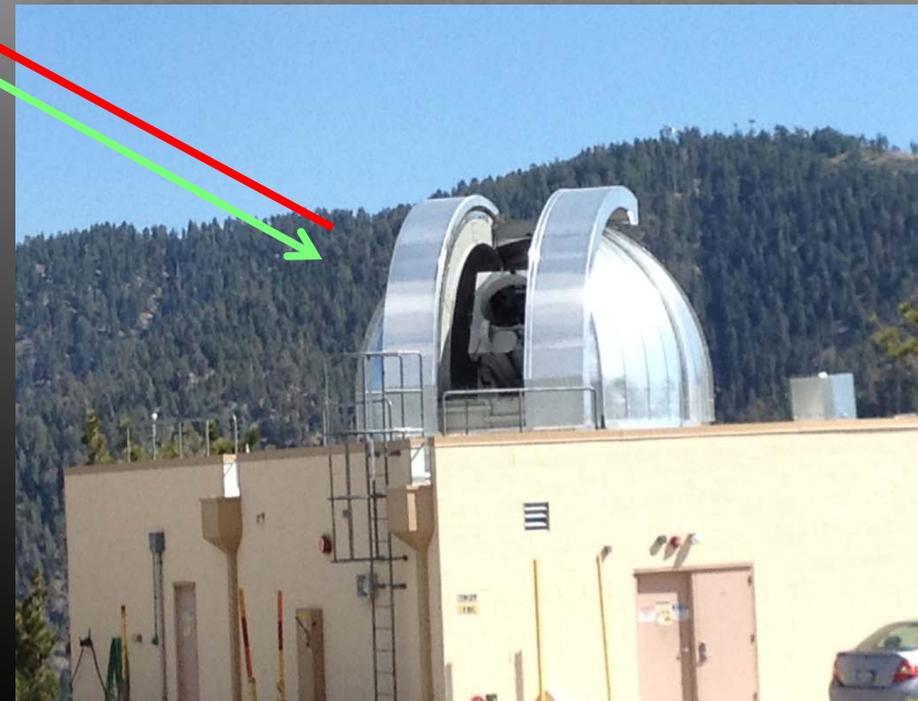




# Lunar Lasercom OCTL Terminal (LLOT)



Status April, 2013

Joe Kovalik

Jet Propulsion Laboratory  
California Institute of Technology.

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Government sponsorship acknowledged.



- **Optics**
  - Transmit
  - Receive
- **Receiver**
  - PMT
  - Cryostat
- **Telescope Operations**
  - Tracking
  - Light Coupling
  - Scanning
- **Monitor and Control**
- **Operations**

**Project Management  
& Systems Engineering**

Abhijit Biswas

Martin Regehr

**Optical Assembly:**

Tom Roberts

**Beacon Laser Assembly:**

Malcolm Wright

**Receiver Assembly:**

Kevin Birnbaum (Lead)

Meera Srinivasan

Michael Cheng, Kevin Quirk

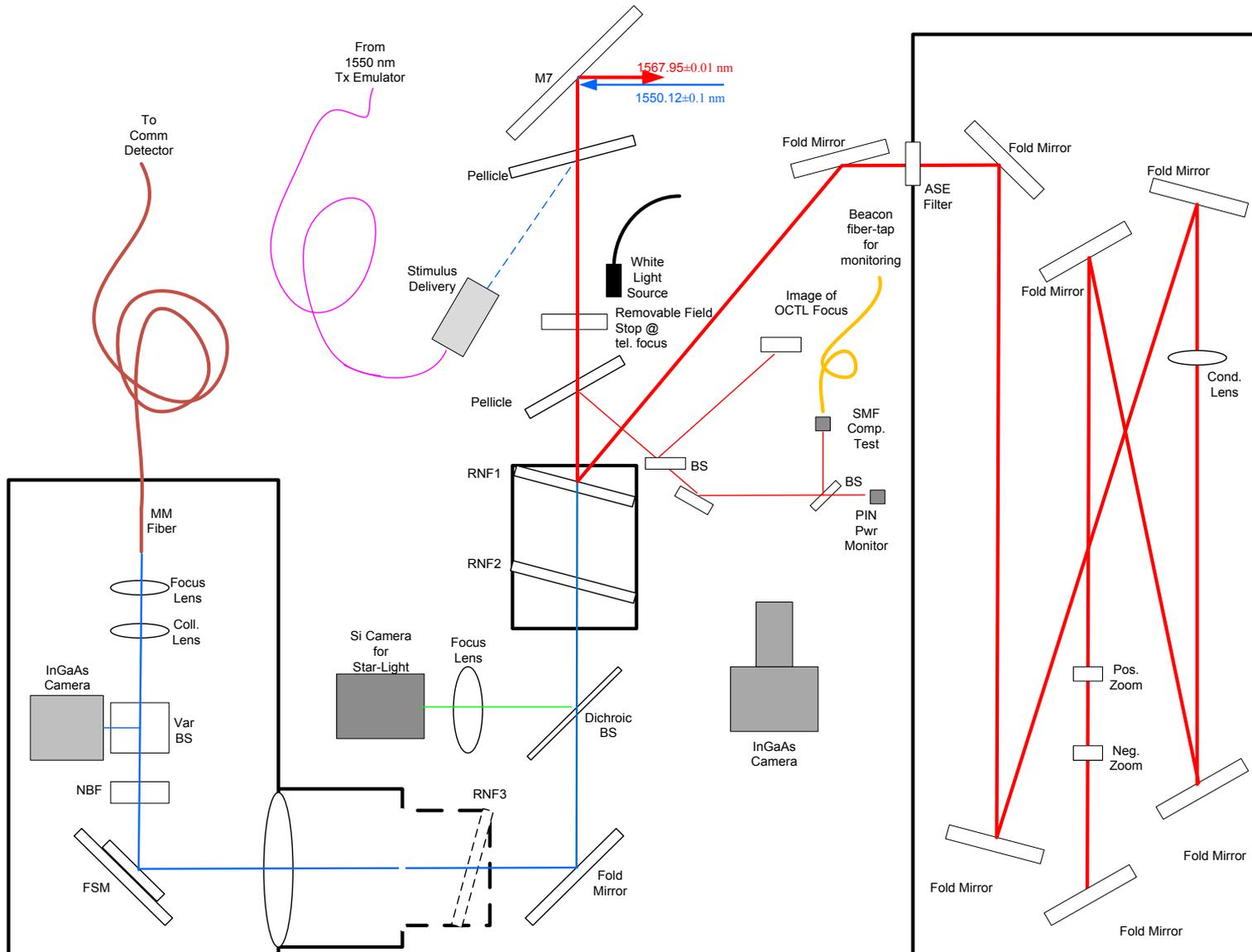
**OCTL Telescope & Operations**

**(Includes Monitor & Control):**

Joseph Kovalik

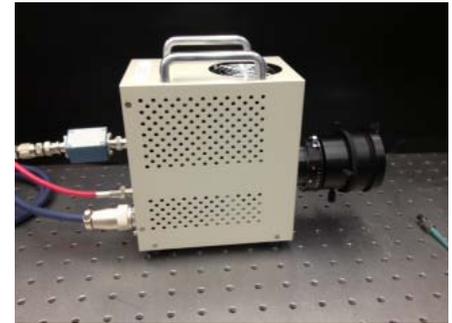
Malcolm Wright (Laser safety)

# TRANSMIT/ RECEIVE



- **Hamamatsu PMT (loaned from GSFC)**

- One PMT 6% detection efficiency
- Demonstrated ability to acquire LLCD downlink with worst case signal and background (clocks tied)
- Correctly identify at least 50% of the frame-acquisition header which is sufficient to set valid PPM flag
- $2.9 \times 10^{-3}$  to  $7.9 \times 10^{-3}$  CWER with 2-repeats
- CWER  $< 10^{-4}$  with 3-repeats based on # of code-words processed



- **Cryostat**

- $< 1^\circ\text{K}$  with  $\sim 8.5$  hrs hold + 1 hr of re-cycle time
- Integrating detector, cabling and amplifiers at JPL

- **Verification and validation**

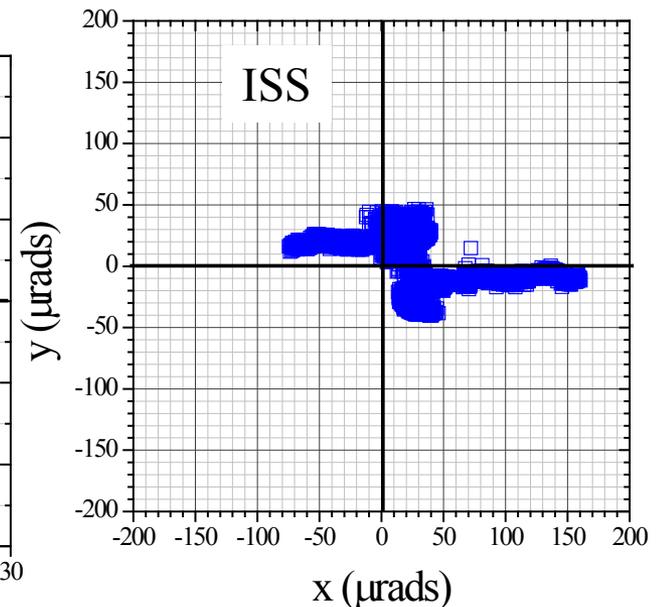
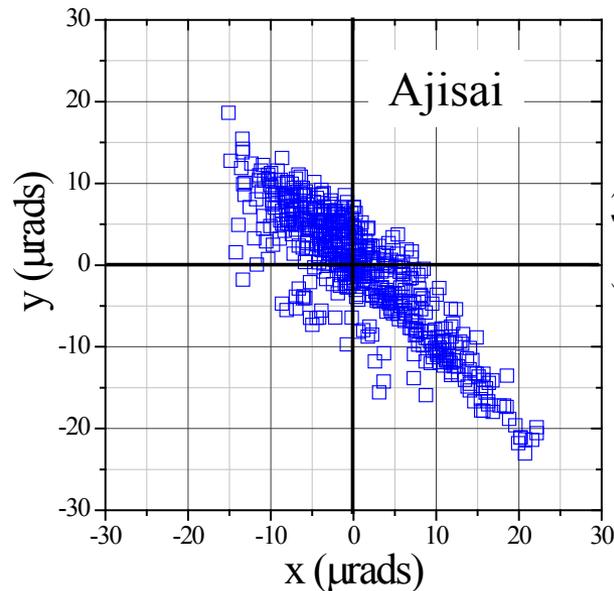
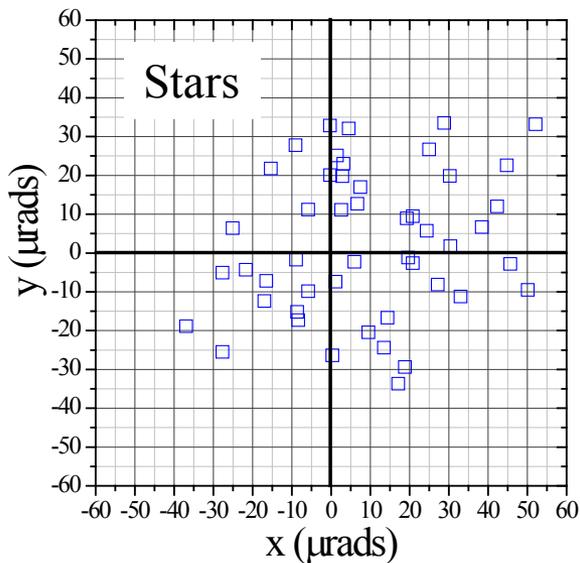
- MIT-LL will bring test set to JPL last week of May
- Testing to be performed at JPL for detector and receiver
- Uplink wavelength and modulation testing to be performed at OCTL



# TELESCOPE TRACKING



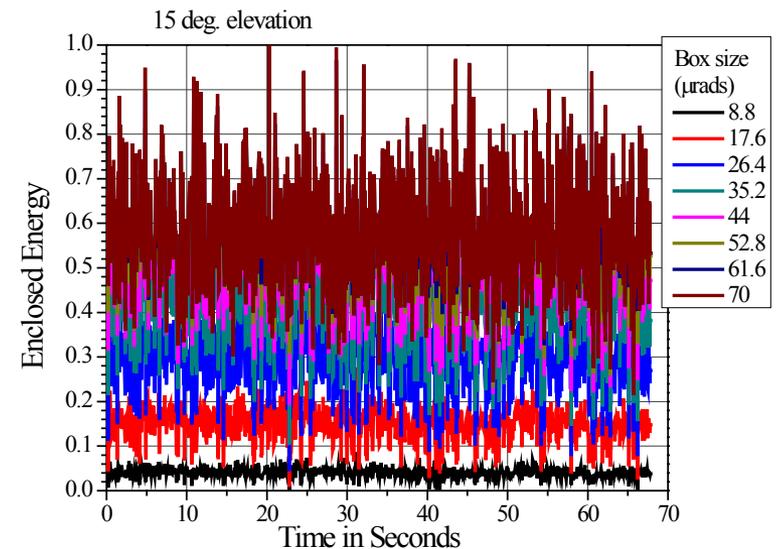
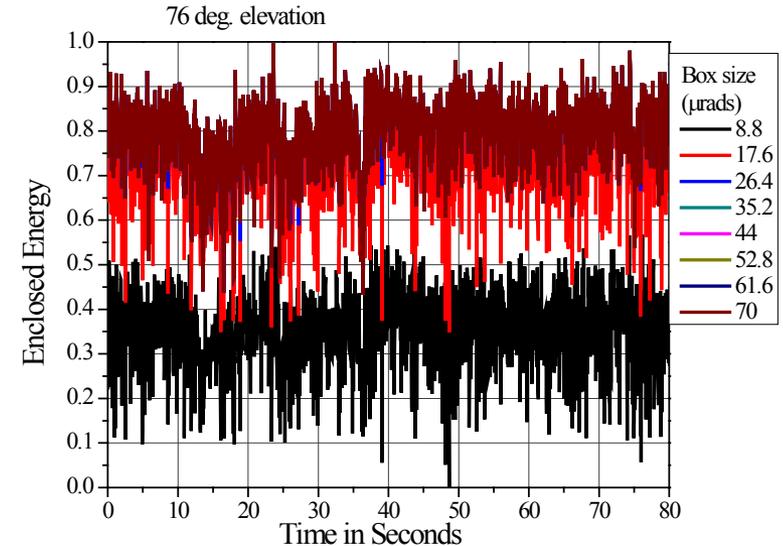
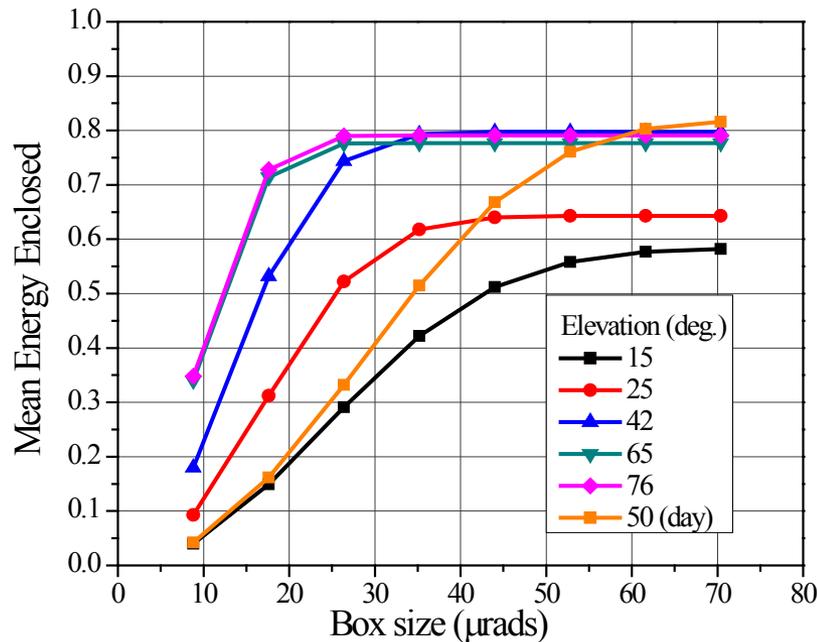
- **Perform semi-automated mount calibration**
  - Use star catalogue to point to 30+ stars
  - Measure star offset in camera and use feedback to centre image
  - Record telescope readback
  - Produce calibration transform with commercial software
- **Test with satellites and stars**
  - Ajisai: use consolidated predict ephemeris
  - ISS: use ephemeris generated by OPALS team at JPL



# TELESCOPE LIGHT COUPLING



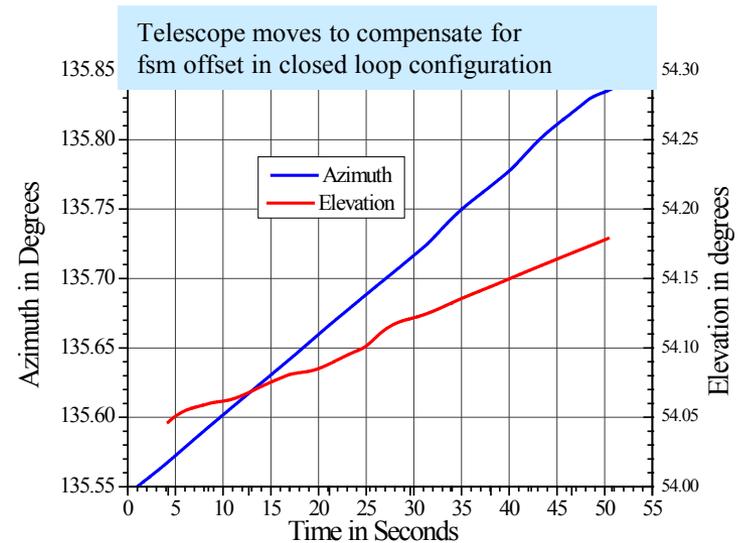
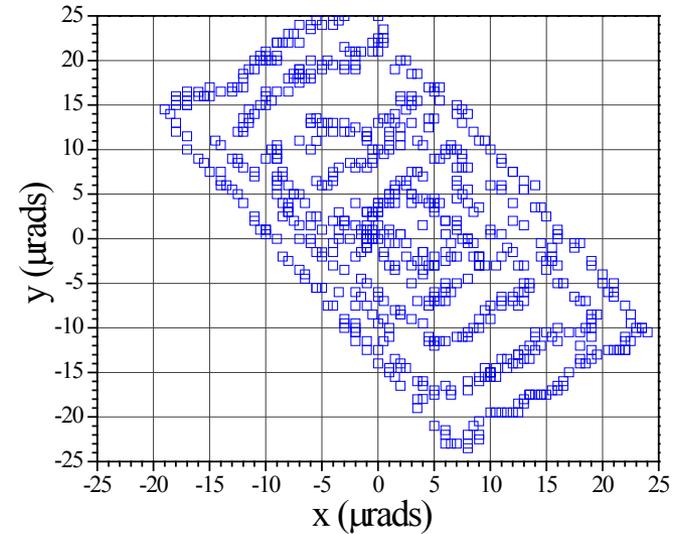
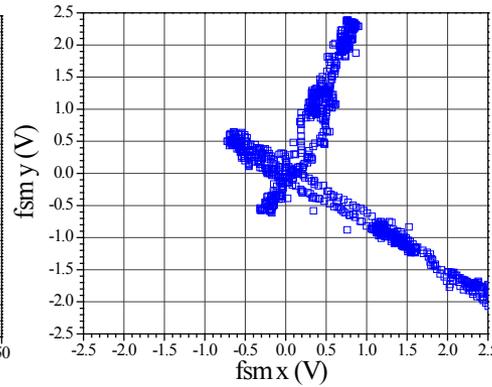
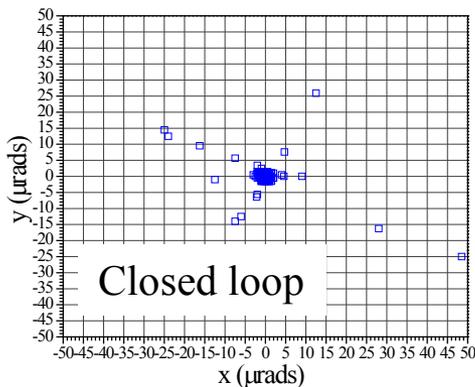
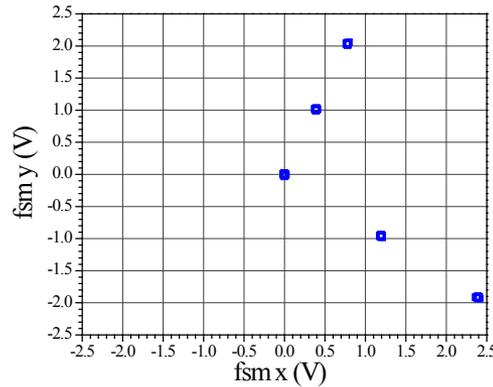
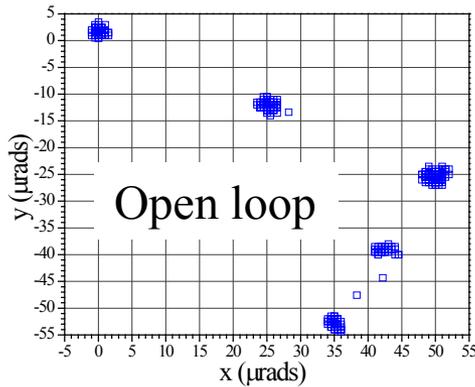
- **Measure light coupling of telescope**
  - Use star as a test source with sidereal tracking
  - Servo using FSM
  - Offload offset from FSM to an offset in sidereal tracking
- **Future:**
  - Measure coupling into fibre
  - Use laser test source from horizontal 1.6 km path



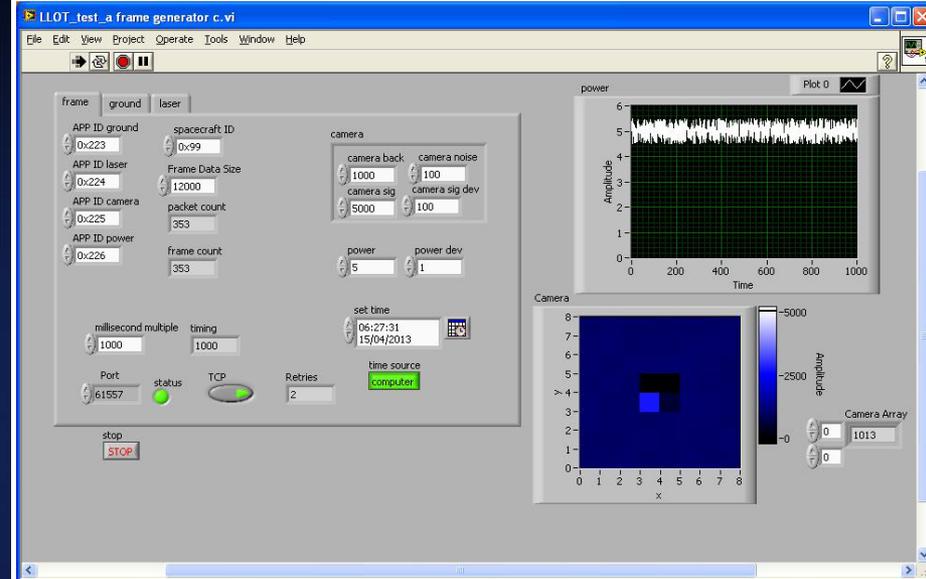
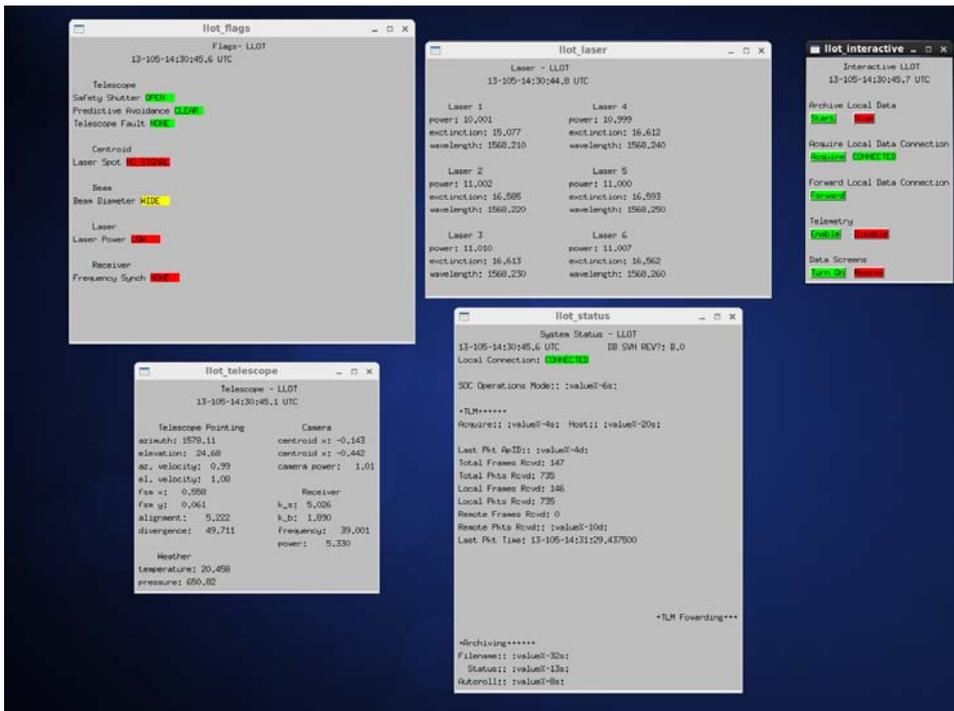
# TELESCOPE SCANNING



- **Scan telescope in az/el**
  - Sidereal star track
  - Measure star offset in camera
- **Test point ahead**
  - Sidereal star track
  - Move fsm 10,20,30  $\mu$ rads in az/el
  - Measure star offset in camera, fsm position
  - Open and closed loop

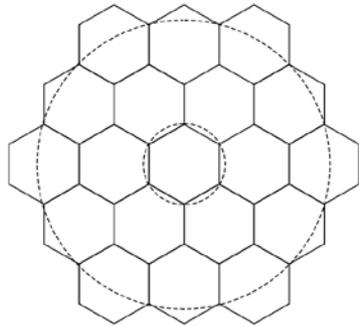


# MONITOR AND CONTROL



- **ITOS Controller**
  - Databases created
  - Simple control and display GUI's
- **Data emulator**
  - LabVIEW on PC with simulated data
- **Subsystem interfaces**
  - Monitor and control for subsystems mostly finished
  - Still need to integrate with control room
- **Networking**
  - Secure network hardware to be installed by late May
  - Network turned on July (monthly fee)

# CONCEPT OF OPERATIONS



19-step step-stare scan with 5-s dwell time  
110  $\mu\text{rad}$  uplink divergence  
~ 100 s to search out 253- $\mu\text{rad}$   
uncertainty diameter

RSS'd Ephemeris + Blind-pointing  
uncertainty 191  $\mu\text{rad}$  diameter

## ACQUISITION

Beacon Irradiance  
36  $\text{nW}/\text{m}^2$   
@ 1567.95  $\pm$  0.1 nm

## TRACKING

Beacon Irradiance  
3.6  $\text{nW}/\text{m}^2$   
@ 1567.95  $\pm$  0.1 nm  
Beam divergence 106  $\mu\text{rad}$

## ACQUISITION

Downlink Irradiance  
0.17  $\text{nW}/\text{m}^2$   
@ 1550.12  $\pm$  0.1 nm

## TRACKING

Irradiate with  
2.1  $\text{nW}/\text{m}^2$   
@ 1550.12  $\pm$  0.1 nm



OCTL Telescope

2

OCTL tracks on downlink  
Narrows beacon divergence to 40  $\mu\text{rad}$

- **Operations Preparation**

- How many simultaneous voice lines are needed during operations?

- **Pre-Pass**

- How soon after launch will operations begin?
- How much time notice will be given before a pass?
- Does LLOT need to be in a standby mode for any pass?
- What would be the highest frequency of passes in time?
  - Every day, twice a day, once a week, etc.
- Is ephemeris file az/el the actual blind pointing position of the spacecraft (with look behind included) and laser az/el the point ahead blind pointing
  - (ie laser az/el minus az/el is the difference between where the receiver is looking and where the laser is transmitting)?
- Will there be experiments to vary parameters and see the effect on link performance?
  - Mispoint beam, change beam divergence, vary power, etc
  - Need to program telescope operations to perform such experiments

- **During Pass**

- Should there be a delay between time when LLOT sees downlink and the uplink beacon is narrowed down?
  - Or, should this be co-ordinated by LLOC?
- If LLOT scan terminates without contact, should the scan continue or re-start from the initial point?
- When link is established, should LLOT tweak alignment using telemetry information?
- If downlink is lost, should uplink be widened immediately?
  - Or, should this be co-ordinated by LLOC?
- If LLOT supports 155 Mbps link, will optical telemetry be downlinked?