



SGSLR

Space Geodesy Satellite Laser Ranging

Designing NASA's next generation SLR stations with the goal of full automation

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Abstract



NASA's Space Geodesy Project's (SGP) next generation network will include newly designed Very Long Baseline Interferometry (VLBI) and Satellite Laser Ranging (SLR) systems. The Space Geodesy Satellite Laser Ranging (SGSLR) systems are the SLR components of this network. The goal of the SGSLR design is to achieve millimeter level accuracy and stability in the ranging measurement and eventual autonomous operation. Full automation is achieved via both hardware and software, and there is virtually no subsystem in SGSLR whose design is not affected by the requirement for automation. We will present the aspects of the SGSLR design driven by these requirements, our plans for fulfilling the requirements, and the phased approach to full automation. In addition, we will discuss the SGP network plans for global monitoring of the stations from a single location as well as present the current status of the SGSLR system builds.



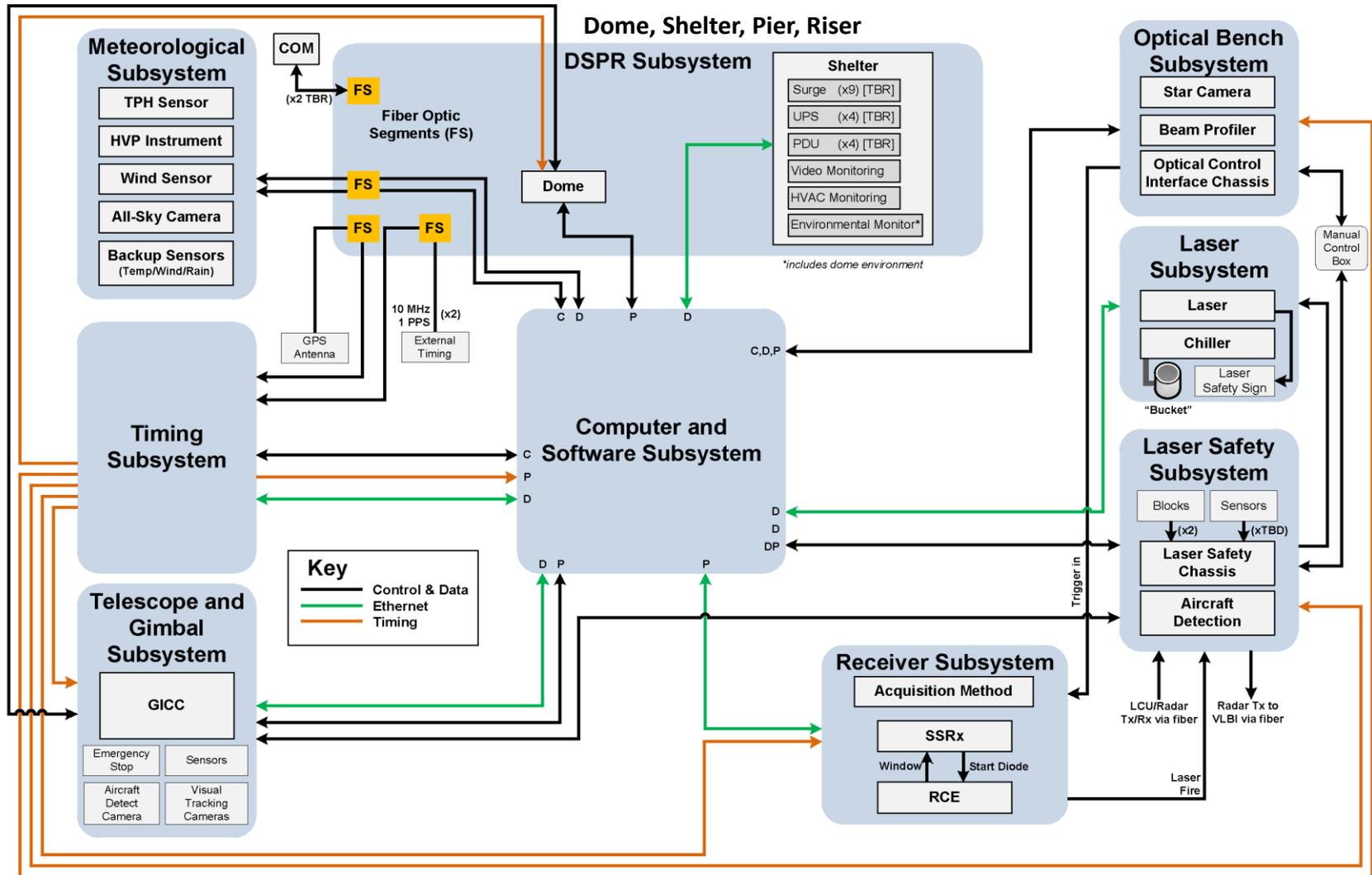
Key SGSLR Requirements



- ◆ LAGEOS NPT data precision < 1.5 mm over month.
- ◆ LAGEOS NPT range bias stability < 1.5 mm over hour.
- ◆ LAGEOS NPT range bias stability < 2 mm over year.
- ◆ SGSLR systems shall not introduce any unquantified biases into the legacy SLR Network.
- ◆ Systems must be capable of producing an annual data volume of 45,000 LEO, 7,000 LAGEOS and 10,000 GNSS NPTs.
- ◆ Systems must be capable of local and remote operation by an operator with a path to full automation.



Simplified SGSLR System Block Diagram





SGSLR's 9 Major Subsystems



- **Timing & Frequency**
 - GPS tie to USNO 30ns RMS
 - Distribute IRIG-B, 10MHz, 1pps
 - 2nd GPS receiver for timing health
- **Meteorological**
 - Pressure, Temperature, Humidity for data quality
 - Horizontal Visibility, Precipitation, Wind, Sky Clarity for automation
- **Telescope and Gimbal (GTA)**
 - Aircraft Detection Camera - Visual aid
 - Visual Tracking Cameras - Diagnostic
 - Temp sensors and accelerometers
- **Optical Bench**
 - Transmit path, Receive path, Star Camera, Motion Control
- **Laser**
 - Low energy, Short pulse, High stability, High repetition rate
- **Laser Safety**
 - NASA/ANSI compliant, Failsafe, Redundant, Highly responsive
 - Aircraft protection is site dependent
- **Receiver**
 - Range Control Electronics (RCE) – Precision gating
 - Range Receiver – Precise signal timing
 - Acquisition Method – Adjustable FOV
- **Dome, Shelter, Pier, Riser (DSPR)**
 - Minimize wind/sun loading, Clean/Stable environment, Stable/Protected power, Lightning protection, Ridged/Solid foundation
- **Computer and Software**
 - Ties all subsystems together for manned, remote, and automated operations

Hardware Designed for Automation as well as Performance



Timing Subsystem

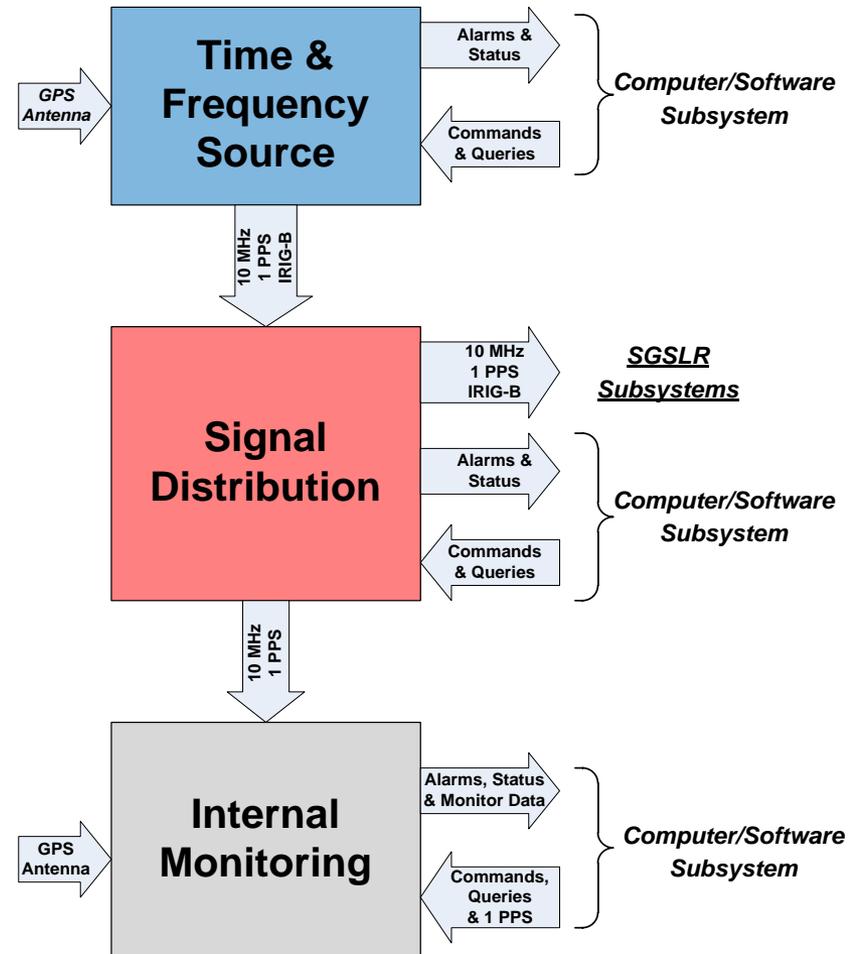


Timing Subsystem performs internal monitoring with independent timing equipment and reports results to the software.

- Rubidium oscillator steered to USNO by GPS
- 10 MHz, 1PPS, IRIG-B (DCLS)
- Status/alarm information

- Multiple isolated/buffered outputs for each signal
- Status/alarm information

- 1PPS compared to independent GPS reference
- Provides data for analysis
- Status notification

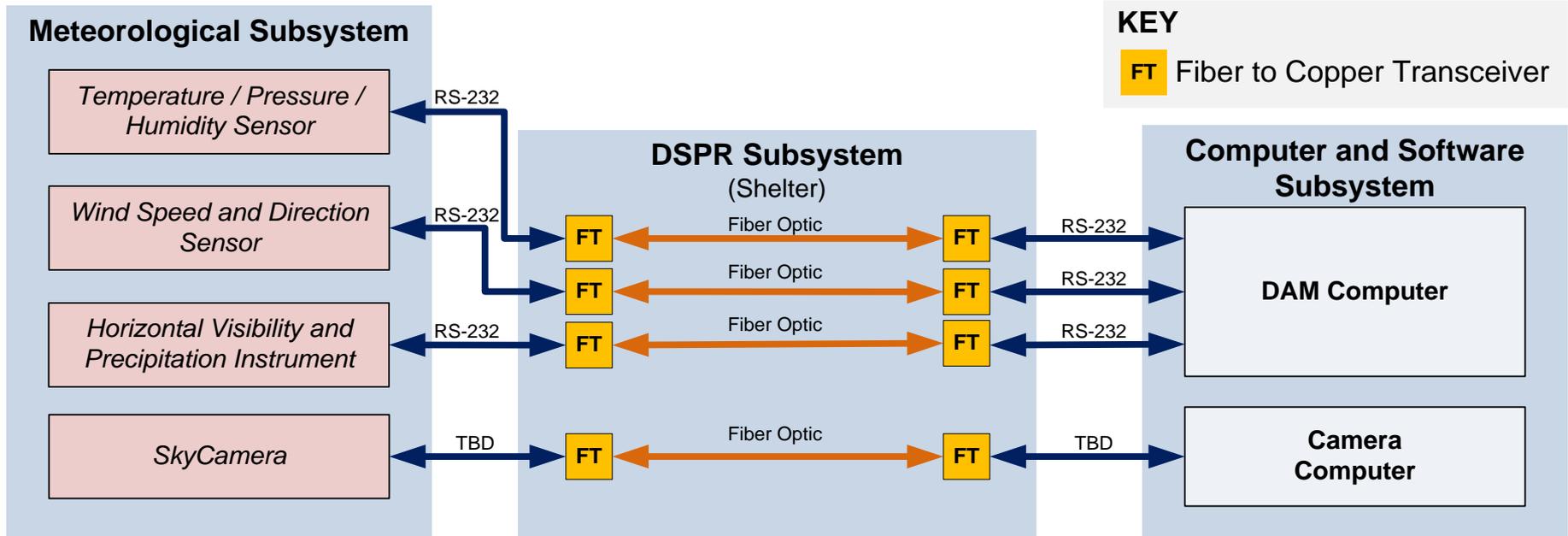




Meteorological (MET) Subsystem



MET subsystem provides information to correct the range data but also provides information needed for the system to protect itself from weather, to determine if and where the sky is clear enough to track.

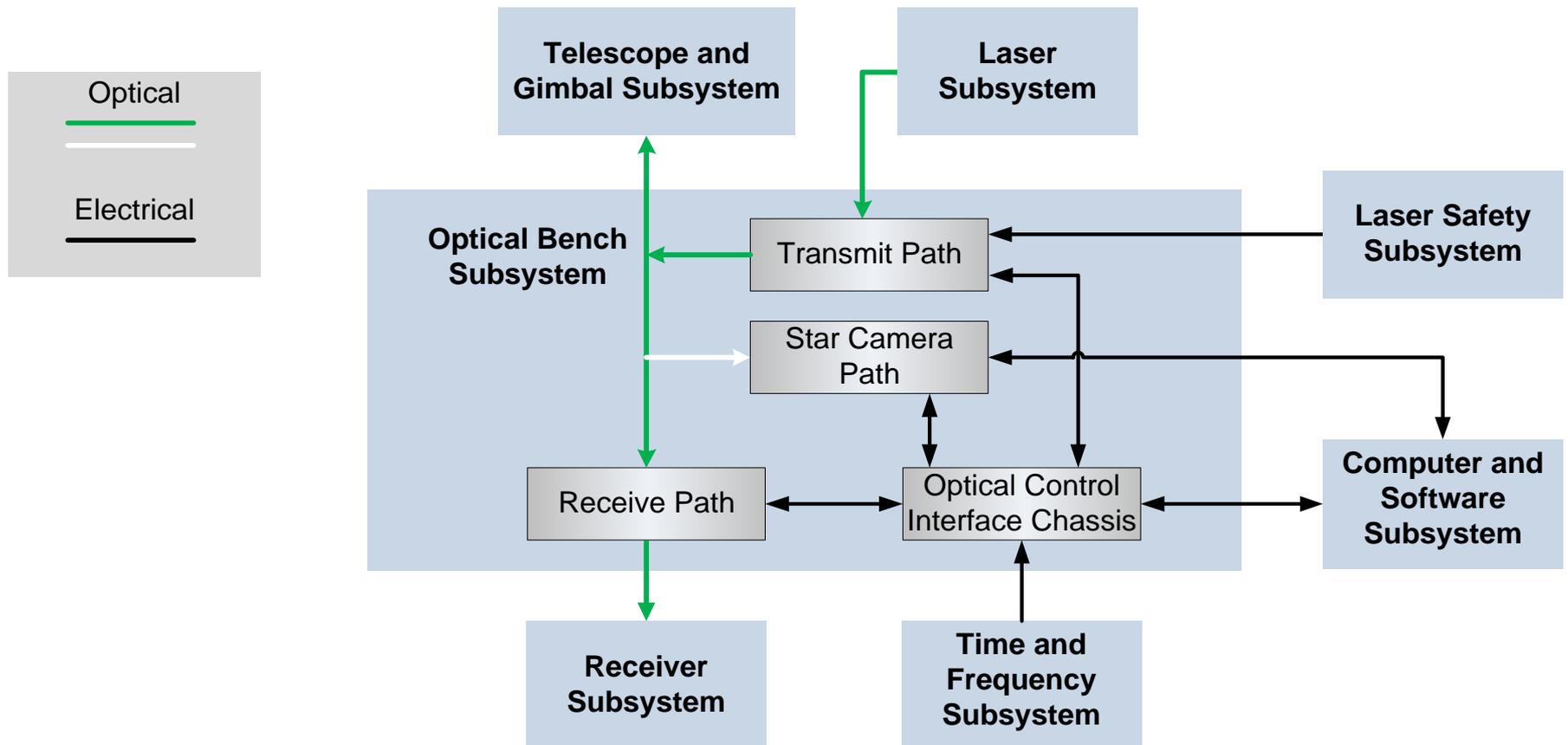




Optical Bench Subsystem



Optical Bench is completely configurable by the software for all operational modes (satellite tracking, star calibration, ground calibration).

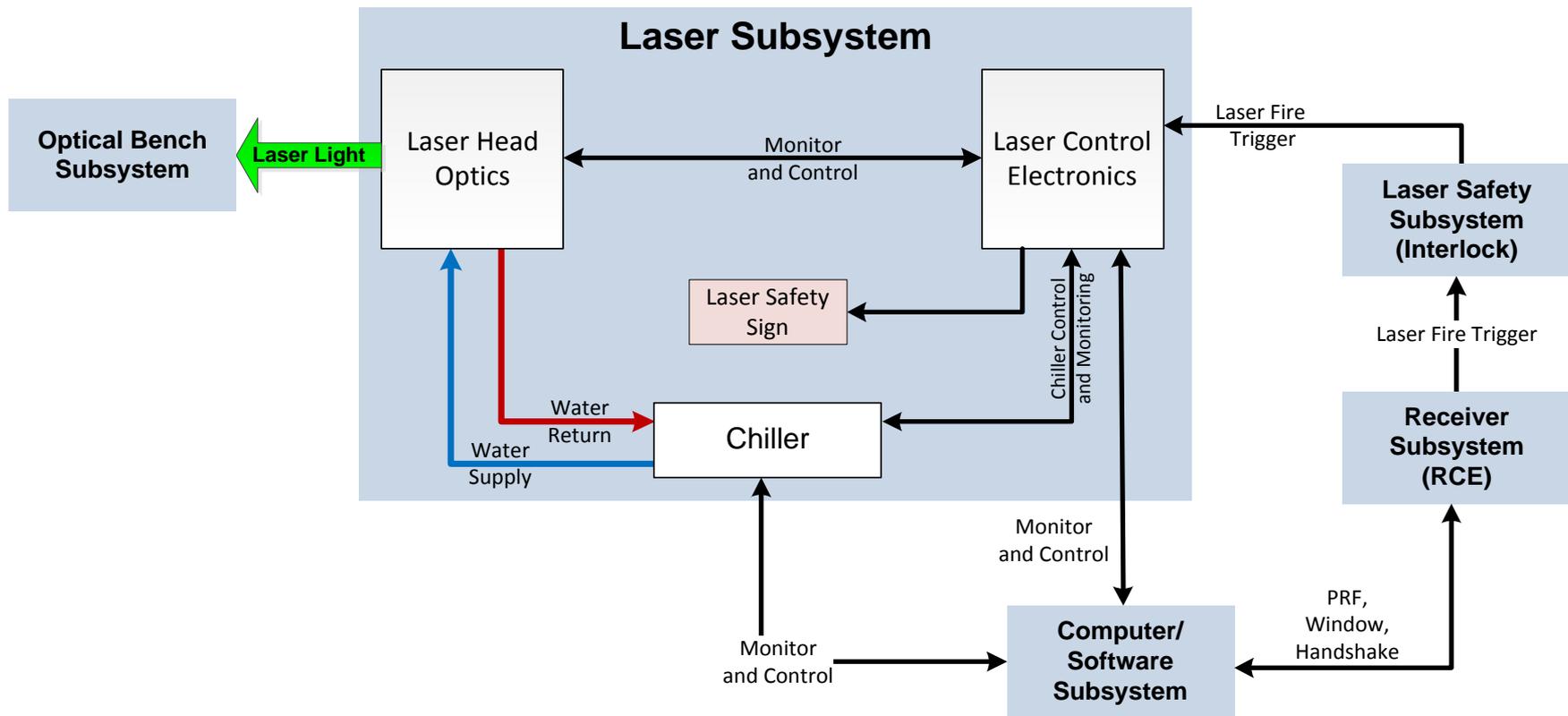




Laser Subsystem



Laser will be powered up, monitored and configured by the software. Laser fire trigger provided via Ranging Control Electronics from software.

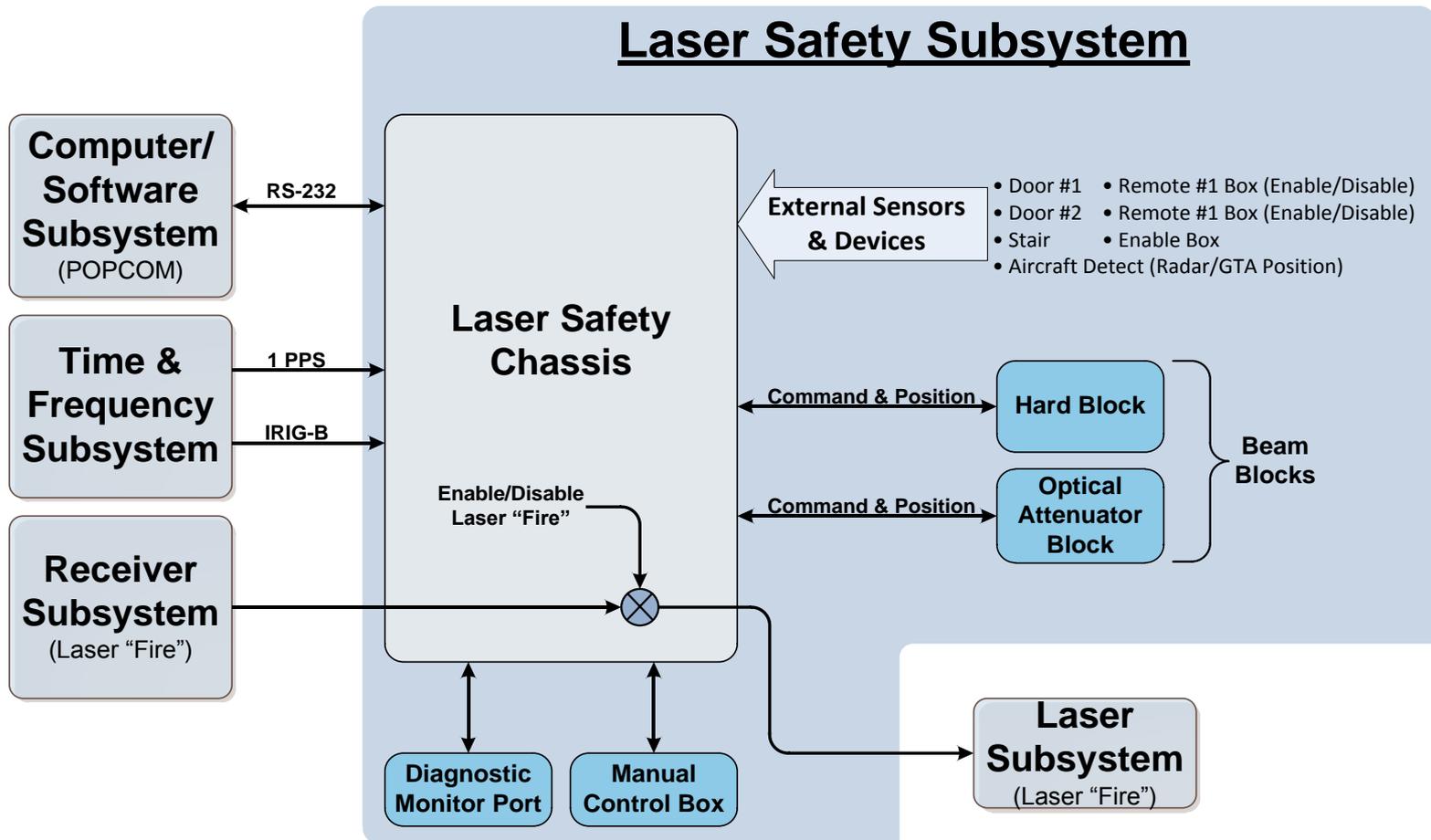




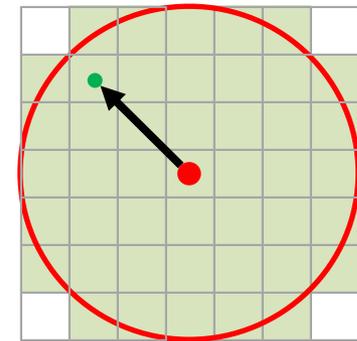
Laser Safety Subsystem



Laser Safety Subsystem prevents personnel from exposure to laser light inside or outside the SGSLR shelter and prevents the transmitted laser beam from striking an aircraft. Communicates with SGSLR software but is not controlled by software.



- **Provide Closed Loop Tracking**
 - 7x7 pixelated detector array (4 corners unused)
 - Count # of events in each pixel in support of signal detection and satellite location in RFOV
- **Make Precise, High Resolution Timing Measurements For All Pixels Over Long Distances**
 - Start Events: Single measurement per shot
 - Stop Events: Multi-stop, low dead-time
 - Ancillary Events (1pps, etc)
- **Selection based on proven heritage hardware from Sigma Space aircraft and space-flight designs.**
 - Proven on altimeter missions (aircraft & spaceflight)
 - SGSLR hardware with improved higher resolution has been demonstrated in the lab.
 - Demonstration at NGSLR in progress to evaluate in an SLR environment.



Degnan presentation in this Session has more details.

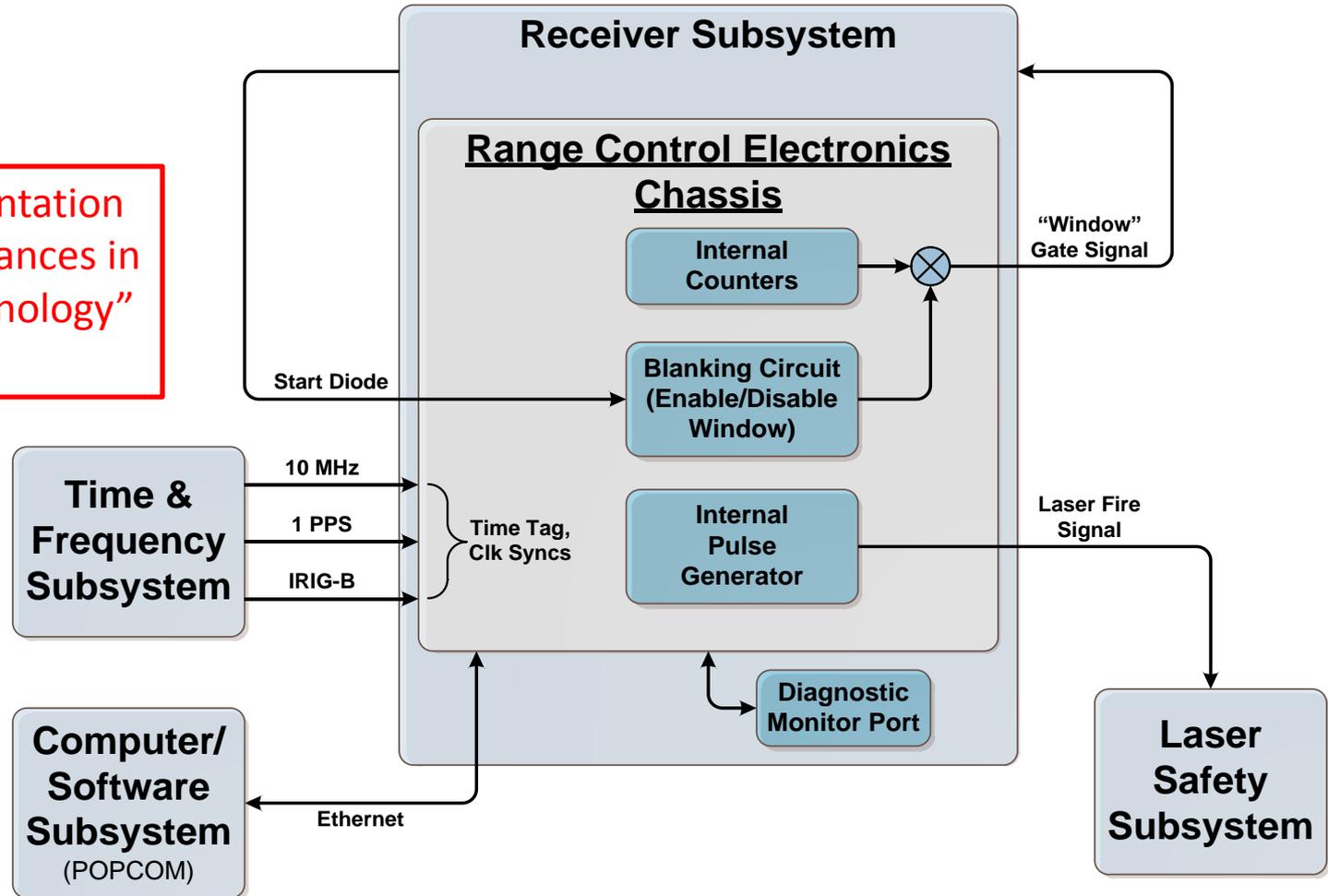


Receiver (Ranging Control Electronics)



Ranging Control Electronics (RCE) generates the software requested RANGE GATES to reduce noise and protect detector, and generates the LASER FIRE COMMANDS at the software requested PRF.

See Hoffman presentation in the Session "Advances in Laser Ranging Technology" for more details.





Shelter and Dome with Gimbal & Telescope Assembly (GTA)

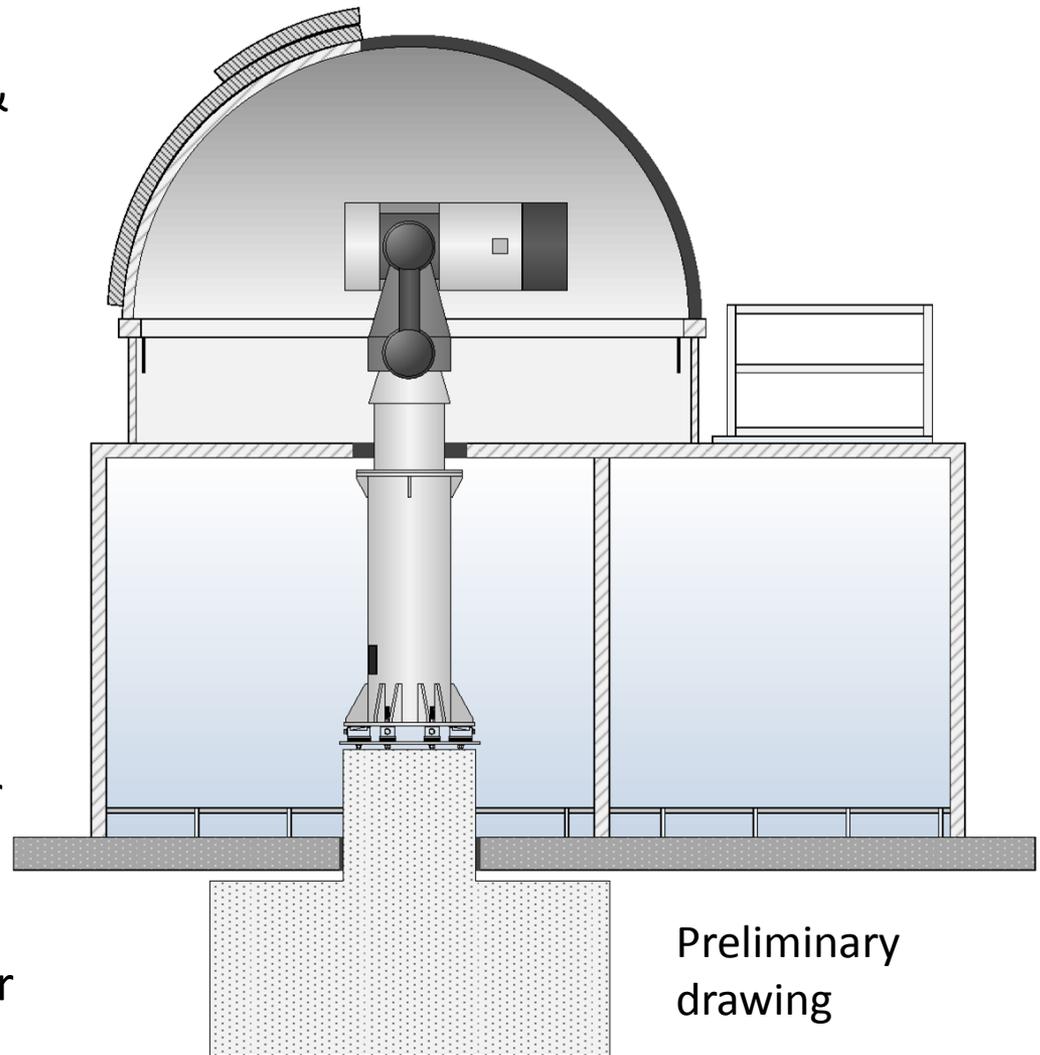


Cobham under contract to build GTAs. CDR conducted August 24 & 25, 2016. **See Donovan presentation in the Session “Advances in Laser Ranging Technology for more details.”**

Work to finalize requirements and select dome and shelter manufacturer is underway.

Dome can be slaved to the gimbal or controlled by software. Shutter will be software controlled

Shelter will be interfaced to SW for monitoring and some control of power and HVAC.



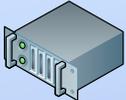
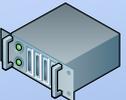
Preliminary drawing



SGSLR Computers



Computer Functions remain mostly the same as NGSLR

- CAM**  The **CAM** (Camera) computer hosts the sky, star and Visual Tracking cameras
- ANA**  The **ANA** (Analysis) computer performs post processing analysis and transfers data to the IGSOC. Also acts as the system NFS Server.
- RAT**  The **RAT** (Remote Access Terminal) allows operator interaction with the system

Many computer functions remain the same as NGSLR, but have multiple changes

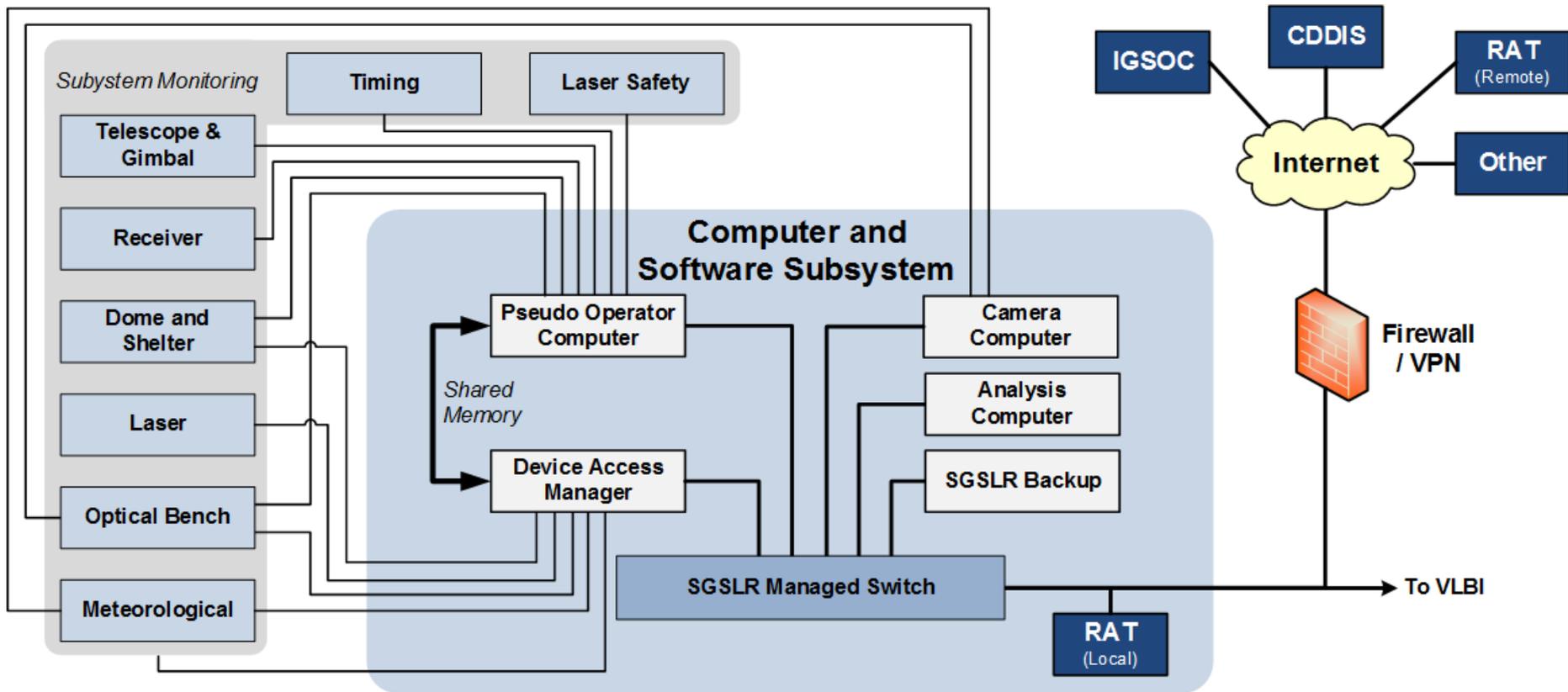
- POPCOM**  The **POPCOM** (Pseudo-OPERator Computer) will control the mount, laser, the ranging electronics, interfaces with the Laser Safety Subsystem and makes many of the operational decisions based on the weather, priority tracking schedule and system readiness
- DAM**  The **DAM** (Device Access Manager) computer controls many components of the optical bench, sets up the laser configuration, hosts the Ratsnest interface to the RAT and receives commands from the IGSOC, interfaces to the meteorological instruments and monitors health & safety to establish system readiness
- SGSLR Backup**  The **SGSLR Backup** computer allows for automatic and routine system and data backup for all other computers



SGSLR Computer Block Diagram



This diagram shows the connections from the computer to the SGSLR subsystems





SGSLR Modes of Operations



- ◆ SGSLR Modes of Operation:
 - Satellite Ranging (science data collection mode)
 - System Calibration (ranging to ground targets)
 - Star Calibration (using stars to generate mount pointing corrections)
 - Vector Tie System Support (automated survey monitoring)
 - Standby / Maintenance
 - Diagnostics / Simulation
 - Shutdown

- ◆ Regardless of the mode, operations will be the same whether a human operator is physically present, remotely controlling, or not participating (automated operation). The only difference will be who makes the decisions - not what functions are performed.

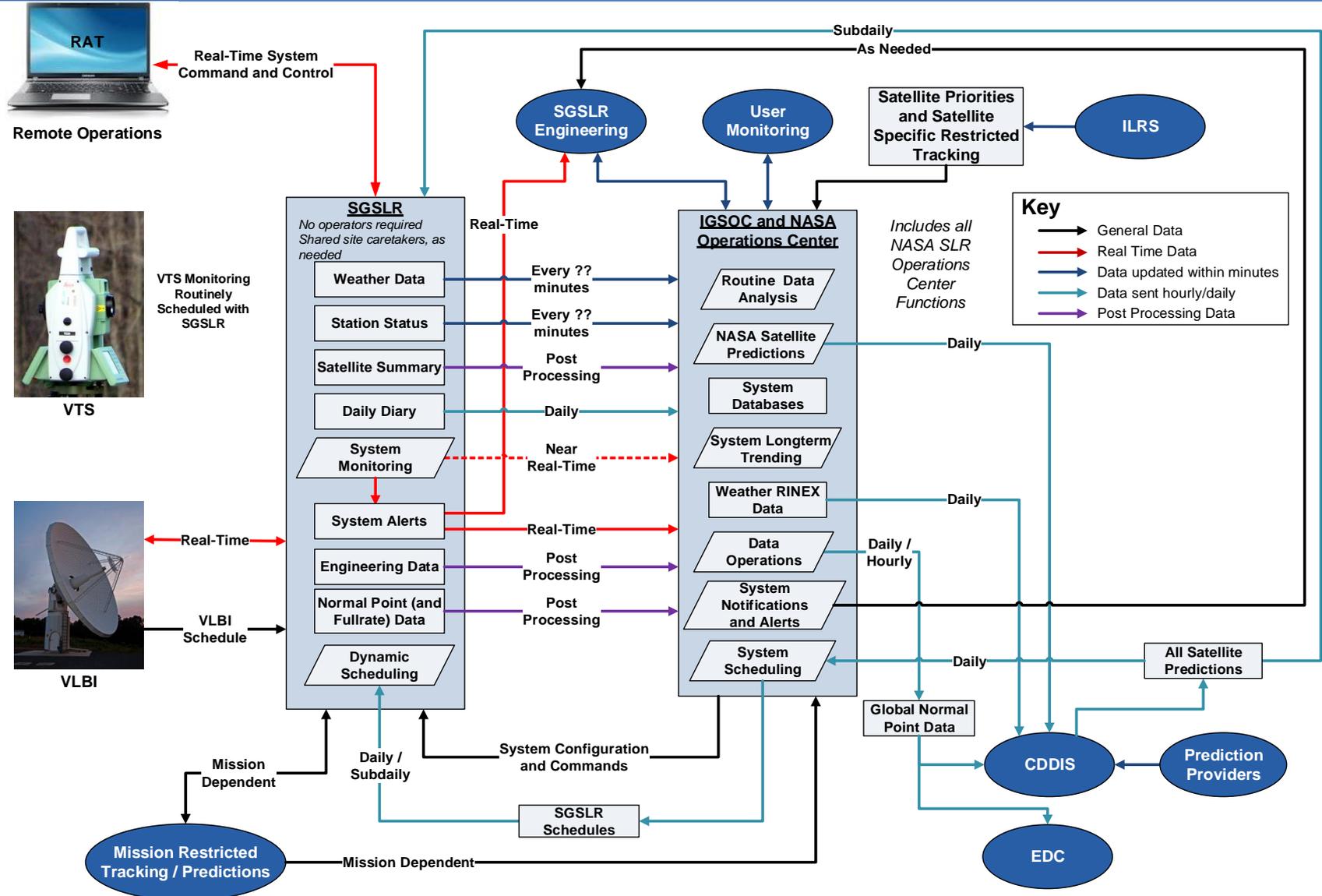


Integrated Geodetic Site Operations Center

- ◆ **Central Facility Operations Center for entire Space Geodesy Network (SGN) – may be virtual**
- ◆ May be manned 24x7 (or much less) and watches over all SGN systems, alerting technicians and engineering when needed
- ◆ Much of the IGSOC functions will be automated and will operate similarly to how spacecraft Mission Operations Centers do
- ◆ Receives real-time status & engineering information from stations
- ◆ Provides web based view of the stations and their performance in near real-time (both public view and a restricted/detailed view)
- ◆ Provides trending analysis for engineers & managers
- ◆ Performs all NASA SLR Data Operations Center functions (including receiving science data from SGSLR and forwarding to CDDIS and its European counterpart)
- ◆ Commands the SGSLR stations as needed
- ◆ Control of the SGSLR stations will require the RAT interface
- ◆ Generates station schedules



SGSLR External Data Flow





Path to Full Automation



- ◆ Initial operation during installation will be local (operator in the SGSLR shelter operating system through RAT).
- ◆ During commissioning the system is expected to be remotely operated from nearby SGP operations building using Remote Access Terminal (RAT). Testing of the automated operations will take place part-time with the operator watching and part-time on its own.
- ◆ After commissioning the systems will be operated remotely (nearby) for multiple daylight shifts per week, while allowing the system to perform automated operations, mostly at night.
- ◆ The knowledge gained during these periods will allow optimization of the automated operations resulting in full automation in the future.

In all cases data flows to the IGSOCC.



SGSLR STATUS



- ◆ SGSLR Preliminary Design Review successfully completed in April 2016.
- ◆ Gimbal & Telescope CDR completed. Three GTAs being built.
- ◆ SGSLR plans in progress for McDonald, Haleakala and Ny-Alesund.
- ◆ Facility at Goddard being built in spring 2017 for Integration & Testing of all SGSLR systems, including collocation with MOBILAS-7.
- ◆ Prototype receiver in testing at NGSRL.
- ◆ Integrated Geodetic Site Operations Center design taking shape. Facility at Goddard is being set-up for preliminary testing in 2017.
- ◆ SGSLR systems are expected to be fully automated by 2021.

See other SGSLR talks & poster: Horvath poster on SGSLR Automation, Donovan talk on GTA, Hoffman talk on RCE (both in Advances in Laser Ranging Technology)



THANK YOU!