

Small Satellite Laser Comm Pointing

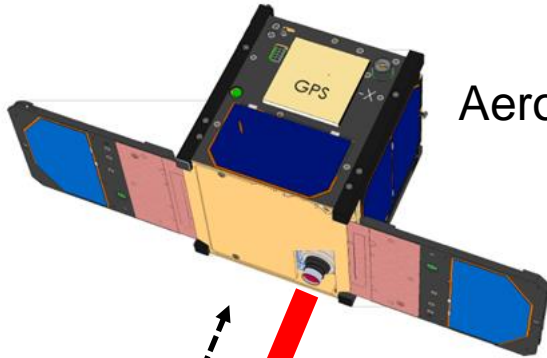
Darren Rowen

Microsatellite Systems Dept.
July 11, 2016

Agenda

- Optical Ground Station Tracking Demo of Cubesat Laser
- OCSD-B/C Design & Configuration
- OCSD-A Star Tracker On-Orbit Performance
- CubeSat Star Tracker Industry Survey

Ground Target Laser Diode Illumination (8/15/2013)

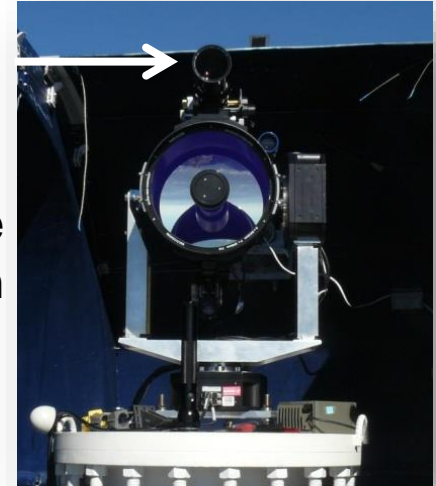


AeroCube 4

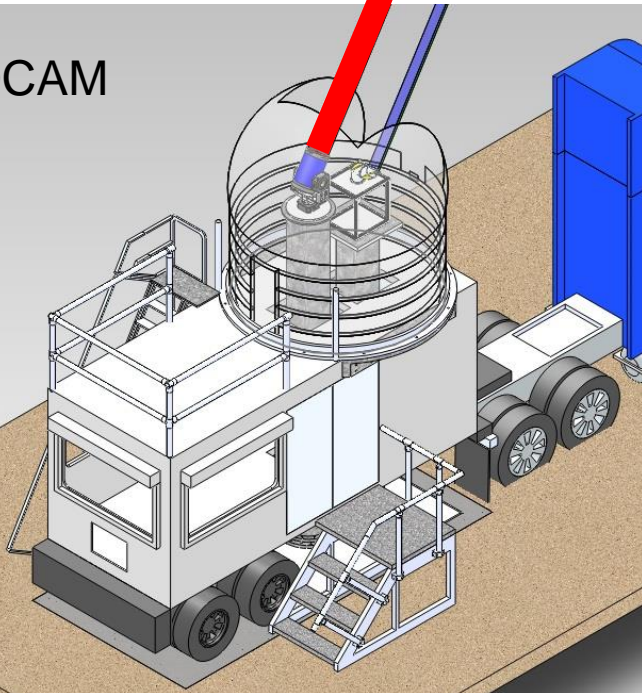
Range 650 - 775 km

Acquisition Scope

MOCAM Telescope Configuration



MOCAM



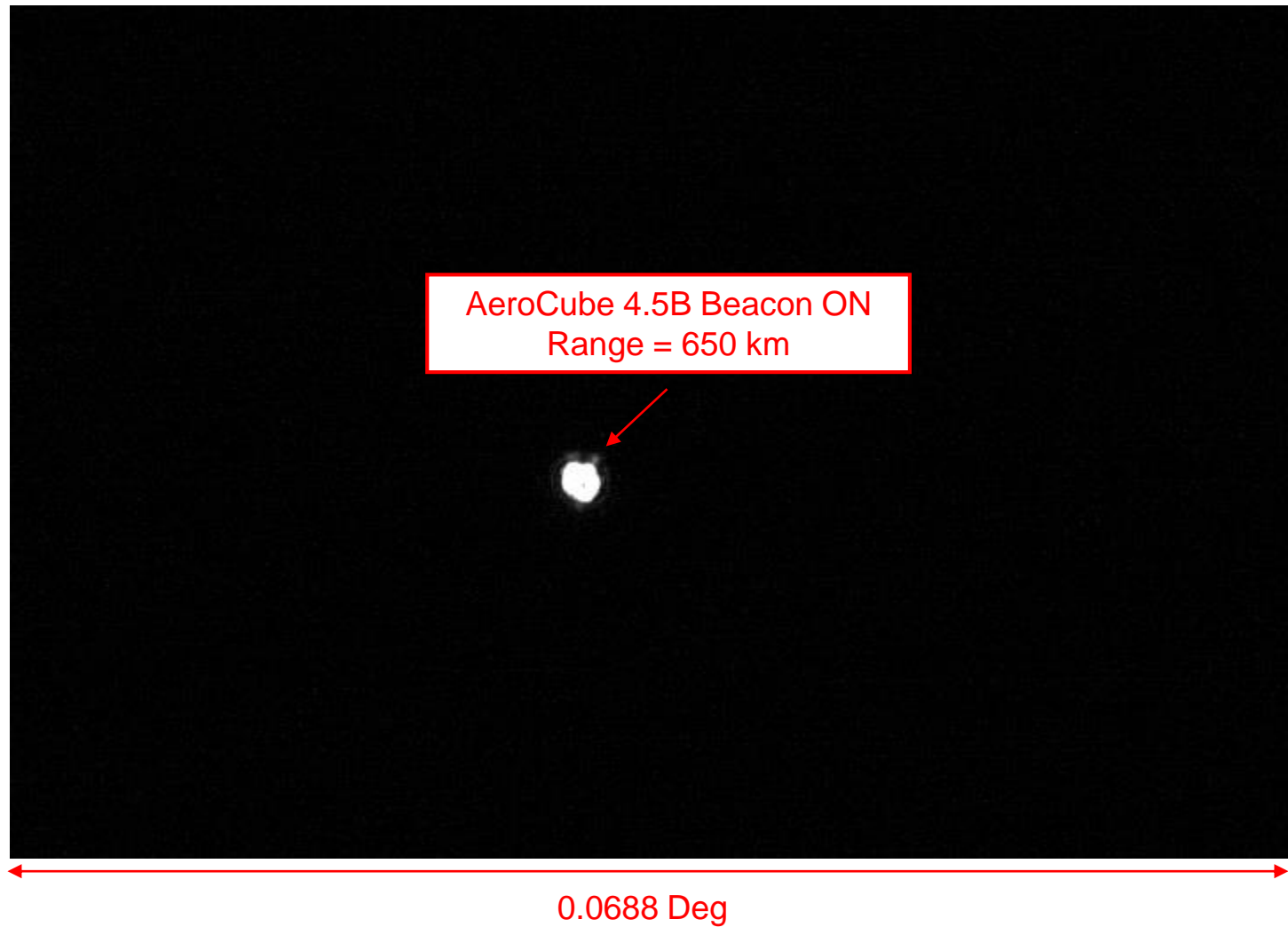
Santa Monica Bay

Pasadena

Mt Wilson Observatory



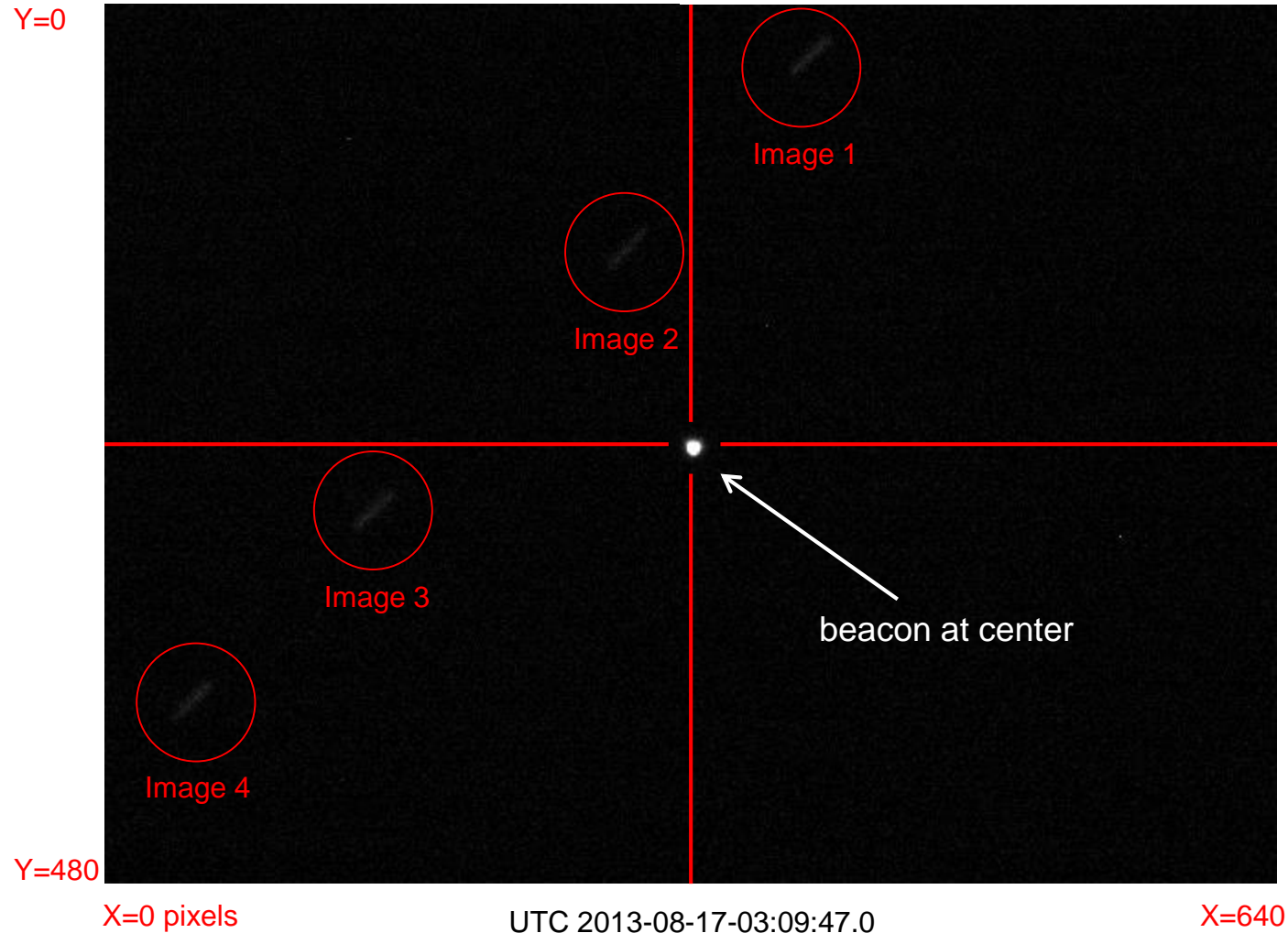
Ground Target Laser Diode Illumination (8/15/2013)



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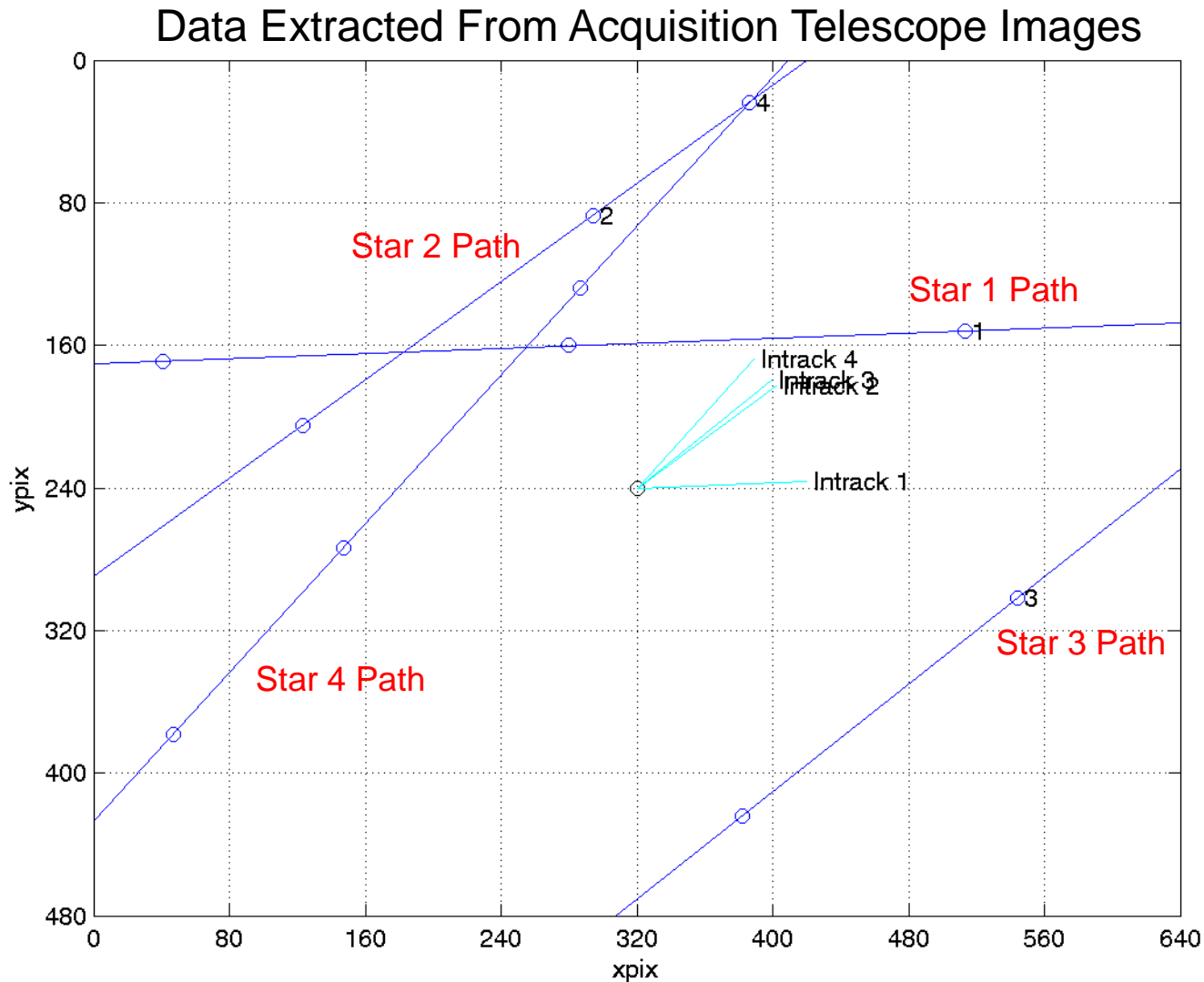
- Star Matching to Verify Ephemeris

Stacked Images From Acquisition Telescope



Ground Target Laser Diode Illumination (8/15/2013)

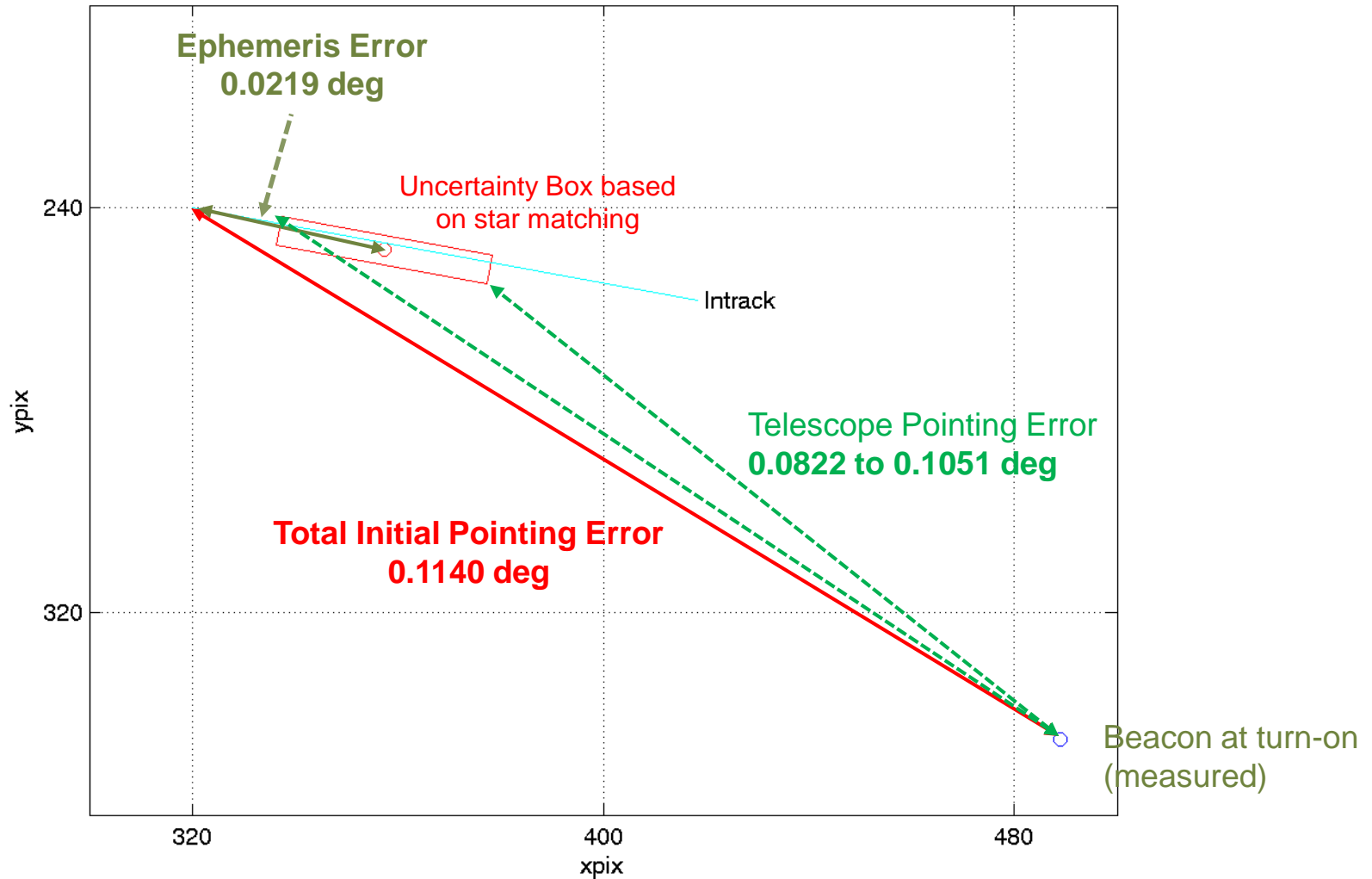
- Star Matching to Verify Ephemeris



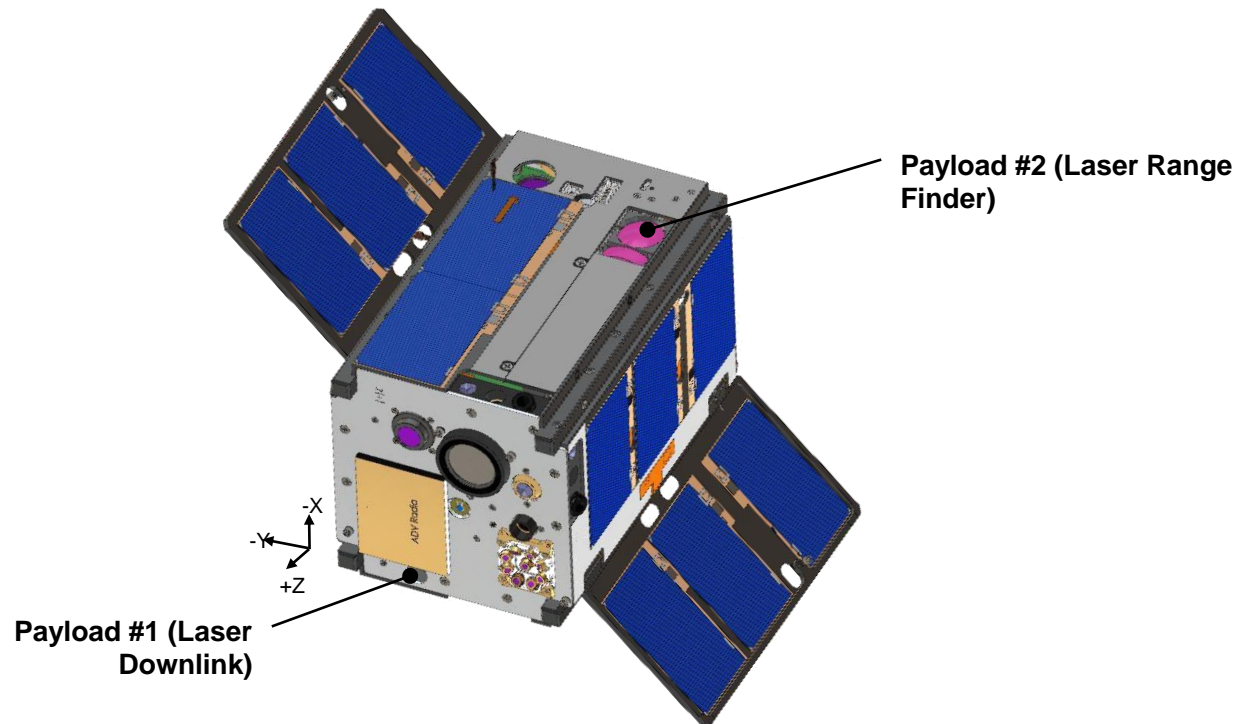
Individual Star Tracks Matched to Catalog Stars

Ground Target Laser Diode Illumination (8/15/2013)

- Open Loop Acquisition Pointing Error Breakdown



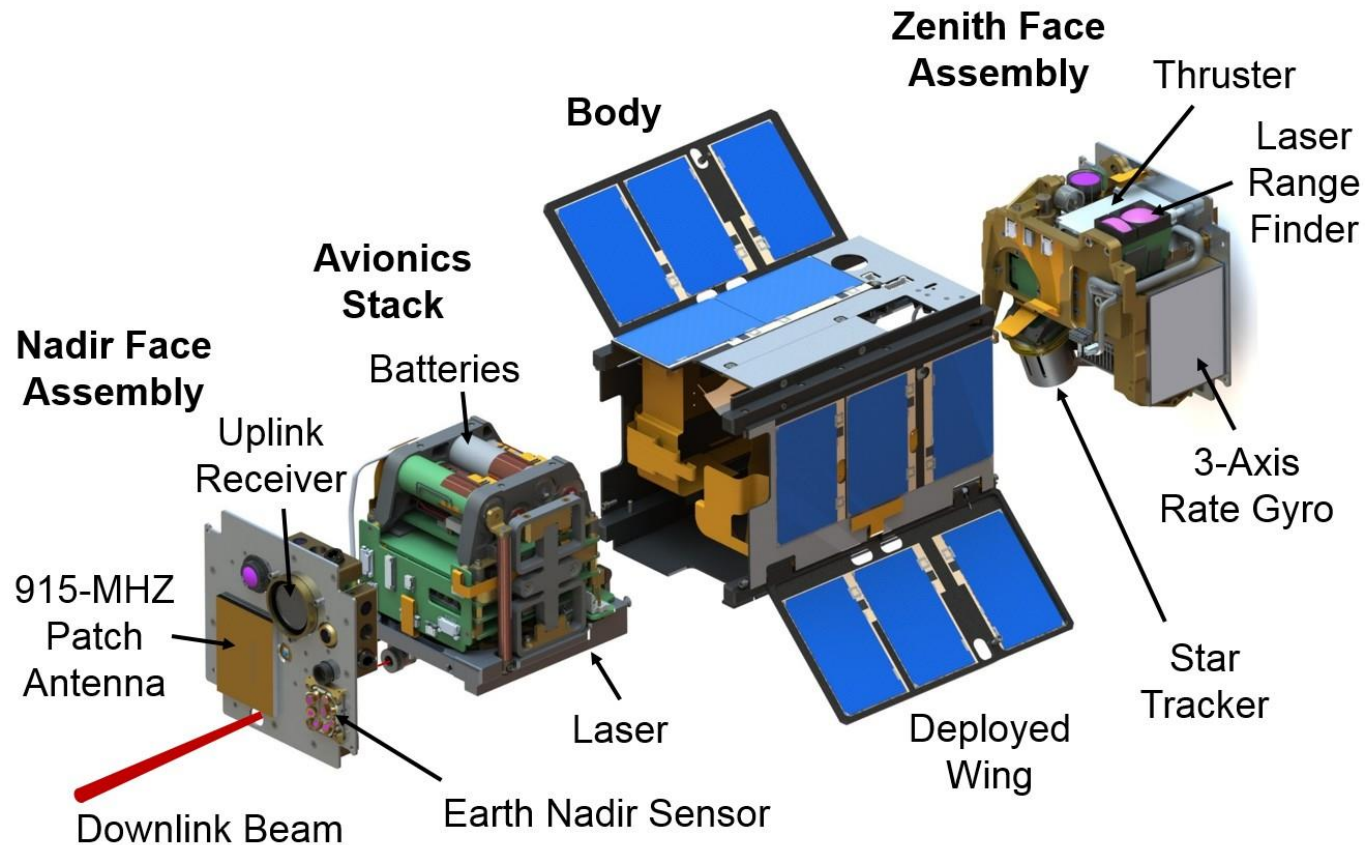
OCSD B/C: Vehicle Configuration



Key exterior features

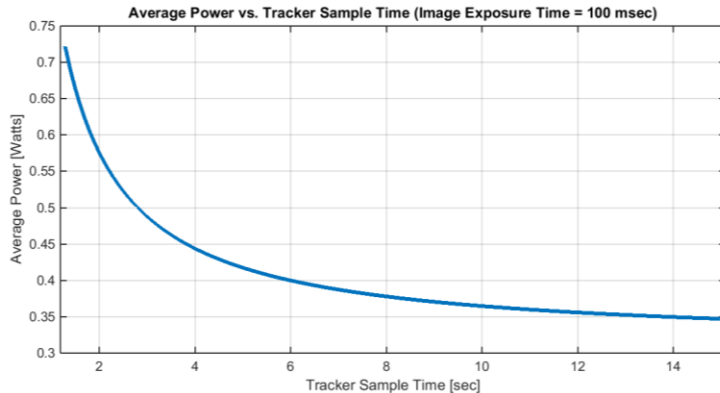
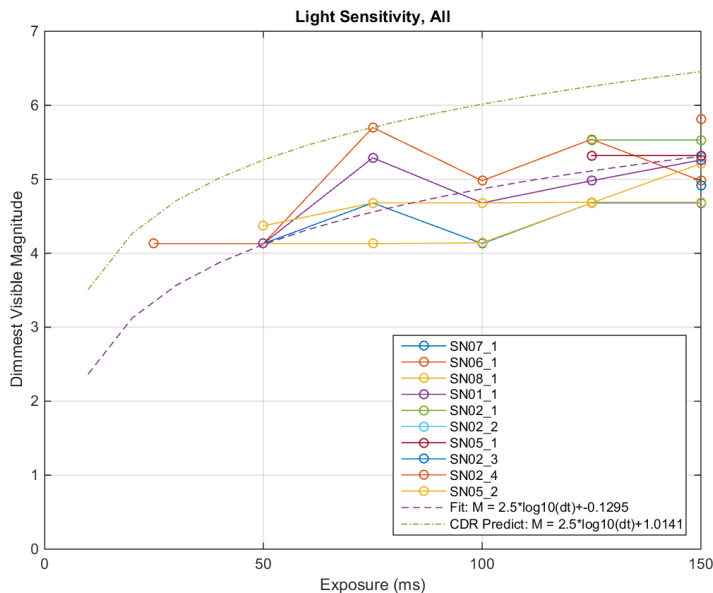
OCSD B/C Layout

Exploded view

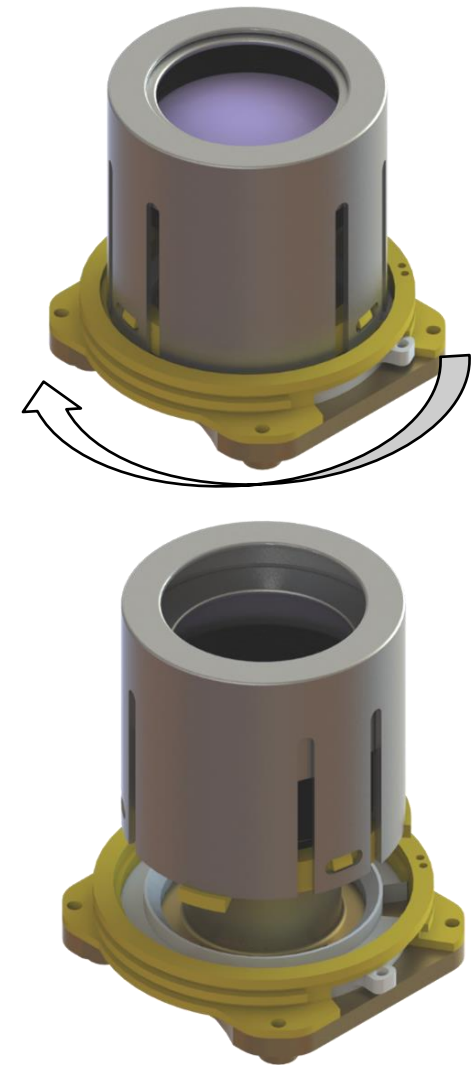
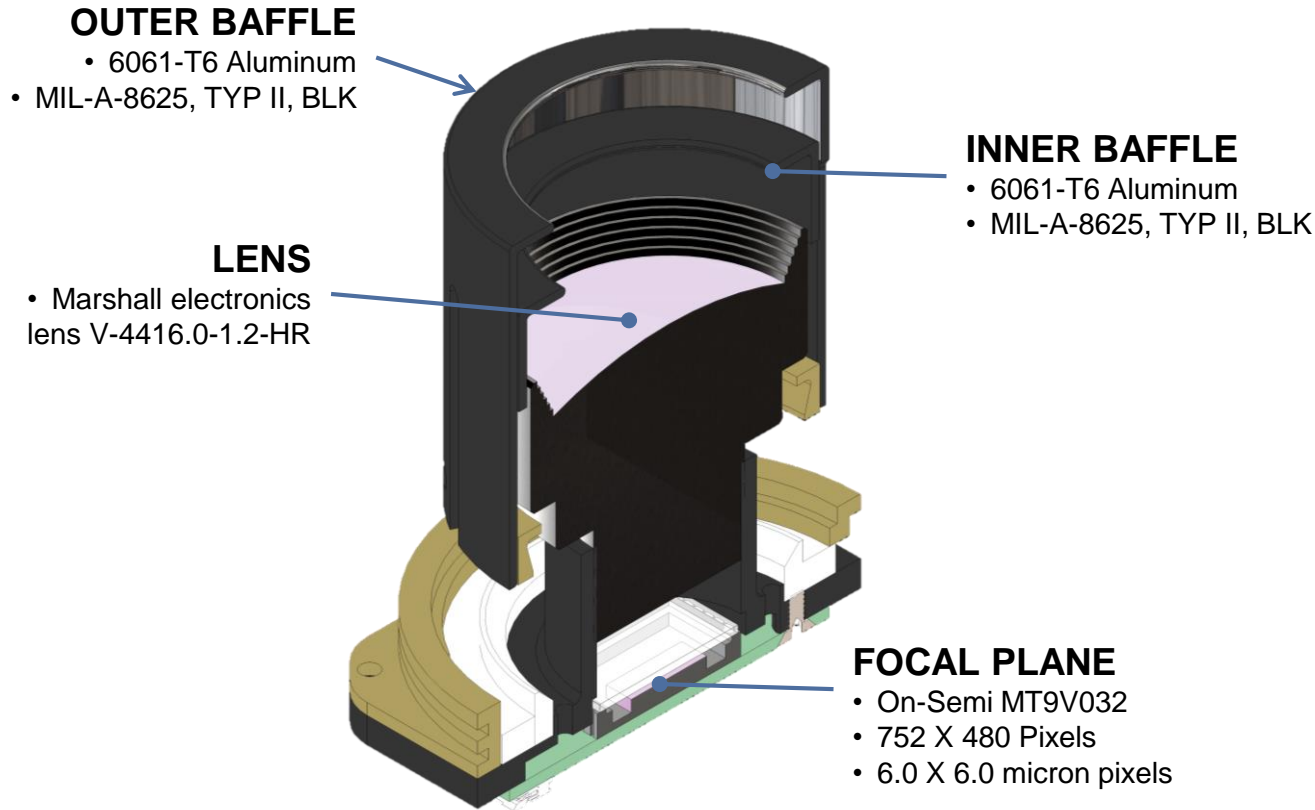


OCSD-B/C Star Camera Acceptance Test (Ground)

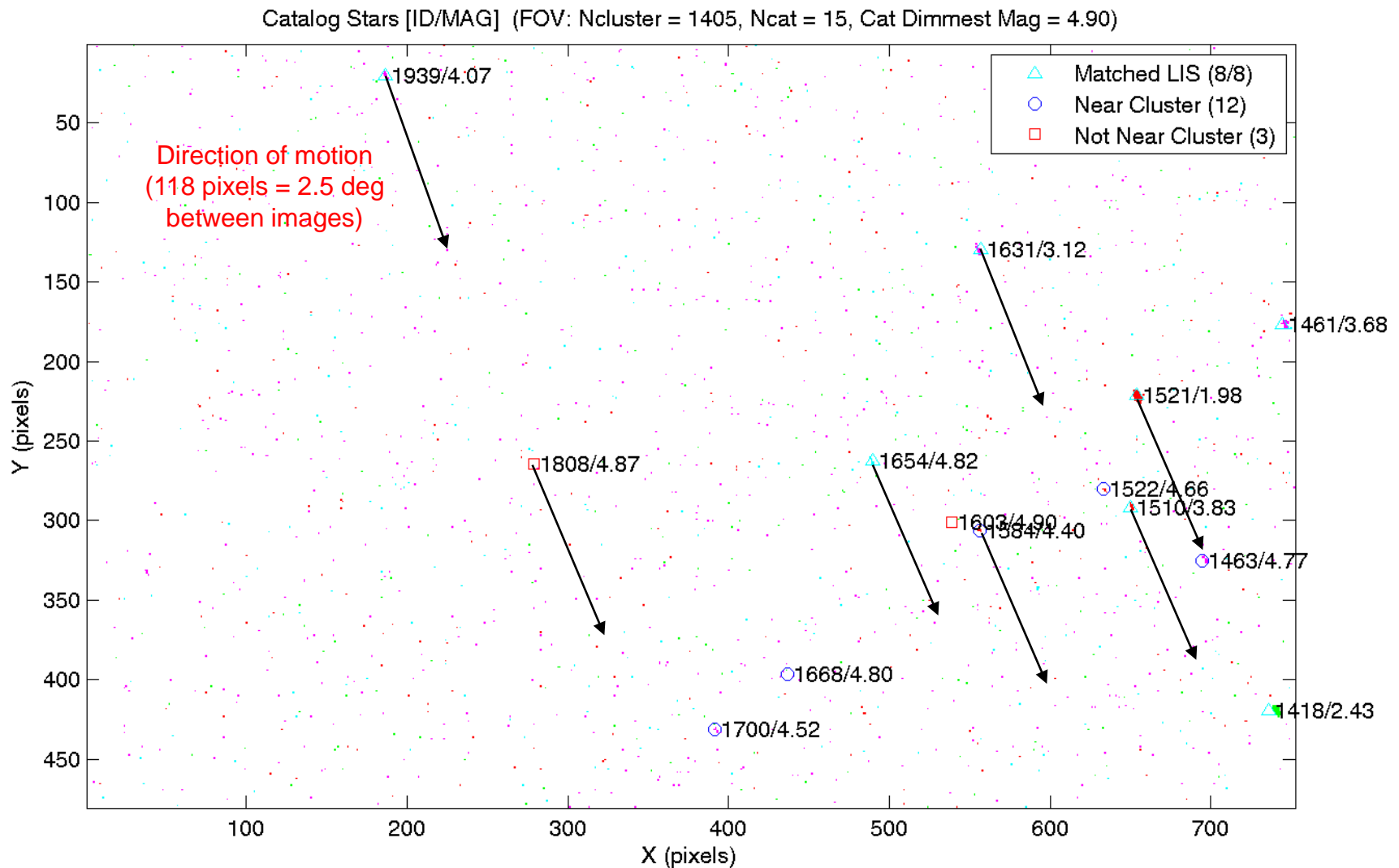
- OCSD B/C Star Tracker Units have been tested for light sensitivity, power consumption via dark sky testing
- Post-vibe verified functionality & focus in the lab, collected dark images for hot pixel mapping



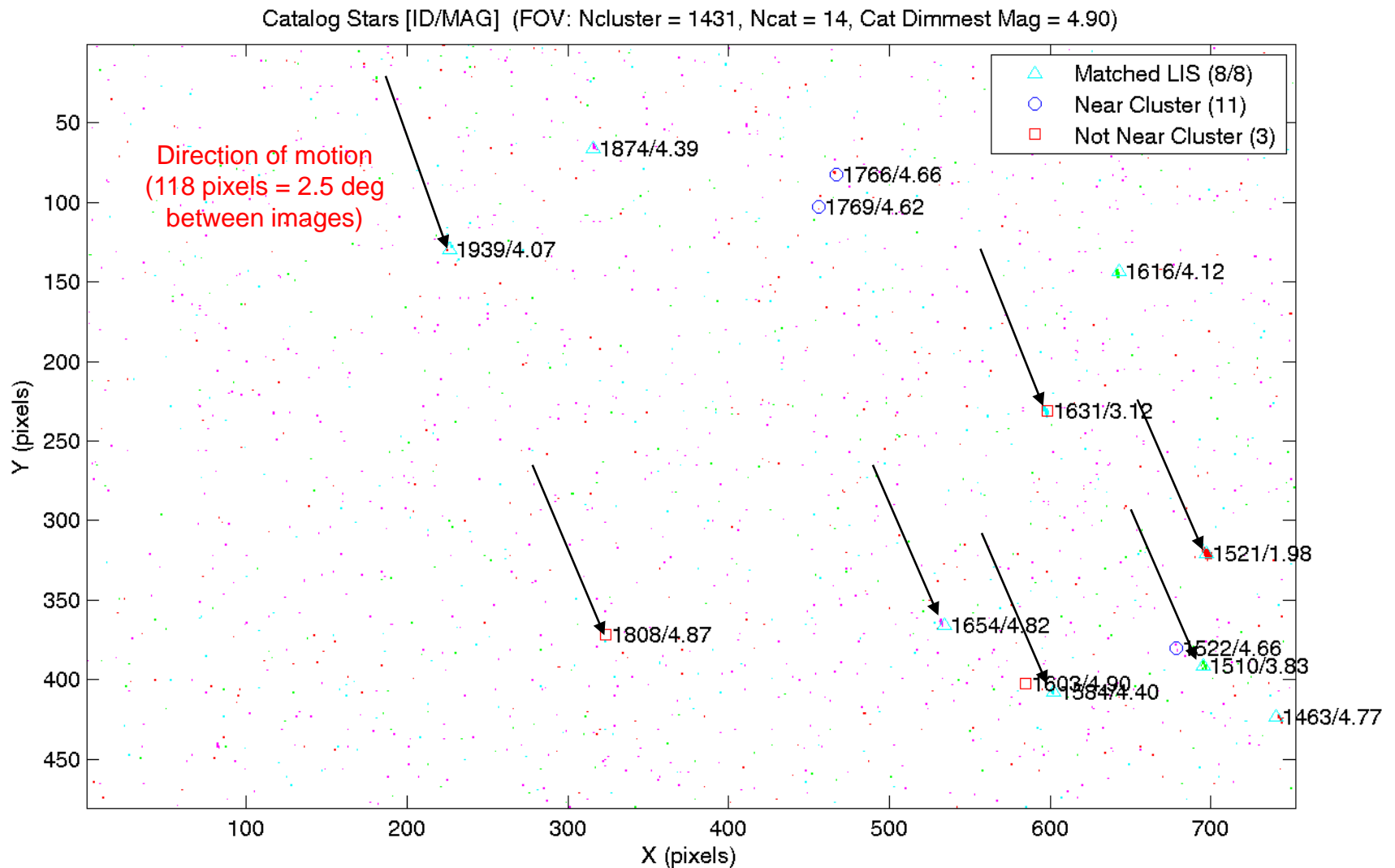
Star Tracker Design & On-orbit Results (OCSD-A)



Post-Processed Star Tracker Image 1 (0.97 deg/s)



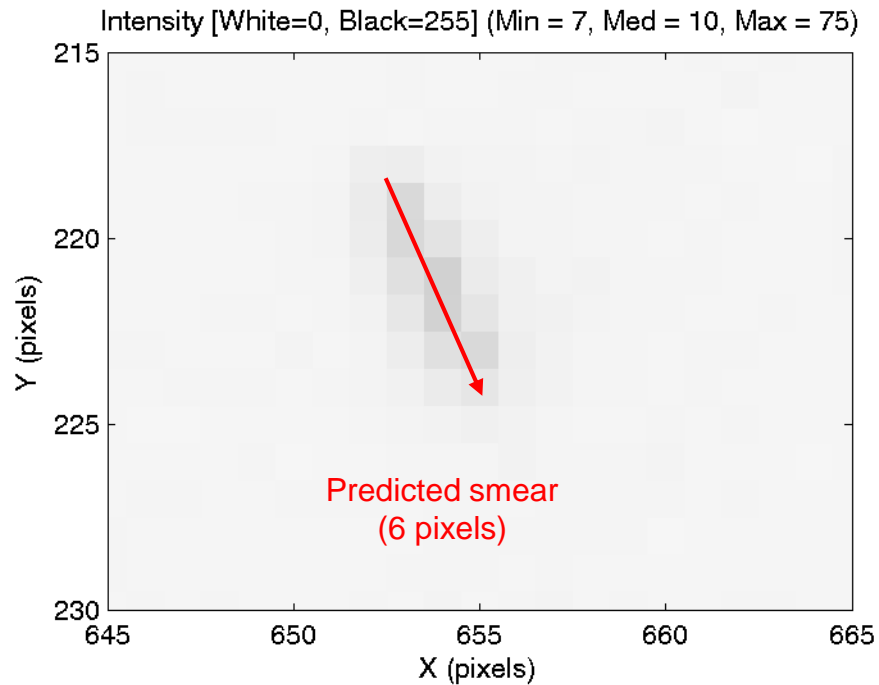
Post-Processed Star Tracker Image 2 (0.97 deg/s)



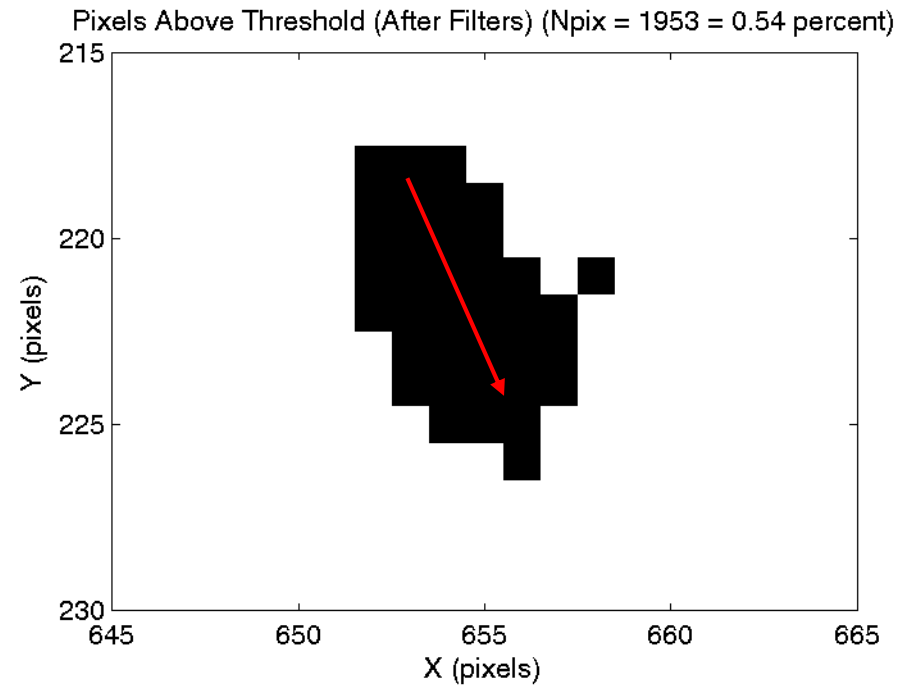
Star Smear Detail

Brightest Star (Mag 1.98)

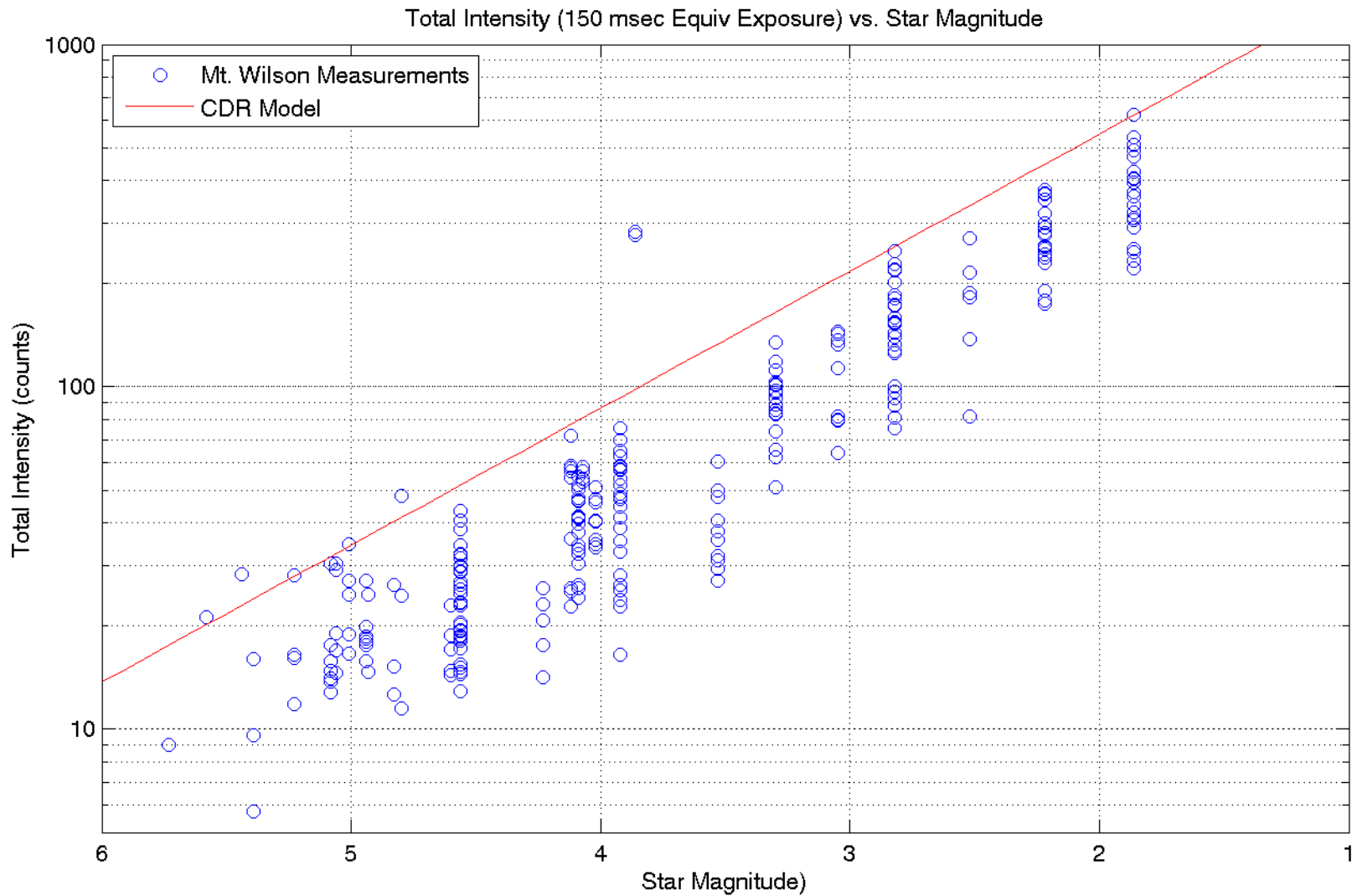
Inverted Image



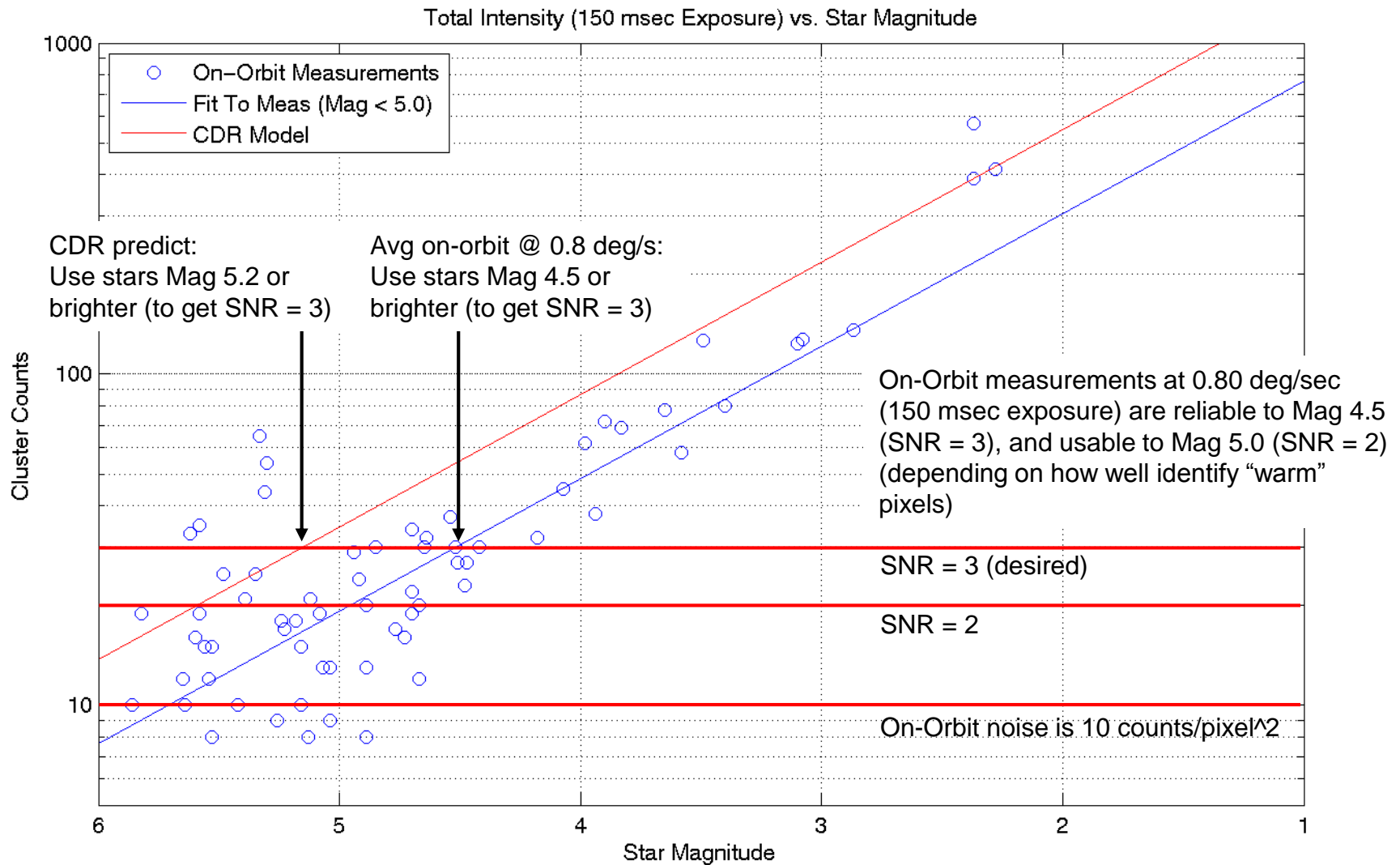
Pixels above threshold



Star Tracker Ground Measurements (Dark Sky)

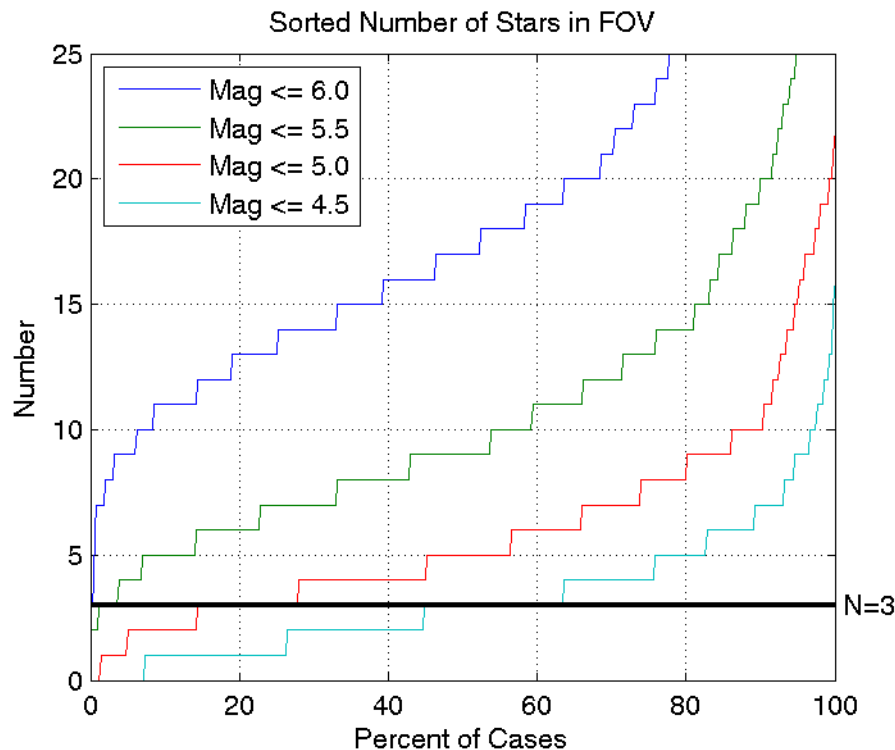


Star Tracker On-Orbit Measurements (0.80 deg/s)



Star Tracker Solution Probability

- On-orbit sensitivity data supports analytical studies to determine the probability of obtaining a valid solution at maximum mission slew rates

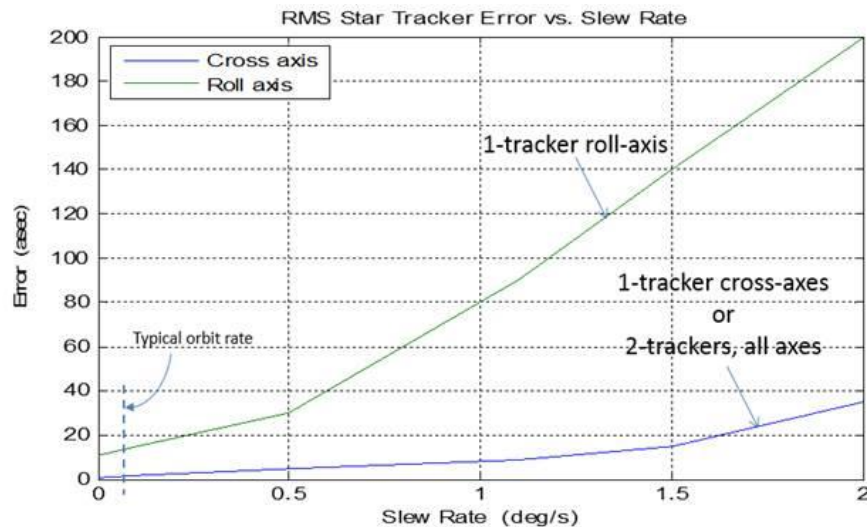


Monte Carlo 500 random attitudes

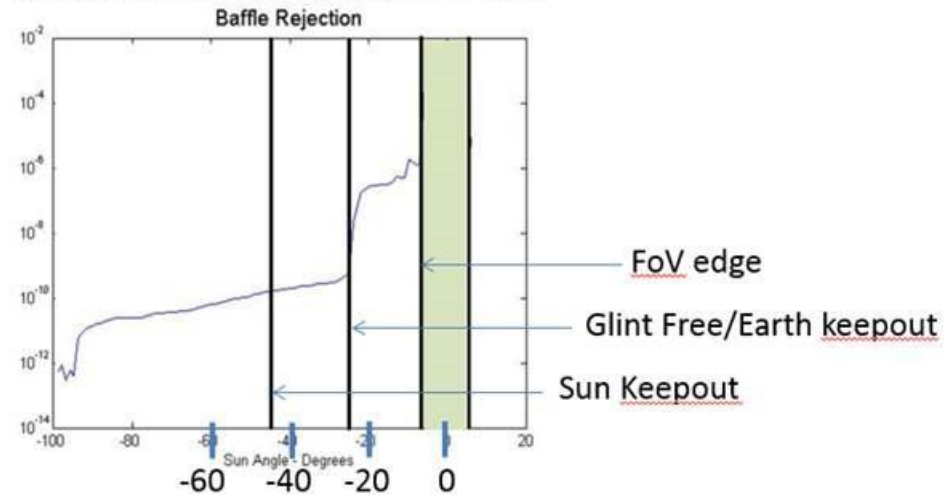
Mag	Cases with fewer than 3 stars in FOV	
4.5	44.6%	← On-Orbit, SNR=3, 150 msec, 0.8 d/s
4.6	39.6%	
4.7	33.6%	
4.8	27.2%	
4.9	20.6%	
5.0	14.2%	← On-Orbit, SNR=2, 150 msec, 0.8 d/s
5.1	9.2%	
5.2	6.4%	
5.3	3.8%	
5.4	2.0%	← CDR, SNR=3, 150 msec, <0.1 d/s
5.5	1.0%	
5.6	0.4%	
5.7	0%	
5.8	0%	
5.9	0%	
6.0	0%	

Blue Canyon Technologies XACT

- MinXSS CubeSat First to fly XACT system
 - 1-sigma cross-axis pointing error better than 8 arcseconds
 - Max tested on-orbit slew rates < 0.15 deg/s
 - Ground test data (below) suggests the following performance for higher slew rates. Note ground test data demonstrates knowledge accuracy of the star tracker but unable to demonstrate closed loop pointing accuracy due to limitations of ground testing.



Results of heliostat testing at CU LASP



Data provide by and presented with permission form Blue Canyon Technologies

CubeSat Star Tracker Performance & SWAP

- Star Tracker Performance Continues to Improve and Size Continues to Shrink
- Note: table shows accuracy at low slew rate, accuracies at higher slew rates are not well characterized for most star trackers

NanoSatellite StarTracker	Attitude accuracy (pitch/roll)	Size/Weight	Max Slew rate (availability >80% for min # stars >=3)	Radiation tolerance
Berlin Space Technologies	30/400 arcsec	36 cm ³ / 50g	1 deg/sec	CMOS – low
Blue Canyon Technologies	6/40 arcsec	250 cm ³ / 350 g	2 deg/sec	CMOS – low
Sinclair ST-16	7/70 arcsec	90 cm ³ / 90g	1 deg/sec	CMOS – low
Aerospace OCSD	12/130 arcsec	52 cm ³ / 77g (113g w/2 cams)	1 deg/sec	CMOS – low
<i>Aerospace next gen</i>	<i>6/40 arcsec</i>	<i>52 cm³ / 77g (113g w/2 cams)</i>	<i>3.9 deg/sec</i>	<i>Silicon on Insulator (SOI) CMOS – better</i>

^[1] Berlin Space Technologies. “ST-200 Flyer: Miniaturised Autonomous Star Tracker” http://www.berlin-space-tech.com/fileadmin/media/BST_ST-200_Flyer.pdf

^[2] T Dzamba, J Enright. “Ground Testing Strategies for Verifying the Slew Rate Tolerance of Star Trackers.” Sensors 2014, 3939-3964.

^[3] J Enright, D Sinclair, K. C. Fernando. “COTS Detectors for Nanosatellite Star Trackers: A Case Study.” Conf. Small Sat. (2011).