

Hyperspectral Cubesat Constellation for Natural Hazard Response (Follow-on)

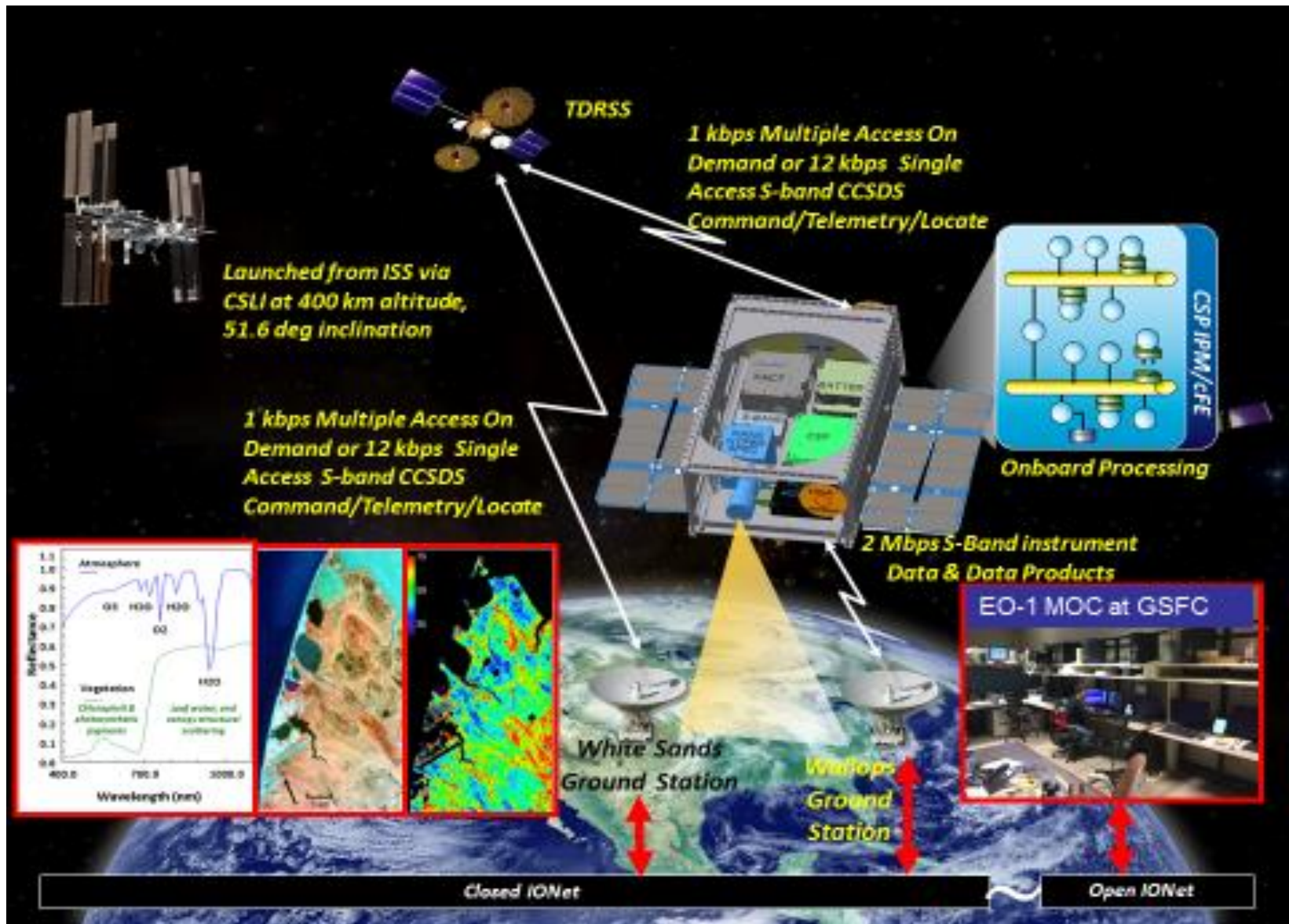
Dan Mandl
NASA/GSFC



Overview

- Design viable constellation of cubesats with hyperspectral sensors which enable daily repeat observations
 - Emulate Earth Observing 1 (EO-1) operations which has a repeat capability of 2-3 days for any spot on Earth
 - Need high performance onboard processing to mitigate reduced downlink capacities due to the use of cubesats
 - Identify potential orbit configurations
 - Identify sustainability issues such as orbit degradation and the ability to perform inclination maneuvers to maintain orbits
 - Identify radiation and thermal issues versus selection of cost-effective components
 - Design communications for continuous coverage and maximum downlink capacity
- Maintain open design to enable a collaborative approach to evolve better designs as new components or ideas emerge
- Original design was submitted to a NASA proposal call for funding, but was declined
- Desire is to resubmit to future calls

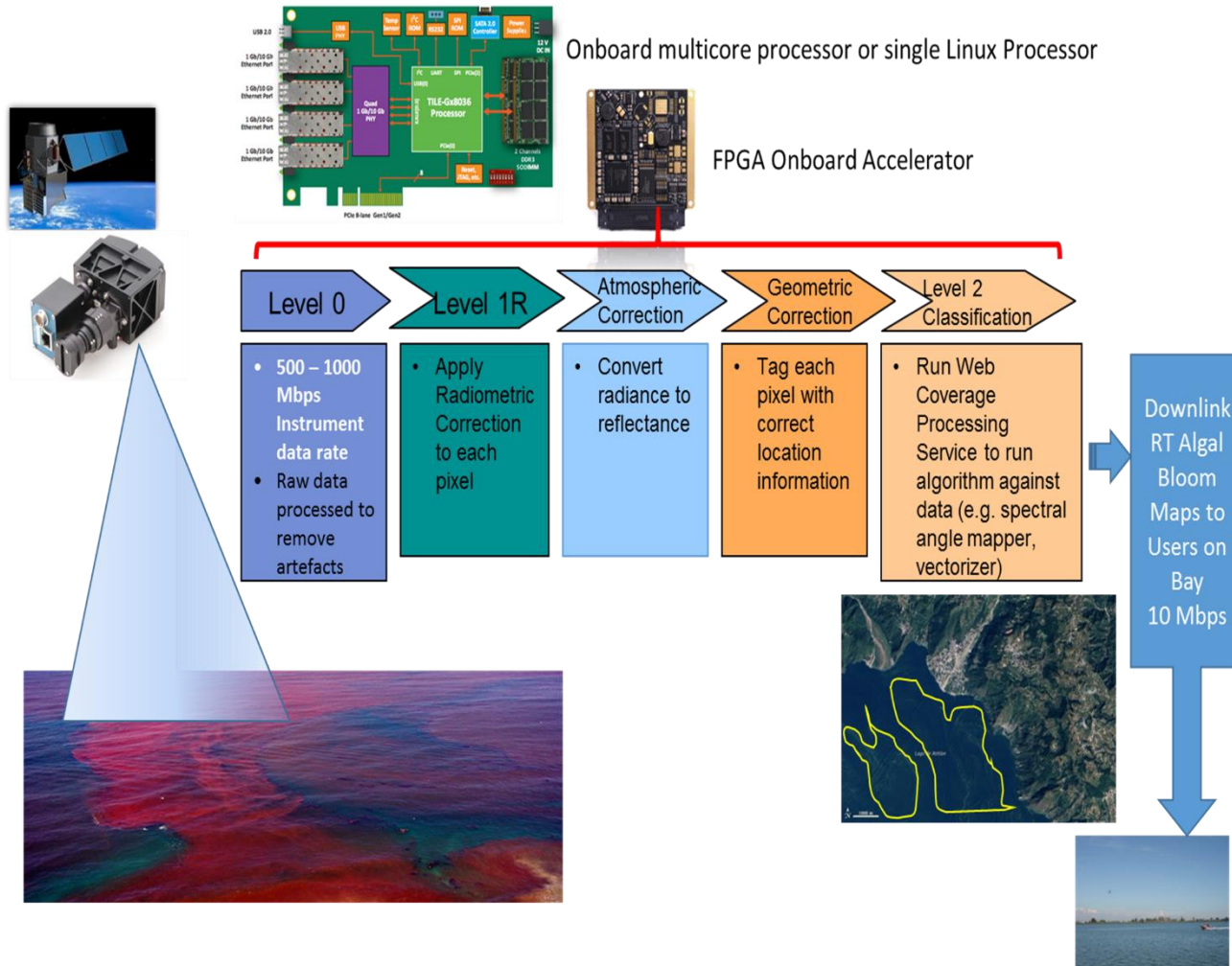
Architecture to Emulate EO-1 Operations



Preliminary Part Selection

Component Name	Vendor	Dimensions	Mass	Count	Cost	TRL	Power
30 Wh Battery	Clyde Space	95.885mm x 90.170 mm x 20.440mm	256g	1	\$3,850	9	
6U CubeSat Side Solar Panel	Clyde Space			2	\$14,300	9	
3U 2-Sided Double Deployed Solar Panel	Clyde Space			1	\$32,750	9	
SCR-102 S-Band radio	Innoflight	(82 X 82 X 35) mm	290g	1	\$80,000	9	8W
3G Flex EPS (Electrical Power System)	Clyde Space	(90.80 x 85.08x14.95) mm	148g	1	\$13,500	9	.39W
Nano-Hyperspec	Headwall	76.2mm x 76.2mm x 119.92mm)	.68 kg		\$200,000 Estimate w/upgrade	9/Aerial, 6/Space	10W
XACT Attitude Determination System	Blue Canyon Tech	10 x 10 x 5 cm	850g	1	\$250000	9	Max 2.83W
SGR-05U Space GPS Receiver (antenna included)	Surrey Satellite Technologies US LLC	70x46x12 mm	20g	1	\$26,300	9	0.8W
CHREC Space Processor	Space Micro	88 x 89 x 15mm	72g	2	\$30,000	9	2.5W
6U Box					\$10,000	9	

Sample Onboard Processing Data Stream



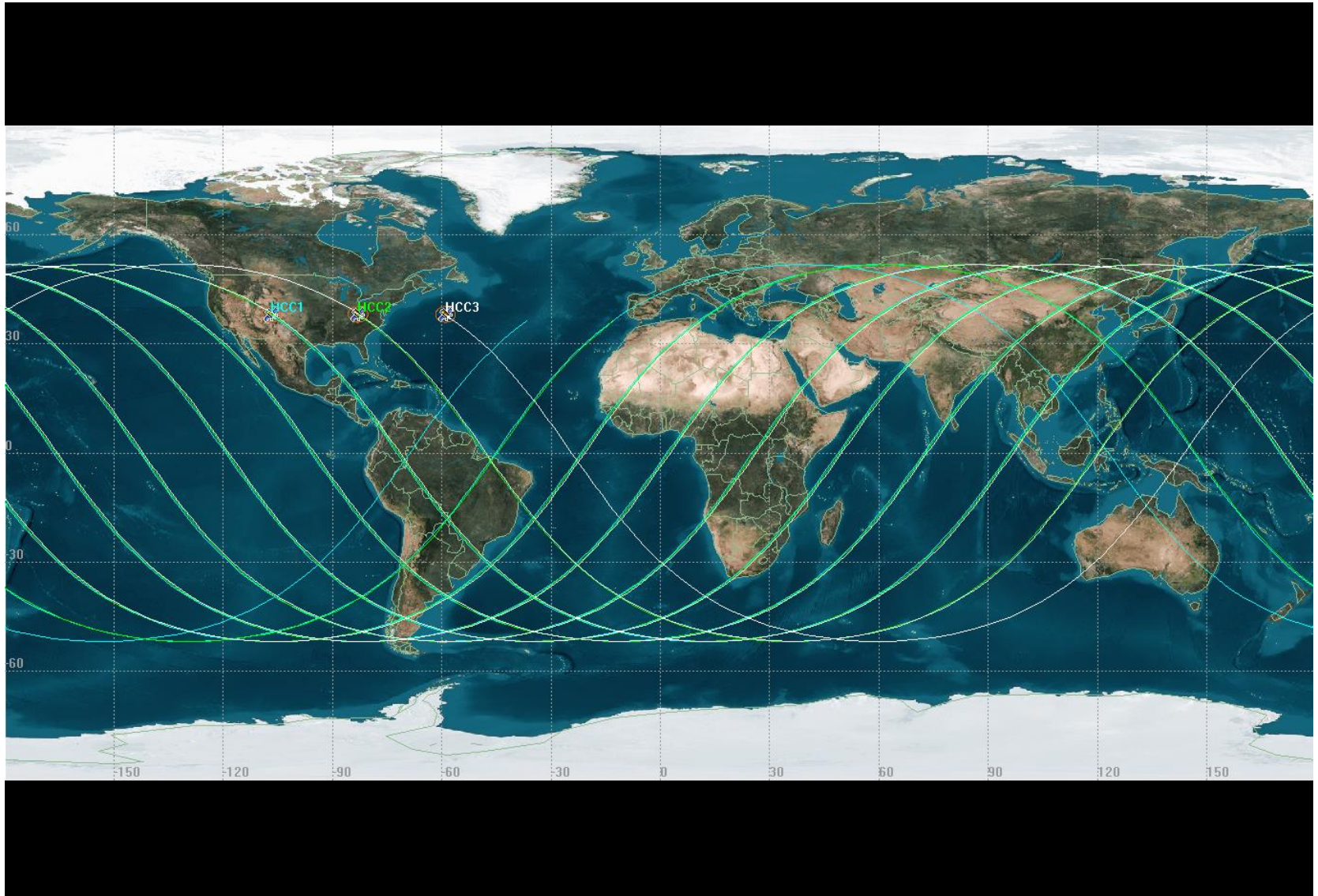
- Onboard data reduction and data product production thus reducing downlink capacity requirements
- Onboard processors consume less than 10 watts

Preliminary Instrument - Headwall Nano-Hyperspec

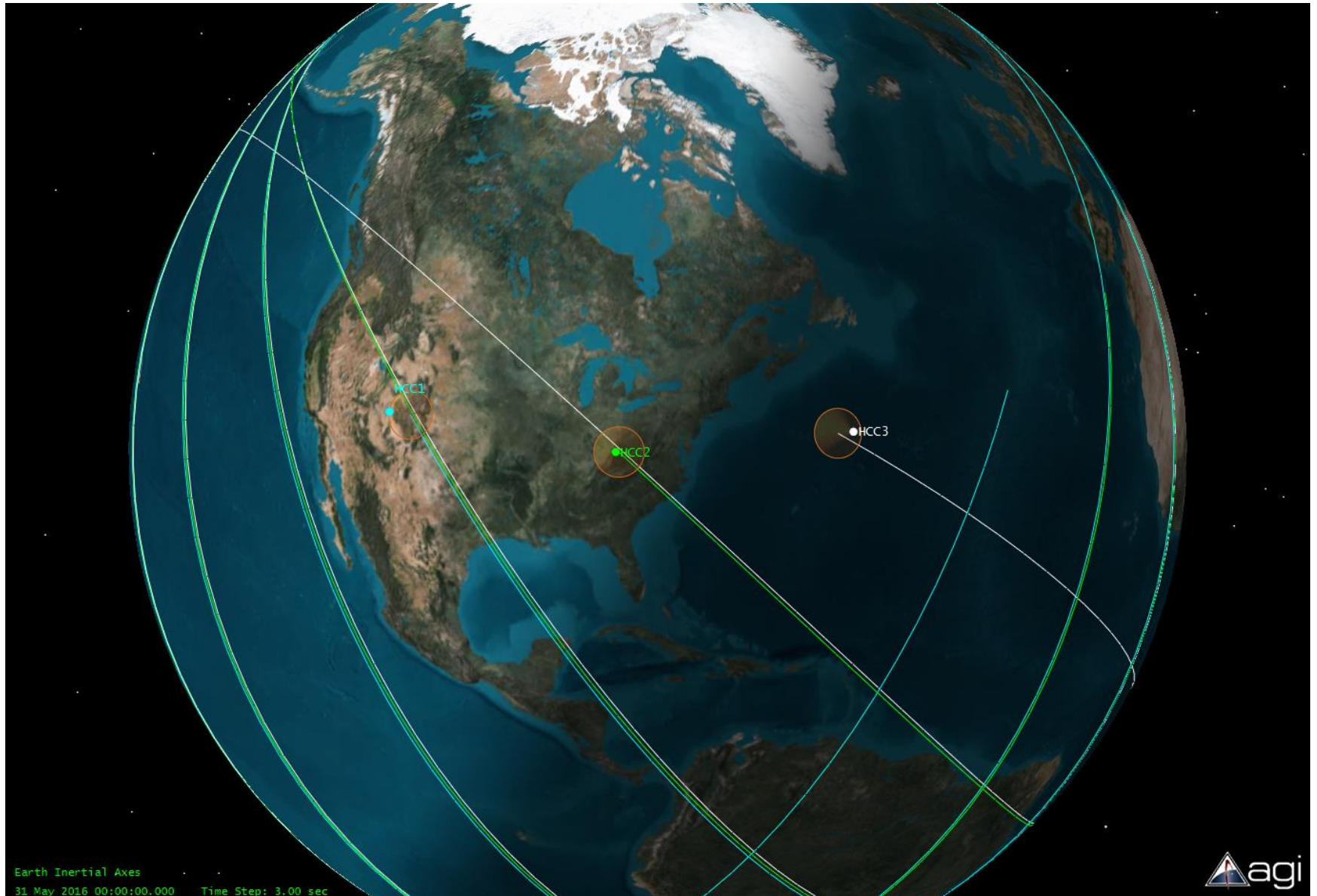


- 640 spatial pixels
- 270 spectral bands (400 – 1000 nm)
- ~2.2nm spectral sampling interval
- 5nm spectral resolution (FWHM with 20-micron slit)
- 17mm lens (standard) – Use 1500 mm lens for Cubesat application
- 480GB storage capacity (~ 130 minutes at 100 fps)
- Connectivity: Gigabit Ethernet
- Size (exclusive of GPS): 3" x 3" x 4.72" (76.2mm x 76.2mm x 119.92mm)
- Weight: less than 1.5 lb. (0.68kg)

Orbit Which Provides Daily Coverage for Selected Spots on Earth



3D View of Orbit



Orbital Decay with No Propulsion

The screenshot shows a software interface for simulating orbital decay. The main window has several sections:

- Satellite Characteristics:** Drag Coefficient: 2.20000000, Reflection Coefficient: 1.50000000, Drag Area: 0.06 m², Area Exposed to Sun: 0.06 m², Mass: 15 kg.
- Solar Data:** Solar Flux File: SolFlx_Schatten.dat, Solar Flux Sigma Level: 1.
- Buttons:** Advanced..., Compute, Report ..., Show Graphics (checked), SGP4 Compute, Graph ...
- Atmospheric Density:** Model: Jacchia 1970 Lifetime.
- Bottom Buttons:** Close, Apply, Help.

An **Information** dialog box is open, displaying the following text:

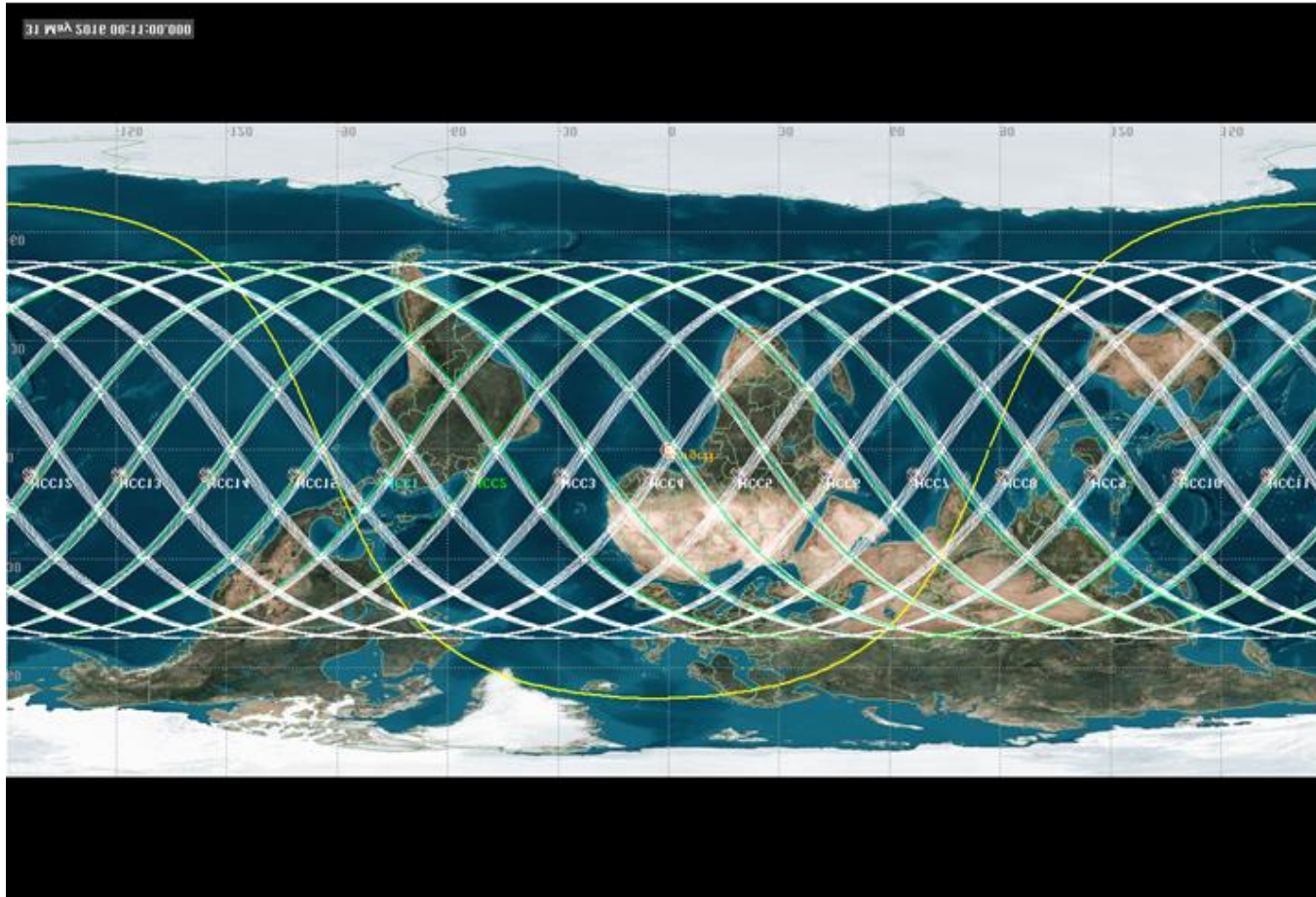
HCC1 decay is estimated to be on 8 Oct 2017 10:55:00.410 after 7750 orbits. The lifetime is 1.4 years.

OK

➤ Assumptions

- Each Cubesat is 15 Kg (6U configuration)
- Surface area is about 0.06 m²
- Orbit stays at Space Station orbit (400 km) with 90% of elevation for 1.4 year

Alternative Orbit Configuration



➤ Assumptions

- Each Cubesat is 15 Kg (6U)
- 15 cubesats at 400km elevation

Setup Parameters for this Orbit Configuration

Propagator: J4Perturbation Initial State Tool...

Start Time: 20 Jun 2016 00:00:00.000 UTC

Stop Time: 20 Jun 2016 00:00:00.000 UTC

Step Size: 60 sec

Orbit Epoch: 20 Jun 2016 00:00:00.000 UTC Apogee Altitude: 400 km

Coord Epoch: 1 Jan 2000 11:58:55.816 UTCG Perigee Altitude: 400 km

Coord Type: Classical Inclination: 52 deg

Coord System: J2000 Argument of Perigee: 0 deg

Prop Specific: Special Options... RAAN: 0 deg

True Anomaly: 0 deg

Adjust this per satellite

➤ Assumptions

- 15 Cubesats provide coverage for selected portions of Earth approximately every 42 minutes thus enabling hyperspectral observations diurnally
- Need 3 sets of 15 cubesats to enable any spot on Earth to be observed approximately every 42 minutes, minus the polar regions

Programmatic Approach

- Cost per cubesat estimated at about \$500K or less once non recurring engineering costs subtracted
 - Operations costs not included, but original plan was to piggyback on EO-1 operations
 - This won't be viable in future since EO-1 operations ends in 2017
- Operations emulates EO-1 operations
 - Makes use of TDRSS for continuous coverage at 1 kbps
 - Makes use of NASA Ground Stations to downlink data products at 2 Mbps
- Preliminary orbital design assumes 3 cubesats at 400 km elevation and that the orbit degrades to 90% in 1.4 years
 - Launch new cubesat every 4 months
 - After one year, cubesat replaces first cubesat launched
 - Maintain 3 satellite constellation at \$1.5 million per year plus operations costs
 - As time goes on, cubesat costs reduced and increase capability by folding in new improved technology
- Sustainable approach is also expandable
 - Could launch additional cubesat that make use of additional spectral bandwidth such as greater than 1000 nm
 - Additional sensors could be added on ongoing basis once process begun, cost-effectively

Conclusion

- Hyperspectral Cubesat Constellation approach provides sustainable pipeline to obtain hyperspectral daily observations, thus making it optimal for observing natural hazards where time series are typically desired
- Approach would engage a large science and applications community since at present, typical hyperspectral missions costs are in the hundreds of millions of dollars. Therefore, launches are infrequent, minimizing data that scientists can work on.
 - Small hyperspectral instruments do not provide the quality of the larger instruments and at present do not provide the same spectral bandwidth
 - Smaller hyperspectral instruments quality are improving