Application of SpaceCube in a Space Flight System

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Code 587

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Note: This is the HANDOUT version of this presentation

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GSFC SpaceCube

- Small, light-weight, reconfigurable multi-processor platform for space flight applications demanding extreme processing capabilities
- Based on Xilinx Virtex 4 FX60 FPGAs, 2 per processor card
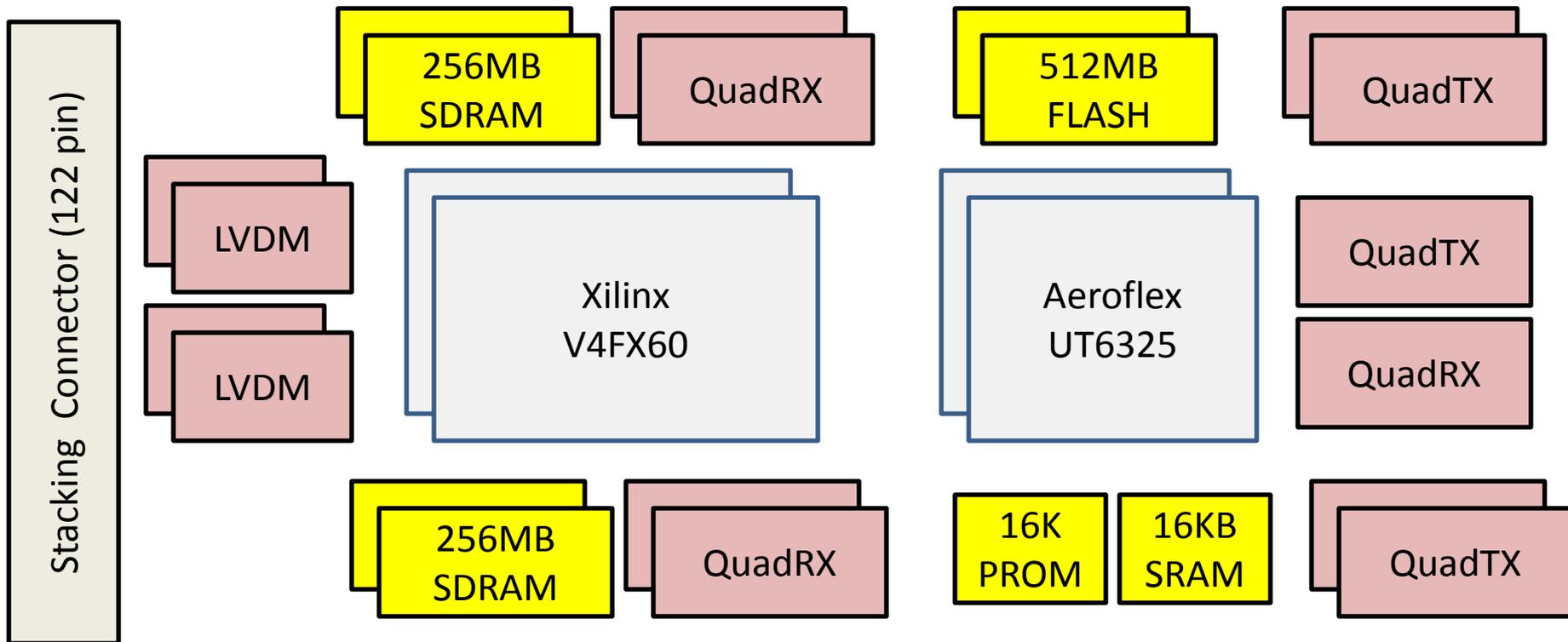- Stackable architecture

Flight Box
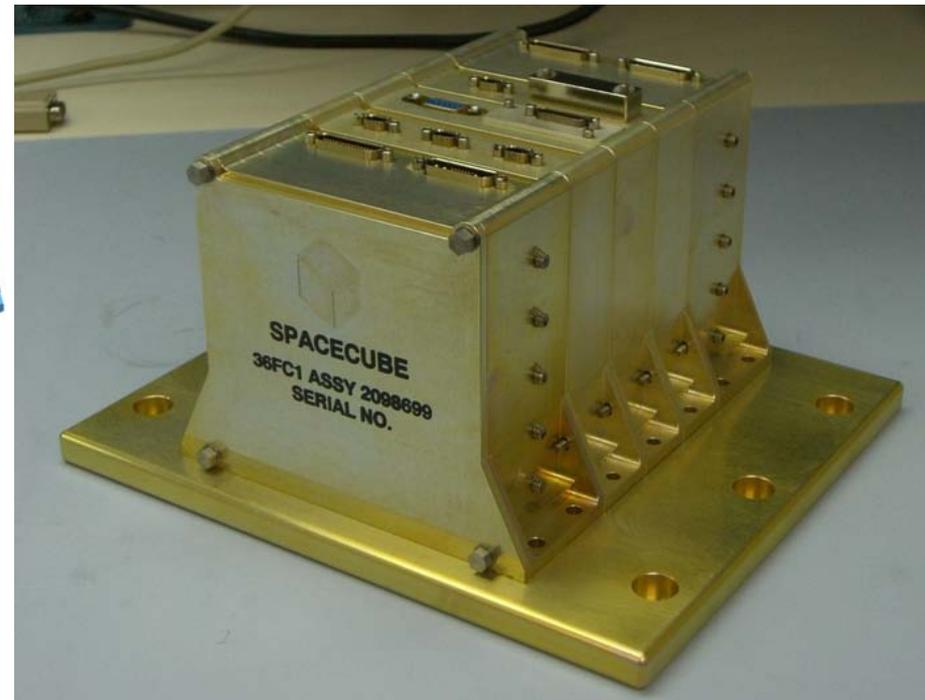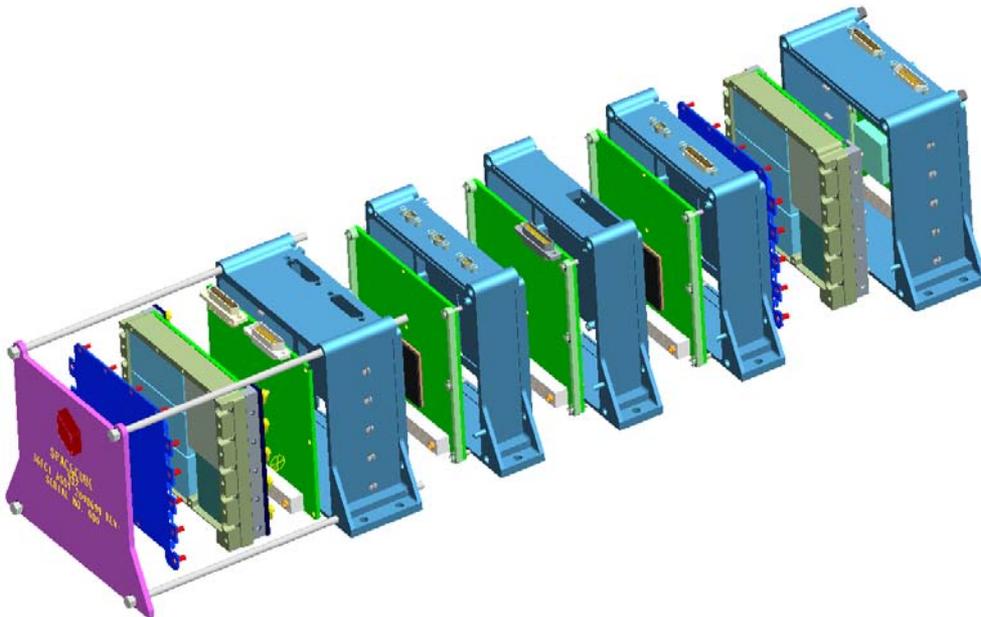
Mechanical: 7.5-lbs,   5"x5"x7"
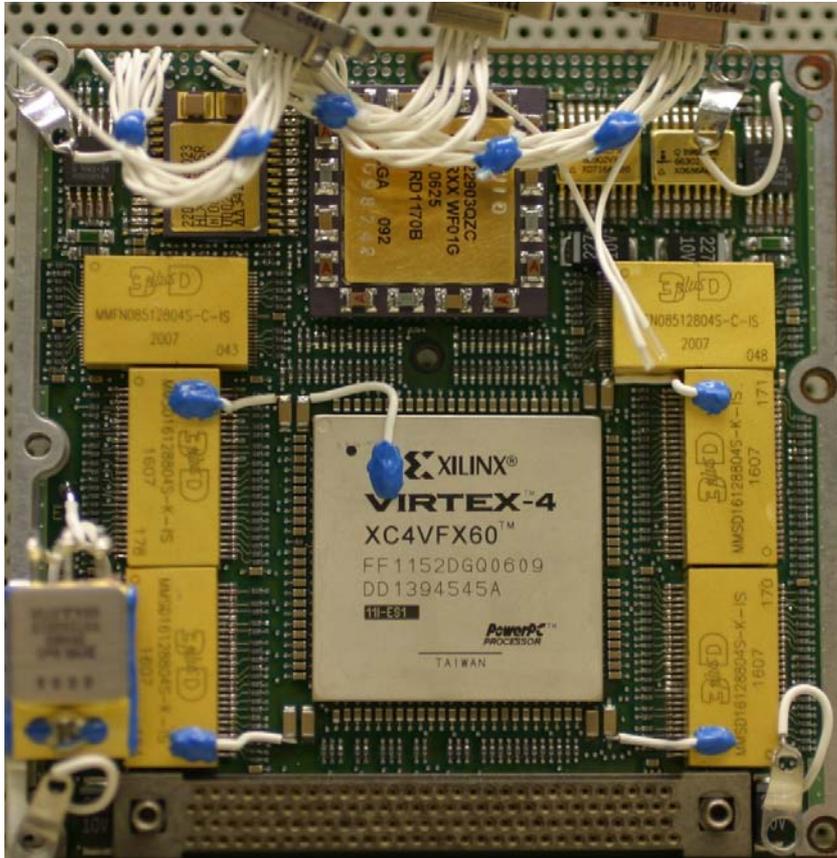Power: 37W (HST Application)

SpaceCube Processor Card

- General: 4"x4" card, Back-to-Back FPGAs (x2), 7W typical power
- Memory: 1GB SDRAM, 1GB Flash, 16KB SRAM, 16KB PROM
- Interfaces: 20 bi-dir differential signals, JTAG
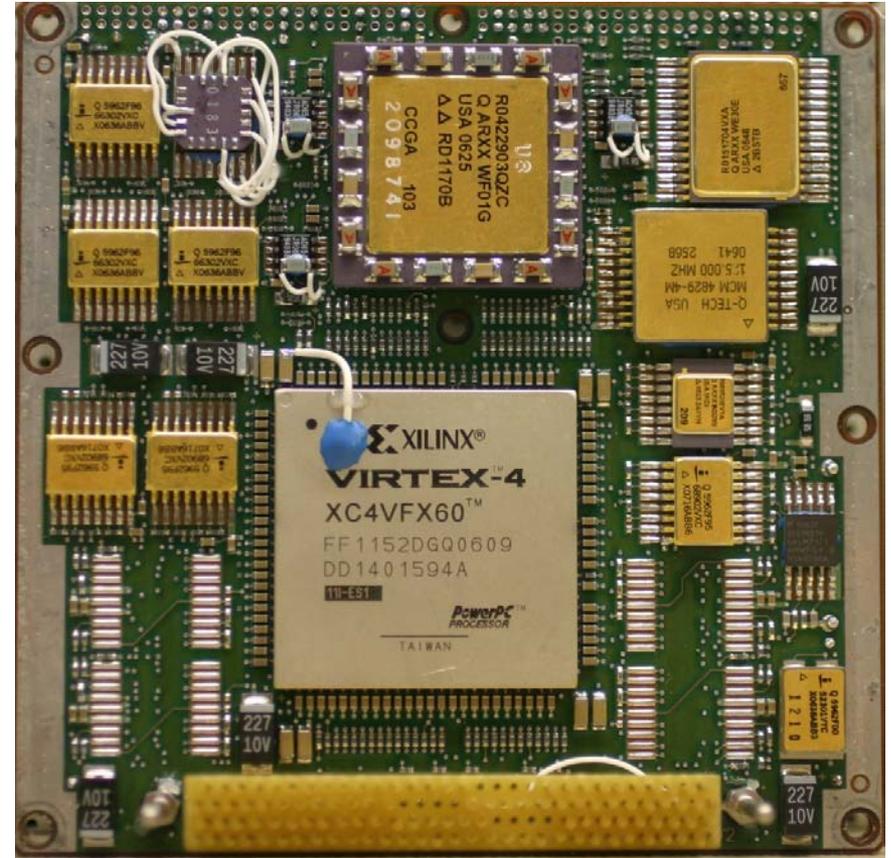- Backplane: Power, 42 single-ended, 8 LVDM, 2 I2C, POR

Stacking Connector (122 pin)

256MB SDRAM

QuadRX

512MB FLASH

QuadTX

LVDM

Xilinx V4FX60

QuadTX

LVDM

Aeroflex UT6325

QuadRX

256MB SDRAM

QuadRX

16K PROM

16KB SRAM

QuadTX

SpaceCube Processor Card

Top Side

Bottom Side

Hubble Servicing Mission 4 (STS-125)

- **R**elative **N**avigation **S**ensors (RNS) – HST Payload
  - Record images of HST during docking and release, in particular the Soft Capture Mechanism
  - Perform on-orbit position and attitude estimation (Pose)

- RNS SpaceCube: Main Avionics Box
  - Controlled 3 cameras, GPS, 960GB memory, telemetry module, shuttle Ku downlink
  - Hosted Linux, VxWorks, C&DH, Automatic Gain and Integration Control, 2 pose image processing algorithms, TMR'd self-configuration scrubber using ICAP
  - Recorded GPS/AGC/POSE flight logs to flash
  - Consisted of 2 processors, 2 low-voltage power cards, 2 digital control cards, 1 JPEG2000 compression card

Relative Navigation Sensors

- RNS originated from HST robotic service mission
- RNS Hardware

  FPGAs

Xilinx	11
Actel	11
Aeroflex	6

  TOTAL: 28

  - 3 1024x1024 cameras   3
  - GPS Navigator   4
  - SpaceCube   11
  - Telemetry Module   4
  - Recorder (8 120GB hard drives)   2
  - Power Module   0
  - Ground Terminal   4

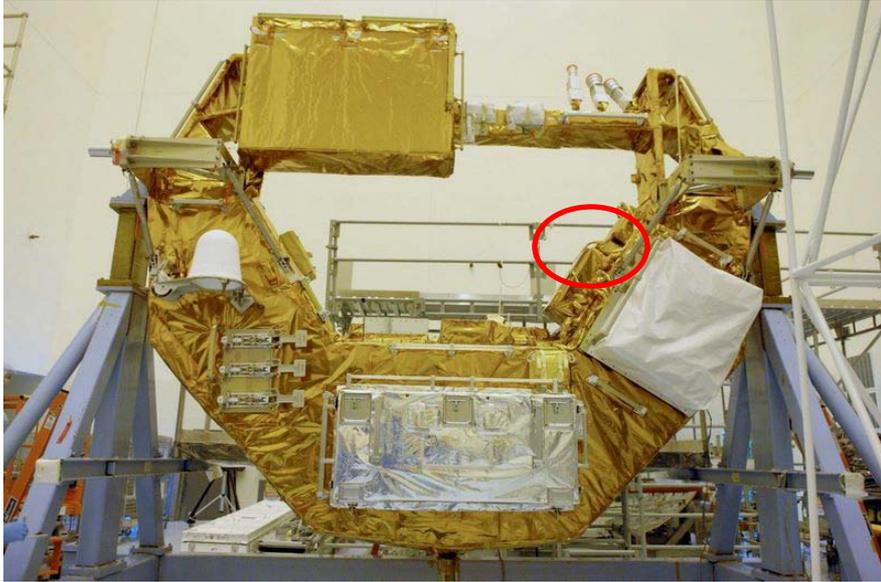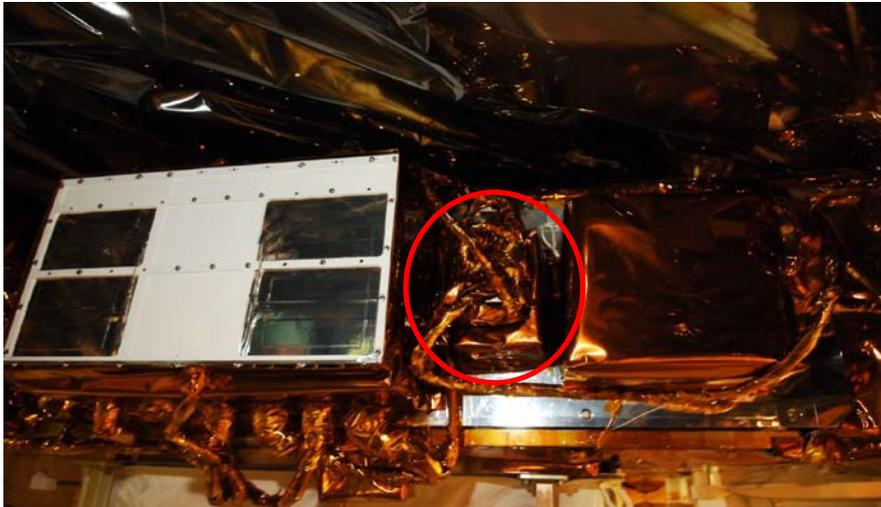- RNS operations conducted from JSC Space Shuttle Mission Control Center, Houston TX
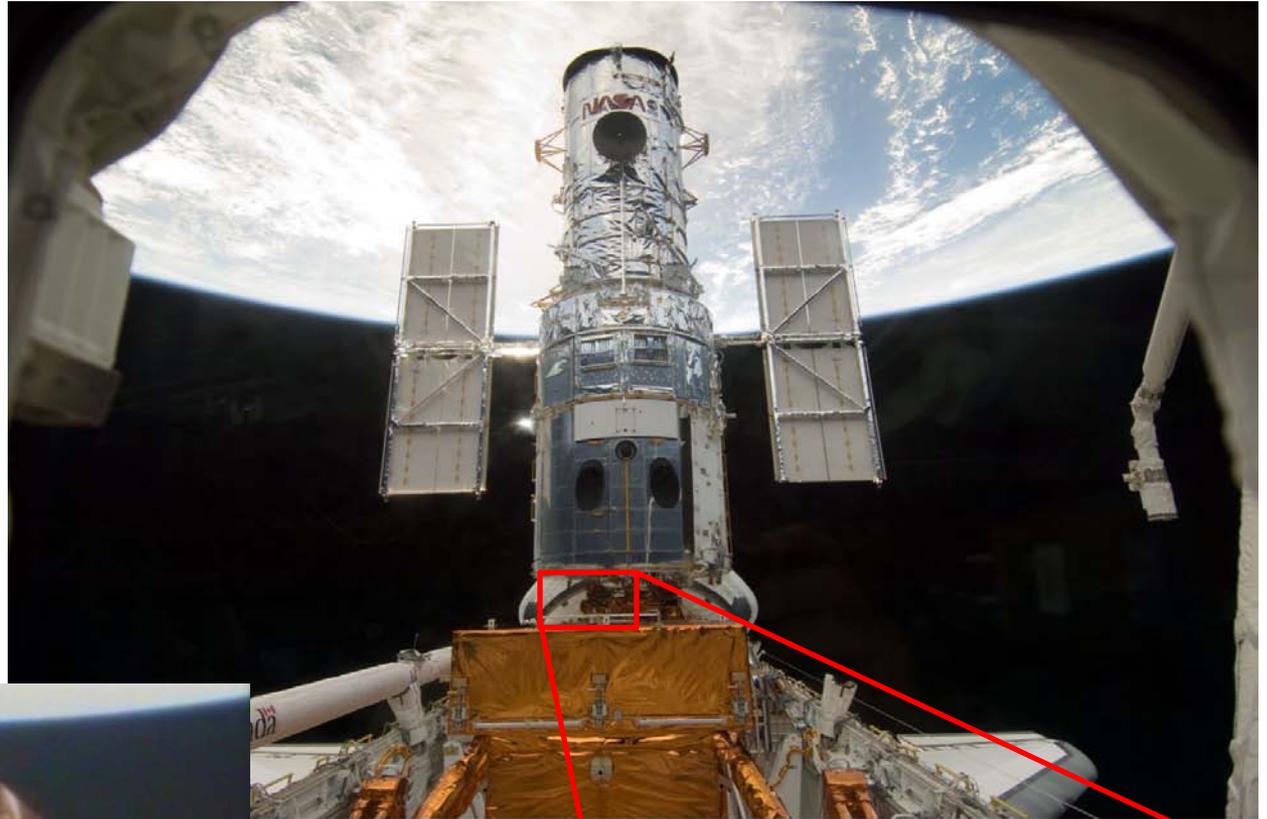
RNS Hardware

MULE Carrier

RNS Avionics Panel

STS-125 Payload Bay

On Orbit

RNS
Cameras

Tough to see,
but our cameras
and SpaceCube
are watching

-C- ALC AV PAN -030.6 FOC 019.0 +15C
CTV GAM BLK TLT -006.8 ZOOM 74.37 T/9
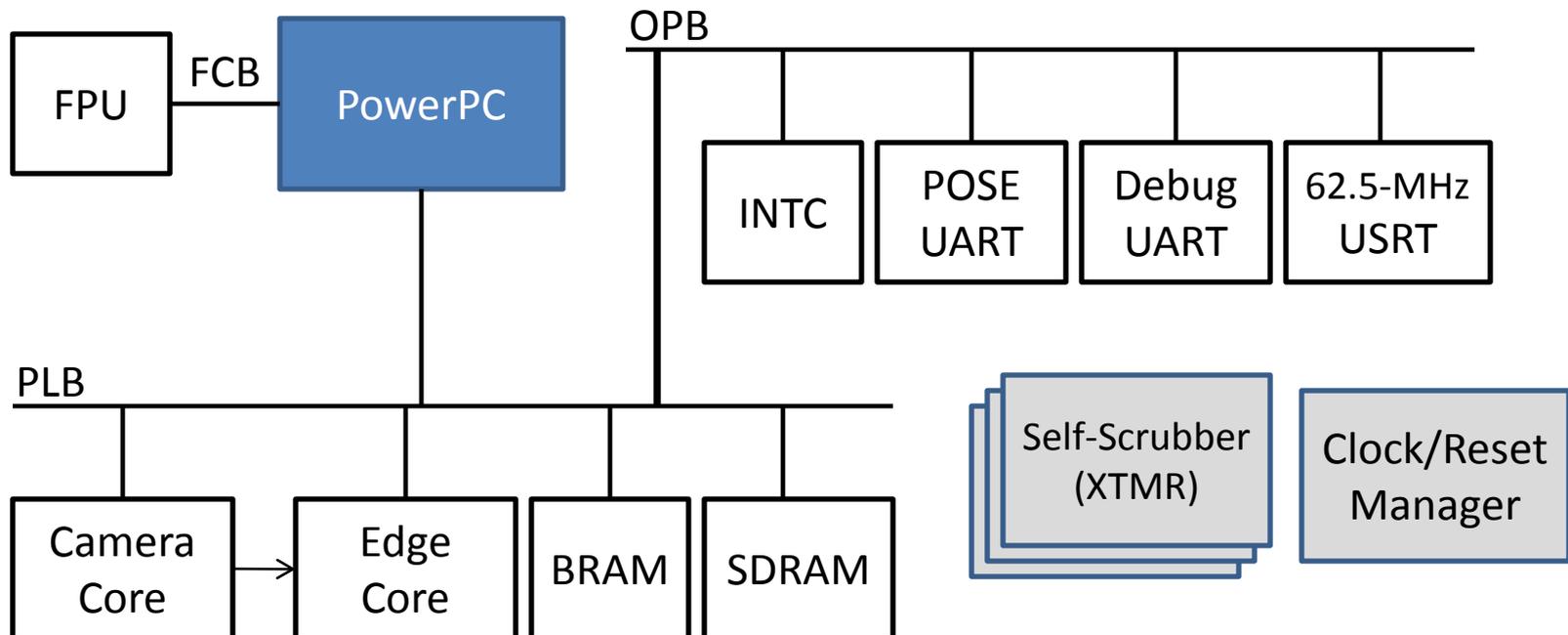GMT 133:01:02:18 AUTO ALC SHOF SUN 0db

S125E006807

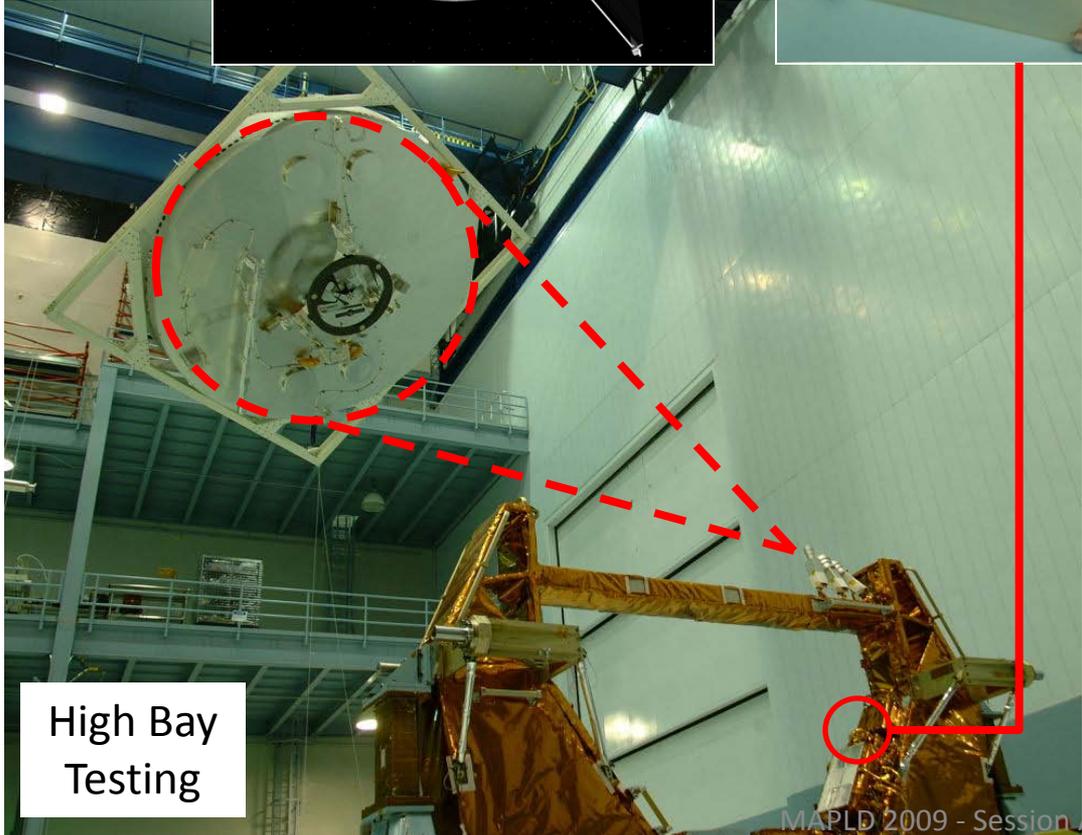# SpaceCube Functional Block Diagram
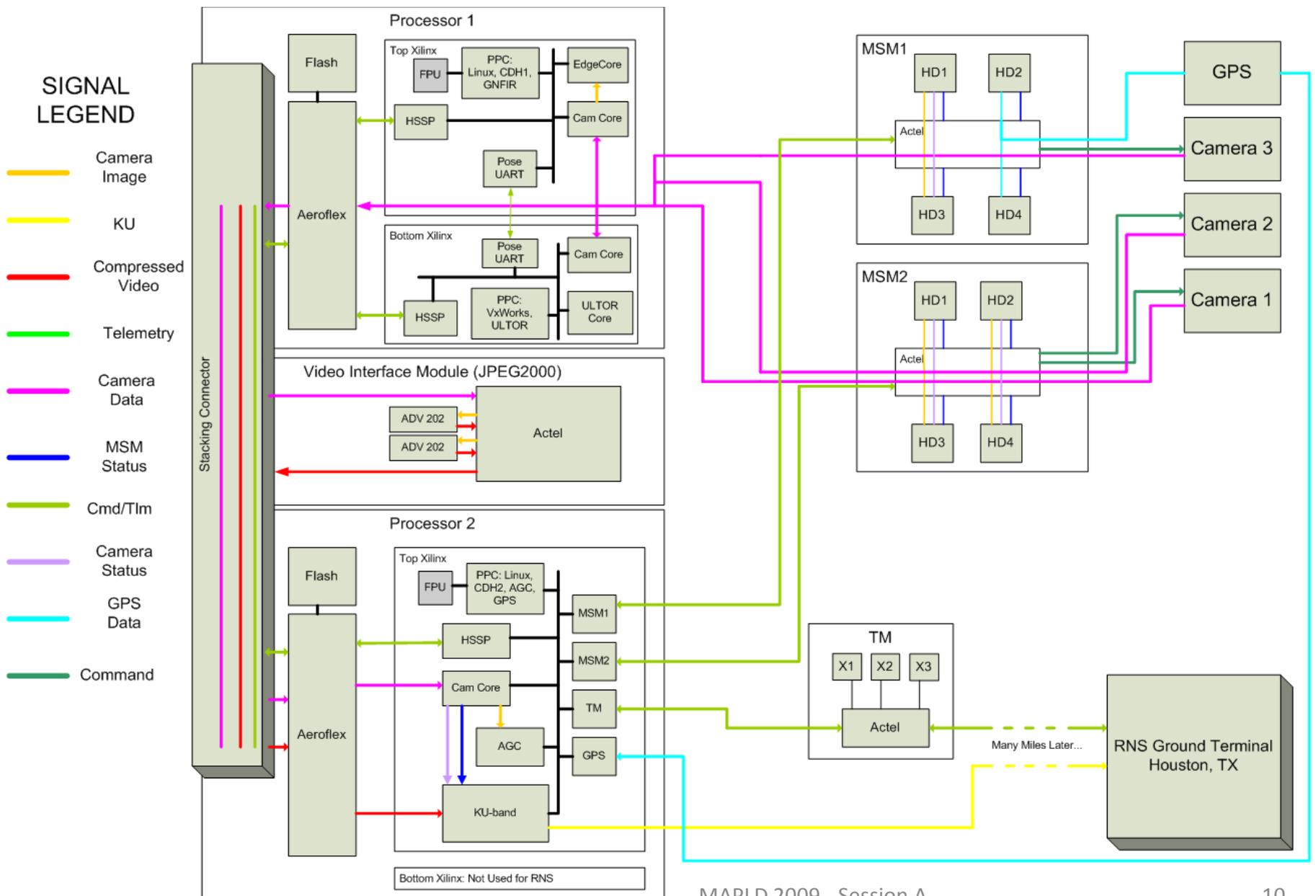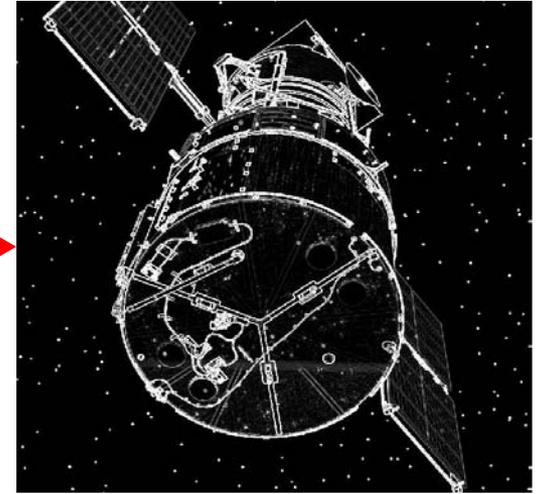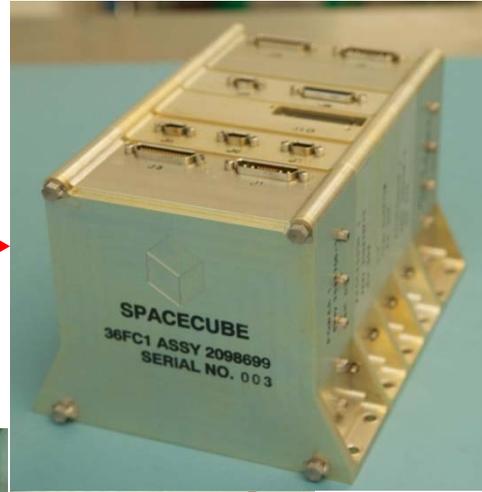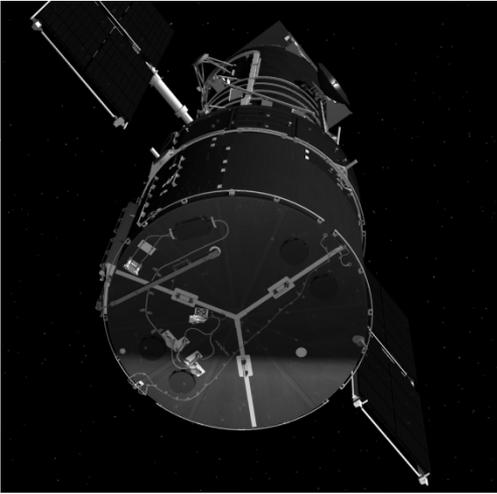
Xilinx FPGA Design(s)

- Heavy PowerPC usage
- Logic: 62.5-125MHz, Processor: 250MHz
- Used 3 of 4 Xilinxs at 60-80% resource utilization

High-Level Example Xilinx Design (POSE #1 FPGA on Processor Card 1)
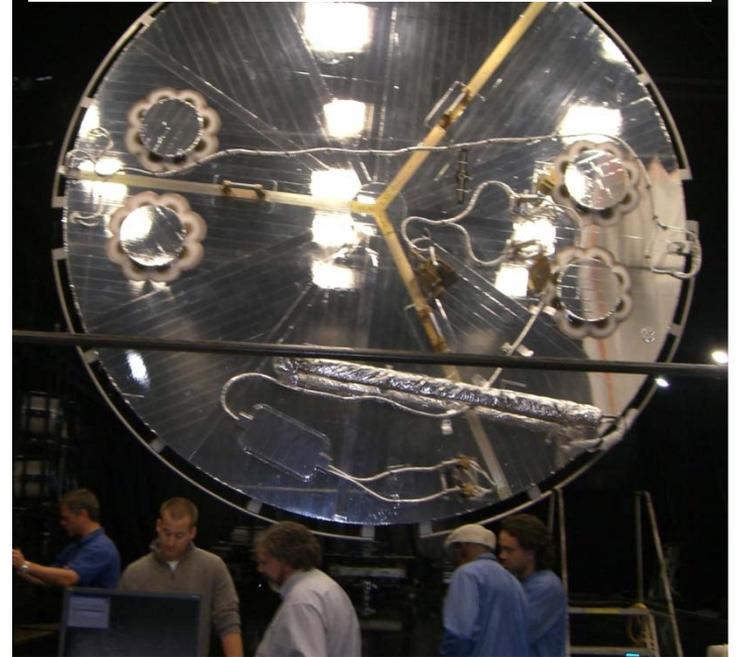
Barrage of System Testing

SPACECUBE
36FC1 ASSY 2098699
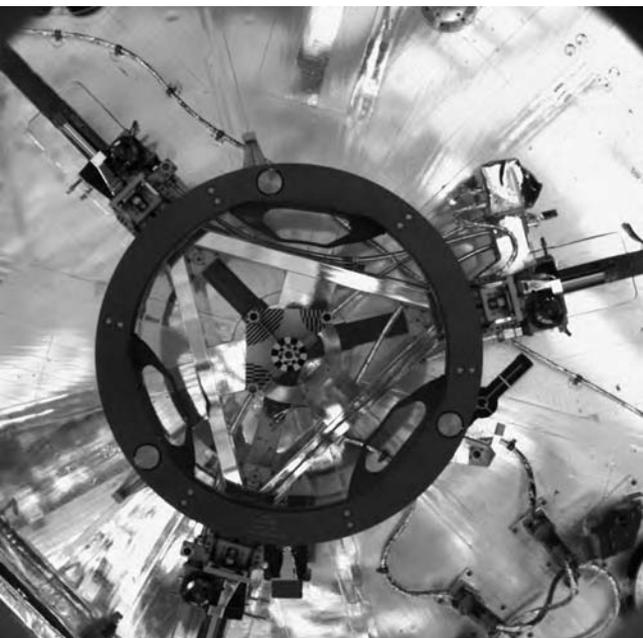SERIAL NO. 003

High Bay
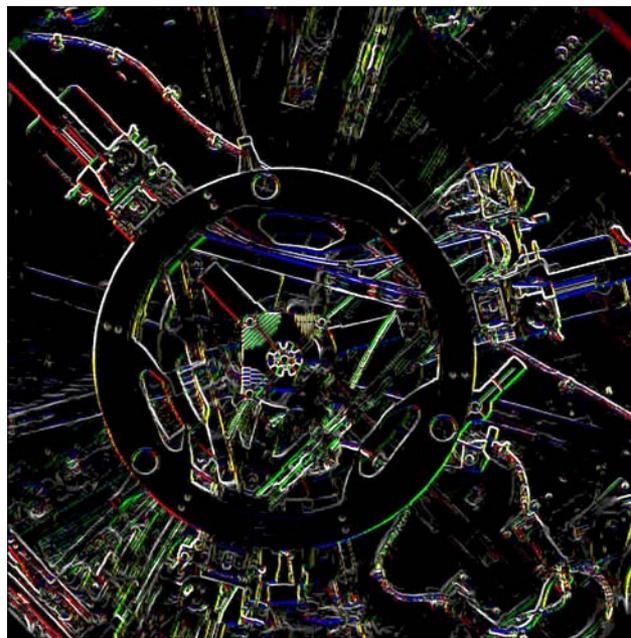Testing

MSFC Flight Robotics Lab Testing
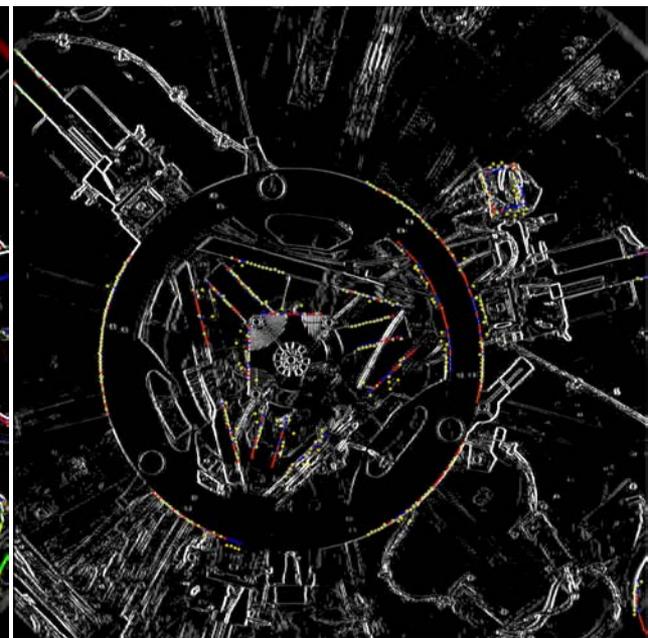
Tracking Algorithms on SpaceCube

Flight Image   Hardware Edge Detection   PPC Search for Features

Tracking Algorithms on SpaceCube

Long Range Camera on Rendezvous

Short Range Camera on Deploy

GNFIR POSE ESTIMATE
GMT: 133:16:28:43.757
Frame ID: 0x73F13002
Quaternion: 0.72654, -0.67387, 0.03428, 0.12983
Position (meters): 1.4498, 7.8250, -81.4431
Pose Quality Confidence: 88.235%

GNFIR POSE ESTIMATE
GMT: 139:11:37:17.231
FrameID: 0x031724fb
Quaternion: -0.64660 0.27127 0.65614 -0.27891
Position [m]: -0.0979 -0.1355 -2.5048
Pose Quality Confidence: 84.706%
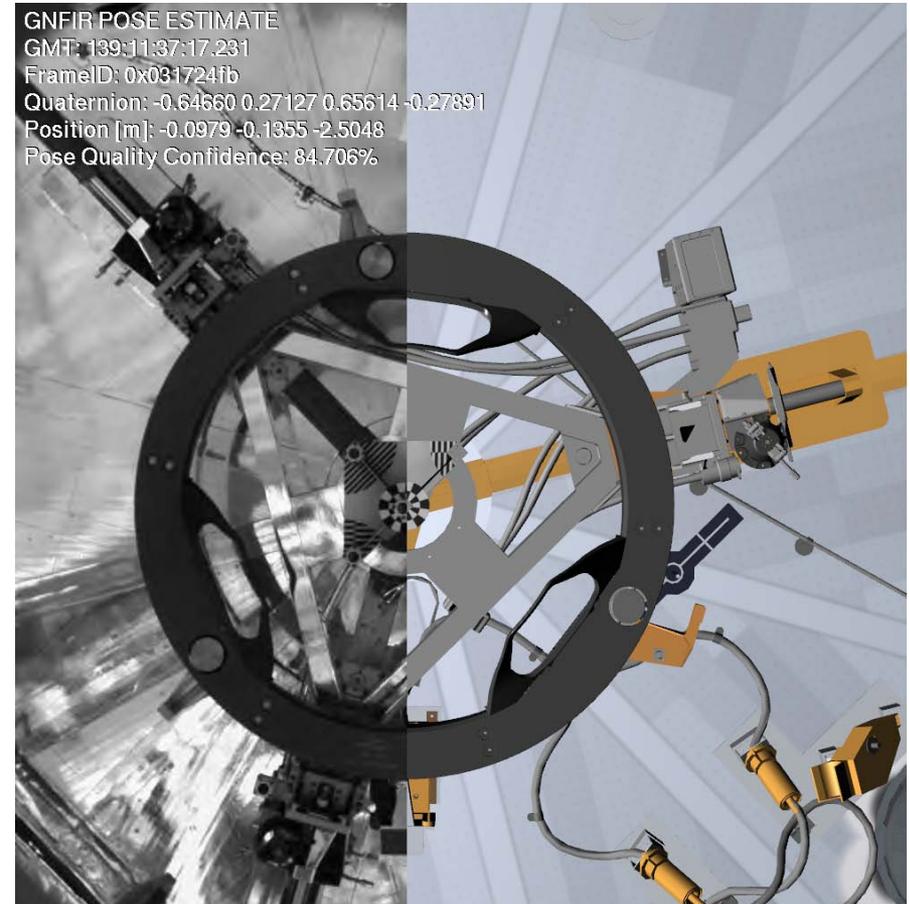
Flight Image   RNS Tracking Solution   Flight Image   RNS Tracking Solution

RNS Results Summary

- SpaceCube enabled RNS to meet all objectives
  - Recorded 6 hours of camera and GPS data
  - Successfully tracked HST during rendezvous for 21 minutes and deploy for 15 minutes
  - Sent 100,000+ compressed images to ground

- SpaceCube powered for 60 hours (8 in SAA)
  - 2 configuration SEUs in SAA scrubbed out
  - 1 PowerPC SEE that watchdog repaired

HST Tracking

Note: This is the HANDOUT version of this presentation, actual version contains movies
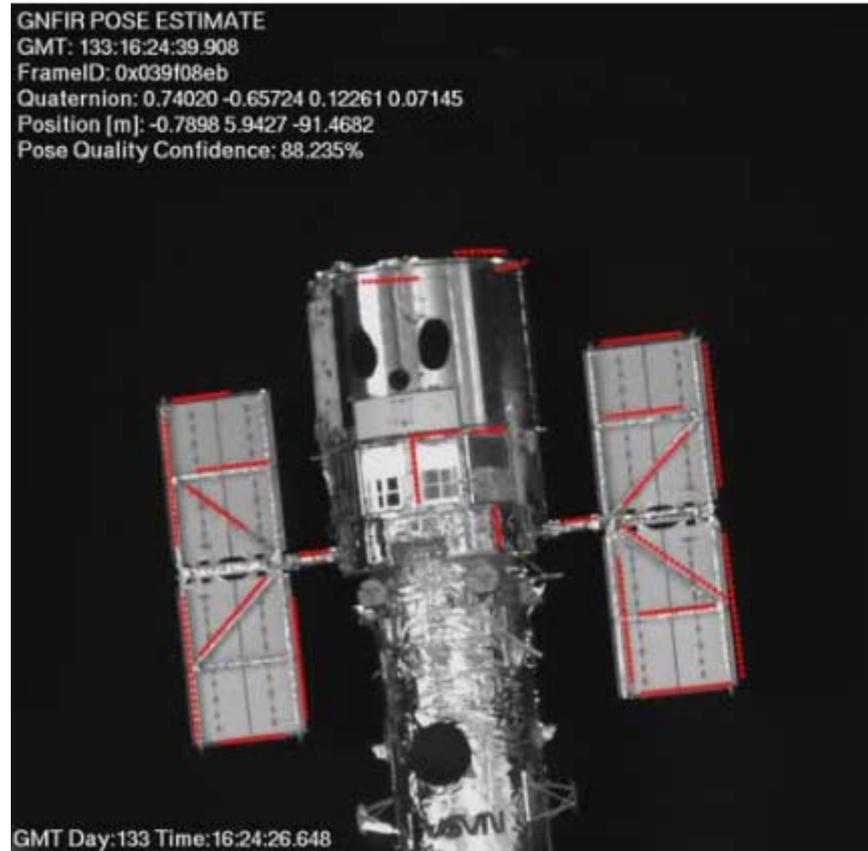
Rendezvous

Deploy

What's Next?

- Just completed raw imagery downloads at GSFC
- Looking for another flight for RNS hardware
  – Possible ISS flight for robotic demonstration
  – Hubble Robotic De-orbit Mission?
- Flight spare SpaceCube going to ISS (STS-129)
  – Serve as NASA test bed for radiation mitigation
- Building two new versions of SpaceCube
  – Covered in Session E presentation

Questions?

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Acronyms

- FPGA: Field Programmable Gate Array
- I2C: Inter-Integrated Circuit
- ICAP: Internal Configuration Access Port
- ISS: International Space Station
- LVDM: Low Voltage Differential Multi-drop
- MULE: Multi-Use Logistics Equipment
- POR: Power On Reset
- PPC: PowerPC
- SEE: Single Event Effect
- SEU: Single Event Upset
- TMR: Triple Module Redundancy