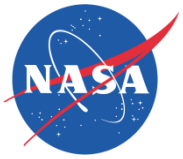

Advanced Hybrid On-Board Science Data Processor - SpaceCube 2.0

Tom Flatley

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Software Engineering Division

NASA - Goddard Space Flight Center

Earth Science Technology Forum

June 23, 2011

On-Board Data Processing For ESDS Era Missions

On-Board Processing

- Data Volume Reduction
- Image Processing
- Autonomous Operations
- Product Generation
- Event / Feature Detection
- Real-time / Direct Broadcast
- Docking / Servicing
- Compression
- Calibration / Correction
- Classification
- Inter-platform collaboration

Hybrid Science Data Processing

- CPU
- FPGA
- DSP

GSFC SpaceCube On-Board Processor

- 10x-100x computing performance
- Lower power (MIPS/watt)
- Lower cost (commercial parts)
- Radiation tolerant (not hardened)
- Software upset mitigation

SpaceCube Family Overview

Unit	Mission	Notes	Specs	Stats	Status
SpaceCube 1.0a	Hubble Servicing Mission 4	Relative Navigation Sensors Experiment STS-125 May 2009	4”x4” card (2) Virtex4	Size: 5”x5”x7” Wt: 7.5 lbs Pwr: 37W	2009 Flight
SpaceCube 1.0b	MISSE-7 (ISS)	added RS-485, RHBS, STS-129 Nov 2009	4”x4” card (2) Virtex4	Size: 5”x5”x7” Wt: 7.5 lbs Pwr: 32W	In Flight
SpaceCube 1.0c	DEXTRE Pointing Package (ISS)	Original RNS unit, w/added 1553 & Ethernet	4”x4” card (2) Virtex4	Size: 5”x5”x7” Wt: 7.5 lbs Pwr: 40W	Final stages of Implementation
SpaceCube 1.5	SMART (DoD/ORS)	adds GigE & SATA, commercial parts, sounding rocket flight	4”x4” card (1) Virtex5	Size: 5”x5”x4” Wt: 4 lbs Pwr: < 20W	
SpaceCube 2.0	Earth/Space Science Exploration missions	Std 3U form factor, GigE, SATA, Spacewire, cPCI	4”x6” card (2) Virtex5 (1) SIRF	Size: 5”x5”x7” Wt: < 10 lbs Pwr: 20-40W	Under Development
SpaceCube 2.0 Mini	CubeSats, Sounding Rocket, UAV	“Mini” version of SpaceCube 2.0, CubeSat form factor	2.5”x2.5” card (1) Virtex5/SIRF	Size: 3.5”x3.5”x3.5” Wt: 3 lbs Pwr: <10W	

Processor Comparison

	MIPS	Power	MIPS/ W
MIL-STD-1750A	3	15W	0.2
RAD6000	35	10-20W	2.33[1]
RAD750	300	10-20W	20[2]
SPARC V8	86	1W[3]	86[3]
LEON 3FT	60	3-5W[3]	15[3]
GSFC SpaceCube 1.0	3000	5-15W	400[4]
GSFC SpaceCube 2.0	5000	10-20W	500[5]

Notes:

1 – typical, 35 MIPS at 15 watts

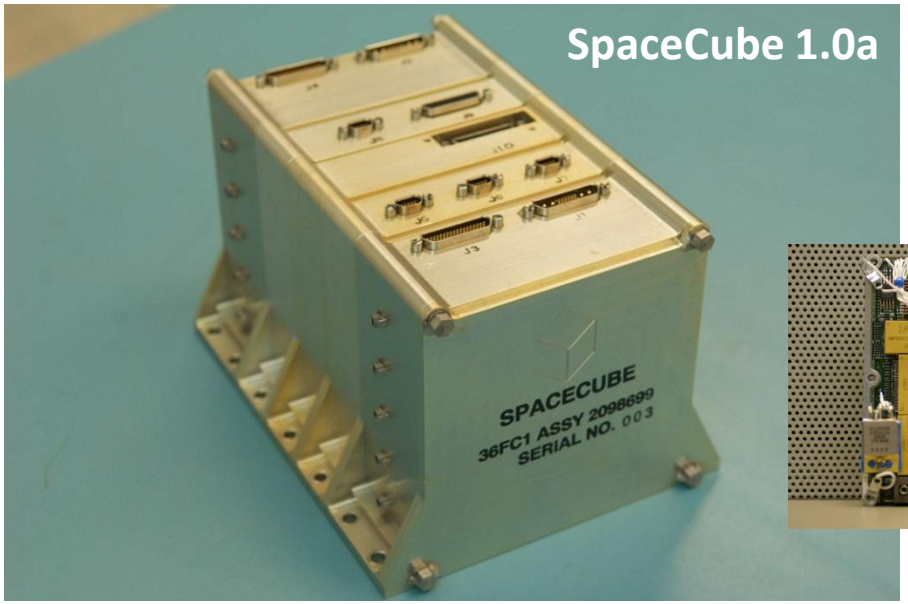
2 – typical, 300 MIPS at 15 watts

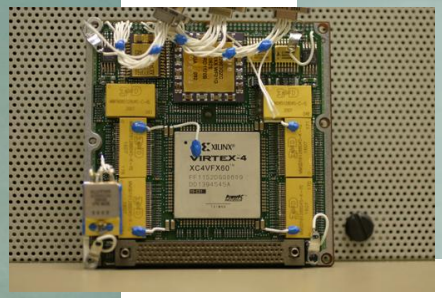
3 – processor device only ... total board power TBD

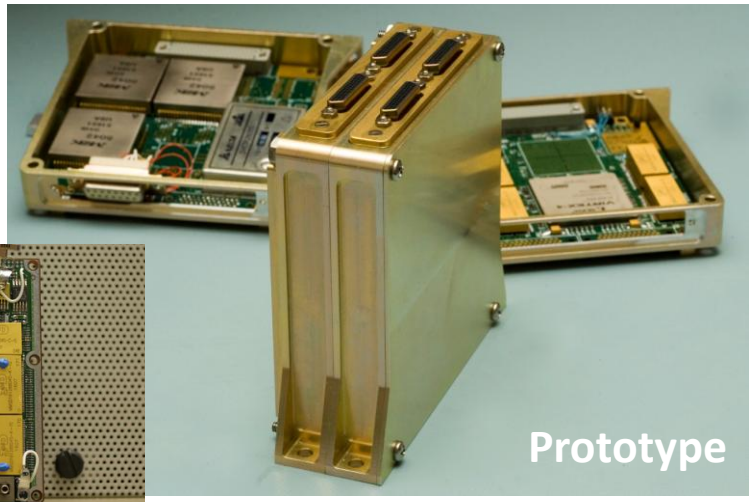
4 – 3000 MIPS at 7.5 watts (measured)

5 – 5000 MIPS at 10 watts (calculated)

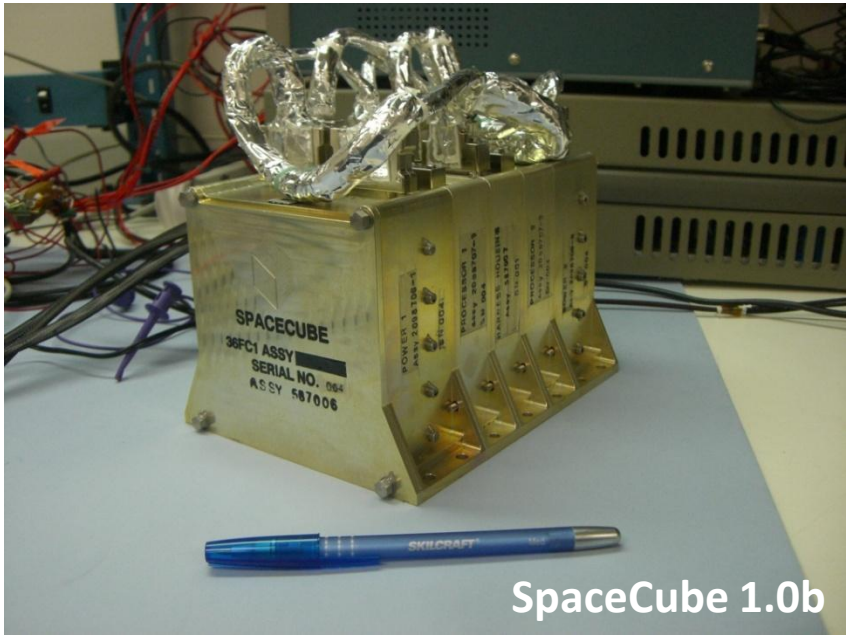
Current SpaceCube Systems







SpaceCube 1.5



On-Board Image Processing

STS-125 Payload Bay

Long Range Camera on Rendezvous

Flight Image **RNS Tracking Solution**

Short Range Camera on Deploy

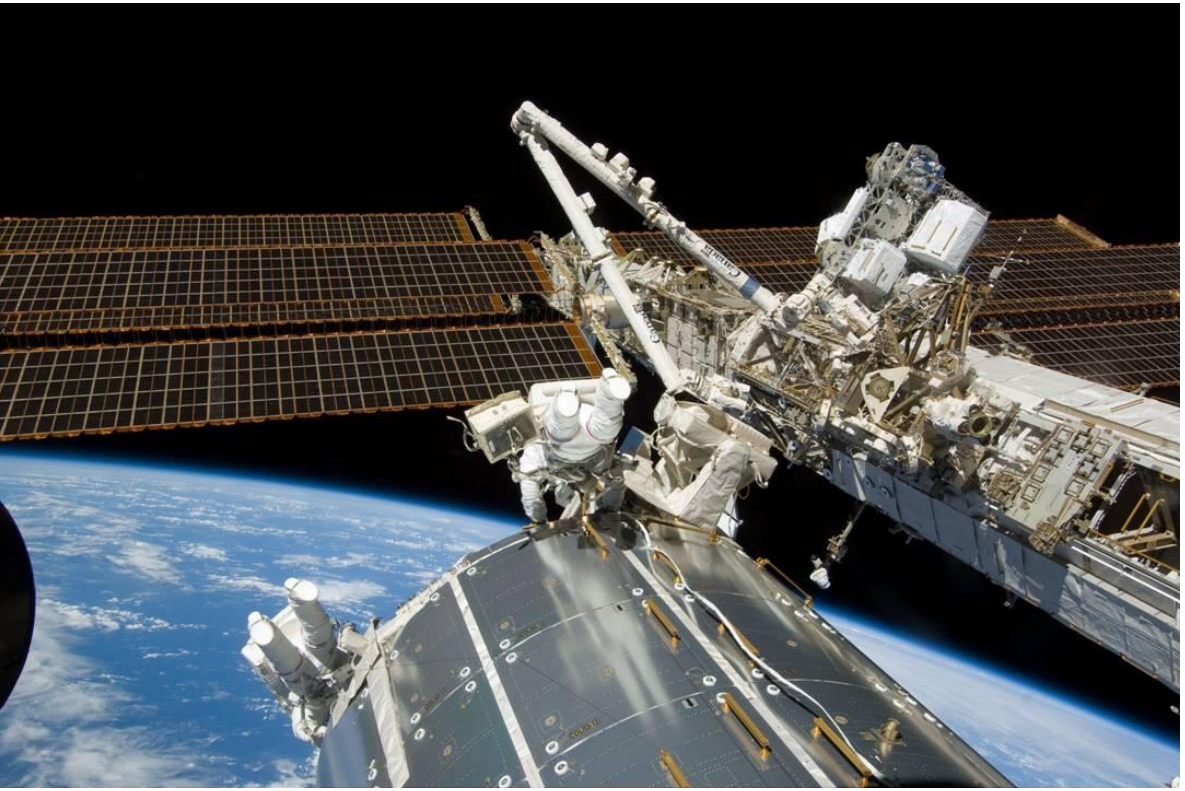
Flight Image **RNS Tracking Solution**

HST-SM4

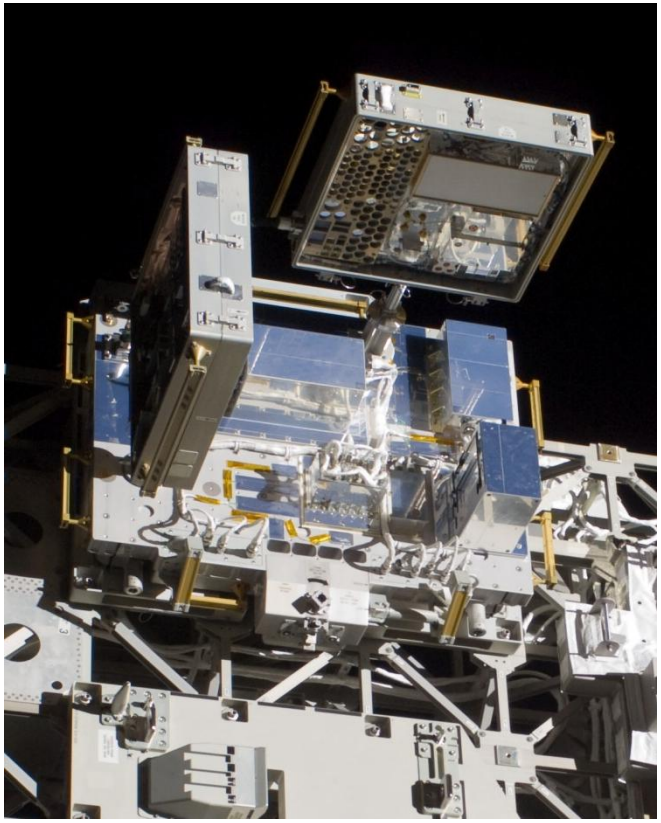
GSFC SpaceCube 1.0a - Hubble SM 4 (May 2009):

- Autonomous Rendezvous and Docking Experiment
- Hosted camera AGC and two Pose algorithms

Software Upset Mitigation



GSFC SpaceCube 1.0b (Nov 2009):
- **"Radiation Hardened by Software" Experiment (RHBS)**
- **Autonomous Landing Application**
- **Collaboration with NRL**

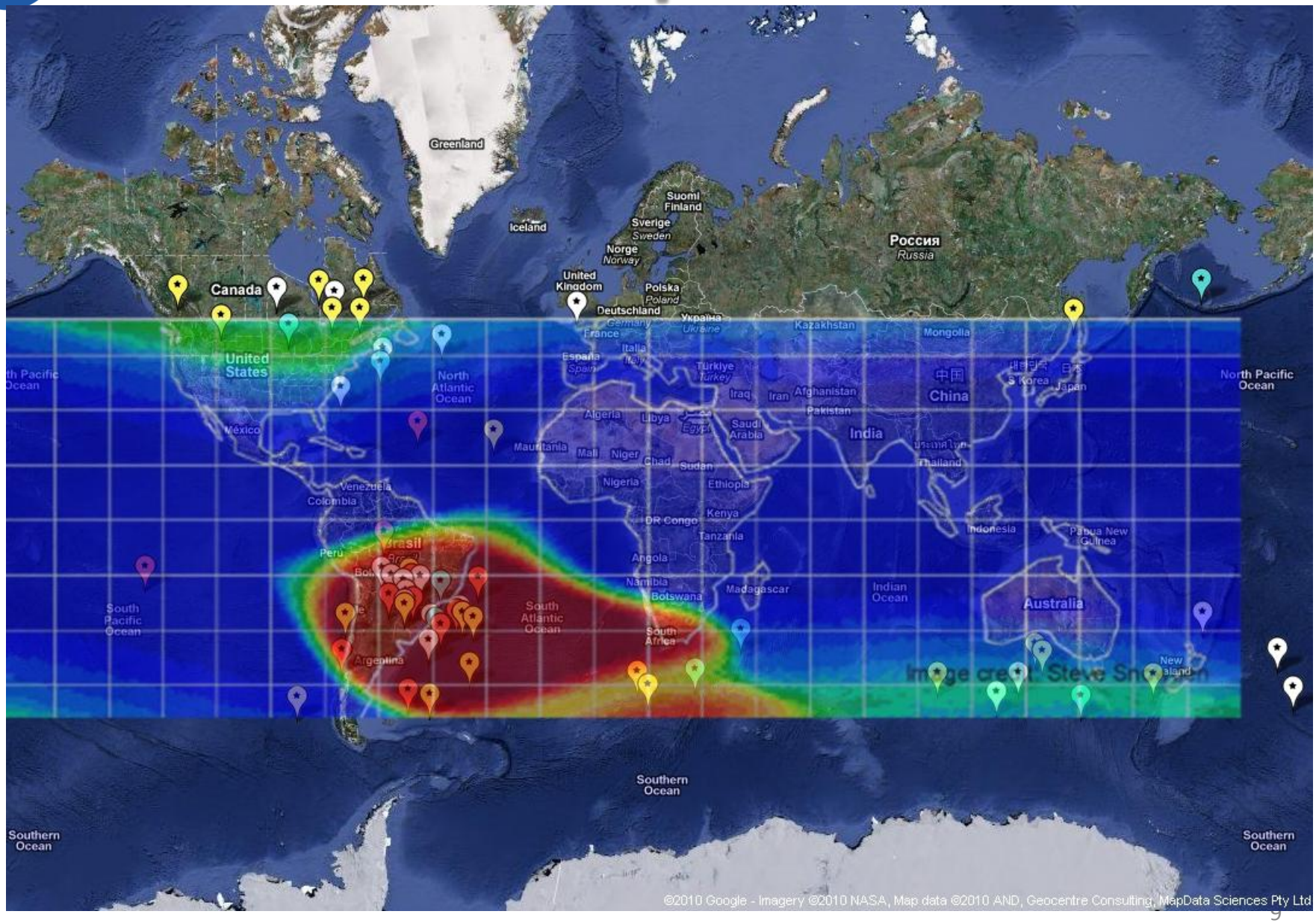


MISSE7

Orbit	ISS
Days Up	550+
Total SEUs	100+
Total Errors	0

On-Orbit Upset Locations

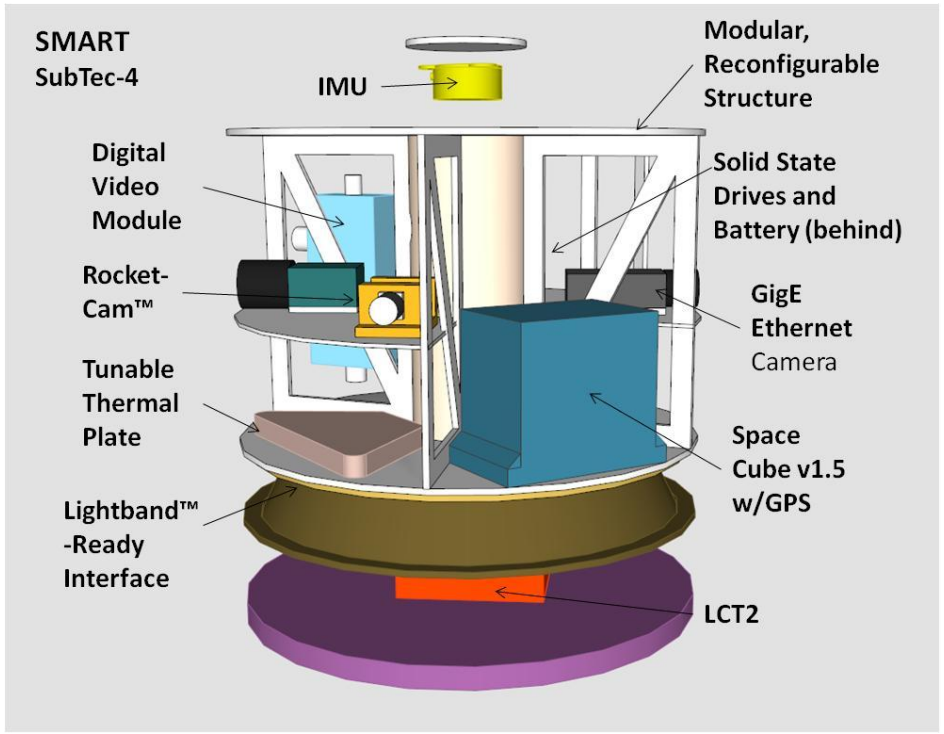
On-Orbit Upset Locations

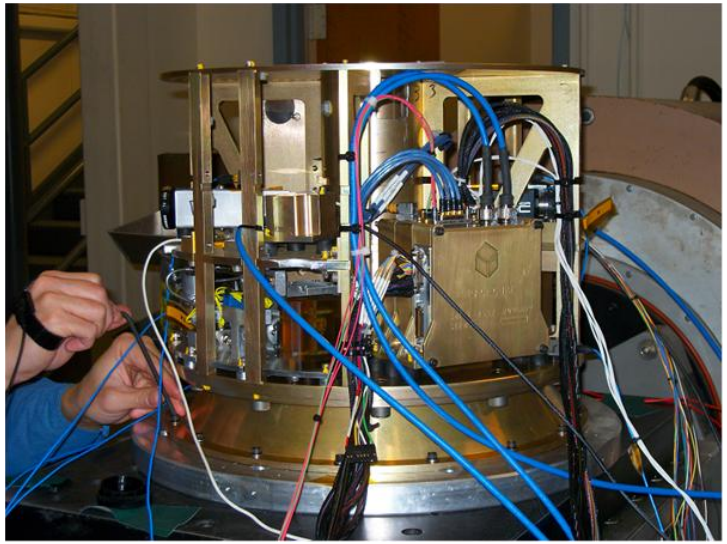


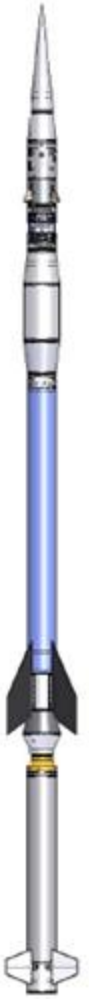
SMART – SpaceCube 1.5

Small Rocket/Spacecraft Technologies (SMART)

- Joint program between NASA and DoD Operationally Responsive Space (ORS)
- Develop faster, leaner, and more efficient approach to space flight
- SpaceCube 1.5 serves as multi-function avionics
- Ingest RocketCam, GigE camera, and sensor data
- On-board storage to SATA drives
- Downlink to ground through transponder







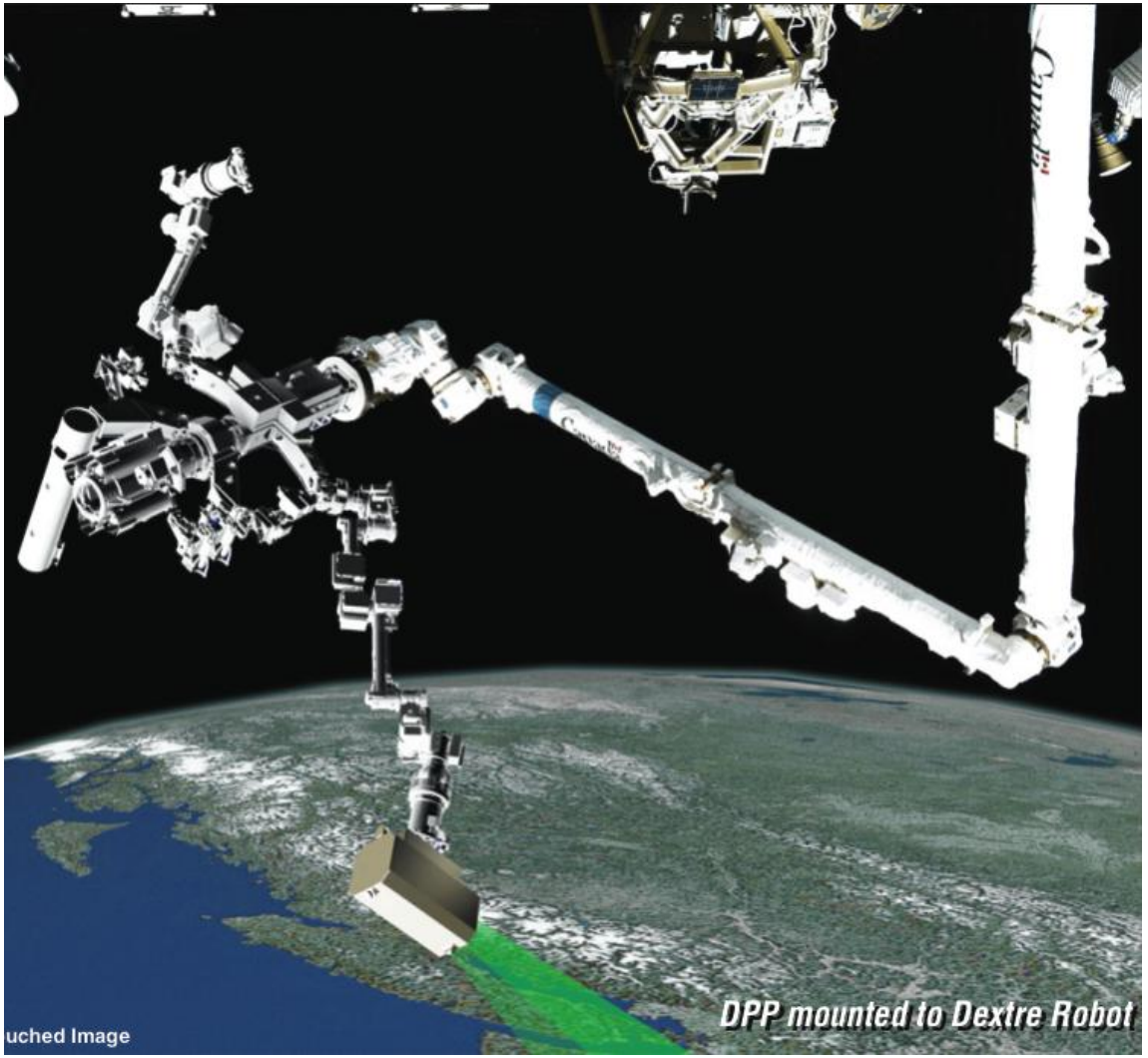
DEXTRE Pointing Package

Special Purpose Dexterous Manipulator (DEXTRE)

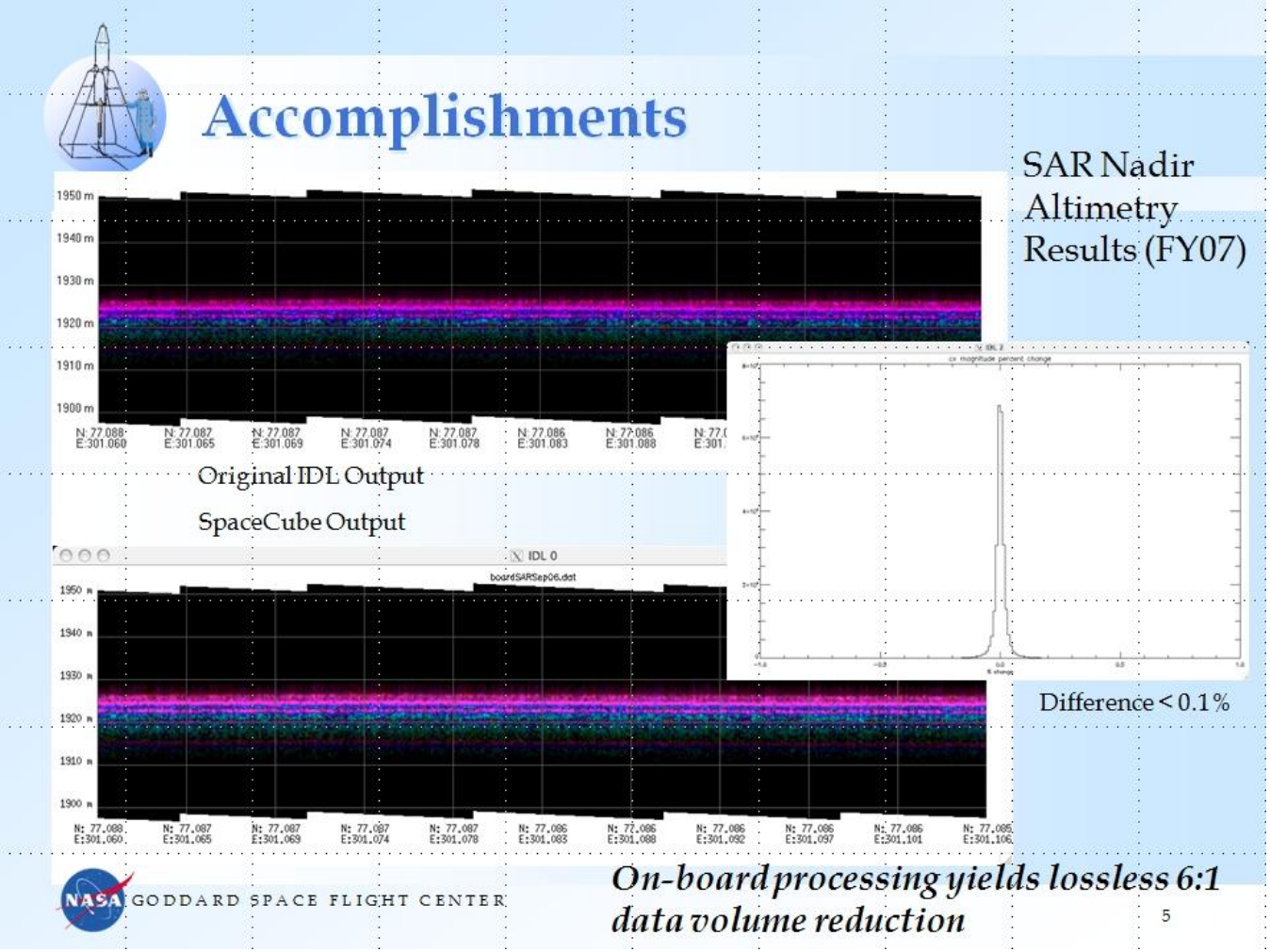
- Installed on ISS 2008
- Two 7-jointed arms
- Body roll joint that allows swiveling of its torso

Dextre Pointing Package (DPP)

- Support interchangeable science payloads
- Enable payload
  - Precise pointing
  - Real-time telemetry
  - Data storage



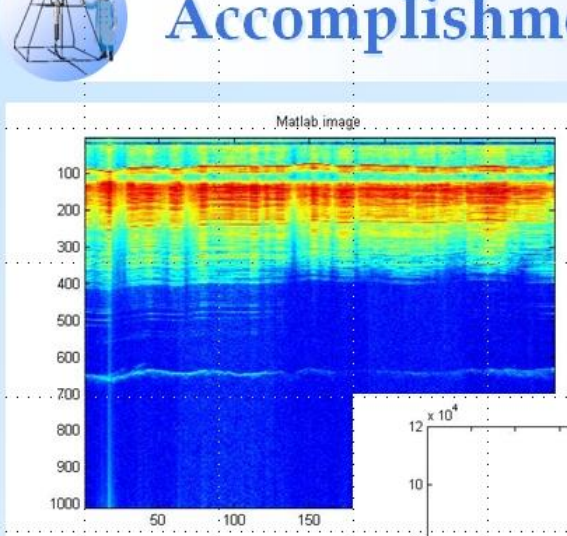
On-Board Data Reduction



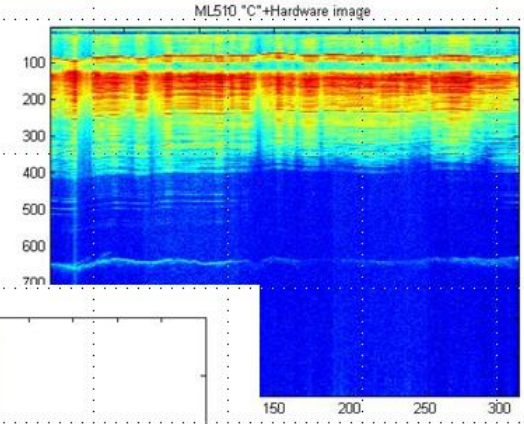
On-Board Data Reduction (cont)

Accomplishments

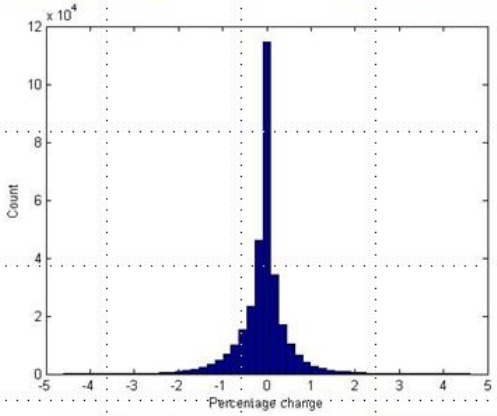
SAR Mapping Results (FY09)



Original Matlab Output



SpaceCube Output



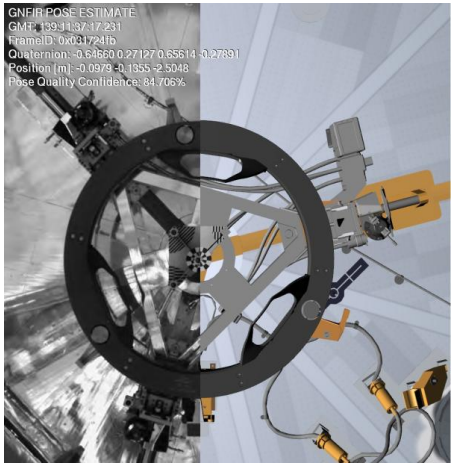
On-board product generation yields factor of 165x data volume reduction

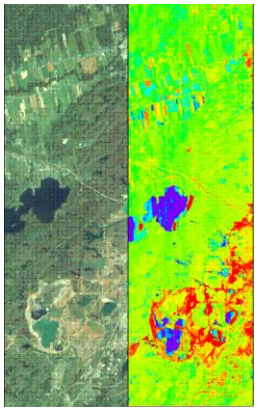
Difference < 1%

NASA GODDARD SPACE FLIGHT CENTER

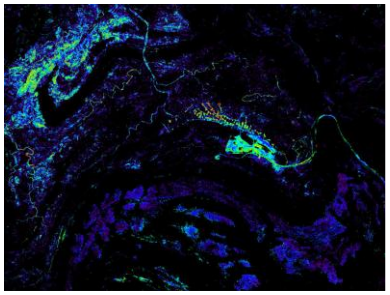
6

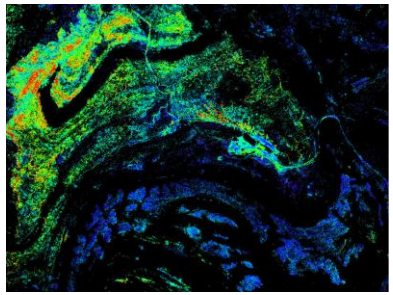
On-Board Product Generation

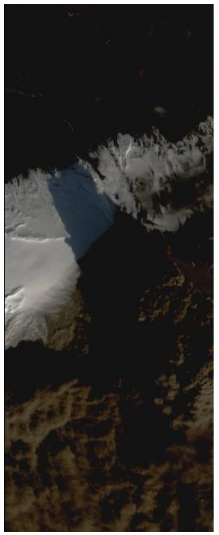


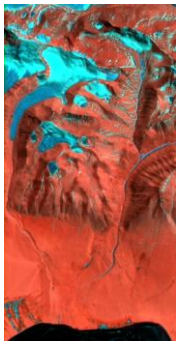


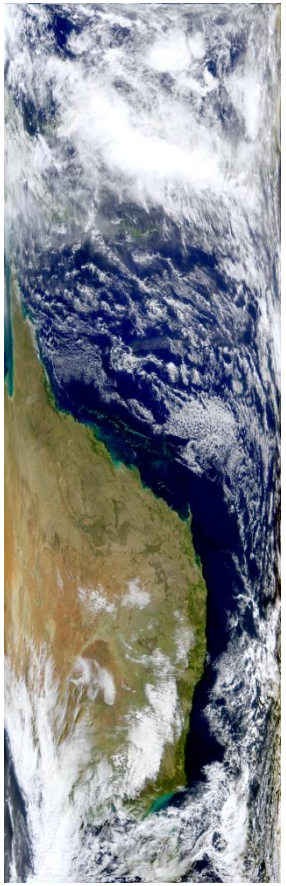
- Classification
- Product Generation
- Event Detection
- Atmospheric Correction

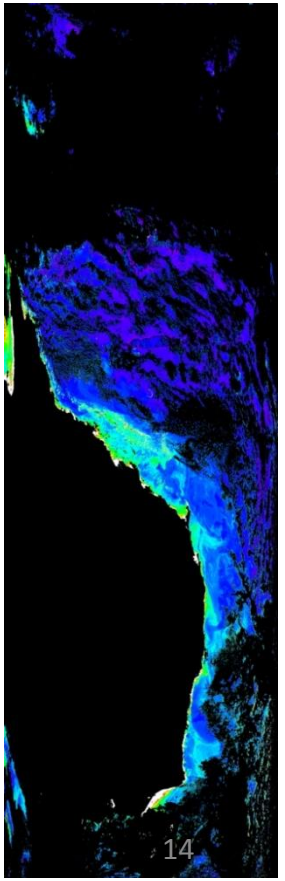




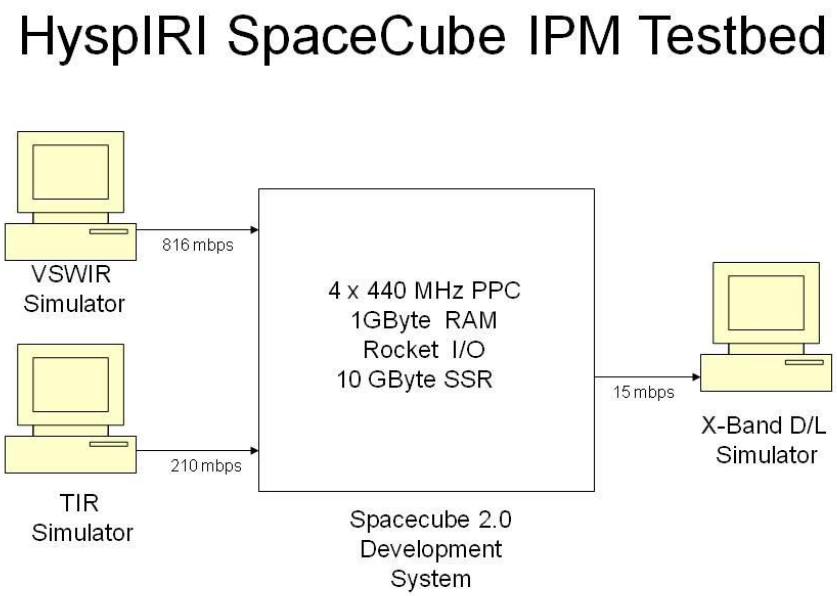


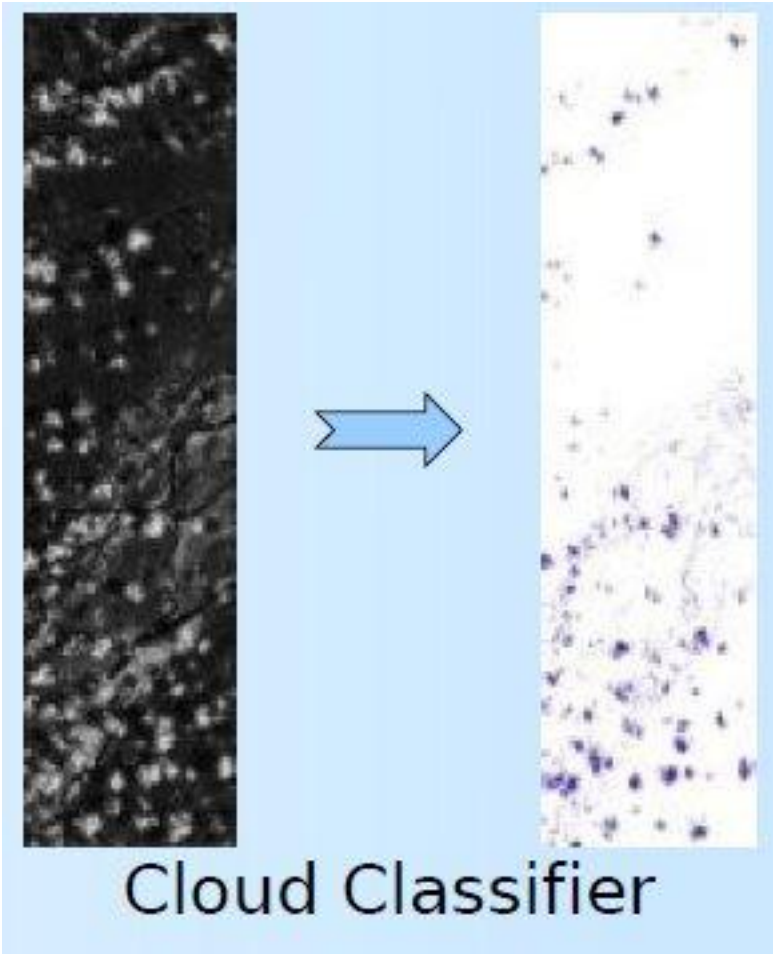




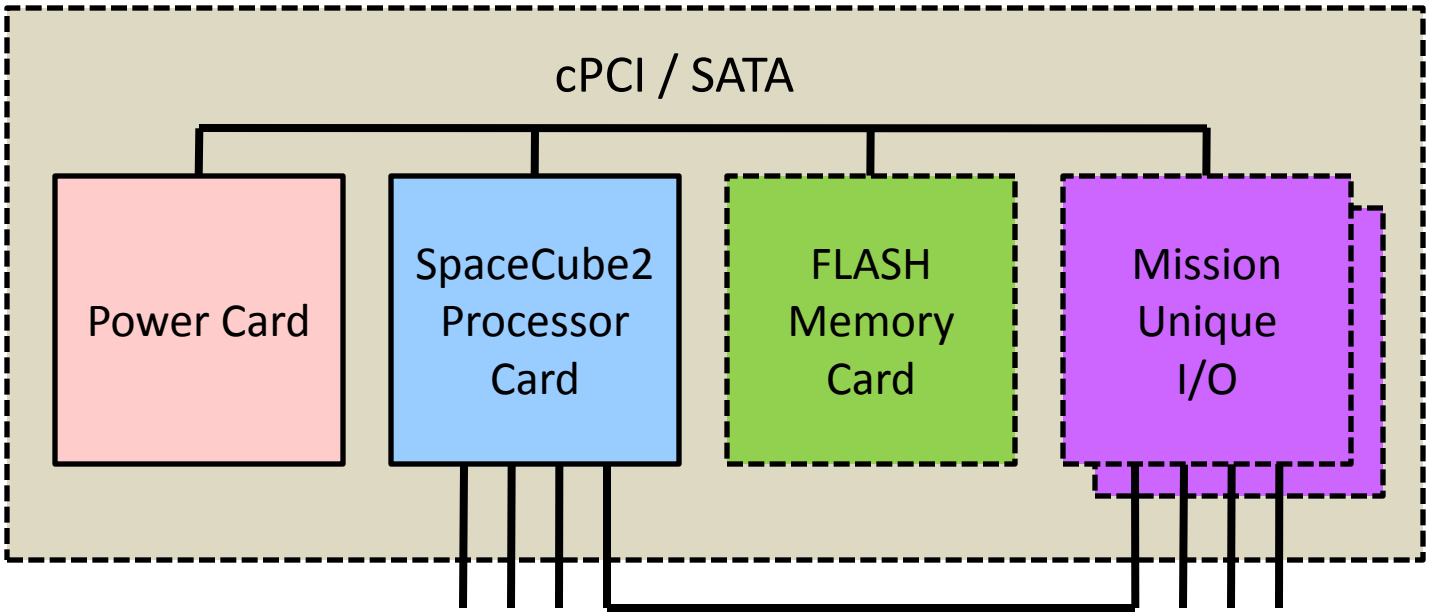


HyspIRI Demonstration Testbed





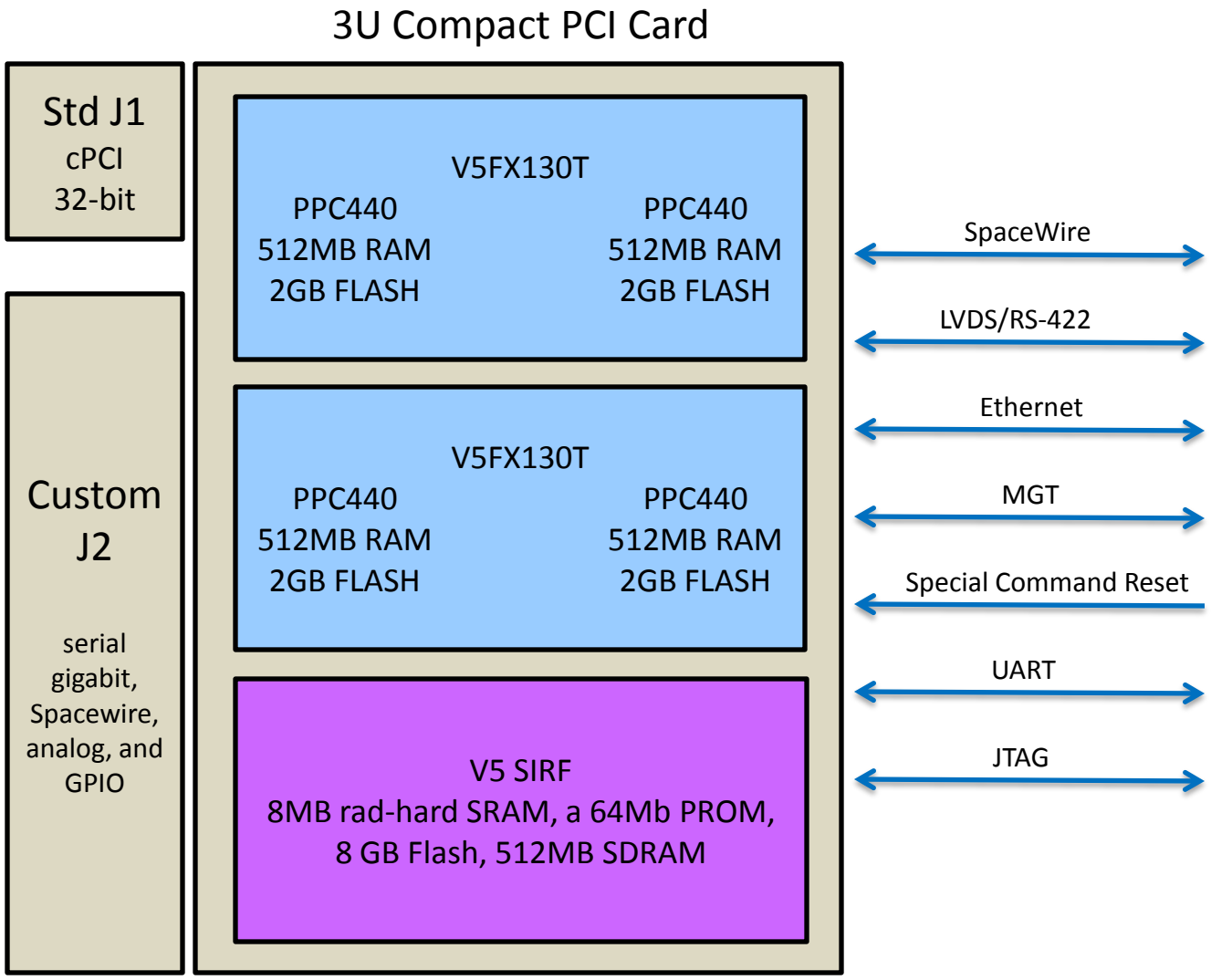
SpaceCube 2.0 Block Diagram



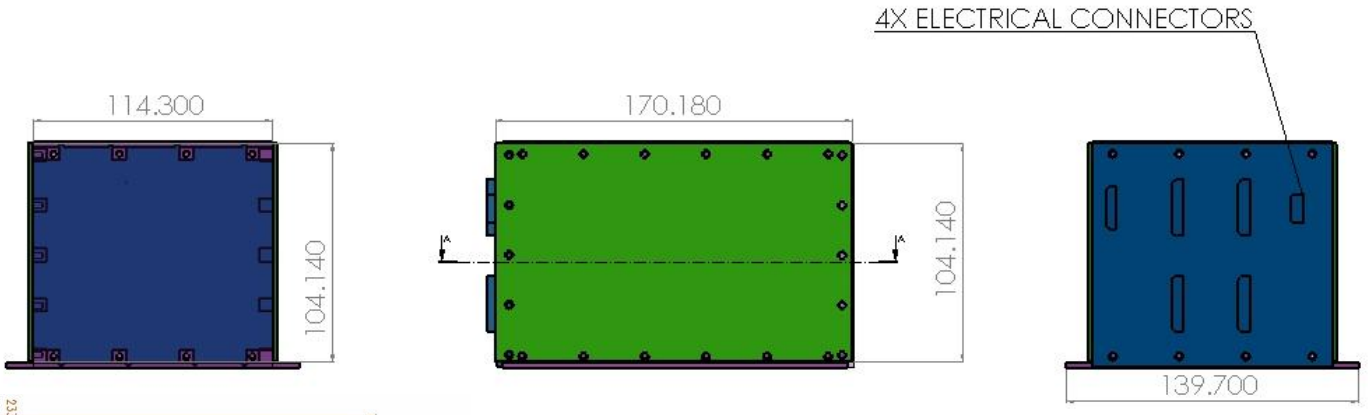
Spacewire / LVDS / MGT / GigE / Mission Unique High-speed

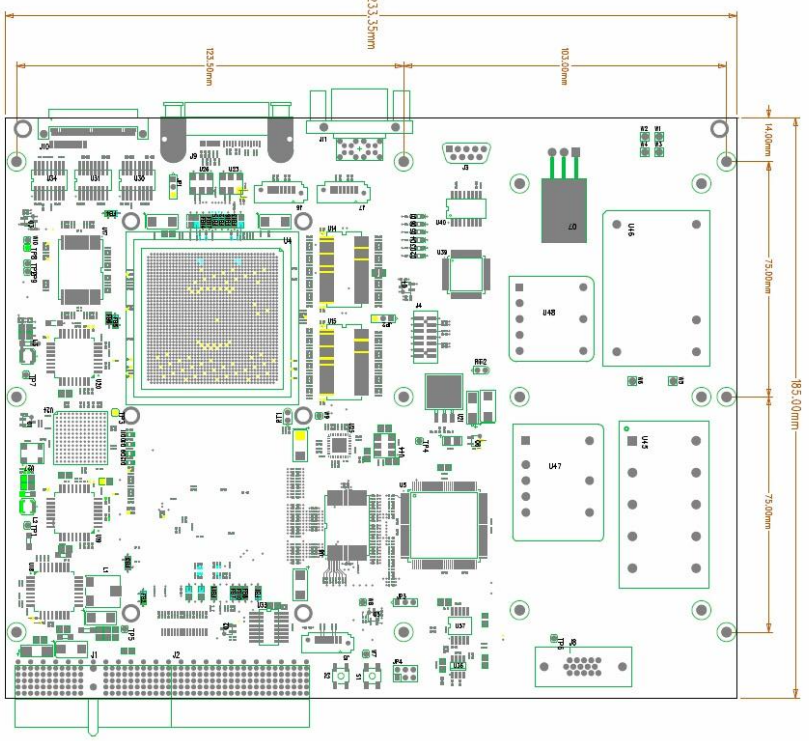
Standard 3U Card Form Factor
Nominal Box Level Parameters:
Size 5”x5”x7”, Weight 10-15 lbs, Power 10-20 watts

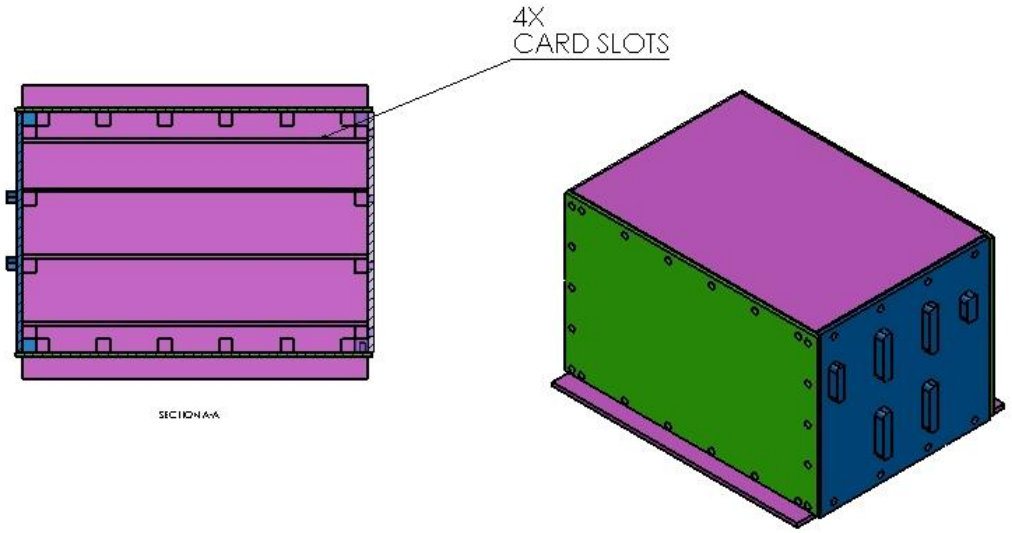
SpaceCube 2.0 Processor Card



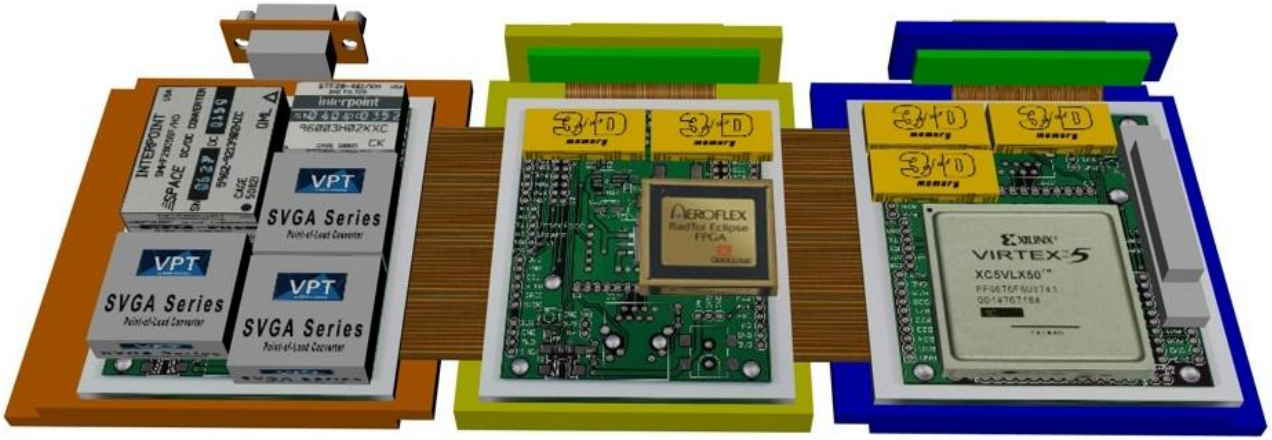
SpaceCube 2.0

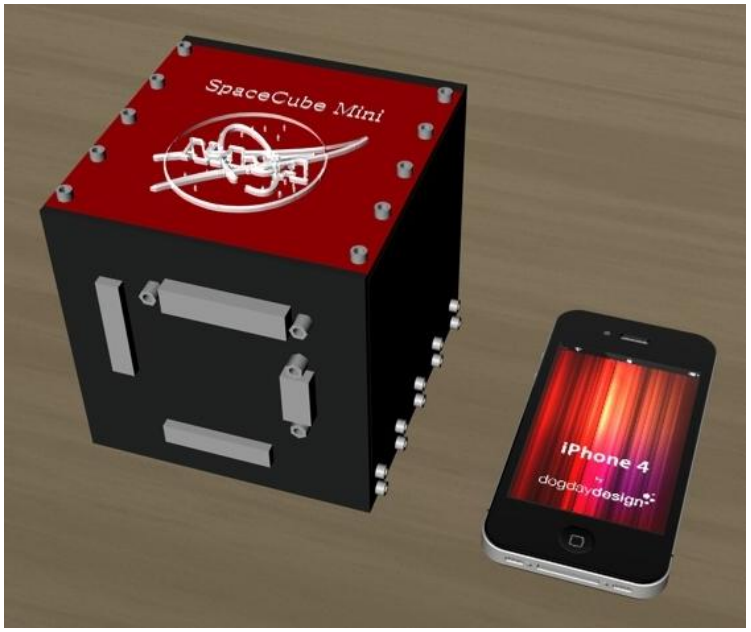


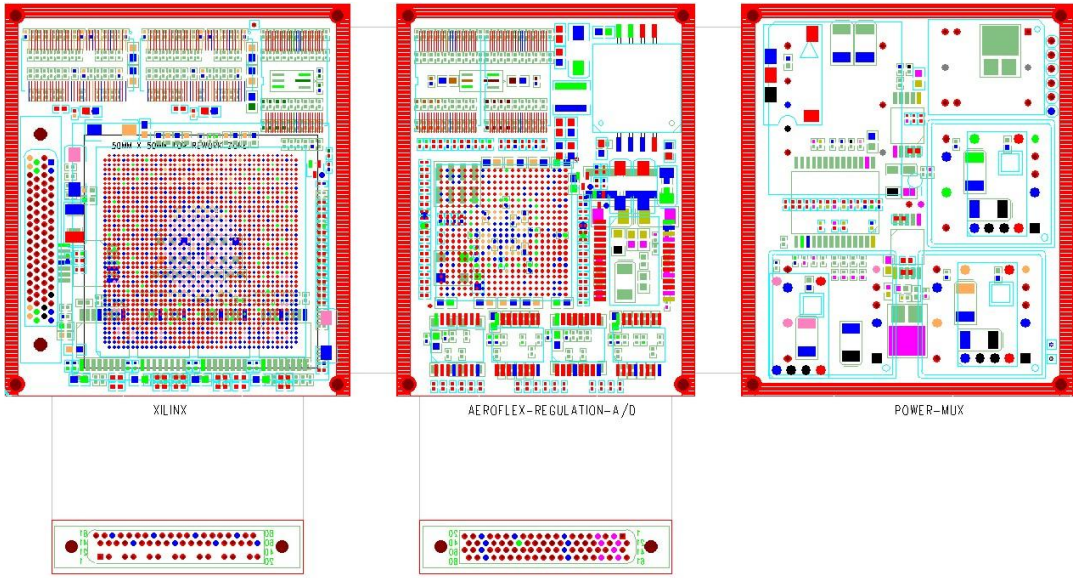




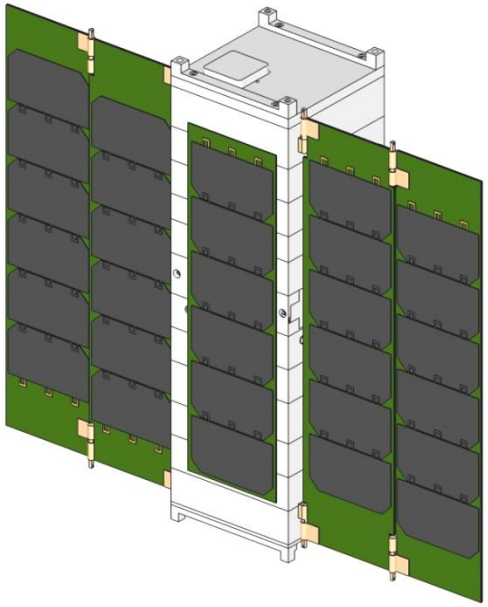
SpaceCube "Mini"

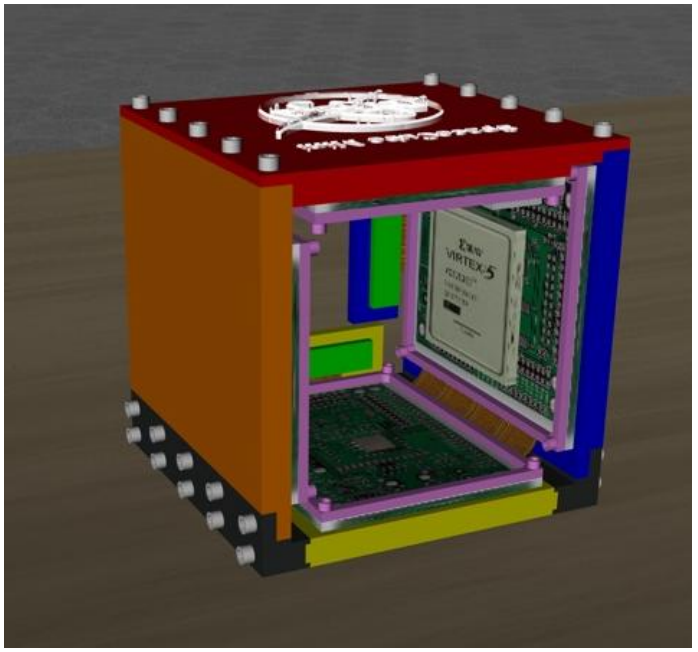


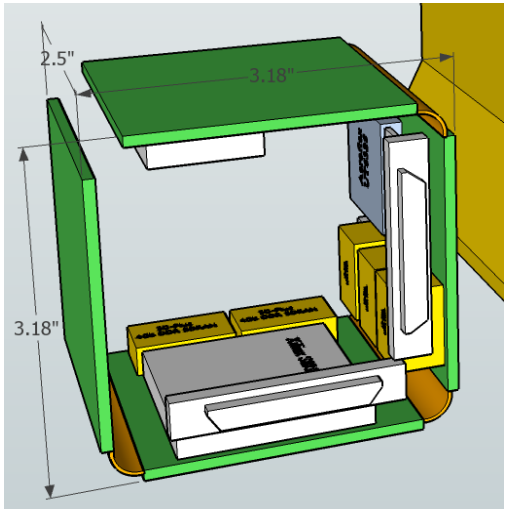


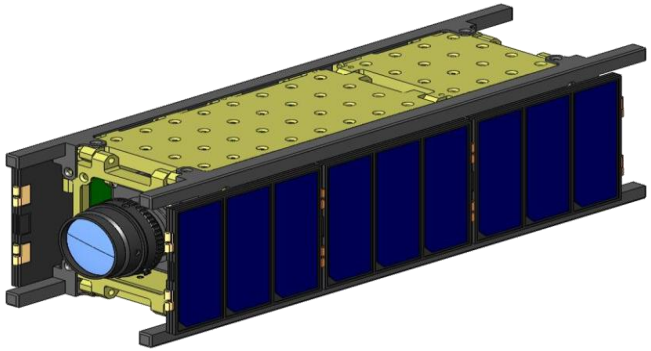


CubeSats: IPEX & TechCube 1









STP-H4 / ISE 2.0 Location & FOV

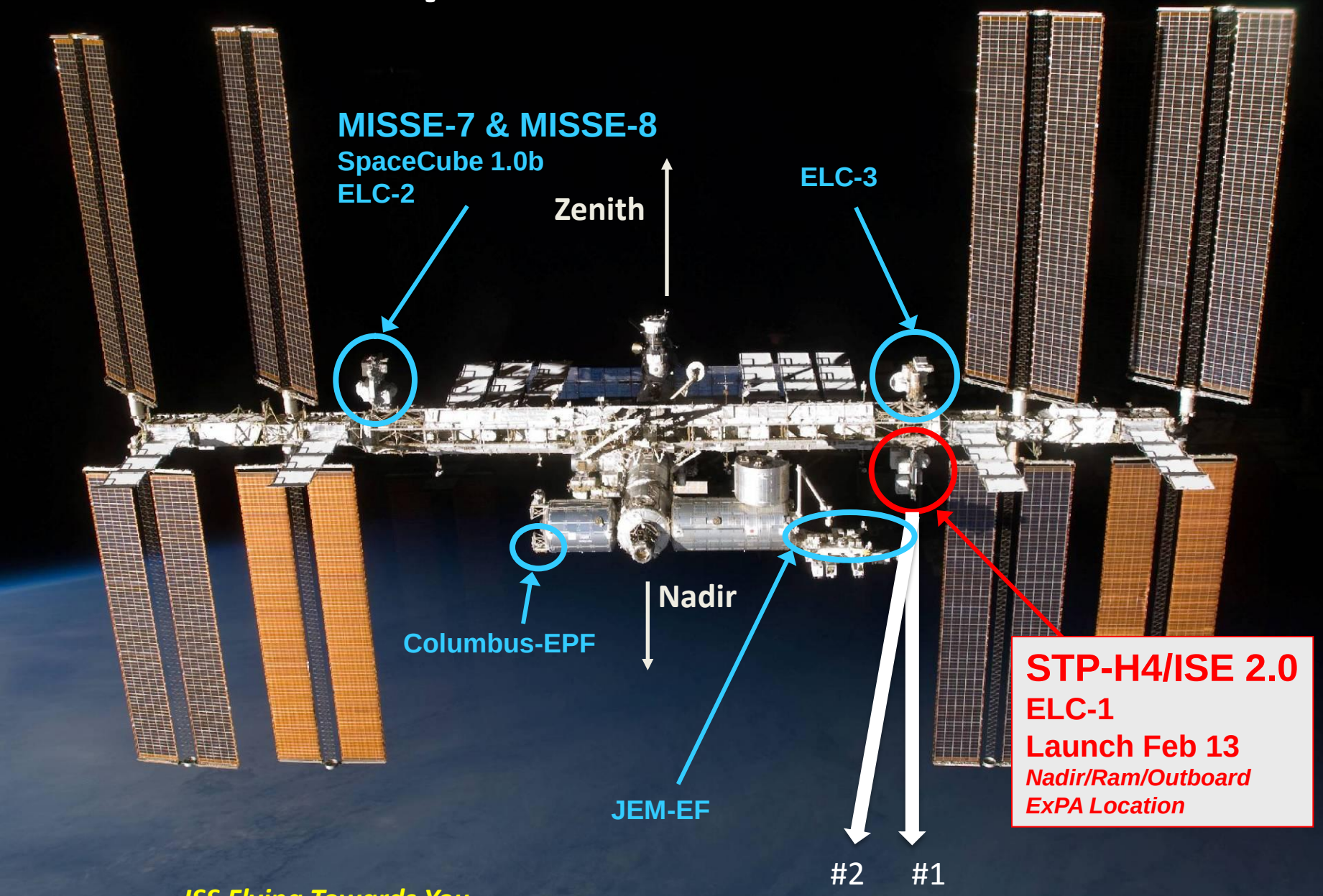
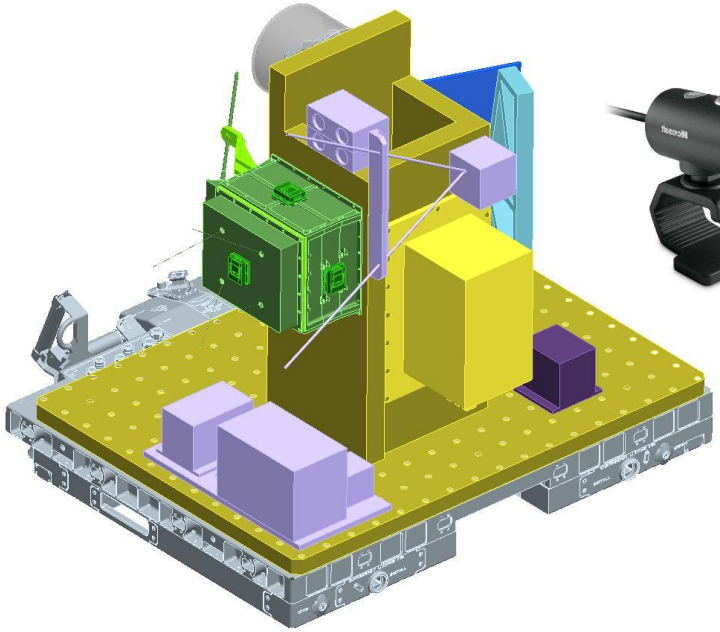
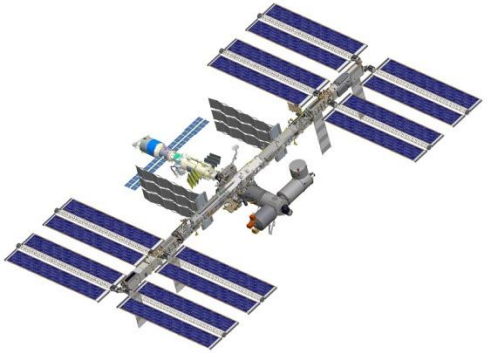


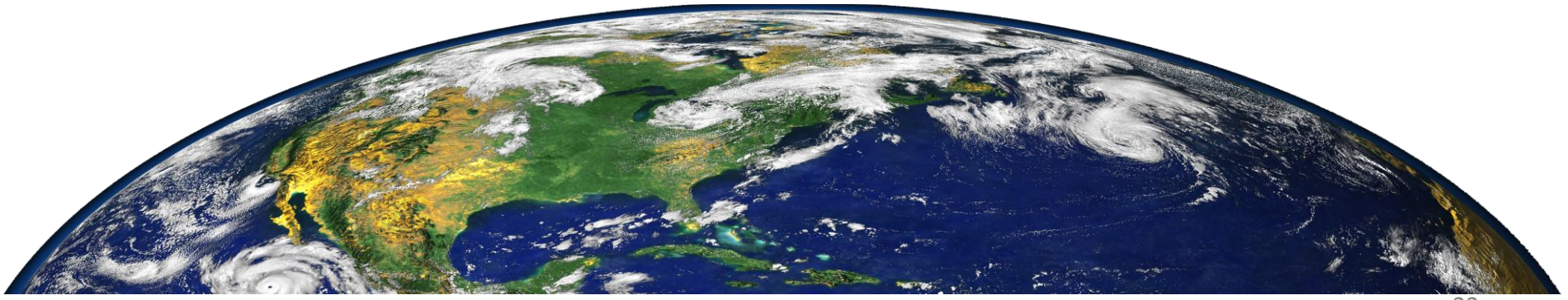
Image Credit: DoD Space Test Program

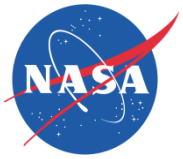
ISS SpaceCube Experiment 2.0 (ISE 2.0)





Payload Image Credit: DoD Space Test Program





Questions ?

tom.flatley@nasa.gov

http://en.wikipedia.org/wiki/SpaceCube

http://gsfctechnology.gsfc.nasa.gov/SpaceCube.htm