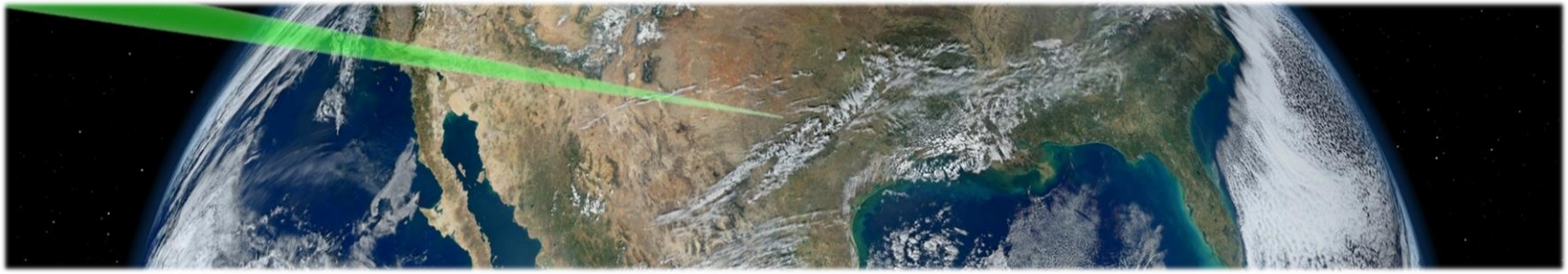

# The Gimbal and Telescope Assembly for NASA's Next Generation Space Geodesy SLR Systems

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# Outline

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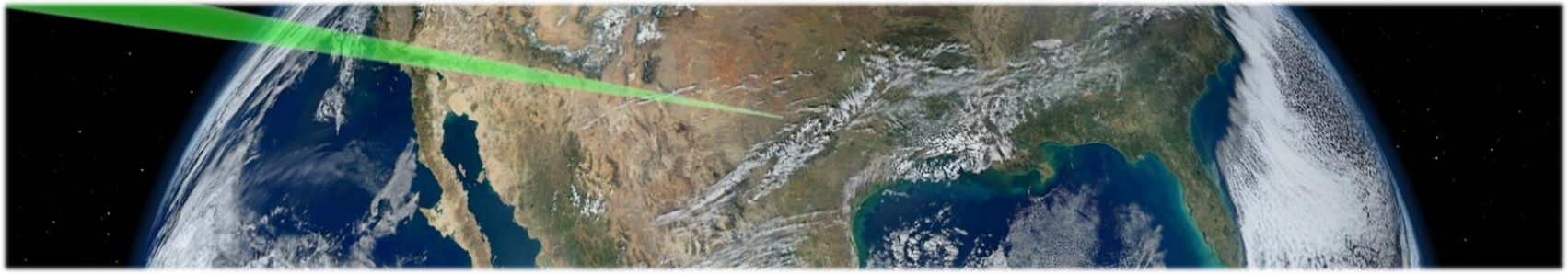
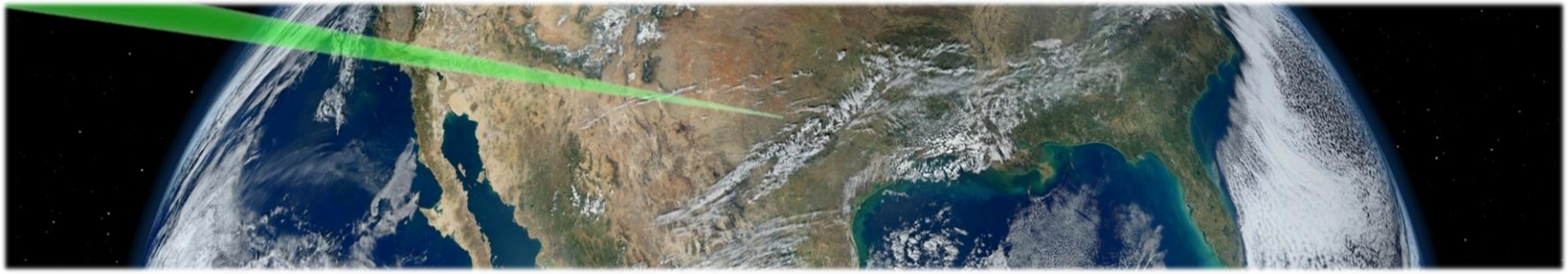


# INTRODUCTION

# Introduction

- The Gimbal and Telescope Assembly (GTA)
  - One of the most important components of an SLR system
  - The component with the longest lead time item
- Specification and Procurement
  - The SGSLR GTA team developed very stringent specifications in 2015
  - The NASA Space Geodesy Project (SGP) is in the process of procuring three highly precise and very stable GTA systems
- Design and fabrication efforts include complex modeling which ensures
  - Precise telescope pointing
  - A very stable invariant point through a wide range of temperatures
    - Required due to the variations in the climate at the expected NASA SGP network sites
- SGSLR GTA will need to take advantage of the pixelated receiver subsystem which provides range and angular information needed for automated tracking operations
  - See John Degnan's paper "PROGRESS ON THE MULTIFUNCTIONAL RANGE RECEIVER FOR SGSLR"



# GTA LOCATIONS

# SGSLR Locations

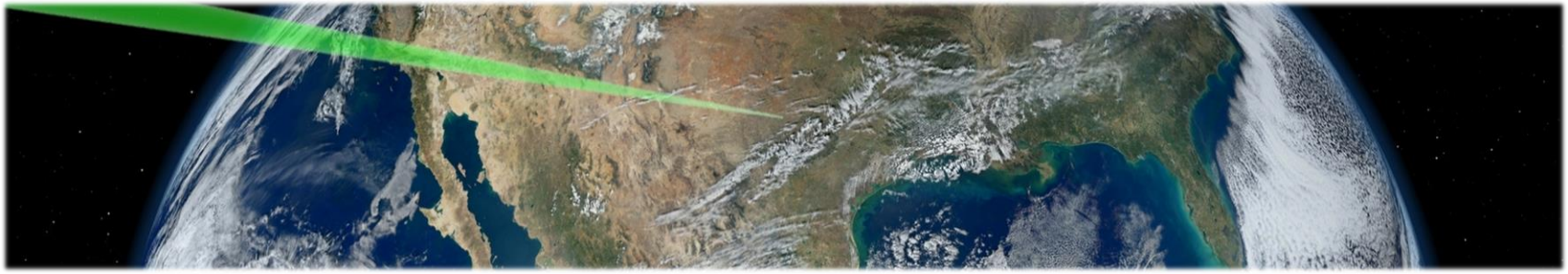

- GTA #1 delivered to GSFC in Greenbelt, MD: Field Acceptance Testing then shipped to Ny-Alesund, Norway Norwegian Mapping Agency (NMA)
- GTA #2 delivered to GSFC in Greenbelt, MD: Field Acceptance Testing, then to Haleakala, HI
- GTA #3 delivered directly to MLRS in Ft. Davis, TX: Filed Acceptance Testing

# Features of the Ny-Ålesund Site

- Colder than any site currently in operation for NASA SLR Network
  - Reaches -20°C, average minimum for coldest month is -15°C
  - Average high 5°C with a max of 11°C
  - GTA will be able to handle these temperatures
- Star calibrations must be done in daylight
  - Mount stability is expected to hold mount model for months
  - Technique developed where two offset images are taken then one is subtracted from the other to remove background

# Features of the Texas & Hawaii Site

- Texas - No extreme weather conditions
  - Average low is -17°C but has reached -20°C
  - Average high 37°C but has reached 45°C
  - GTA will be able to handle these temperatures
- Hawaii - No extreme weather conditions
  - Average low is 8°C but has reached -9°C
  - Average high 17°C but has reached 23°C
  - GTA will be able to handle these temperatures



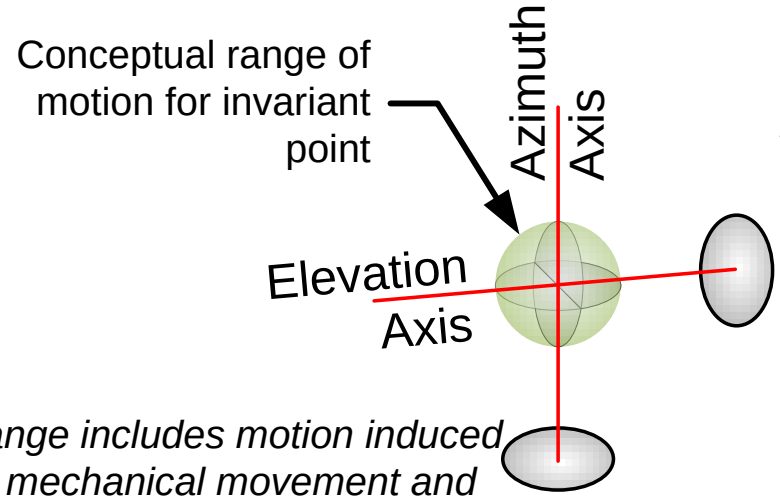
# SPECIFICATION DEVELOPMENT

# GTA Requirements

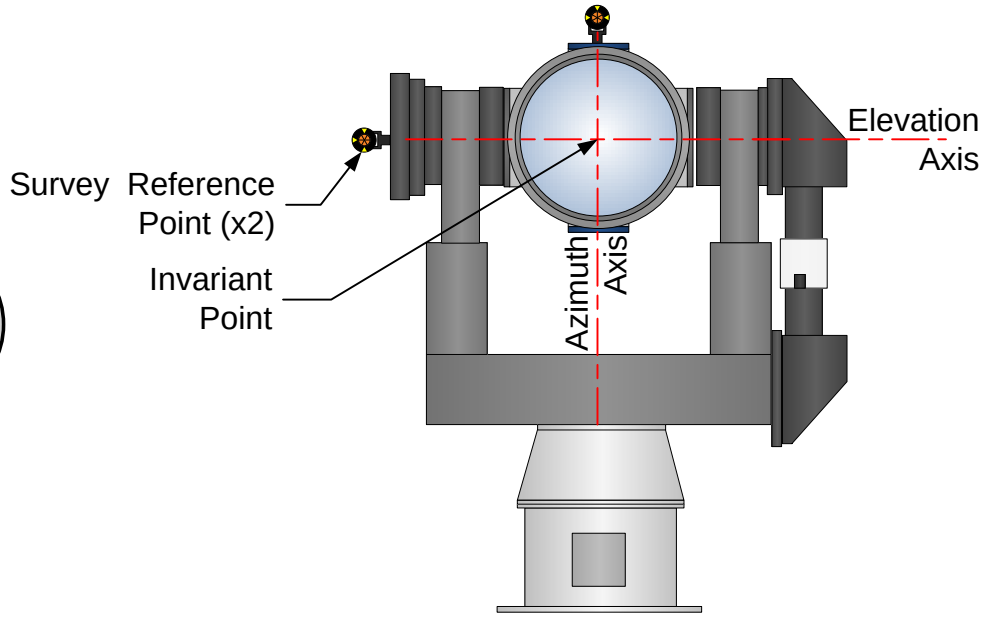
- Tracking requirements:
  - Satellite altitudes
    - 300 km  to 22,000 km (LEO to GNSS), day & night
    - 42,000 km geosynchronous and geostationary, night only
  - Tight divergence, low laser energy, small receiver FOV
    - Requires precision pointing to place and maintain the low laser energy on the satellite and the receiver in the FOV
    - Support varying velocities, high accelerations, and high inertial loads while providing smooth trajectory to maintain link to the satellite
    - Gimbal pointing must synchronously intersect the satellite trajectory coincident with the laser 2 kHz transmit rate

# GTA Requirements

- Invariant Point (System Origin)
  - Motion of the intersection of the GTA axes must be known with respect to external reference points and measured by survey
  - Affected by temperature, bearing wobble, bearing runout, axis orthogonality, and axis intersection
  - Knowledge reduces range measurement uncertainty
  - Knowledge increases the accuracy of the GTA position location




*Range includes motion induced by mechanical movement and optical alignment*

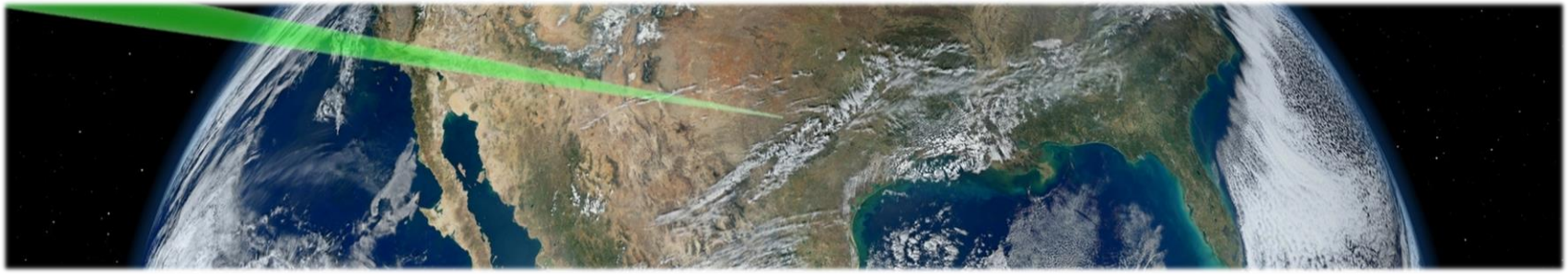


# Invariant Point

- Origin of SGSLR system is the theoretical point used by the Science Community to define the location of the SLR system
  - Location where theoretical azimuth and elevation axes meet
- Theoretical start and stop of the range time measurement is the time of the laser pulse as it crosses the invariant point
- The distance to the satellite is measured from the invariant point
- As azimuth and elevation angles move and the temperature changes, actual origin of the GTA can move around
- To achieve accurate to the millimeter level ranging measurements, the invariant point of the system must be known at all times to within 1 millimeter
- Vector Tie System (VTS) will monitor external points on the gimbal and determine movement
- Movement of the invariant point with respect to these external points is important so the Science Community can fully determine the system's origin at all times

# GTA Requirements

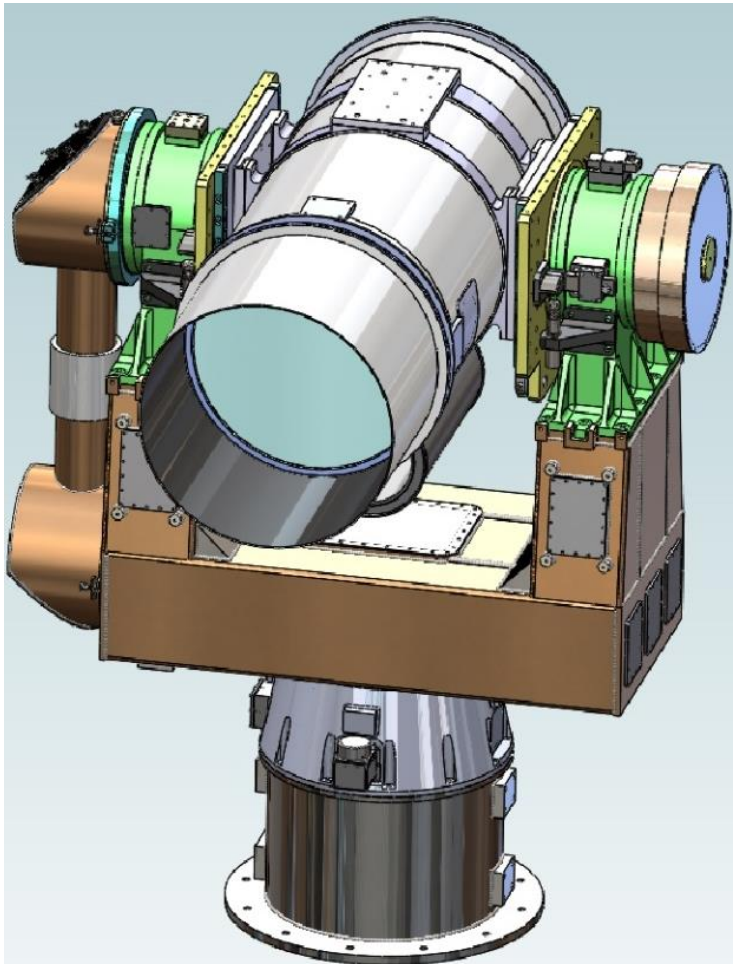
- Gimbal Stability and Stiffness
  - Invariant point knowledge to meet range measurement uncertainty requirement
  - Tight pointing capability to meet target tracking requirements
  - Day/night operations required over large temperature swings
  - Operational range -40°C to +50°C
  - Survival Temperature: -50°C to 55°C
  - Solar and wind loading managed using a open slit dome
- High Reliability
  - 24/7 continuous operations with minimum downtime
  - Gimbal design must be very robust and require little maintenance to achieve automation



# VENDOR SELECTION

# Vendor Selected

- COBHAM
  - Selected as the Vendor for the SGSLR Gimbal Telescope Assembly



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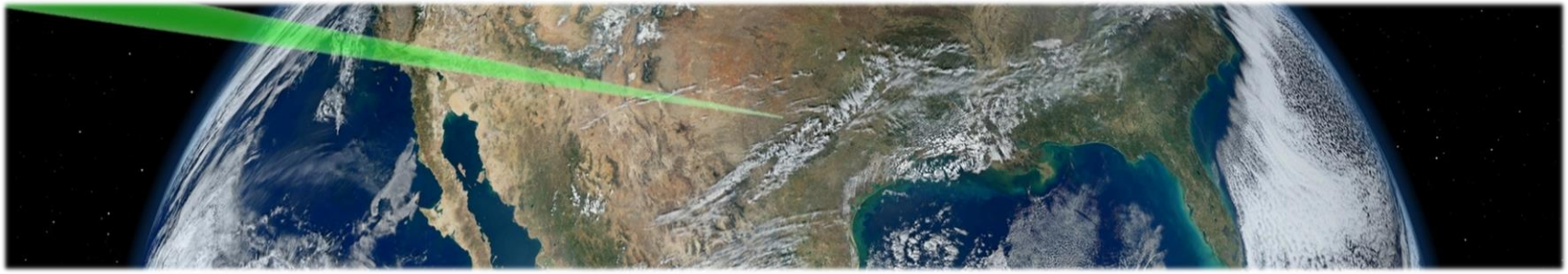
# Procurement Status

- NASA tasked Honeywell to
  - Develop a procurement strategy and RFP with a team of subject matter experts (NASA, Honeywell, Sigma Space) to procure 3 GTA's
- Key Dates
  - RFP Released May 2015
  - Cobham Selected as SGSLR GTA Vendor – November 2015
  - Cobham Preliminary Design Review – March 2016
  - Cobham Critical Design Review – August 2016
- First GTA delivery expected July 2017
- Final GTA delivery expected November 2017

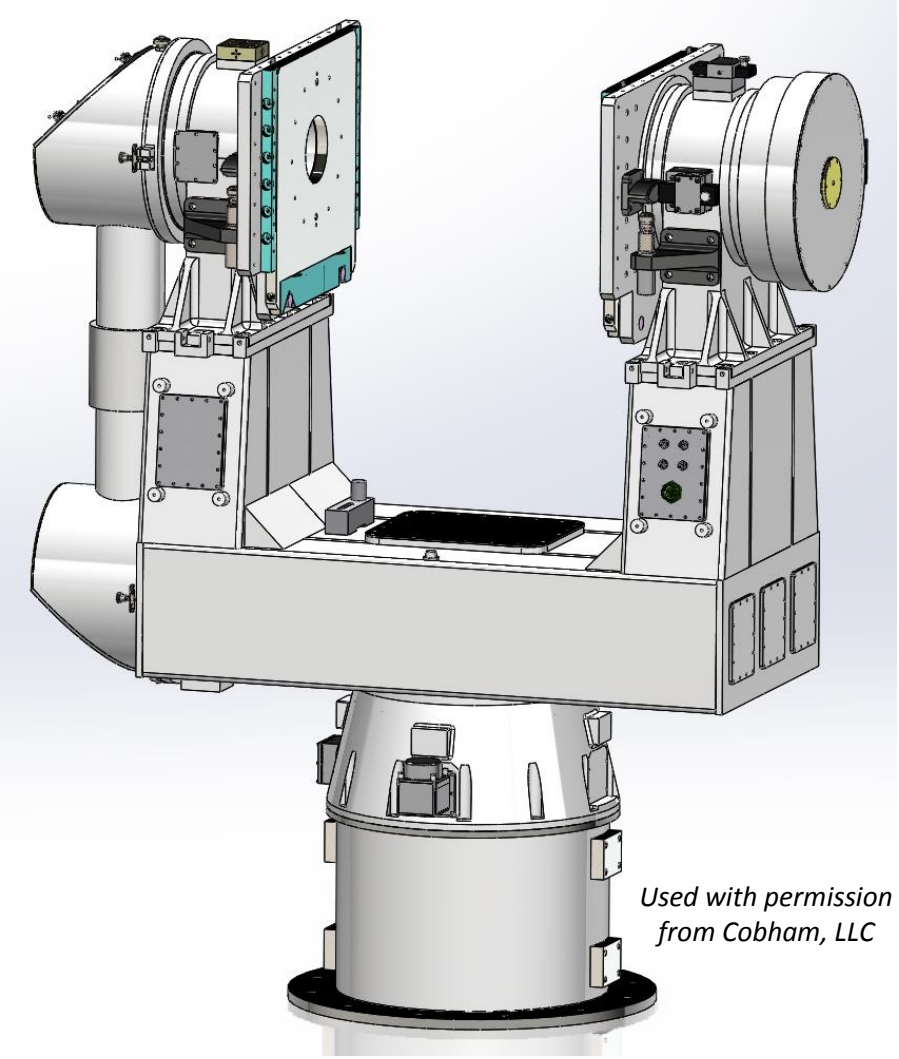


# DESIGN STATUS

## GIMBAL

# Gimbal Design

- Steel and ductile iron casting construction (with corrosion protection) for thermal stability
- Slotless, brushless, frameless torque motors
- Angular contact bearing in a kingpost arrangement
- Modularized inductosyn and resolver encoder package
- Enclosed coudé path
- Over travel shock absorbers, elevation
- Manual brakes in azimuth and elevation



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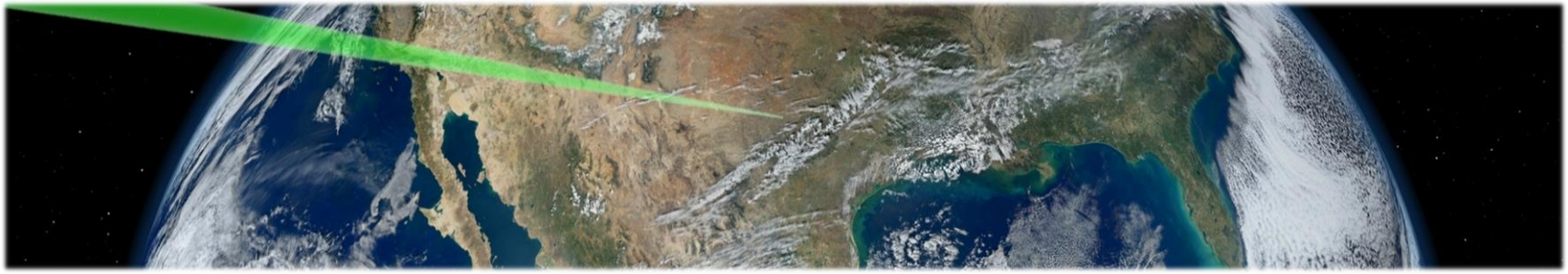
# Gimbal Primary Specifications

| Specification | Allocation |
|---|---|
| **Jitter:** | 1 arcsec RMS |
| **Absolute open loop pointing:** | ≤ 3 arcsec RMS |
| **Invariant Point:** | 1mm in 3D space |
| **Tracking Az Velocity:**<br>**Tracking Az Acceleration:**<br><br>**Tracking El Velocity:**<br>**Tracking El Acceleration** | 0°– 10°/sec<br>0°– 1°/sec$^2$<br><br>0°– 2°/sec<br>0°– 0.5°/sec$^2$ |
| **Slew Az Velocity:**<br>**Slew Az Acceleration:**<br><br>**Slew El Velocity:**<br>**Slew El Acceleration:** | ≥20°/sec<br>≥5°/sec$^2$<br><br>≥20°/sec<br>≥5°/sec$^2$ |

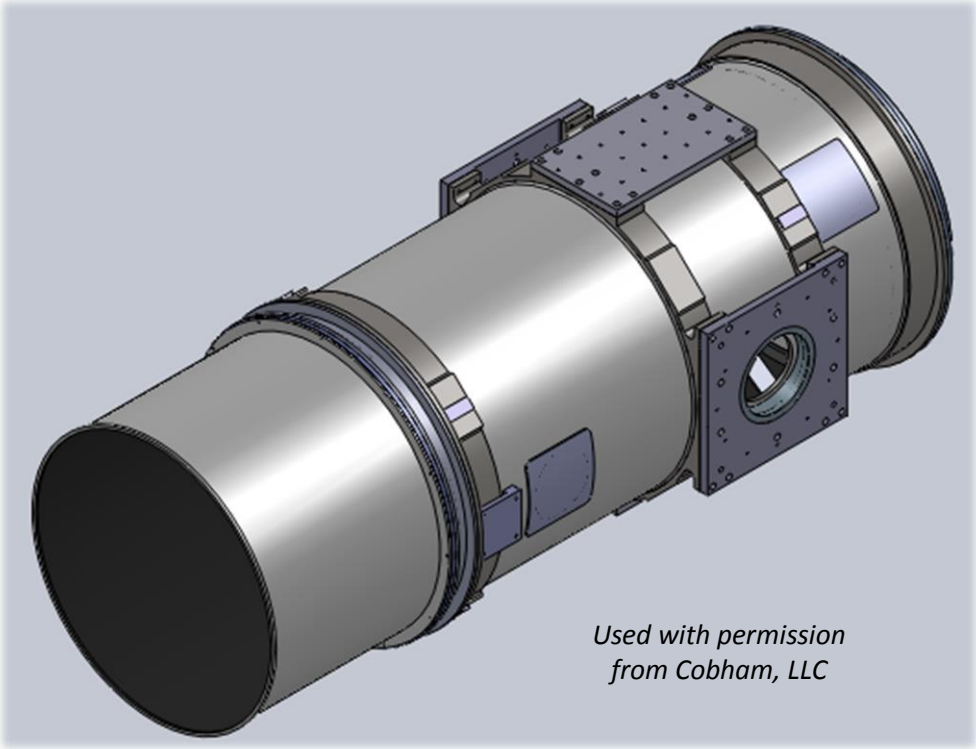


# DESIGN STATUS

## OPTICAL

# Telescope Design

- Theoretical performance analyzed by the NASA/Honeywell/Sigma Space team optical subject matter experts
- Diffraction limited performance over the full field and temperature range
- A-focal design
- Carbon fiber tube
- Sealed System



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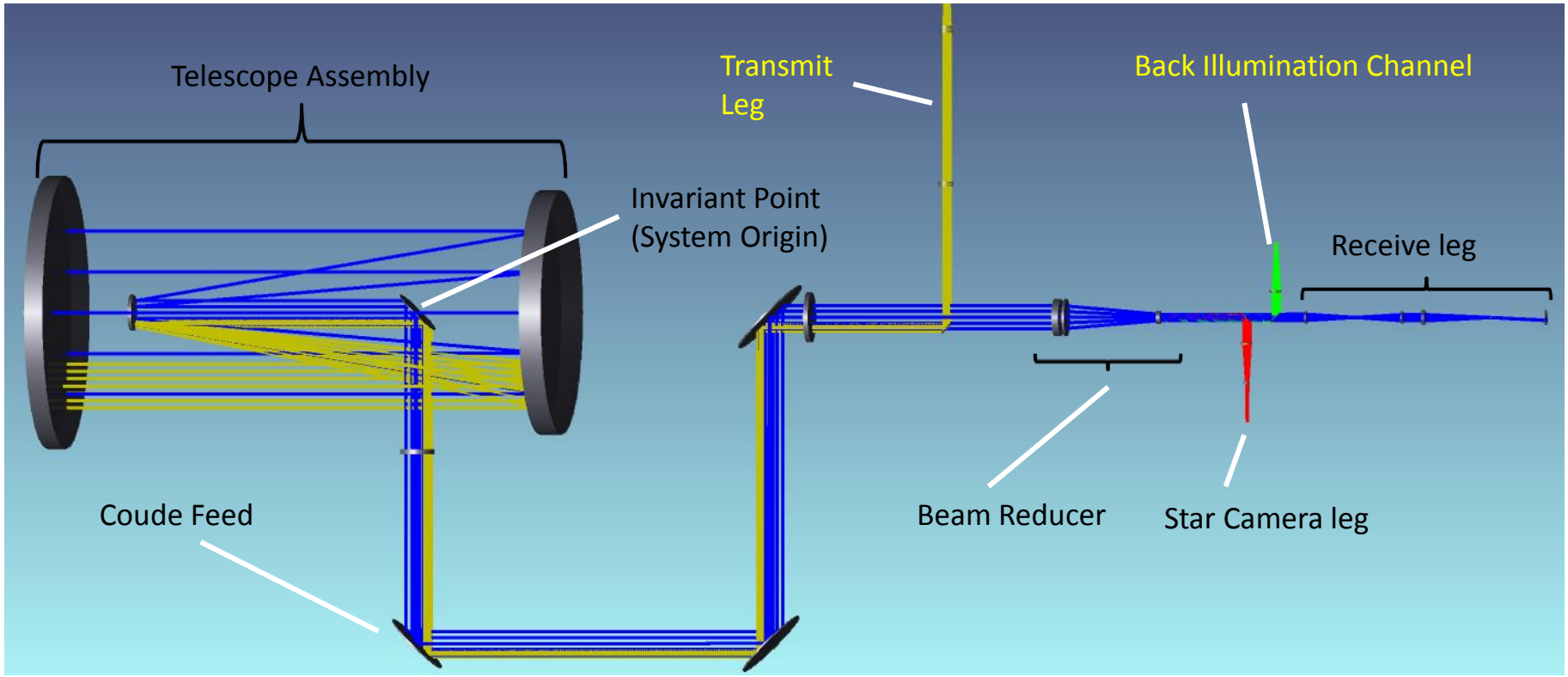
# Telescope Primary Specifications

| Specification | Allocation |
|---|---|
| **Type:** | A-focal, Monostatic |
| **Diameter:** | 0.5 meters |
| **Wavelength:** | 532nm, 1064nm, 1550nm, Broadband |
| **Throughput:** | <2% loss per surface |
| **Stray Light Rejection:** | $10^6$<br>9.5° to 85° acceptance angle |
| **System FOV:**<br>**Acquisition**<br>**Tracking**<br>**Star Calibration** | <br>60 arcsec<br>14 arcsec<br>2.5 arcmin |
| **Telescope and Relay Path:** | Sealed |
| **Wavefront Quality:** | 80% encircled energy for 0.8 arcsec diameter full field circle @ 532nm |

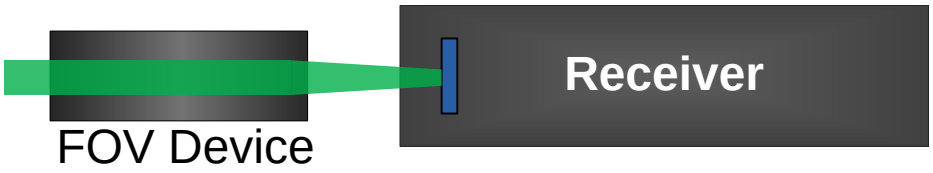
# Simplified Optical System Layout



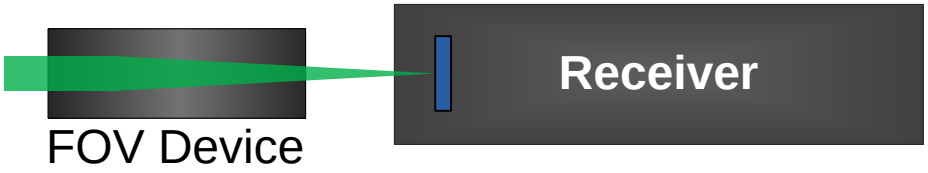

- Classic Coudé feed
- Rotational axes and mechanical axes are co-aligned
- Transmit and receive path are coupled using an insertion fold mirror
- A beam illumination path to perform boresight using GSE equipment

# Telescope FOV to Receiver

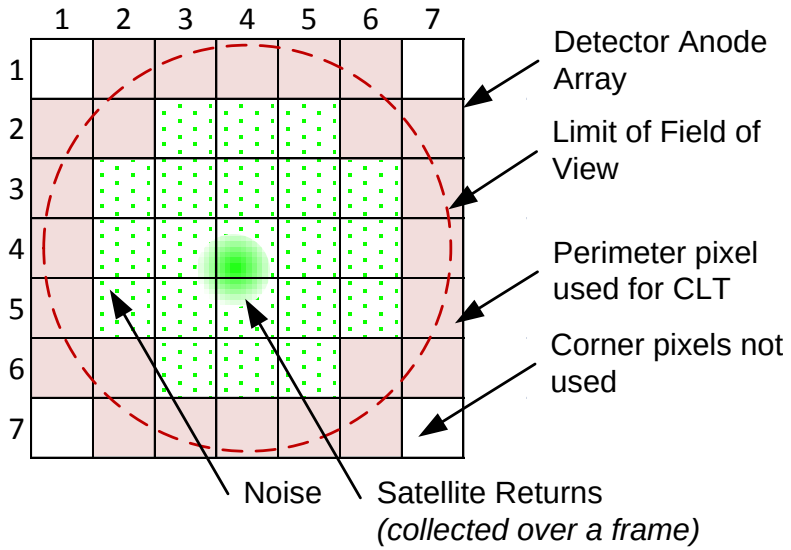
- Closed loop tracking
  - Signal Identification (esp. for weak GNSS returns)
  - Automatically maximize return signal
  - Decrease acquisition time



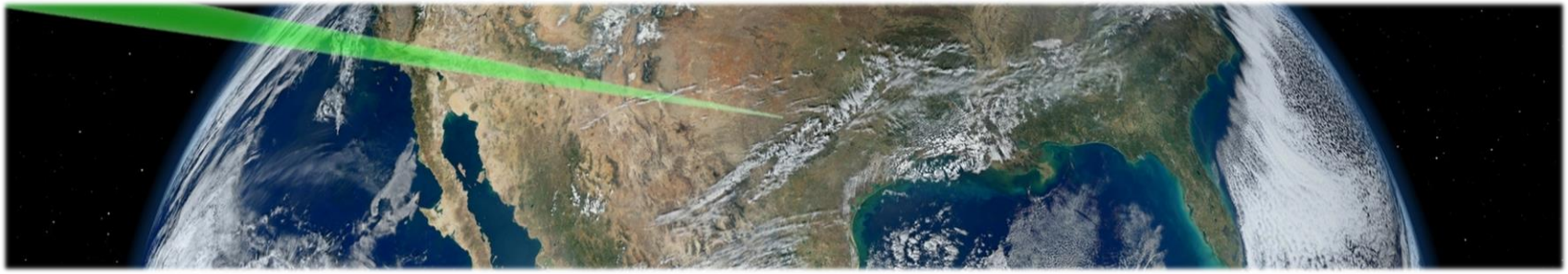

**Wide FOV for Acquisition**




**Narrow FOV for Tracking**




Please see John Degnan's presentation "Progress on the multifunctional range receiver for SGSLR"



# SUMMARY

# Summary

- GTA is one of the most important components of the SLR system
- GTA will be robust to support 24/7 tracking operations
- SGP project level requirements for data quantity and quality require a precise gimbal and telescope assembly
- GTA performance is key to the data volume
  - Tracking performance (extremely good tracking RMS up to relatively high velocities and accelerations, slewing speed, and stability throughout large temperature variations) will increase the amount of data collected/data volume and and will also increase the data collection rate, improving the NPT precision
- Knowledge of invariant point is key to getting to the 1 mm ranging level
  - Expect to achieve knowledge of the invariant point to 1 mm
- First Cobham GTA delivery expected July 2017 with the final GTA delivery expected November 2017

# Thank You!

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