OCSD-A / AeroCube-7A Status Update

Darren Rowen
Richard Dolphus
Patrick Doyle
Addison Faler

Microsatellite Systems Dept.
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Agenda

- Concept of Operations Overview
- Spacecraft Configuration
- Software Update Anomaly Overview
- Software Architecture Design Modifications
- Star Tracker Checkout & Analytical Results
- 10MP Imager Test Images

Darren.W.Rowen@aero.org
Microsatellite Systems Dept.

OCSD Concept of Operations Overview (1/2)

- The mission includes the following primary objectives:
  - *The CubeSat shall demonstrate an optical downlink at 5 megabits per second.*
  - *Two CubeSats shall demonstrate passive and active orbital rephasing maneuvers to bring them within 200 meters of each other.*
  - *One CubeSat shall demonstrate tracking of the other.*

- These objectives are to be completed by a pair of 1.5U Cubesats: OCSD-B & OCSD-C to be launched in the summer of 2016

- OCSD-A demonstration added in 2015 as an additional mission to buy down risk for the mission of record
  - *ACS verification and pointing accuracy goals*
  - *Laser and other subsystems verification*
  - *Laser Downlink CONOPS refinement*
  - *Calibration procedure & tool refinement*

Darren.W.Rowen@aero.org
Microsatellite Systems Dept.

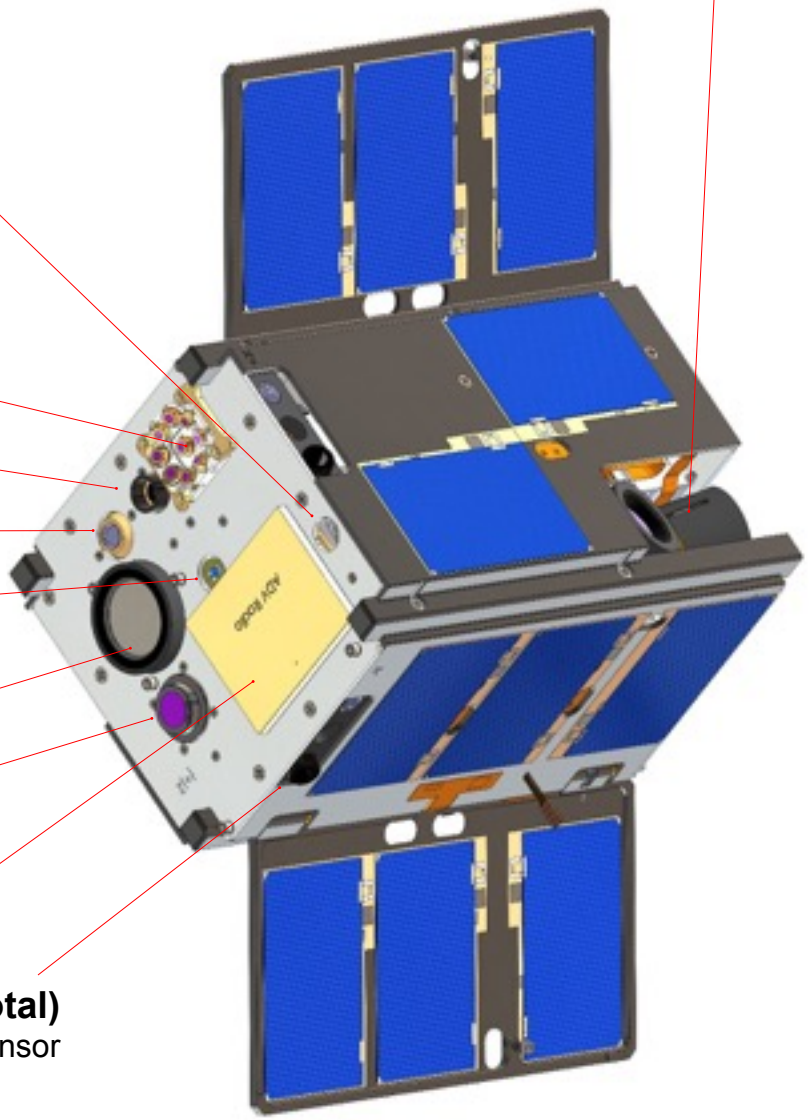
OCSD Concept of Operations Overview (2/2)

- A software update anomaly disabled the attitude control main processor, which results in the following loss of functionality:
  - *Inability to control the spacecraft attitude or spin rate*
  - *Inability to communicate with or operate the laser downlink communication payload*
  - *Inability to communicate with or operate the laser range finder payload*
  - *Inability to propagate & estimate the spacecraft attitude in real-time*
    - Note that discrete attitude solutions using the star tracker are possible, but only when the tracker happens to be pointed in a favorable orientation

- OCSD-A Still Reduces Risk for the primary mission, although a sub-set of the risk reduction objectives can not be accomplished:
  - *ACS verification and pointing accuracy goals (Partial, limited to Star Tracker Checkout)*
  - ~~*Laser*~~ *and other subsystems verification (Other subsystems can be tested: Power, Camera, GPS, Radio, Deployment Mechanisms)*
  - ~~*Laser Downlink CONOPS refinement*~~
  - *Calibration procedure & tool refinement (Partial, limited to Star Tracker Checkout)*

Darren.W.Rowen@aero.org
Microsatellite Systems Dept.

OCSD Spacecraft Configuration



Sensor Suite (1x Sensor Package per long face, 4x total)
1 Earth Horizon Sensor, 1 retroreflector, and 1 Sun Sensor

Darren.W.Rowen@aero.org
Microsatellite Systems Dept.

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OCSD-A Software Update Anomaly Overview

- The ACS main microcontroller was rendered permanently unresponsive during a software update. While this issue could have been identified prior to upload, the ground pre-upload verification process was not perceptive enough to catch the problem.
- The verification procedure at the time was to program an engineering unit to match the flight configuration then load the update and verify a match to the desired program binary post update.
- Pre-upload ground simulation did not exactly match actual upload process
  - *Flight upload was loaded incrementally over several ground contact periods*
  - *Between ground contacts, the vehicle executed a regularly scheduled power-cycle*
  - *The power-cycle process re-booted the ACS processor into a partially updated program which prevented proper initialization.*
  - *The power-cycle re-boot was not included in the pre-upload ground simulation.*
- Prior flight vehicles have experienced the same conditions many times, but a change in the partition order necessitated a different upload sequence to preserve proper initialization when the processor is in the partially updated state.

Root cause has been identified

Darren.W.Rowen@aero.org
Microsatellite Systems Dept.

OCSD-A Inoperable Components

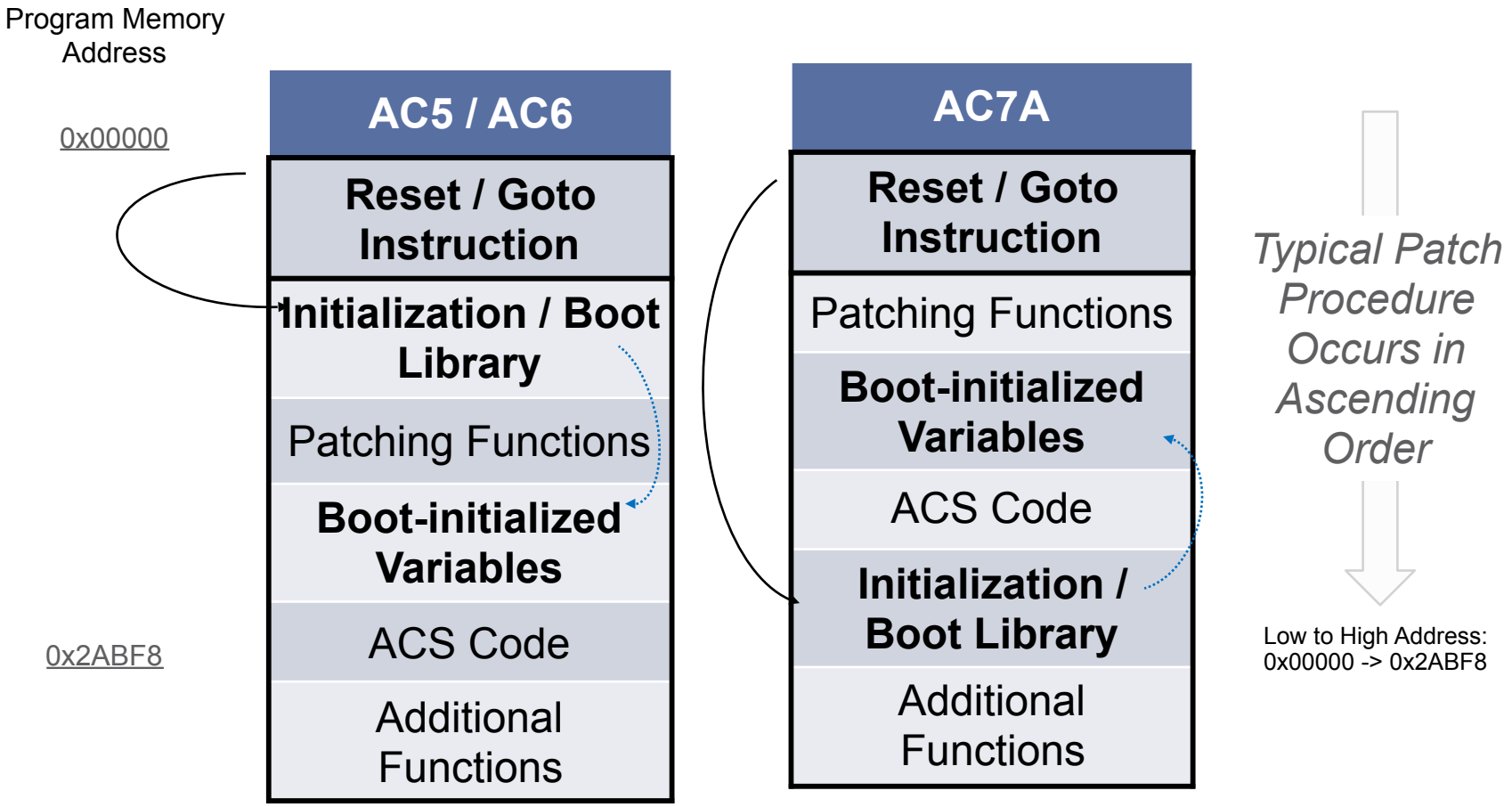
- The following items have been rendered inoperable after the software update anomaly (items in BLUE were tested prior to the update):
  - *Sun Sensors*
  - *Earth Nadir Sensor*
  - *Earth Horizon Sensor*
  - *Rate gyros (STIM & VectorNav)*
  - *Reaction Wheels*
  - *Laser transmitter (powered on digital electronics and got response but did not fire laser)*
  - *Torque rods*
  - *Laser Range finder*
  - *Magnetometer*

Many of the now inoperable components were tested prior to the update

Darren.W.Rowen@aero.org
Microsatellite Systems Dept.

Memory Partitioning

Example Memory Map of 16 Bit PICs used on AeroCube



> Boot Library references table of Boot-initialized variables

> Table must match Boot Library or reset will cause errors

Darren.W.Rowen@aero.org
Microsatellite Systems Dept.

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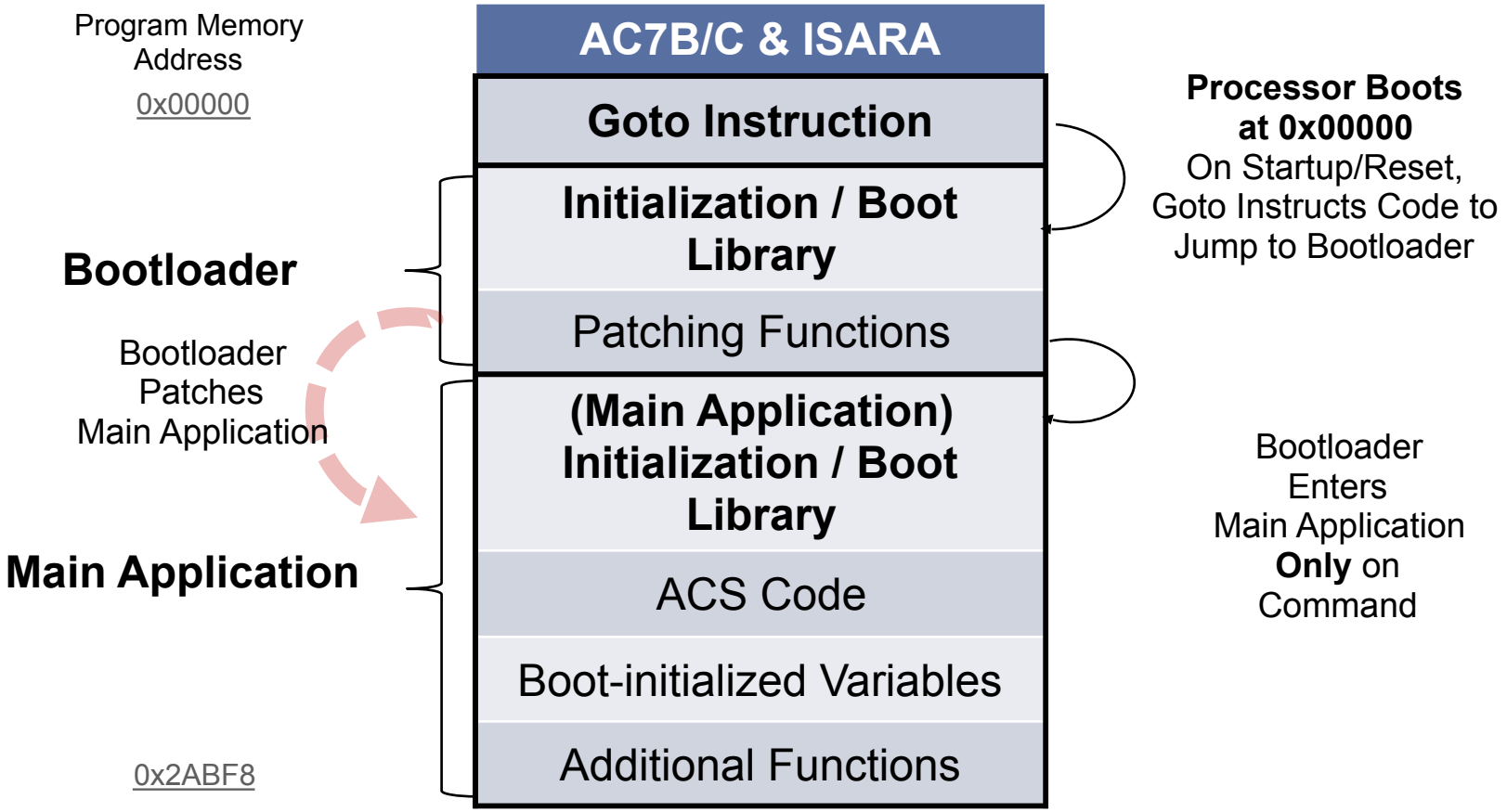
Bootloader Application

Separate Patch Functions from Main Application



> If Main Application Fails, Bootloader can still patch/update the application

> Currently on 8-bit Sensor, Propulsion and Reaction Wheel PICs

Darren.W.Rowen@aero.org
Microsatellite Systems Dept.

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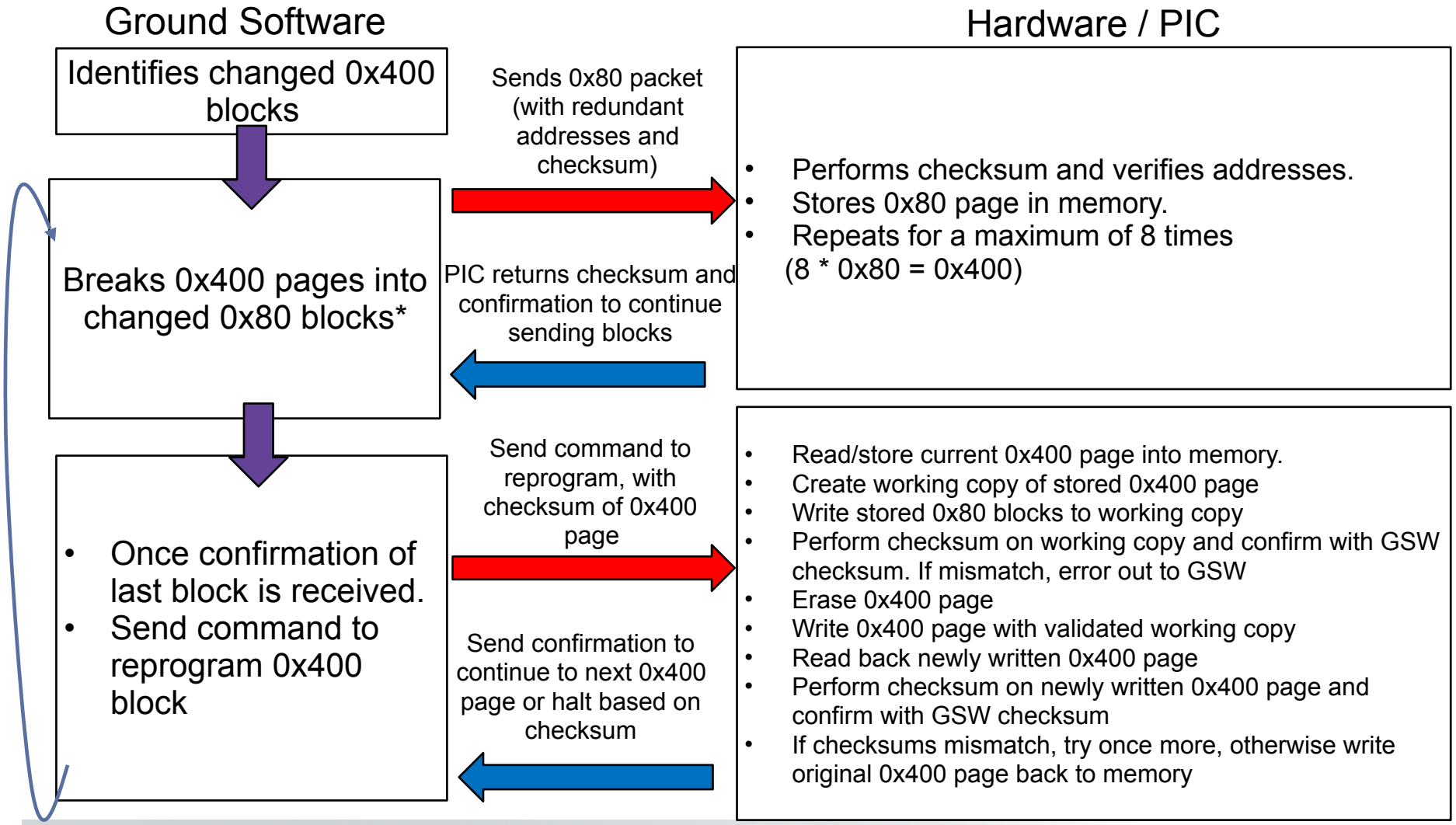
Bootloader Application

Updated Patching Routine



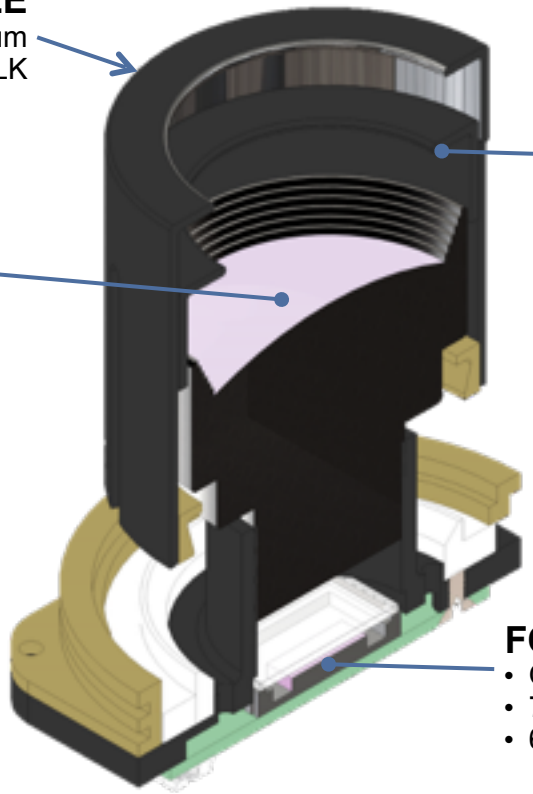
0x80 and 0x400 discretization is due to flash read/write library constraints on PIC

Darren.W.Rowen@aero.org
Microsatellite Systems Dept.

Star Tracker Design & On-orbit Results

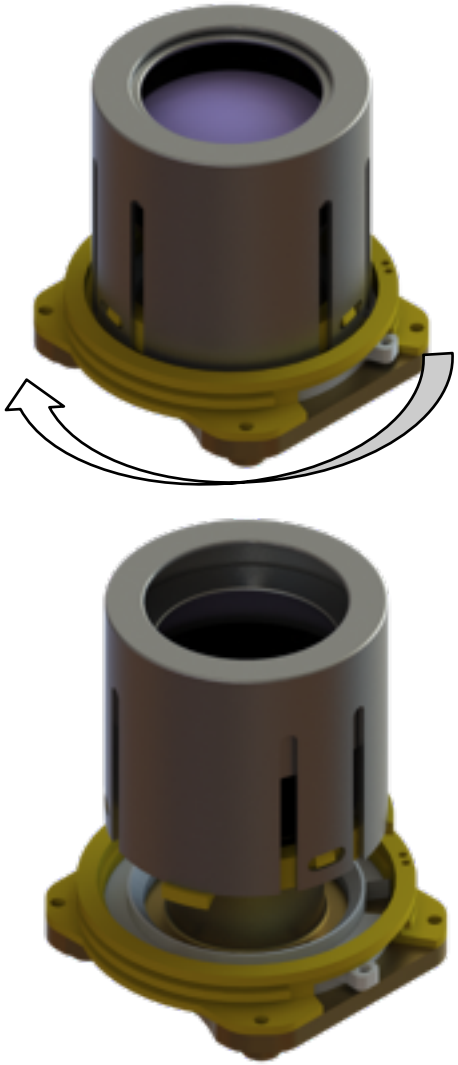
OUTER BAFFLE
- 6061-T6 Aluminum
- MIL-A-8625, TYP II, BLK

LENS
- Marshall electronics lens V-4416.0-1.2-HR



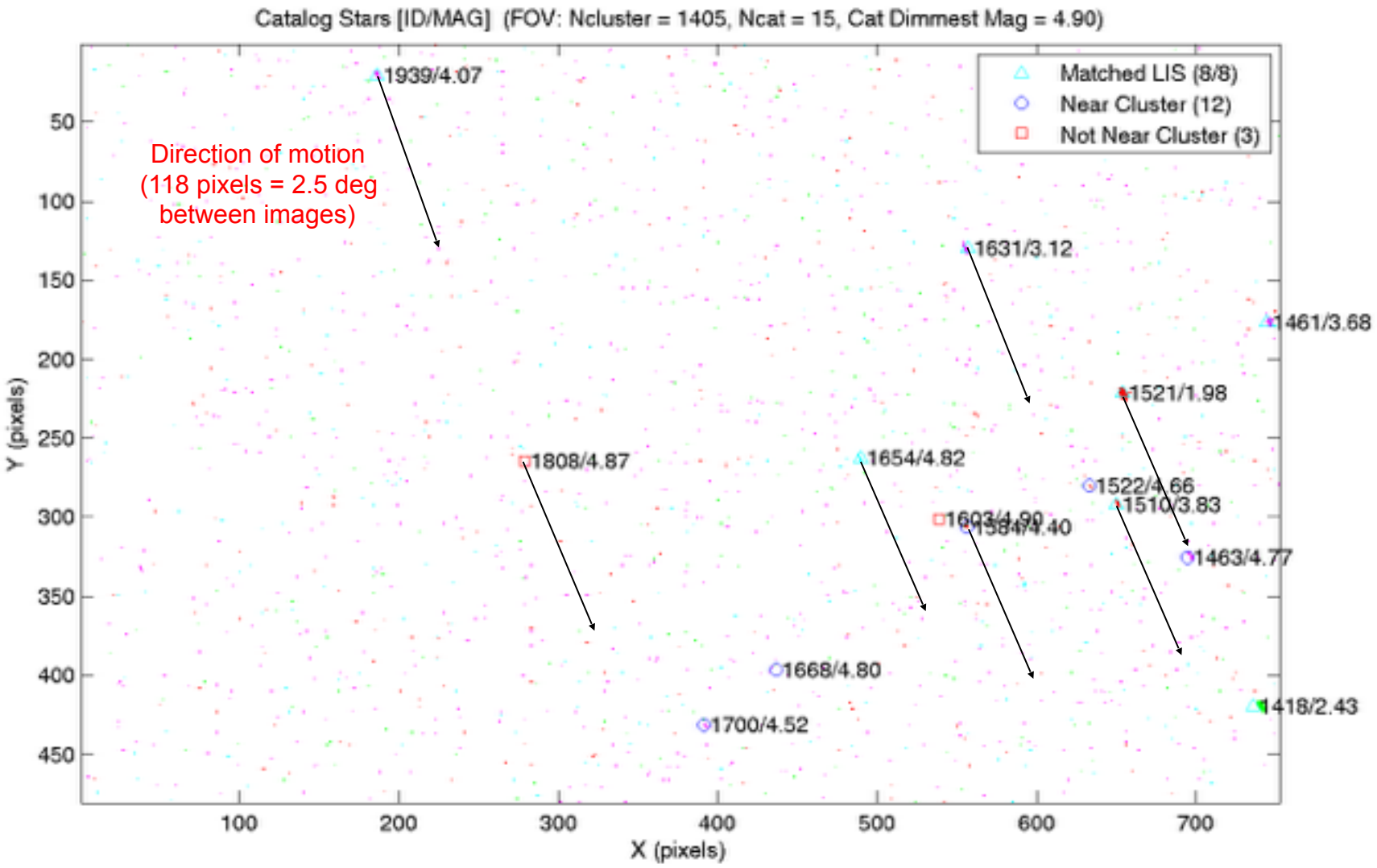
INNER BAFFLE
- 6061-T6 Aluminum
- MIL-A-8625, TYP II, BLK

FOCAL PLANE
- On-Semi MT9V032
- 752 X 480 Pixels
- 6.0 X 6.0 micron pixels



Darren.W.Rowen@aero.org
Microsatellite Systems Dept.

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



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Microsatellite Systems Dept.

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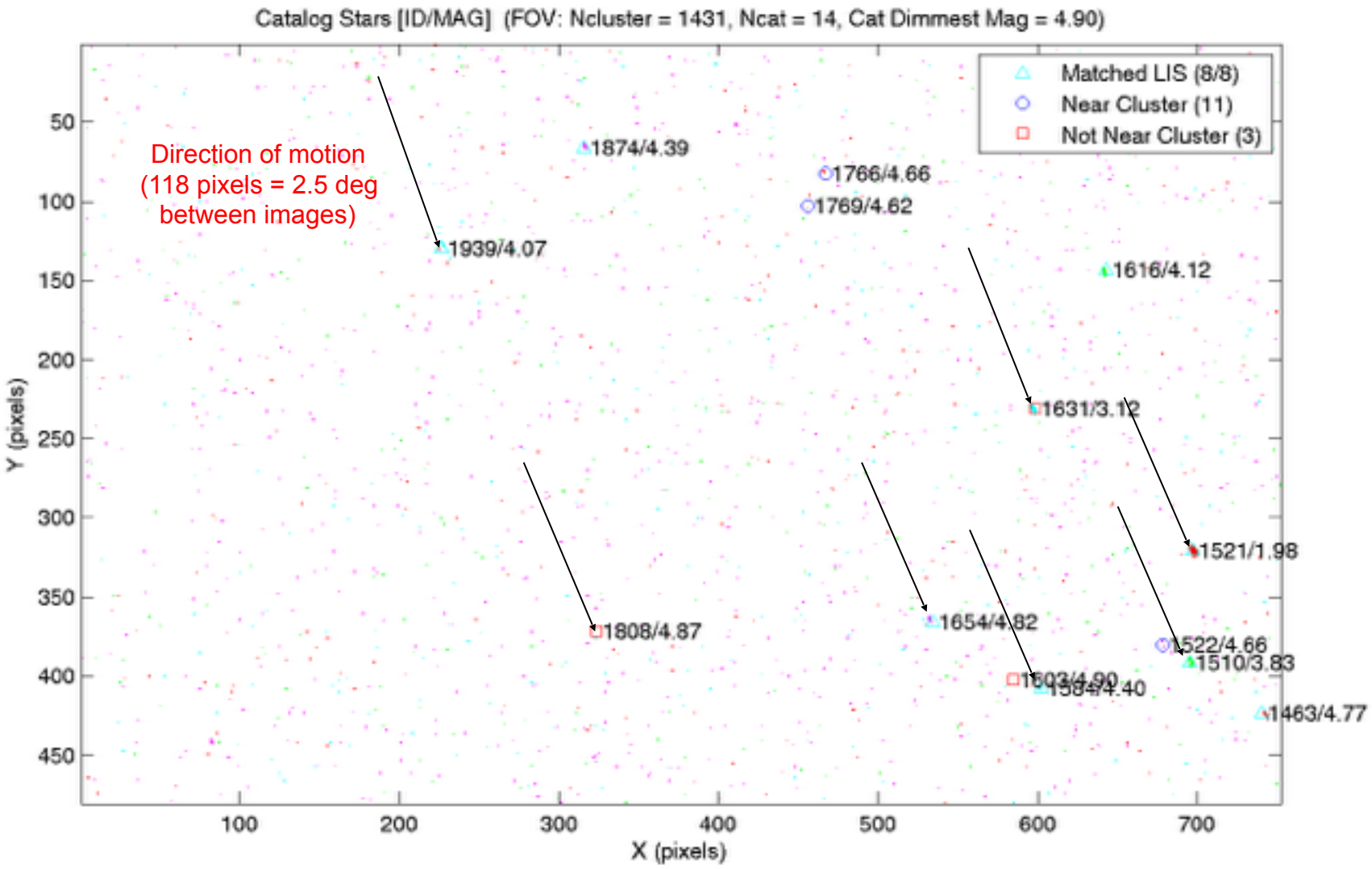
Post-Processed Star Tracker Image 2 (0.97 deg/s)



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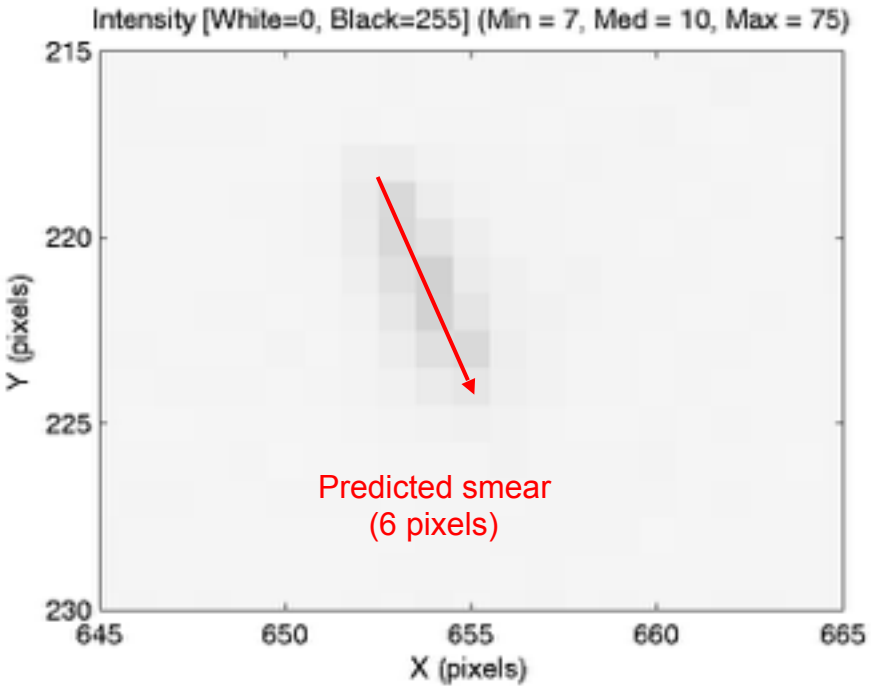
Microsatellite Systems Dept.

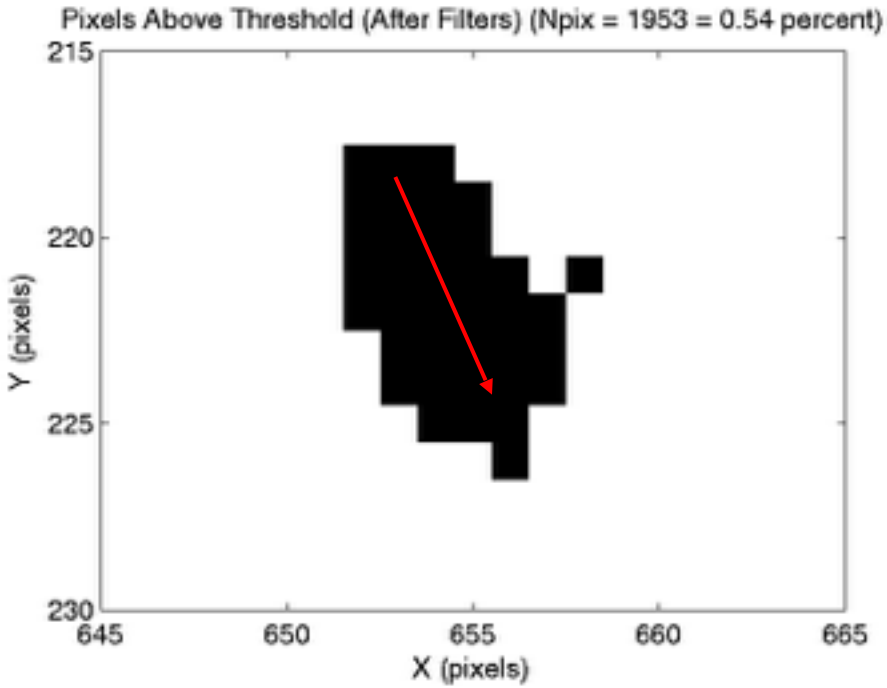
Star Smear Detail

Brightest Star (Mag 1.98)

Inverted Image



Pixels above threshold



Darren.W.Rowen@aero.org
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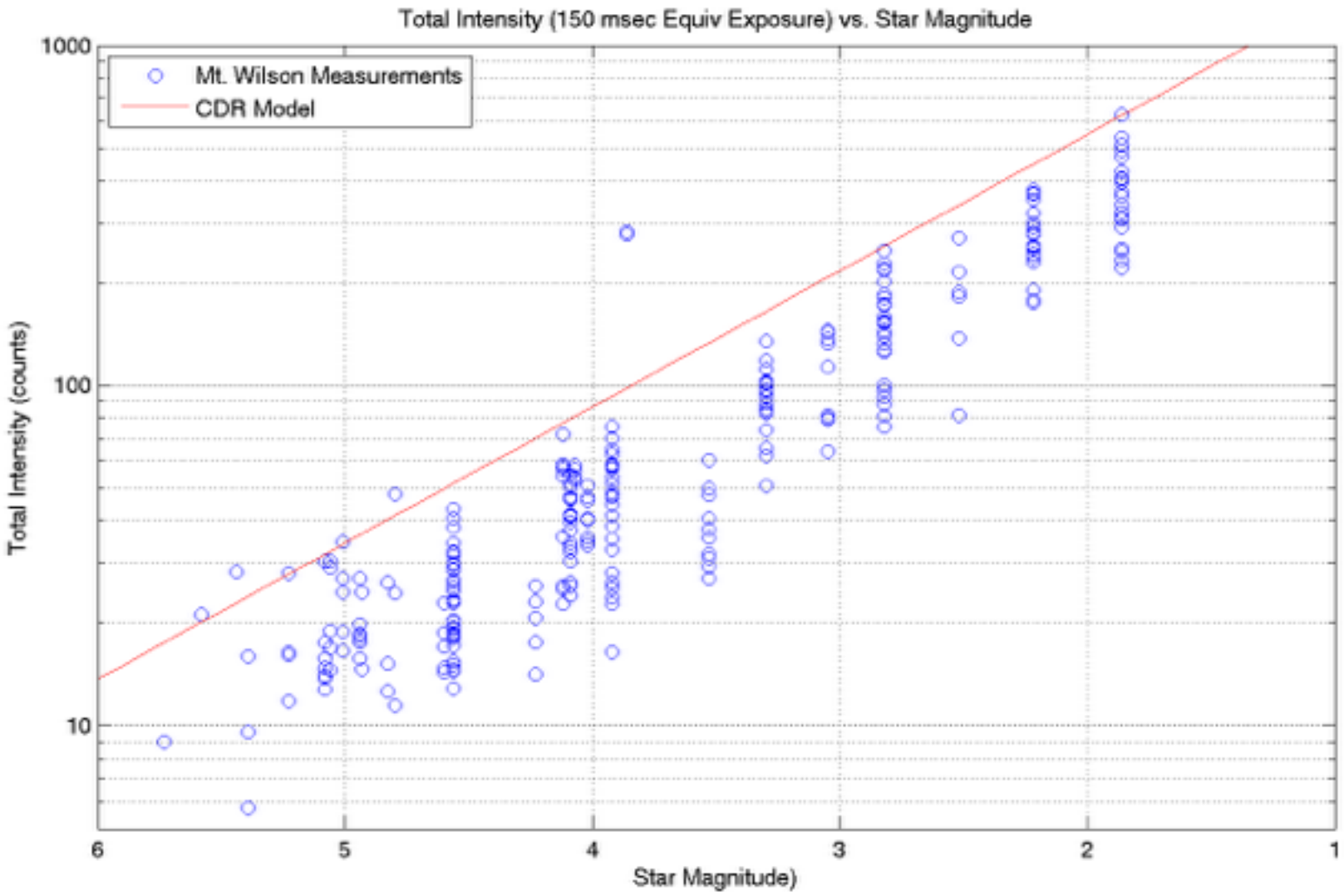
Star Tracker Ground Measurements (Dark Sky)



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Microsatellite Systems Dept.

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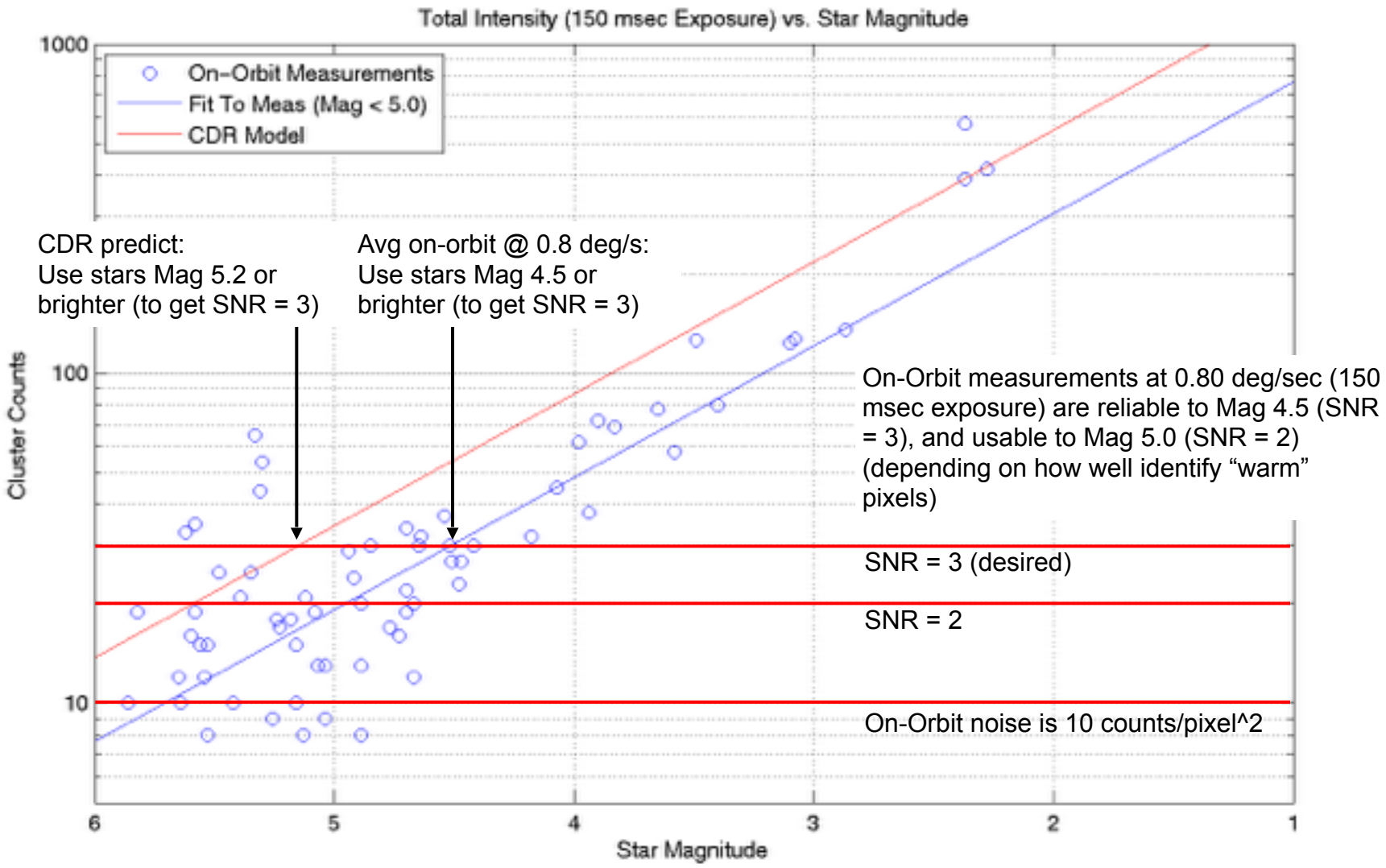
Star Tracker On-Orbit Measurements (0.80 deg/s)



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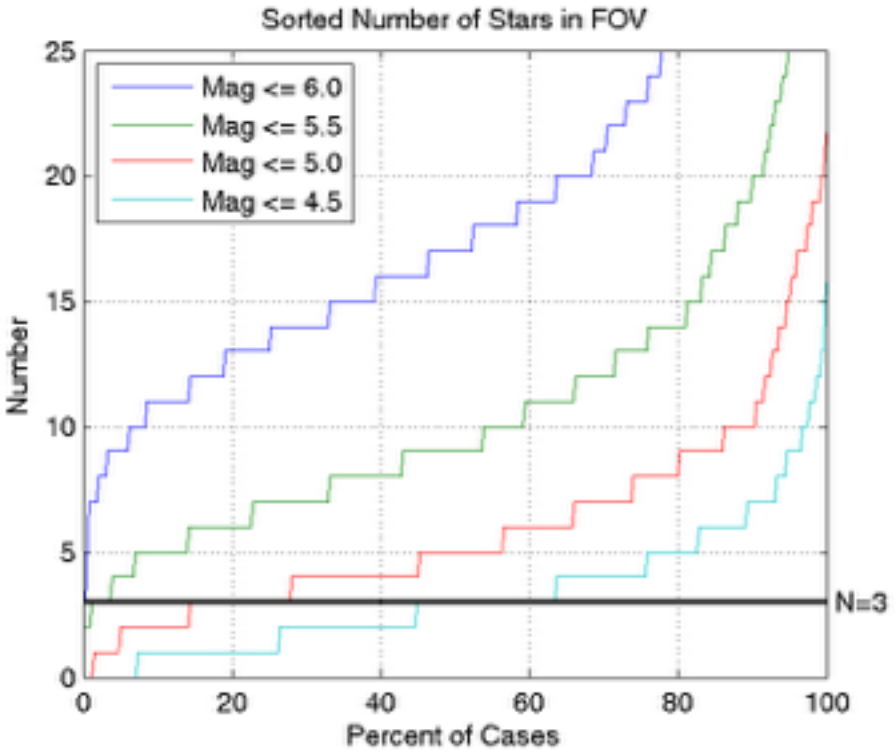
Star Tracker Solution Probability

- 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%	

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Yukon Delta (Alaska) & Bering Sea – 10MP imager test photos

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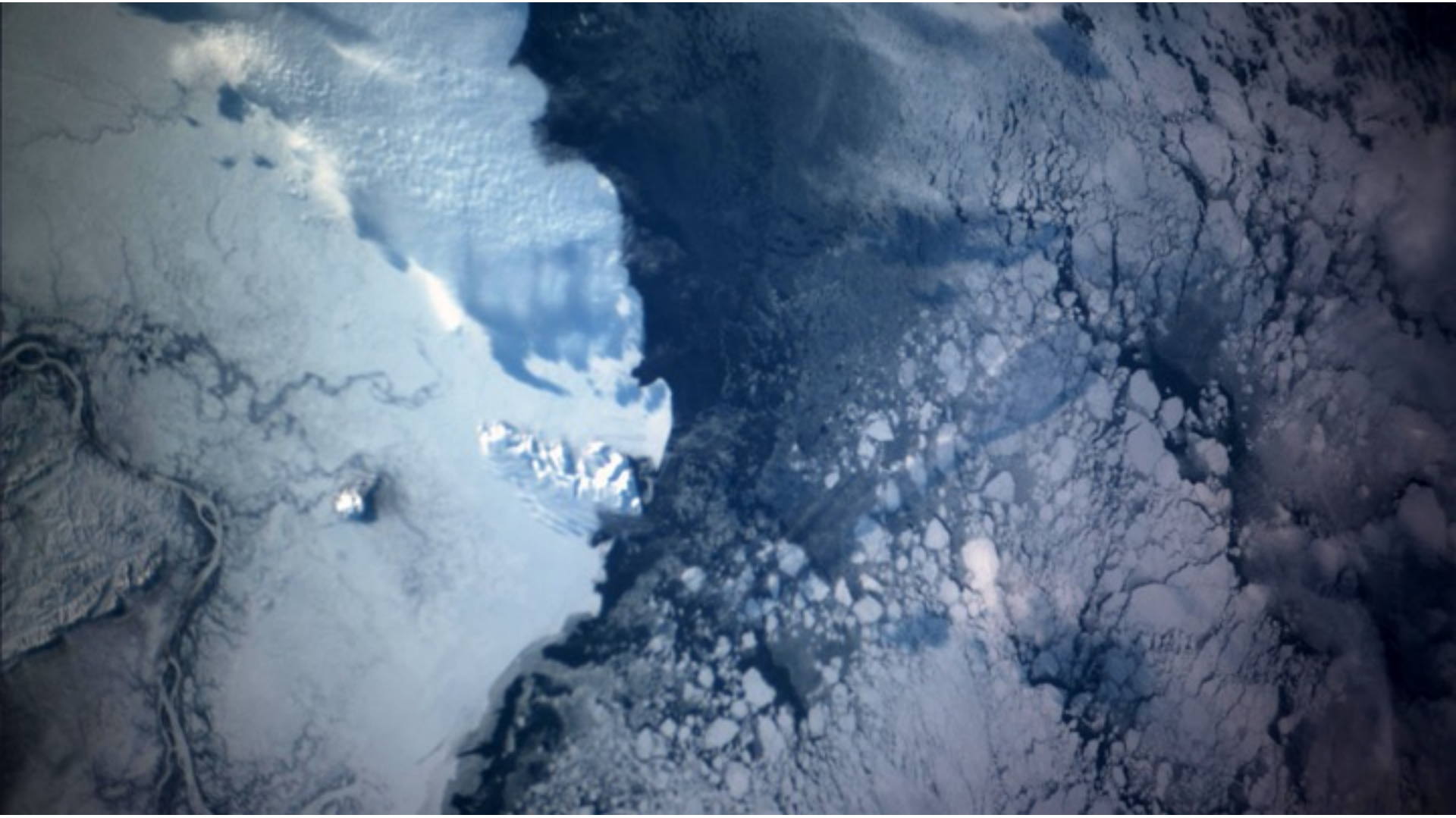

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Microsatellite Systems Dept.

OCSD-A Status Update Summary

- The Star Tracker data downloaded demonstrated that valid attitude solutions can be obtained at mission slew rates (up to 0.97 deg/s), which allows the laser communication system to point accurately while the vehicle is tracking the ground station

- The test images downloaded from the 10 MP imager demonstrate that the optics remained focused after launch and the imager can support the proximity operations objective – the ability to detect the locator LED beacon on the partner satellite.

- The modified design for the on-orbit reprogramming adds robustness and decreases the risk of disabling any of the processors in future missions during the patching process

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