain the required annual normal point data volume.
4.4.7	SLBP 3.7 SLBP 3.7.1	The laser subsystem shall be capable of being placed into a "safe mode" in the event of an unexpected power failure.	Required for safety of the equipment.
4.4.8	SLBP 3.7	The laser subsystem shall support local, remote, and fully automated operations.	Required for remote/automated operations and for monitoring, decision making, and transfer to IGSOC.
4.4.9	SLBP 3.6	The laser head of the laser subsystem shall be mountable on the optical bench subsystem.	Required for modularity and resources impacts and to maintain the relative stability between the laser, receiver and other optics.
4.4.10	SLBP 3.4	The laser subsystem shall support external firing using input from the RCE.	Needed to allow PRF changes by the software to avoid collisions between outgoing and incoming pulses
4.5		**Laser Safety SUBSYSTEM**	
4.5.1	SLBP 3.7.1	The laser safety subsystem shall ensure that no one is exposed to non eye safe laser light during normal operations.	NASA and FAA safety regulations and laws.
4.5.2	SLBP 3.7.1	The laser safety subsystem shall ensure that no one is exposed to non eye safe laser light outside of the laser operations area and dome during non operational periods.	NASA and FAA safety regulations and laws.
4.5.3	SLBP 3.4 SLBP 3.6	The laser safety subsystem shall be designed to have a system downtime no greater than 1.5% (TBR), which consists of scheduled maintenance, MTBF and MTTR.	Reliability is important to meet data volume requirements and to keep operations costs under control.
4.5.4	SLBP 3.4	Outdoor components of the laser safety subsystem shall be capable of operation within -40 deg C and +50 deg C.	The laser safety subsystem must be able to be located in and operate at sites with wide temperature ranges.

4.5.5	SLBP 3.7 SLBP 3.4	Outdoor components of the laser safety subsystem shall be capable of survival at -50 deg C and +55 deg C.	The laser safety subsystem must be able to be located in and survive in a wide variety of climates.
4.5.6	SLBP 3.7	The laser safety subsystem shall be capable of automated and manual reset.	Required for automated/remote operations.
4.5.7	SLBP 3.7.1	The laser safety subsystem shall be capable of detecting aircraft and ensuring that aircraft are not exposed to laser light.	NASA and FAA safety regulations and laws.
4.5.8	SLBP 3.7.1	The laser safety subsystem shall not allow transmission of non eye safe laser radiation below the minimum tracking elevation angle 10 deg (TBR)	NASA and FAA safety regulations and laws.
4.5.9	SLBP 3.7.1	The laser safety subsystem shall allow for full power operation, 5 Watts (TBR), of the laser for alignment purposes without exposing persons outside of the laser operations area (nominal hazard zone).	Different configurations may be required for various alignments/testing.
4.5.10	SLBP 3.7	The laser safety subsystem shall provide status and configuration information to the system software.	To support remote and/or automated operations and NASA safety requirements
4.5.11	SLBP 3.7 SLBP 3.7.1	The laser safety subsystem shall be capable of commanding by the system software without allowing the software to override safety settings.	To support remote and/or automated operations and NASA safety requirements
4.5.12	SLBP 3.4 SLBP 3.7	The laser safety subsystem shall be designed to support local, remote and fully automated operations.	To support remote and/or automated operations

4.5.13	SLBP 3.6	Applicable laser safety subsystem components shall be designed to occupy a minimal footprint on the optical bench.	Reduce impact on other subsystems
4.5.14	SLBP 3.7 SLBP 3.7.1	The laser safety subsystem shall be capable of being placed into a "safe mode" in the event of an unexpected power failure.	To support remote and/or automated operations
4.5.15	SLBP 3.7.1 SLBP 3.7	The laser safety subsystem shall default to a fail safe mode in case of a subsystem failure.	NASA safety regulations.
4.5.16	SLBP 3.7.1	Laser safety system shall be fully compliant with NASA safety standards.	NASA safety regulations.
4.6		**Time and Frequency**	
4.6.1	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.5	The time and frequency subsystem shall provide stable and accurate date/time and frequency signals relative to GPS.	To maintain the required accuracy of the normal points the timing subsystem must be stable and accurate
4.6.2	SLBP 3.4 SLBP 3.6	The time and frequency subsystem shall be designed to have a system downtime no greater than 0.3% , which consists of scheduled maintenance, MTBF and MTTR.	In order to maximize tracking data, the system downtime must be minimized.
4.6.3	SLF 3.1 SLF 3.1.1 SLBP 3.4	The outdoor components of the time and frequency subsystem shall be capable of operation from -40 deg C to +50 deg C.	In order to maximize tracking data, the system should be capable of full operation within the local environmental conditions.
4.6.4	SLBP 3.7 SLBP 3.4	The outdoor components of the time and frequency subsystem shall be capable of survival from -50 deg C to +55 deg C.	Survivability ensures that the system will recover from downtime outside of operational range of environmental conditions and can reduce the need to replace components.
4.6.5	SLF 3.1 SLF3.1.1 SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.5	The time and frequency subsystem shall provide the timing signals (analog and digital) required by the SGSLR subsystems.	Functional performance requirement. All subsystems must have a common time & frequency source.

4.6.6	SLBP 3.7	The timing and frequency subsystem shall be capable of full control by the computer and software subsystem, and shall provide all relevant data to the computer and software system.	Required for remote/automated operations and for monitoring, decision making and transfer to the IGSOC.
4.6.7	SLBP 3.5 SLBP 3.6 SLBP 3.7	The time and frequency subsystem shall be able to accept external time and frequency sources.	Maintain ability to supply timing signals and check that timing is remaining accurate and for the ability to use centralized SGP site timing if available.
4.6.8	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.4 SLBP 3.5 SLBP 3.7	The time and frequency subsystem shall be capable of self-monitoring its frequency and timing pulses by comparison to an included independent GPS source.	Required to detect frequency and timing anomalies that would corrupt the accuracy of the normal point data and report them to the computer and software subsystem.
4.6.9	SLBP 3.7	The time and frequency subsystem shall be designed to support local, remote and fully automated operations.	Required for remote/automated operations
4.6.10	SLBP 3.7 SLBP 3.7.1	The time and frequency subsystem shall be capable of being placed into a "safe mode" in the event of an unexpected power failure.	Required for safety of the equipment
4.6.11	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.4 SLBP 3.5	The time and frequency subsystem shall meet its required performance within a 24 hour period of time from power on.	In order to maximize tracking data, the system warmup period must be minimized and predictable.
4.7		**Meteorological**	
4.7.1	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.7 SLBP 3.8	The meteorological subsystem shall measure wind speed and direction (average and gust), atmospheric pressure, temperature, relative humidity, visibility, precipitation, and cloud cover.	Meteorological information is necessary for accurate calibration of satellite ranging and is necessary to support automated decision making on weather parameters.
4.7.2	SLBP 3.4 SLBP 3.6	The Meteorological subsystem shall be designed to have a system downtime no greater than 0.6%, which consists of scheduled maintenance, MTBF and MTTR.	In order to support data volume requirements the system must minimize downtime

4.7.3	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.7 SLBP 3.8	The meteorological subsystem shall be capable of producing consistently accurate data within the operational range of -40 deg C to +50 deg C.	Must be able to support operations in a wide range of environmental extremes for both the safety of the system and accurate correction of the ranging measurements.
4.7.4	SLBP 3.4 SLBP 3.7	The meteorological subsystem shall be capable of survival between -50 deg C and +55 deg C.	Must be able to support operations and survive in a wide range of environmental extremes for the protection of the system.
4.7.5	SLBP 3.7	The meteorological subsystem shall provide environmental data when requested by the system software within a 60 s response time for all except precipitation and wind which require a 10 s response time.	Required to support automated decision making for ranging and the safety of the system.
4.7.6	SLBP 3.7	The meteorological subsystem shall be capable of full control by the SGSLR system software, and provide all relevant data to the system software.	To support remote/automated operations and for monitoring, decision making, and transfer to IGSOC.
4.7.7	SLBP 3.7	The meteorological subsystem shall be designed to support local, remote, and fully automated operations.	To support remote/automated operations and for monitoring, decision making, and transfer to IGSOC.
4.7.8	SLBP 3.7 SLBP 3.7.1	The meteorological subsystem shall be capable of being placed into a "safe mode" in the event of an unexpected power failure.	Required to support remote and automated operations, and decision making for system safety.
4.8		**Dome, Shelter, and Pier**	
4.8.1		Dome	
4.8.1.1	SLBP 3.4 SLBP 3.7.1	The dome and shutter shall protect the GTA and associated components from the elements and support system performance.	Required for safety of system and to support system performance.
4.8.1.2	SLBP 3.4 SLBP 3.6	The dome subsystem shall be designed to have a system downtime no greater than 2.1% (TBR), which consists of scheduled maintenance, MTBF and MTTR.	Reduced MTBF to maintain required normal point production and maintenance costs improve operational costs to the project.

4.8.1.3	SLBP 3.4 SLBP 3.7 SLF 3.1 SLF3.1.1	The dome subsystem shall be able to support operations in temperature between -40 deg C and +50 deg C, and wind speed of up to 18 m/s.	The SGSLR Network will be deployed all over the world using a common architecture. The dome must be able to handle conditions at the locations it is deployed to.
4.8.1.4	SLBP 3.7 SLBP 3.4	The dome subsystem shall be capable of survival at -50 deg C to +55 deg C and wind speeds up to 60 m/s.	The SGSLR Network will be deployed all over the world using a common architecture. The dome must be able to survive conditions at the locations it is deployed to.
4.8.1.5	SLBP 3.4 SLBP 3.7	The dome subsystem shall be designed to mitigate the effects of condensation.	Condensation may lead to leaking onto the telescope optics or onto/into the gimbal
4.8.1.6	SLBP 3.4 SLBP 3.7 SLBP 3.7.1	The dome subsystem shall keep precipitation from entering the interior of the dome with the shutter fully closed.	To protect the telescope and gimbal from moisture and particulates
4.8.1.7	SLBP 3.7	Environmental conditions inside the dome shall be available for monitoring by software.	System must have capability for remote monitoring and later control. Knowledge of environmental conditions within the dome is key to the identification of potential system problems before they occur or before they cause system failure.
4.8.1.8	SLBP 3.4 SLBP 3.7	The dome and shutter shall be capable of closed loop position control by the computer subsystem to an accuracy of 5 degrees (TBR).	To support remote/automated operations
4.8.1.9	SLBP 3.7	The dome subsystem shall be capable of full control by the SGSLR system software, and provide all relevant data to the system software.	Required for remote/automated operations and for monitoring, decision making, and transfer to IGSOC.

4.8.1.10	SLF 3.1 SLF 3.1.1 SLBP 3.4 SLBP 3.7	The dome shall be capable of being slaved to the Telescope and Gimbal subsystem to an accuracy of 5 degrees (TBR).	In order to be able to track satellites the dome and telescope must be paired to ensure transmit and receive success. The dome must be able to slew/track with the telescope, accurately, to ensure tracking success.
4.8.1.11	SLBP 3.4 SLF3.1 SLF 3.1.1	The dome and shutter shall allow the telescope and auxiliary equipment an unobstructed view of satellites and ground targets.	Must allow for unobstructed tracking of ground targets and satellite tracking up to +90 degrees elevation.
4.8.1.12	SLBP 3.6 SLBP 3.7.1 SLF 3.1 SLF3.1.1	The dome subsystem shall allow full telescope Az and El rotation with the shutter open or closed.	This will allow for full rotation of both axes for moving without restriction and for testing during inclement weather with the dome fully closed.
4.8.1.13	SLBP 3.7.1 SLBP3.6	The dome subsystem shall allow for manual control of the dome and shutter motors without the use of the system operational software.	To meet all safety requirements and to support maintenance.
4.8.1.14	SLBP 3.7.1 SLBP3.6	The dome shall be able to be rotated and the shutter opened/closed without the use of motors.	To meet all safety requirements and to support maintenance.
4.8.1.15	SLBP 3.7 SLBP 3.7.1	The dome subsystem shall be capable of being placed into a "safe mode" in the event of an unexpected power failure.	Required for remote/automated operations and to support the safety of the system.
4.8.1.16	SLBP 3.4 SLF 3.1 SLF3.1.1	The dome shall be capable of a minimum 20 deg/s (TBR) angular velocity.	In order to be able to track satellites the dome and telescope must be paired to ensure transmit and receive success. The dome must minimize any obstruction of the telescope when tracking and must minimize its impact on the telescope keyhole.
4.8.1.17	SLBP 3.7	The dome subsystem shall be designed to support local, remote, and fully automated operations.	Required for remote/automated operations and for monitoring, decision making, and transfer to IGSOC.
4.8.2		Shelter	

4.8.2.1	SLBP 3.4 SLBP 3.6 SLBP 3.7.1	The shelter shall be of suitable size and construction to support SLR operations, house system components, provide workspace for repairs, maintenance, and logistics, and provide a buffer from the environment.	The shelter would be of suitable size to house all components and provide some workspace for repairs, maintenance and to support operations of at least SLR.
4.8.2.2	SLBP 3.4 SLBP 3.6	The shelter subsystem shall be designed to have a system downtime no greater than 2.1% (TBR), which consists of scheduled maintenance, MTBF and MTTR.	Reduced MTBF and maintenance costs improve operational costs to the project and ensure that we meet data volume requirements.
4.8.2.3	SLBP 3.4	The shelter subsystem shall be capable of operation between -40 deg C and +50 deg C and wind speeds up to 18 m/s.	The shelter must be able to protect the equipment and personnel inside.
4.8.2.4	SLBP 3.4 SLBP 3.7 SLBP 3.7.1	The shelter subsystem shall be capable of survival and protection of the system equipment from -50 deg C to +55 deg C and in wind conditions of up to 60 m/s.	The shelter must be able to protect the equipment and personnel inside in conditions that may be harsh.

4.8.2.5	SLBP 3.4 SLBP 3.7	Environmental conditions inside the shelter shall be capable of being monitored and controlled by software.	System must have capability for remote monitoring and later control. Knowledge of key voltage, and meteorological conditions within the shelter is key to the identification of potential system problems before they occur or before they cause system failure.
4.8.2.6	SLBP 3.7	The lights, cameras, communications, and power of the shelter shall be capable of being monitored and controlled by software.	Required for remote/automated operations and for monitoring, decision making, and transfer to IGSOC.
4.8.2.7	SLBP 3.7.1	The shelter roof shall be capable of supporting the dome dead load of 3000 pounds; a uniform live load of 50 pounds per square feet (psf) (TBR) or a concentrated live load of 1000 pounds over 12 inch x 12 inch area (TBR)	To ensure operations and maintenance, the shelter must be able to support the weight of the dome, any equipment, and personnel on the roof without sagging/breaking/failure. Failure to support these could result in damage to the equipment below and or the safety of those within the shelter
4.8.2.8	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.7.1	The shelter shall be partitioned to allow for separate environmental conditions and safety considerations.	To keep sensitive components/subsystems clean and at a highly controlled temperature which will support the data stability and quality.
4.8.2.9	SLBP 3.7 SLBP 3.7.1 SLBP 3.6 SLBP 3.1 SLBP 3.2 SLBP 3.3	The shelter shall be sealed to prevent contamination to the shelter interior.	To keep sensitive components/subsystems clean and at a highly controlled temperature which will support the data stability and quality.
4.8.2.10	SLF 3.1 SLF 3.1.1	The shelter floor and roof shall provide openings for the telescope and telescope support structure.	Functional requirement to allow the telescope to reside on the roof of the shelter and the pier to go into the ground through the shelter floor without being vibrationally attached to floor.

4.8.2.11	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.4	The shelter shall be physically isolated from the telescope and telescope support structure to provide an isolation efficiency of 95% (TBR).	Allow for vibrational isolation of the GTA, pier and riser
4.8.2.12	SLBP 3.7 SLBP 3.7.1	The shelter subsystem shall have the capability to monitor security and emergency conditions and report to the software subsystem.	Required to meet NASA safety
4.8.2.13	SLF 3.1 SLF 3.1.1 SLBP 3.7.1	The shelter power shall be sufficient to supply the 30 kilowatts total for 3 phases needed to operate the system with margin.	Required to provide power distribution for the other subsystems
4.8.2.14	SLBP 3.7.1	The shelter subsystem shall provide a suitable ground for safety and system performance.	Required to meet NASA safety and system performance
4.8.2.15	SLBP 3.7.1	The shelter subsystem shall provide conditioned power to operational equipment.	Protect equipment against surges, sags, phase drop, spikes, and power loss.
4.8.2.16	SLBP 3.7.1	The shelter subsystem shall mitigate lightning damage.	Protect equipment from damage.
4.8.2.17	SLBP 3.7	The power provided to the shelter subsystem shall be capable of monitoring by the SGSLR system software.	Required for remote/automated operations and for monitoring, decision making, and transfer to IGSOC.
4.8.2.18	SLBP 3.7	The power provided by the shelter subsystem shall be capable of monitoring and control by the SGSLR system software.	Required for remote/automated operations and for monitoring, decision making, and transfer to IGSOC.
4.8.2.19	SLBP 3.7.1	The shelter subsystem shall provide fiber optic cable interface for all equipment and data connections external to the shelter.	To minimize damage due to lightning strikes

4.8.3		Pier and Riser	
4.8.3.1	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.4 SLBP 3.7.1 SLBP 3.8 SLF 3.1 SLF3.1.1	The pier and riser shall be constructed to rigidly support the GTA while maintaining the optimum performance of the GTA. Fundamental frequency is greater than or equal to 80 Hz (TBR).	The pier and riser must be able to support the telescope and gimbal and maintain stability.
4.8.3.2	SLF 3.1 SLF 3.1.1	The pier and riser shall be constructed to support the Coude path to the optical bench.	Light needs to get to the optical bench from the telescope.
4.8.3.3	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.4 SLBP 3.8 SLF 3.1 SLF 3.1.1	The pier shall have > 95% (TBR) vibration isolation efficiency from the shelter and its pad.	The telescope and gimbal must be vibrationally isolated from the shelter and the system pad to maintain optical stability.
4.8.3.4	SLF 3.1 SLF 3.1.1	The riser shall be designed to include a leveling mechanism for the GTA with a +/- 2 arc seconds accuracy.	To allow the GTA azimuth rotation to match horizontal.
4.9		Computer and Software	
4.9.1	SLBP 3.7	The computer and software subsystem shall be designed to support (a) local operations, (b) remote operations, and (c) fully automatic operations with no human present on site but with remote monitoring of the system.	Future SGP budgets will require much lower operating costs than now. To do this will require more automation, however, an operator must always be able to take control of the system.
RAT Operations			
4.9.2	SLBP 3.7	Remote Access Terminal (RAT) shall include a user interface to allow both local and remote access to the data generated by the system.	RAT is the human interface to the system both for control and for system monitoring. This should be possible for operators at the station as well as across the world.

4.9.3	SLBP 3.7	RAT shall maintain a display of critical subsystem and operational parameters accessible to both local and remote users.	The operator needs to have easy access to viewing critical parameters when operating the system.
4.9.4	SLBP 3.7	Remote Access Terminal (RAT) client and server software shall be able to manage at least two (TBR) internet connections.	Multiple RAT GUIs need to be able to connect to the system for viewing, although only one can have control at a time. A single laptop in the IGSOC will need to control multiple SGSLR stations at the same time.
4.9.5	SLBP 3.7 SLBP 3.7.1	Remote Access Terminal (RAT) software shall allow remote and local control of operations and of operating parameters such that there is no effect on the health and safety of the system or surrounding environment (e.g., aircraft avoidance).	The system health and safety, including all human and equipment safety inside and outside of the shelter, must be maintained during all modes of operations. The software will not override any hardware safety function.
Computer Hardware			
4.9.6	SLBP 3.4	Any computers requiring deterministic timing shall have a real-time operating system with a known latency that is < 100 microseconds.	Because of hard real-time hardware interfaces the OS must be deterministic.
4.9.7	SLBP 3.4 SLBP 3.6	The computers selected shall have backplanes that can support the types of interfaces (serial, USB, Ethernet, parallel) and number of cards required for the SGSLR subsystems.	Subsystem must be able to interface to all of the SGSLR hardware.
4.9.8	SLBP 3.4	The computer subsystem shall have > 4 GB (TBR) memory, > 2 GHz (TBR) CPU, and > 500 GB (TBR) drive space capacity.	Subsystem must be sized to handle the tracking, data processing, and data volume.
4.9.9	SLBP 3.4 SLBP 3.6	The computer subsystem shall be designed to keep down time to less than 2.55% (TBR) on average over a year.	Data collection must be maximized. Down time includes scheduled maintenance, MTBF, MTTR and required reboot.
4.9.10	SLBP 3.7 SLBP 3.4	The software shall be capable of running successfully in an independent operational state for > 7 days (TBR) .	System will eventually be fully automated and must operate for days with no human intervention.

4.9.11	SLBP 3.6 SLBP 3.7 SLBP 3.4	The computers shall have the capability of sharing data.	Information is collected by various computers, but all of the computers need information collected from other computers to perform their required functions - both for decision making as well as for generation of the science data product.
ILRS Specifications			
4.9.12	SLF 3.1 SLF 3.1.1 SLBP 3.4 SLBP 3.7	The software shall be capable of processing satellite, ground calibration, and star calibration data.	Satellite data is the science product of the system. Ground calibration data and star calibration data are needed to calibrate the system and produce an accurate science product.
4.9.13	SLBP 3.7.2	The software shall be capable of handling the ILRS predictions for tracking satellites.	As part of the ILRS, the SGSLR systems must be able to handle predictions in the ILRS format.
4.9.14	SLBP 3.7.2	The software shall follow the ILRS procedure for handling leap seconds.	Leap seconds can occur twice a year and must be handled properly.
4.9.15	SLBP 3.7.2	The software shall be capable of generating science data in the ILRS formats.	As part of the ILRS, the SGSLR systems must be able to generate the data products in the ILRS format.
4.9.16	SLBP 3.7.2	The software shall comply with all ILRS restricted tracking requirements.	As part of the ILRS, the SGSLR systems must be able to track most of the targets, this includes tracking targets that have restrictions on their tracking. The ILRS requires that stations follow the mission tracking restrictions.
4.9.17	SLBP 3.7.2 SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.8	The software shall follow ILRS guidelines for normal point formation.	As part of the ILRS SGSLR must standardize to their processes.
Data Product Transmission (Normal Point)			
4.9.18	SLBP 3.4 SLBP 3.7 SLBP 3.7.2	The software shall be capable of transmitting the SLR data products in the timeframe specified by the ILRS.	ILRS requested timeframe for delivery of data. For rapid analysis review of data this is needed. Rapid analysis gives semi-real-time performance indicators for stations which allows quicker response by SGP to performance problems.
Error Handling			

4.9.19	SLBP 3.7 SLBP 3.4	The software shall be capable of handling error conditions, logging them locally and making them accessible to remote user(s).	When errors occur in an automated system they must be handled to avoid the program/system crashing and prevent erroneous results in the science product. Reporting error conditions can reduce down time in the system.
Computer & Software Communications w/ Hardware Subsystems			
4.9.20	SLF 3.1 SLF 3.1.1 SLBP 3.7	The computer & software subsystem shall interact with all of the hardware subsystems.	The computer and software subsystem controls the automated SGSLR system, and provides the interface to the user and/or to the IGSOC.
4.9.21	SLBP 3.4	The time critical software tasks shall run in a real-time environment, and finish in specified time intervals associated with each task.	Time critical tasks need to start when required and finish without over-running their time slot. Otherwise all of the functions they need to perform will not happen at the right time with respect to the hardware, and if the tasks over-run the required functions will not get completed.
4.9.22	SLF 3.1 SLF 3.1.1 SLBP 3.4	The computer hardware shall be capable of generating timing interrupts and the software shall be capable of handling the interrupts.	Time critical functions in real-time systems are best initiated by timing interrupts.
4.9.23	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.5 SLBP 3.8	The software shall be capable of handling the time tagging of the data to provide the Normal Point range measurement time with < 0.1 microsecond (TBR) time tags.	The fire and satellite return time tags are used to form SGSLR's primary science product and must satisfy the resolution, stability and accuracy requirements.
4.9.24	SLBP 3.1 SLBP 3.2 SLBP 3.3 SLBP 3.8	The software shall be capable of combining the data acquired from the hardware to construct the range measurement in a manner which provides the Normal Point range precision and stability required for LAGEOS ranges.	To satisfy the science (ITRF) requirements
System Logging and IGSOC			

4.9.25	SLBP 3.7	The software shall record data, activities, events and report status and error information to the IGSOC on defined intervals.	Automated and remotely controlled systems need feedback to remote monitors
4.9.26	SLBP 3.7	The software shall be capable of sending alerts and warnings immediately to the IGSOC and selected personnel.	Automated and remotely controlled systems need to alert humans when the system has issues (errors or alarms).
NASA IT Security			
4.9.27	SLBP 3.7.1 SLBP 3.4	The computers and software shall adhere to NASA's IT Security policy (NPR 2810.1a Security of Information Technology).	All NASA computer systems must adhere to NASA IT Security policy.
Computer Receiving Star and Sky Images			
4.9.28	SLBP 3.7 SLF 3.1 SLF 3.1.1	The software shall be capable of receiving star and sky image data from the camera systems and transferring them to the IGSOC.	Star images are needed to perform star calibrations. Mount camera is needed to monitor where telescope is pointing.
4.9.29	SLBP 3.7 SLF 3.1 SLF 3.1.1	The software shall be capable of processing star images to generate star centroids for star calibrations, and sky images to generate cloud cover for sky clarity determination.	Star and Sky images need to be analyzed (processed) before their information can be used.
Monitoring			
4.9.30	SLBP 3.7	The computers shall be capable of receiving and monitoring status information from the subsystems.	An automated system needs the software to monitor all subsystems.
4.9.31	SLBP 3.7 SLBP 3.4	The software shall be capable of determining each subsystem's status and determining the overall system status.	The software must get enough information from each subsystem and it must be able to interpret the information to determine the subsystem status.
Backups			
4.9.32	SLBP 3.4	The software shall have an automatic backup procedure for system and data recovery.	The system state needs to be captured at regular periodical intervals. Included in the backups should be the software and the input databases and recent output data.

Tracking, Star Cals, Ground Cals, Star Assessment			
4.9.33	SLF 3.1 SLF 3.1.1 SLBP 3.4 SLBP 3.7 SLBP 3.7.2	The software shall be capable of command and control of the system 24/7, to perform satellite tracking and ranging, for a majority of the ILRS list of active satellites, when conditions permit.	The software must be able to operate the system in a fully automated manner but also handle commands from the IGSOC whenever they are sent.
4.9.34	SLF 3.1 SLF 3.1.1 SLBP 3.2 SLBP 3.3 SLBP 3.4 SLBP 3.7 SLBP 3.8	The software shall be capable of performing ground calibrations 24/7 when conditions permit.	Same rationale as above.
4.9.35	SLF 3.1 SLF 3.1.1 SLBP 3.4 SLBP 3.7	The software shall be capable of performing star calibration 24/7 when conditions permit.	Same rationale as above.
4.9.36	SLF 3.1 SLF 3.1.1 SLBP3.4 SLBP 3.7	The software shall be capable of performing star assessments 24/7 when conditions permit.	Same rationale as above.
Automation			
4.9.37	SLBP 3.7 SLBP 3.4	The software shall be able to control operations by making decisions based on weather, sky clarity, pointing bias, and system and subsystem monitoring.	An automated SLR system must be able to change its targets based on the sky clarity, its pointing based on receiver inputs, and must be able to protect itself from harmful weather.

4.9.38	SLBP 3.7 SLBP 3.7.2 SLBP 3.4	The software shall be capable of automatically following the daily SGSLR schedule, including satellite passes, scheduled ground calibration, scheduled star calibration, and routine maintenance.	In order to ensure that all ILRS satellites get tracked as needed, the ILRS priority list is used to generate an SLR schedule for each station. The schedule also includes required calibrations and routine maintenance.
4.9.39	SLBP 3.7 SLBP 3.4	The software shall be capable of making real-time changes to the tracking schedule based on system information, real-time information from the VLBI antenna and external input from the IGSOC.	A fully automated SLR system must be able to compensate for issues that arise, continually working toward maximizing the data collection.
Diagnostics/Simulations			
4.9.40	SLBP 3.7 SLBP 3.6	The computer and software subsystem shall allow for diagnostic control and simulation both locally and remotely.	Because these systems will be remote from the more expert engineering support, simulations and diagnostic tools will be needed to support diagnosing and determining the source of problems.
System Protection			
4.9.41	SLBP 3.7.1	The software shall not be able to override the laser safety subsystem.	The hardware must have control of the laser safety.
4.9.42	SLBP 3.7 SLBP 3.7.1	The software shall check that all conditions are nominal before requesting the laser to fire.	This adds one final layer of checking before firing.
4.9.43	SLBP 3.7 SLBP 3.7.1	The software shall operate in a manner to protect any nearby VLBI antenna from the SLR radar.	VLBI can be damaged by the SLR radar. There will be handshaking that will take place between then two systems to ensure that the VLBI signal chain does not get damaged.
4.9.44	SLBP 3.7 SLBP 3.7.1 SLBP 3.4	The software shall be capable of making decisions and taking action to protect the system.	With no human on site the software must take the action to protect the system from damage.
4.9.45	SLBP 3.7 SLBP 3.7.1	The software shall be capable of restricting lasing in certain exclusion areas at, or near, the ground, through the use of a mask.	A mask is often used in SLR systems to keep the laser from firing at objects near the ground (buildings, towers, etc.).

4.9.46	SLBP 3.7 SLBP 3.7.1 SLBP 3.4	The software shall be capable of protecting the system from erroneous user input.	The system must be capable of protecting itself by rejecting inputs from the user via RAT, or commands from the IGSOC that cause error conditions, that may cause the system damage, or that could compromise safety.
Schedule			
4.9.47	SLBP 3.7	The software shall be capable of accepting a schedule generated by the IGSOC or generating a satellite prioritized schedule onsite.	SGSLR requires a daily schedule in order to operate.
Configuration			
4.9.48	SLBP 3.7 SLBP 3.4	The software shall be capable of site specific and target specific configurations.	Each site will be unique and each target could have unique characteristics.
4.9.49	SLBP 3.7 SLBP 3.4	The software shall be capable of setting system configurations for optimum return rates, including blanking, PRF, ND wheels, time & pointing bias, beam divergence and TBD.	A fully automated SLR system must be able to perform optimization in order to get the data quality and quantity required.