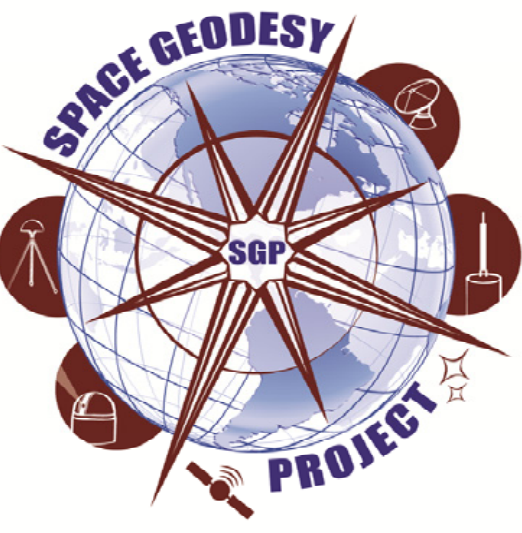


Automating NASA's Space Geodesy Satellite Laser Ranging (SGSLR) System



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ABSTRACT: Following the successful performance verification of NASA's Next Generation SLR (NGSLR) prototype system, NASA plans to build and deploy two Space Geodesy Satellite Laser Ranging (SGSLR) Systems within the next few years. These new systems will use much of the software already developed and tested on the NGSLR. While many aspects of system automation were built into the NGSLR, more development is necessary to fully complete SLR system automation. In particular, software and subsystems will be added or upgraded that will close the tracking loop, manage and monitor the system health and safety, and make operator decisions all without human intervention. This poster will present the SGSLR system automation plans.

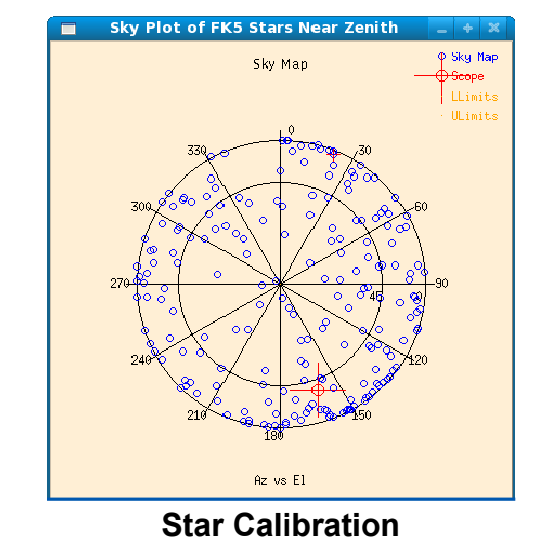
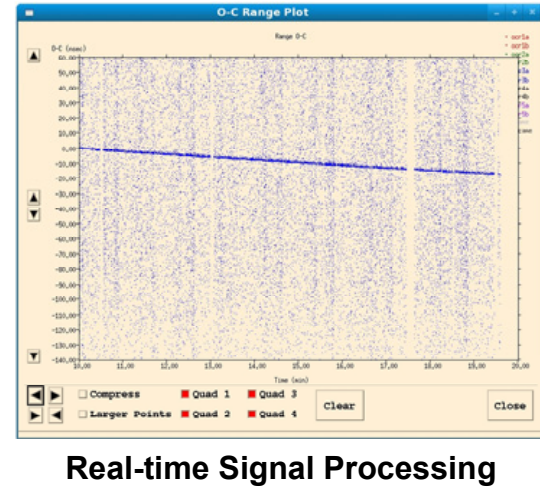
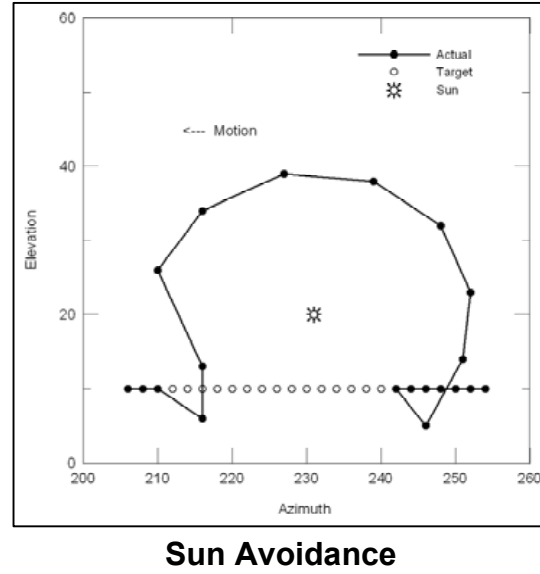
Introduction

NASA's Next Generation Satellite Laser Ranging (NGSLR) system, located at the Goddard Space Flight Center, was designed in the mid-1990's and was originally intended for fully automated, eye-safe SLR operations. As the NGSLR requirements were modified for increased levels of performance and GNSS daylight tracking, focus was shifted to upgrade the system to produce the type of performance that is required for today's International Terrestrial Reference Frame (ITRF). Full automation was never realized for NGSLR, but due to the detailed design and significant efforts of the NGSLR hardware and software engineers, the future NASA SLR systems will be developed to be capable of fully automated operations.

NGSLR Demonstrated Automation

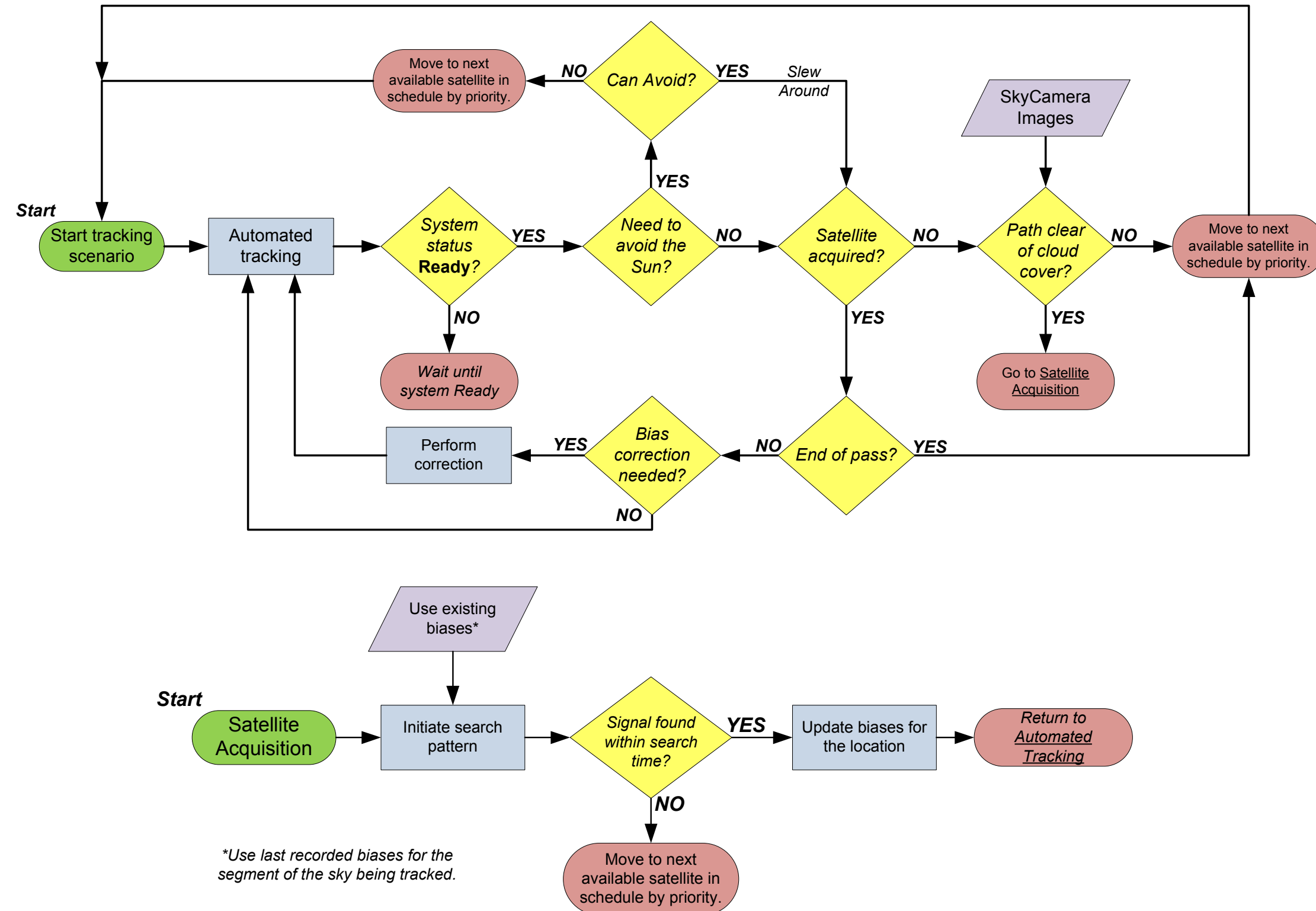
Although full automation was not achieved in NGSLR, many automation features were demonstrated during and after the NGSLR / MOBLAS-7 collocation, and will be implemented on NASA's SGSLR systems. Other automation features, although never fully proven, were designed and integrated into the NGSLR system. Automated cloud decisions, satellite search, and operator decisions were coded in NGSLR, but never verified and utilized.

- Data Delivery and Reception** – NGSLR automatically and routinely collects all data necessary for satellite tracking, including the satellite prioritized schedule, predictions and any restricted tracking information. It is also designed to automatically deliver the International Laser Ranging Service (ILRS) post-processed normal point data, the daily meteorological data, and the daily timing data.
- Star Calibration** – Software automatically selects 50 spatially distributed stars in the night sky to calibrate the NGSLR mount.
- Telescope Pointing** – The telescope is automatically pointed using prediction interpolation. The very narrow beam divergence and the narrow field of view of the receiver in NGSLR requires the point ahead / look behind feature for acquiring satellites. A Risley prism pair automatically steers the laser up to 11 arcseconds ahead along track.
- Aircraft Avoidance** – The radar based Laser Hazard Reduction System (LHRS) monitors the airspace surrounding the transmitted laser beam for aircraft. The Laser Safety Subsystem automatically inhibits the laser when an aircraft is detected within 3° of the beam.
- Real-time Signal Processing** – Using returns from within the range window, the real-time software distinguishes signal from noise. The signal determination is used for the search routine and is flagged to assist in the post processing of the data.
- Post Processing** – The software filters observations within a predetermined time/range of the flagged data from the real-time signal processor. Noise suppression is performed and the remaining observations are smoothed and filtered using a sigma multiplier to generate the normal points.
- Satellite Selection** – Tracking is directed and coordinated using a schedule based on the ILRS priority list. Should the primary target be unavailable, other lower priority satellites can be automatically selected based on their position within the tracking hierarchy. SGSLR satellite selection will include the newly adopted normal point algorithm for interleaving after achieving mm precision.
- Sun Avoidance** – Avoidance functionality is embedded in both the scheduling and tracking software to provide redundant layers of protection for the system.
- Automated Ground Calibration** – Transmission of the laser energy is automatically attenuated, accounting for visibility conditions to the ground target, to produce the desired return rates for single photon detection, as well as to meet eye safety requirements.



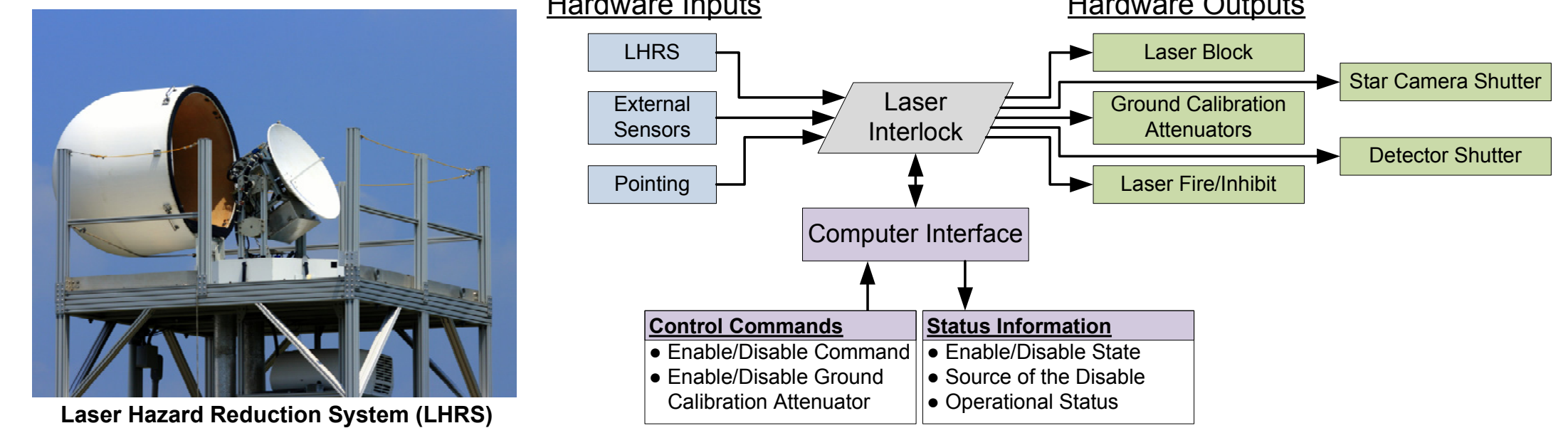
Automated Operations

Automated operations requires a delicate balance of multiple threads for polling, decision making, sub-system coordination, and system checks. The following flow diagram shows the basic steps for automated SLR operations at SGSLR.



Automation of Laser Safety

Automated safety and system protection features have been integrated into the design of SGSLR to protect personnel and equipment. The Laser Safety Subsystem is tasked with preventing accidental exposure to the transmitted laser beam. At the core of the system is the Laser Interlock, which inhibits the firing of the laser and controls devices on the optical bench to physically block and attenuate the transmitted beam, dependent on the status of safety sensors or on commands from the software system. These sensors include laser disable signals from the Laser Hazard Reduction System (LHRS), an activated stair or door sensor. The design also includes shutters for the detector and the Star Camera to prevent damage to these delicate components. The SGSLR system will include automation for laser re-enable after the aircraft has cleared the radar field of view, pending FAA approval in the USA.



Completing the Automation for SGSLR

Building upon what has been completed and tested in the NGSLR system, the implementation of SGSLR will finalize the automation process. Several key areas remain to be completed including:

- Automating Operator Decisions** – This involves the automation of basic functions normally performed by an operator. This includes satellite return optimization, system health and safety decisions, Az/EI & Time bias search, laser performance monitoring, and the ability to re-enable the laser after a hazard condition is detected.
- Closed Loop Tracking** – The receiver system provides spatial information that allows the software to perform and record small bias corrections during tracking. This allows the tracking system to optimize the signal.
- Satellite Search** – If sky conditions are clear enough for satellite tracking, but the system isn't receiving satellite returns, the system will automatically begin a search for the satellite, incorporating the recorded system bias to determine where the search will begin.
- System / Subsystem Monitoring (Alerts and Notification)** – System / subsystem status and alert messages are relayed to an operations center where the station can be monitored for any maintenance and data quality issues. Emergency alerts are sent directly to key personnel to direct immediate attention to any possible safety and system emergencies.
- Weather and Inclement Conditions** – SGSLR will monitor existing weather conditions to support system tracking and protect the system from damage. When conditions are outside the normal expected ranges, the system will suspend operations and shut the dome until the environment is within tracking specifications.

Operations Schedule

Prediction information downloaded from CDDIS is used to form an SGSLR Operations Schedule, which interleaves ground calibrations and satellite passes. Star calibrations will be scheduled as needed.

Automated Operations

The system automatically switches between System Modes. While in a System Ready state, the system may continue with, or proceed to, any of the automated System Modes. If the system violates any of the conditions for system readiness, the software will either clear the condition, move to another automated mode, send a notification or alert, or perform a system shutdown. System readiness is checked once per second.

Conditions for System Ready Status

- Laser Safety Clear**
- No disable signal from LHRS, door and stair sensors
 - All safety devices working within specifications
- Weather Conditions Nominal**
- Temperature, barometric pressure, and wind-speed within acceptable range
 - No precipitation
- System State Nominal**
- All sub-systems working nominally

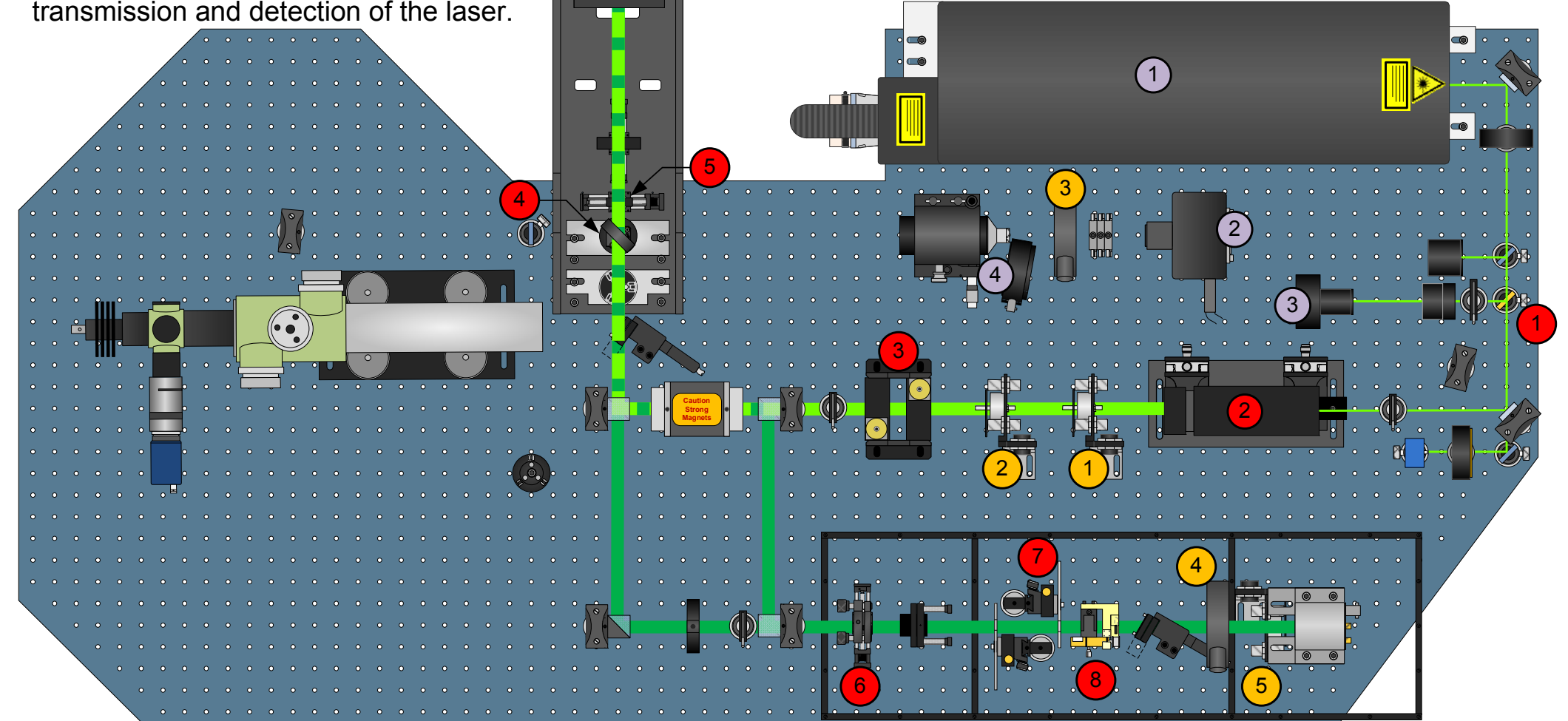
System Modes

- Ground Calibration Mode**
- Performs ranging to a ground target to measure system delay
 - Laser out of the telescope is attenuated to meet system dynamic range / eyesafe requirements
 - ND wheels are used to attenuate signal to single photon level
- Satellite Tracking Mode**
- Using the provider predictions, the system tracks sets of satellite passes following the prioritized operational schedule
 - Automated beam divergence to achieve single photon levels
- Star Calibration Mode**
- System verifies telescope/gimbal pointing by centering up to 50 stars and recording biases
 - Performed during nighttime operations based on bias value/system performance
- Standby/Maintenance Mode**
- Places telescope in stow
 - Places all subsystems in standby

Automation of Optical Bench

The optical bench maintains the position, spacing, and alignment of all the optical components before the coelostat. Devices include the laser head, turning mirrors, lenses, prisms and other similar items related to the transmission and detection of the laser.

Select devices on the optical bench have been automated and are controlled by the system software to allow autonomous operation. See the diagram at right for the placement and control of these components on the Optical Bench.



Optical Bench Automation

- 1 Power Head Insertion Mirror
- 2 Beam Expander
- 3 Risley Prisms
- 4 Star Camera Insertion Mirror
- 5 Corner Cube
- 6 Band Pass Filter
- 7 ND Wheels
- 8 Field of View Iris

Laser Interlock Automation

- 1 Ground Calibration Filter
- 2 Beam Block
- 3 Star Camera Shutter
- 4 Detector Shutter
- 5 Detector ND Filter

Other Automation

- 1 Laser (Control & Status)
- 2 Star Camera (Data Collection)
- 3 Power Head (Data Logging)
- 4 Beam Profiler (Data Logging)

Automated Production of Data Product

The SGSLR post processing software performs noise filtering, post tracking data processing and analysis, creation of data products, and data product delivery. Satellite data is stored until post ground calibration data has been processed. The software will then process the raw data files in the time order of their creation, and submit them for delivery.

