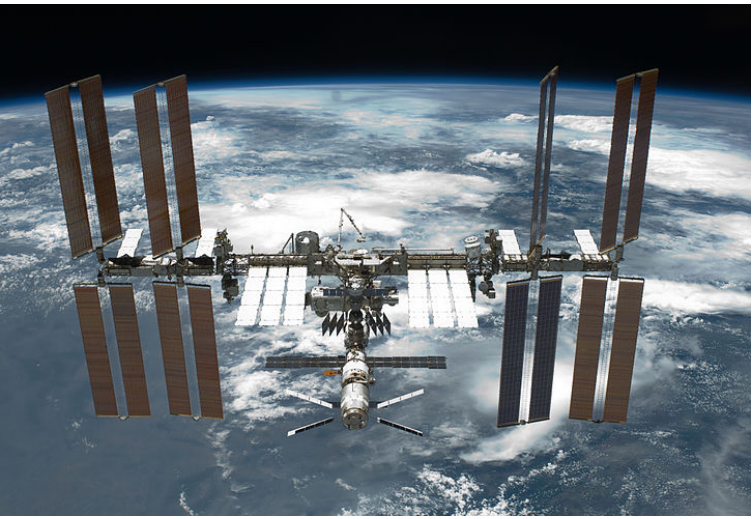
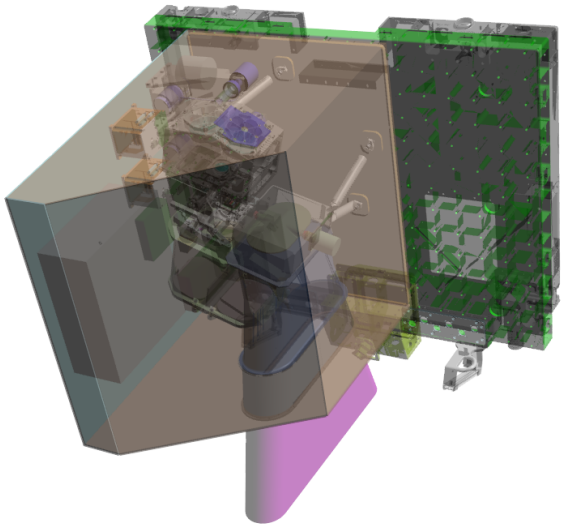
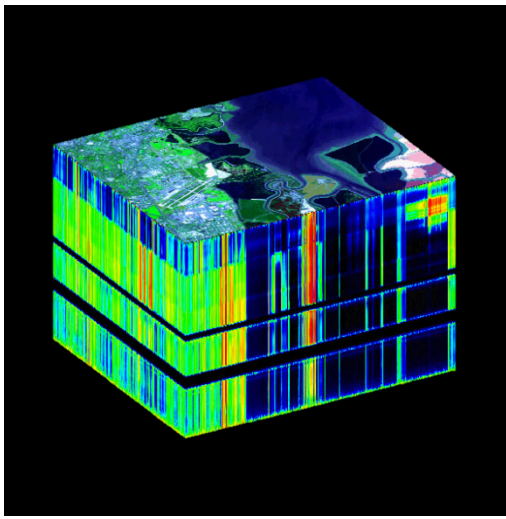
HyspIRI *ISS VSWIR-IS*

Accommodation Study





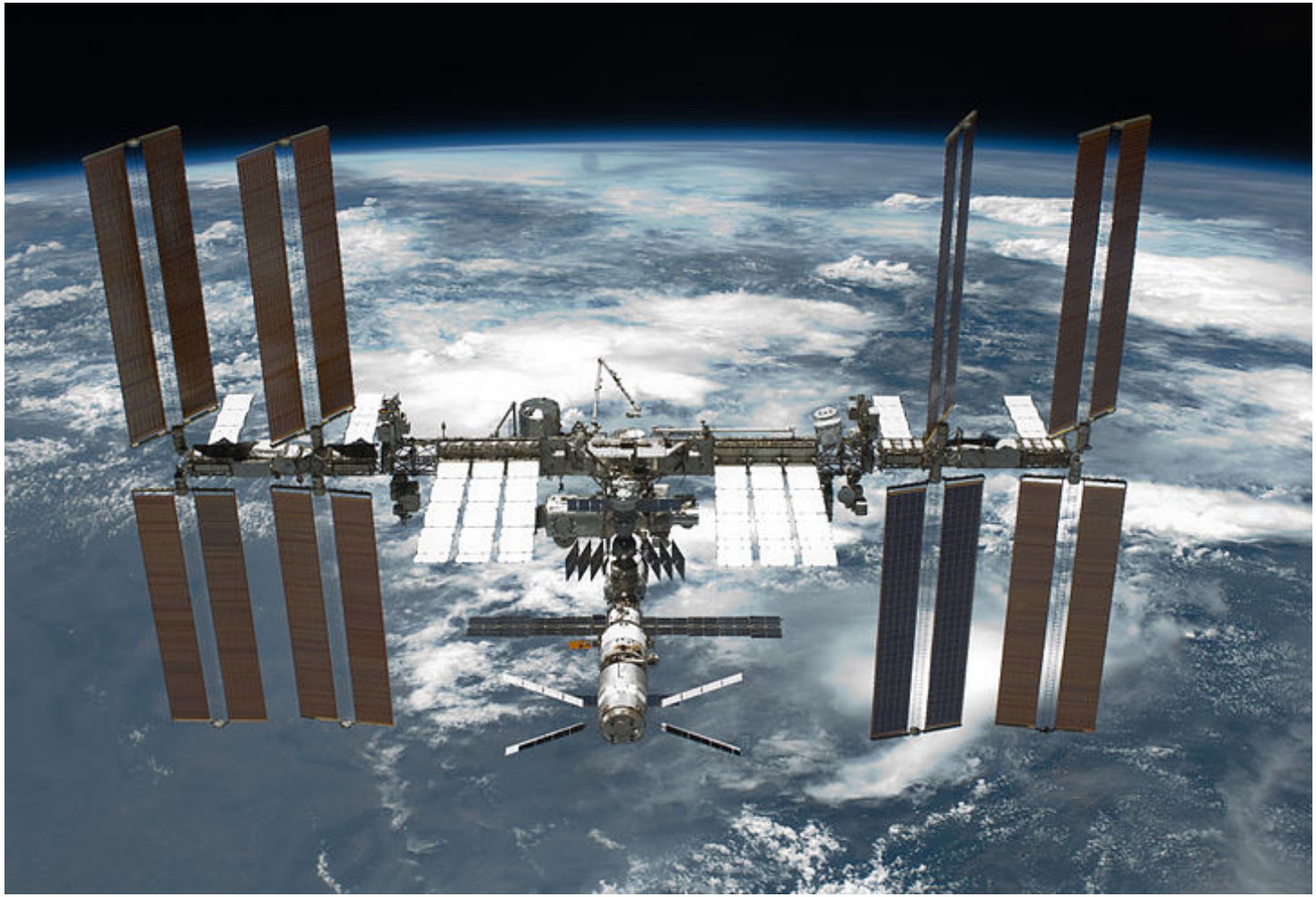


R. Green, C. Bruce, W. Schmitigal and the Imaging Spectroscopy Community

Jet Propulsion Laboratory, California Institute of Technology

HyspIRI ISS VSWIR Study

- The ISS offers an early path for urgent and unique VSWIR science as well as demonstration of VSWIR technology



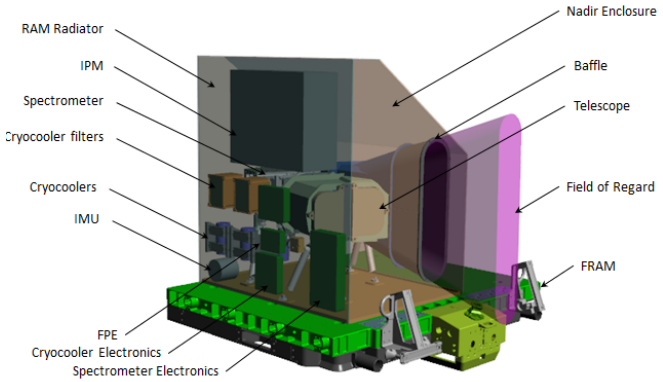
Summary

ISS VSWIR-IS
R. Green, C. Bruce and W. Schmitigal

Objectives:

- Mature and validate the key components for HyspIRI, i.e., spectrometer, slit, detector and detector electronics, cryocooler, compression, IPM, etc.
- Acquire a subset (~20%) of the HyspIRI mission science data that can be used to address key urgent and unique HyspIRI science and applications

Study Candidate:



Approach & Partnerships:

- Utilize existing HyspIRI Mission Study development hardware and AVIRIS-NG designs to configure an VSWIR Imaging Spectrometer that could be flown on the ISS collecting data for a minimum of six months
- Use existing AVIRIS-NG ground alignment and calibration capability as well as data processing system (currently used for HyspIRI preparatory campaign)

Mission Science to be Achieved:

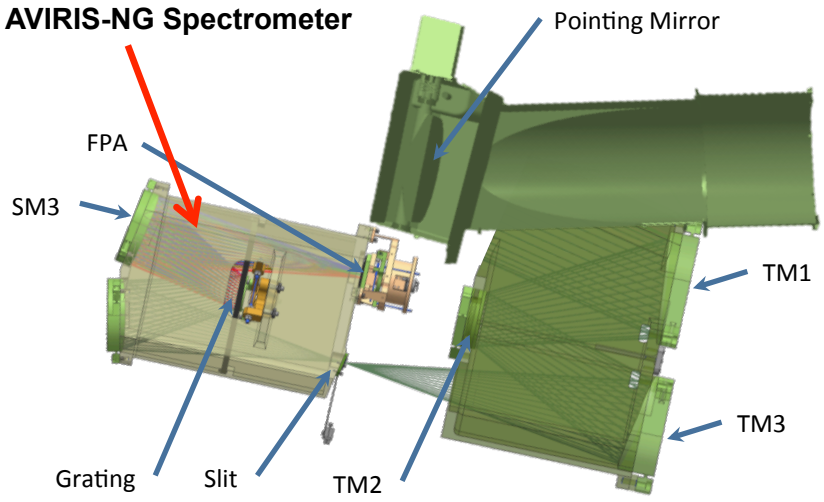
- Ecosystem Measurement for Climate Feedback
- Pattern and Spatial Distribution of Ecosystems and their Components
- Ecosystem Function, Physiology, Diversity and Seasonal Activity
- Biogeochemical Cycles
- Ecosystem Disturbance
- Fires: Fuel, Severity, Recovery, and Carbon Release
- Black Carbon/Dust Effects on Snow and Ice
- Ecosystem and Human Health
- Earth Surface Composition
- Coral reefs

Concept Summary

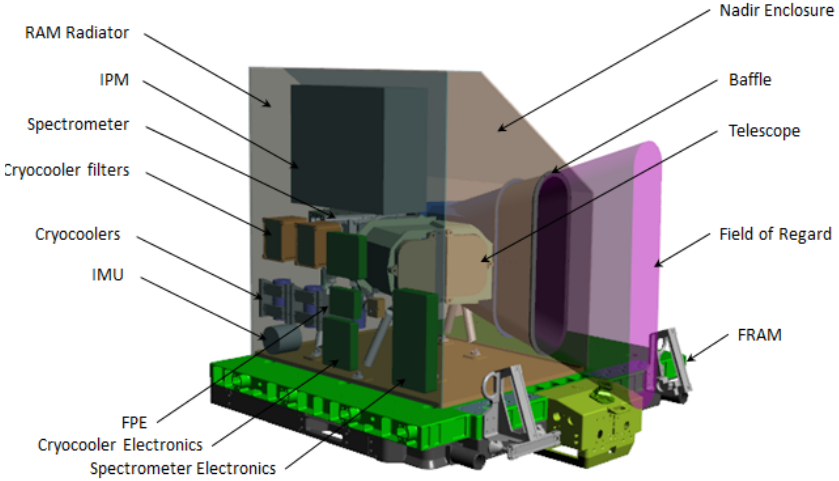
Imaging Spectrometer Specification

Spectral	
Range	≤380 to ≥2510 nm in a single spectrometer
Sampling	≤10 nm {uniform over range}
Accuracy	±0.5 nm
Radiometric	
Range & Sampling	0 to max benchmark radiance, 14 bits measured
Accuracy	≥95% absolute radiometric
Precision (SNR)	≥500 in VNIR (550 nm) and ≥250 SWIR (2200nm)
Spatial	
Cross-Track Samples	1000 (1280 detector)
Swath	30 km
Ground Sampling	30 m
Pointing	±15 degrees
Spectral Uniformity	
Cross-Track	≥90% cross-track uniformity
FOV-Variation	≥90% spectral IFOV uniformity

Opto-Mechanical Layout



Components

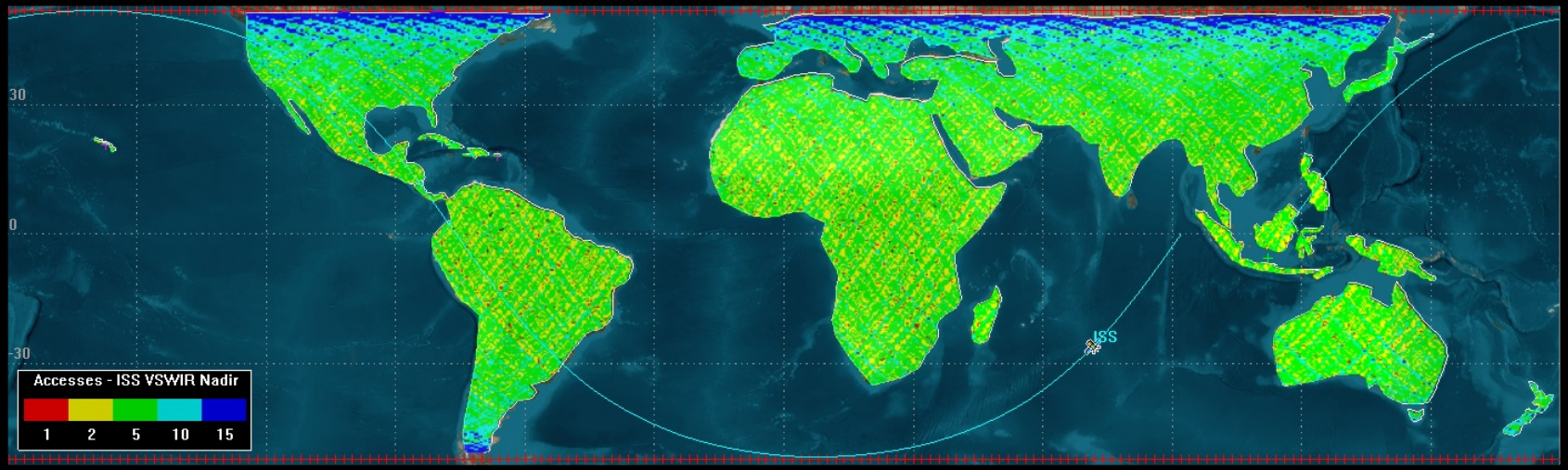


Description

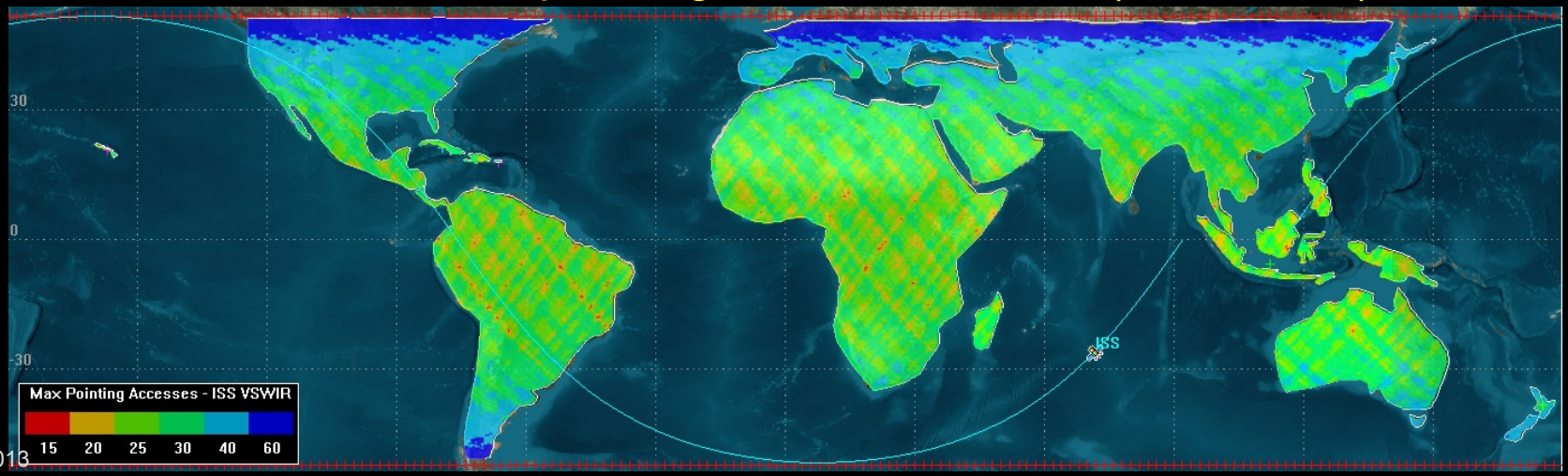
- Push-broom imaging spectrometer with pointing capability of $\pm 15^0$ of ground track
- Uses VSWIR 1280x 480 MCT detector by Teledyne
- Use heritage design from AVIRS-NG for spectrometer and heritage process for Aluminum diamond turned telescope optics
- 30 m ground resolution (LandSat-like)
- Thales Cryocoolers for FPA and spectrometer cooling
- Fast Lossless (FL) compression on FPGA with cloud screening
- Imaging spectrometer data processing system level 0 to level 2 developed for NGIS

Terrestrial and Coastal Coverage
±52° Latitude with 5.76° FOV

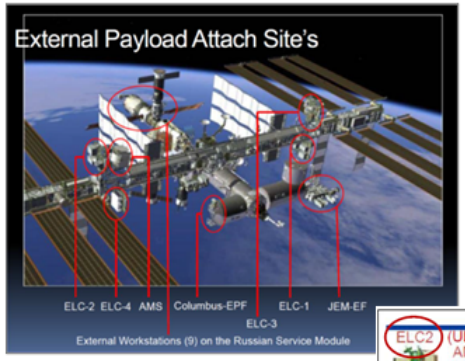
Fixed Nadir Pointing Views in 1 Year



Maximum Target Views using Pointing
+2.5 Swath pointing in each direction (28.8° FOV)



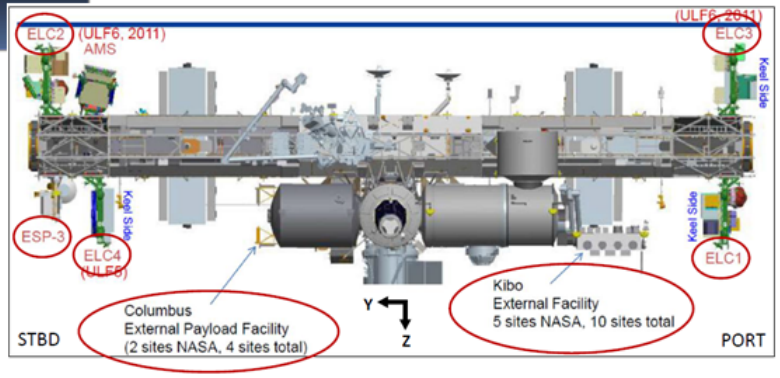
ISS Accommodation Study



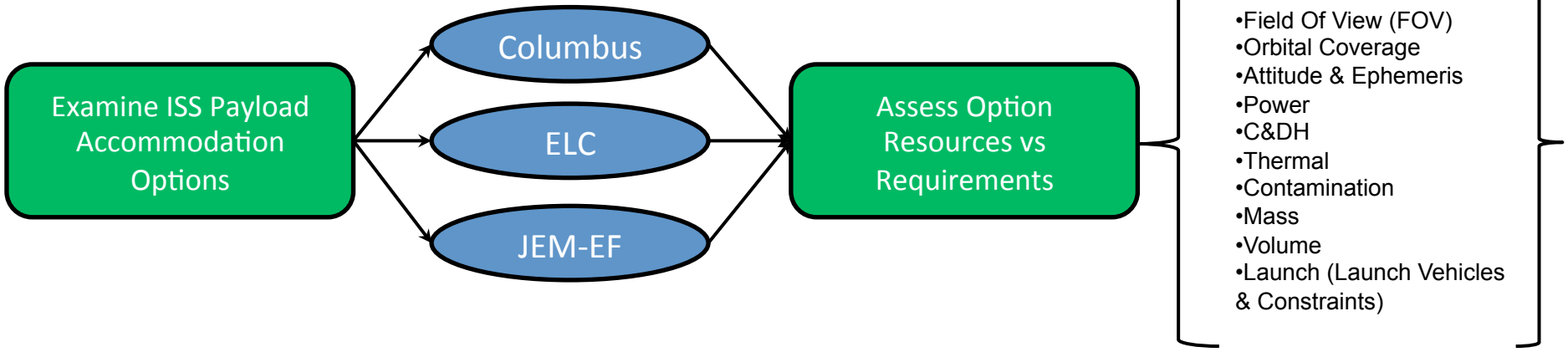
Available Physical Accommodations

Locations w/ access to Earth Nadir views

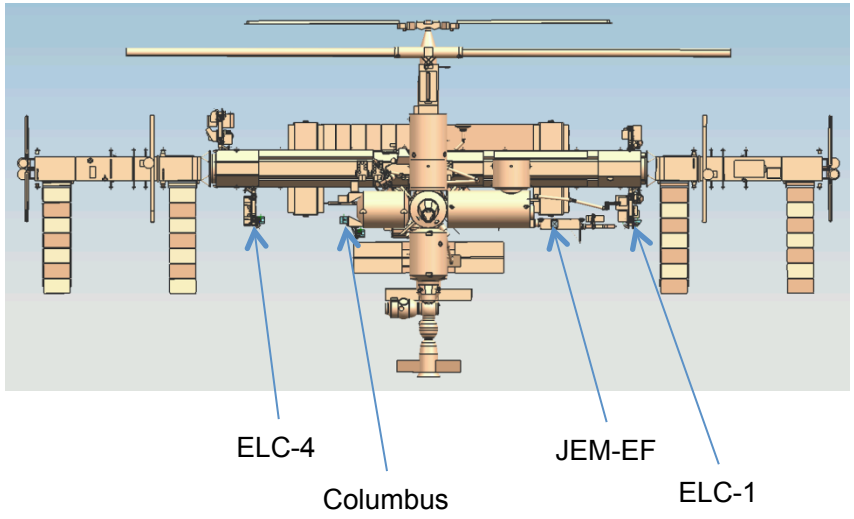
- ELC
  - 2X Pallet mounts @ ECL-1, 1X Inboard Lower & 1X Outboard Lower
  - 2X Pallet mounts @ ELC-4, 2X Inboard Lower
- Columbus EPF
  - 2X Pallet mounts @ 1X SDX & 1X SDN
- JEM EF
  - 7X Sites available @ EFU-1, EFU-2, EFU-3, EFU-4, EFU-6, EFU-8 & EFU-9

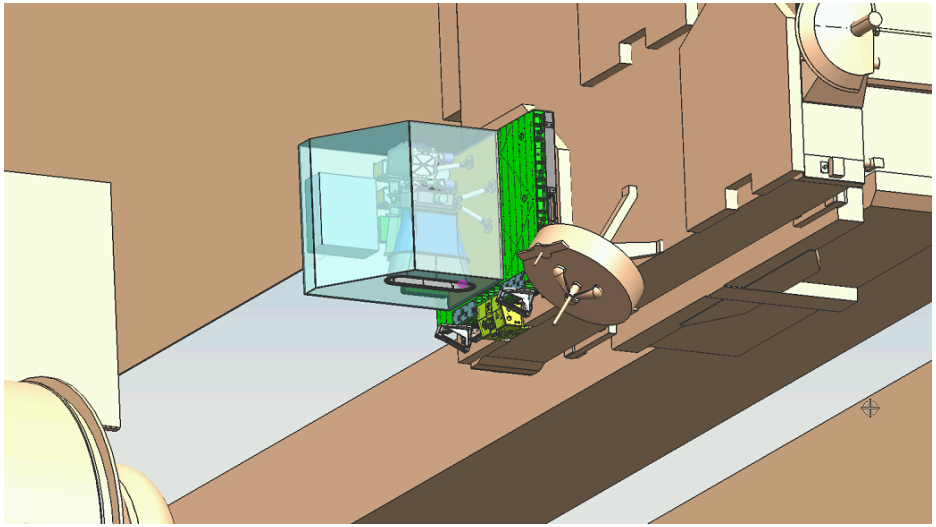


Circled accommodations are those considered to be viable for Earth science missions

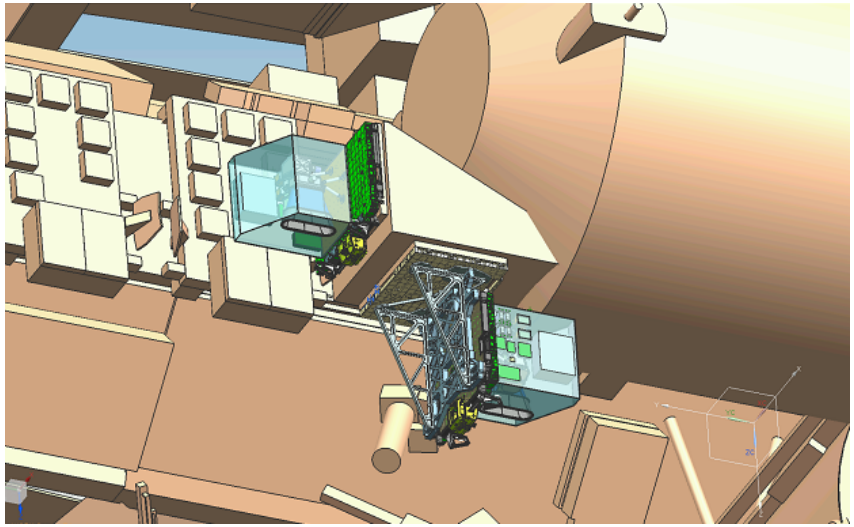


Nadir Accommodations

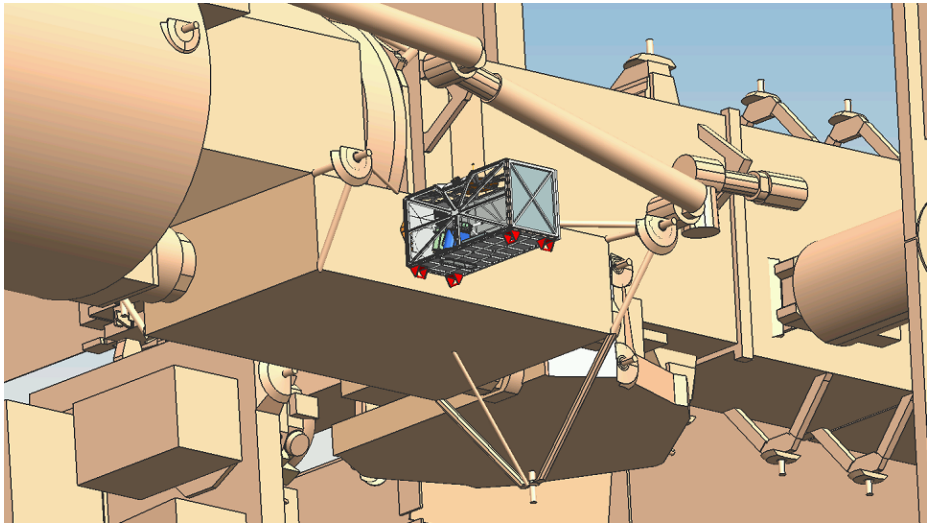




ELC-4



Columbus (SDX & SDN)



JEM-EF

ISS External Payload Accommodations Comparison

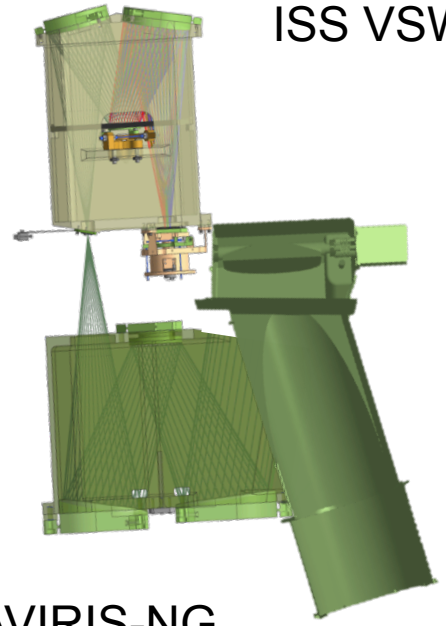
	Estimated Resource Requirements for ISS VSWIR-IS	Express Logistics Carrier	JEM-EF Sites	Columbus Module
Volume	0.9 m x 0.84 m x 0.64 m	1.1 m x 0.86 m x 1.2 m	1.0 m x 0.8 x 1.8 m	1.1 m x 0.86 m x 1.2 m
Mass	125 kg	227 kg for Payload	550 kg for Payload	236 kg for Payload
FOV	Nadir looking 5.2^0 FOV Nadir with $\pm 15^0$ FOR	ELC-4 clear FOR ELC-1 minor obstructions – no science impact	Clear FOR	Clear FOR
Thermal	Instrument cooling req'd either passive or cooling loop if available	Heating power available; Passive cooling	Heating power available Cooling loop provided (3 kW dissipation)	Heating power available; Passive cooling
Data Rate	9.2 Mbps orbital avg.	10 Mbps (shared)	10 Mbps (shared)	32 Mbps (shared)
Power	80 Watts ave. 145 Watts Peak	750 Watts @ 120 ±7 VDC 500 Watts @ 28v	3000 Watts @ 120 ±7 VDC	1250 Watts @ 120 ±7 VDC

- The instrument is nominally powered on for the mission
- Data will be recorded over scheduled illuminated land and coastal regions, compressed and screened for clouds before sending to storage for downlink
- Data measurements will be matched to available storage and downlink
- The system will only be power recycled if there is an event or it has placed in a survival mode with the loss of operational power

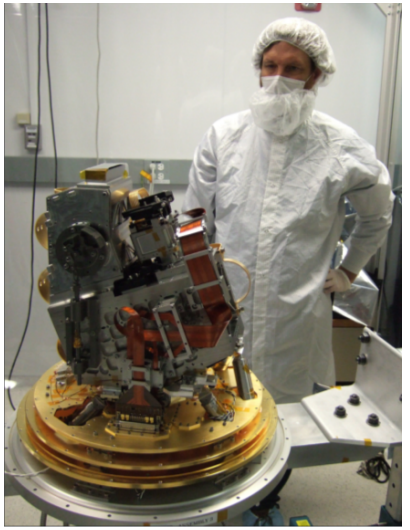
Approach

- Use the AVIRIS-NG Offner spectrometer design with the new VSWIR detector and electronics using up to 1000 cross track pixels
- Scale the MSS all aluminum TMA telescope with pointing mirror mechanism/control design also from MSS
- Use the AVIRS-NG OBC mechanism design
- Attitude knowledge use ISS GPS data and sensor mounted IMU
- On-board V5 computer for instrument control
- Actively cooled with 2 single-stage off the shelf Thales pulse tube cryocoolers with electronics
  - Passive cooling with radiators (or cooling loop depending on ISS location)
  - Four zones; FPA, spectrometer, telescope and electronics
- IPM from GSFC will perform data processing and interface with host

ISS VSWIR



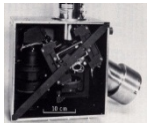
AVIRIS-NG



Schedule

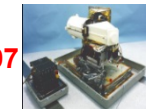
- 20 month development schedule is achievable with build to print spectrometer design
- MSS demonstrated TMA telescope development in 4 months and a delivered imaging spectrometer system in 8mo's using the AVIRIS-NG spectrometer

JPL Imaging Spectrometers & Contributions


1982

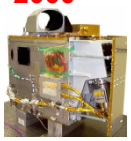

1986


1989

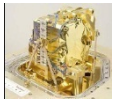

1997


1998

2000




2005



2009


2008

24 Months

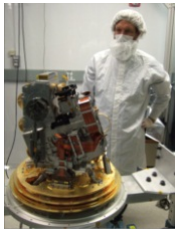
- First Imaging Spectrometer AIS proposed in 1979 first flights in 1982
- AVIRIS imaging spectrometer > 700 refereed journal articles
- NIMS imaging spectrometer to Jupiter
- VIMS imaging spectrometer to Saturn
- MICAS Miniature Integrated Camera and Imaging Spectrometer to Comet
- Enabling partner in Hyperion-Earth, CRISM-Mars and ARTEMIS-Earth imaging spectrometers (gratings, designs, calibration, science)
- Proposed and Developed NASA Moon Mineralogy Mapper (M3)
- > 7 Airborne/Rover-type Imaging Spectrometer operating at cryogenic temperature and in a vacuum (2005-2013)

MaRS
2005


24 Months

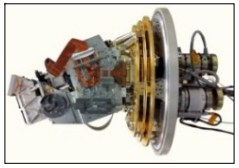
24 Months

CAO
2010

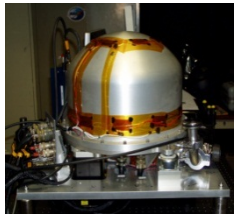


< 12 Months

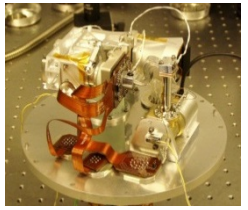
MSS
2011



PRISM
2012



UCIS
2012



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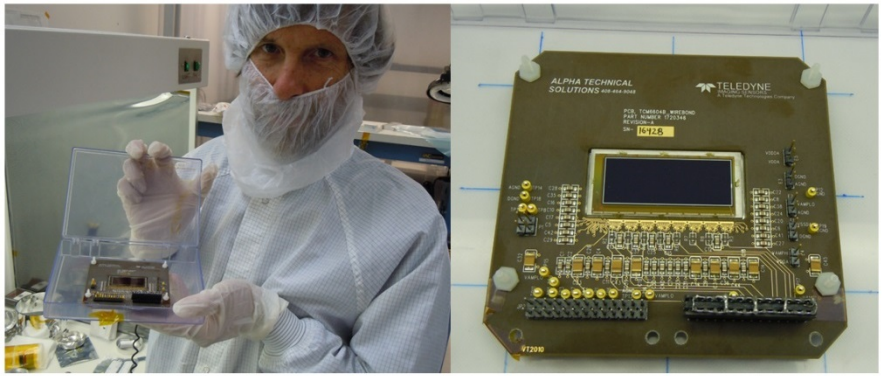
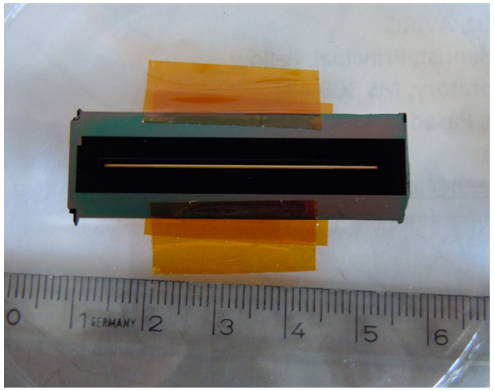
Hardware Status for ISS VSWIR-IS

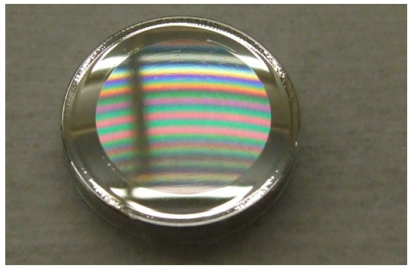
First 1280x480Teledyne Detector Array
for VSWIR Imaging Spectrometer
(280 to 2510 nm @ 10nm)

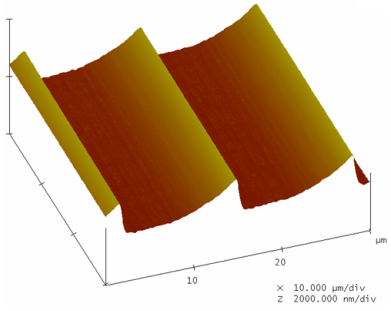


Unique JPL e-Beam Lithography Ultra-Uniform Slit for 1280 wide detector with 30 micron pitch (640 x 27 micron version flown on ARTEMIS)



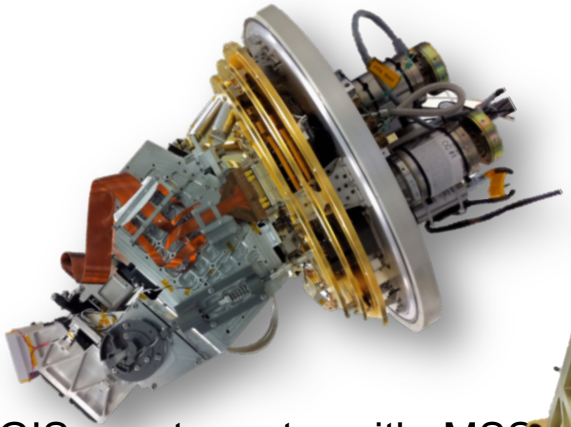
JPL electron-beam lithography grating
with shaped blaze to tune efficiency and
better control scattered light





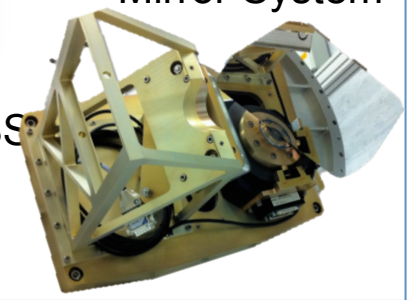
Teledyne Detector Array
Drive Electronics at JPL for Testing

Hardware Status for ISS VSWIR IS (cont.)



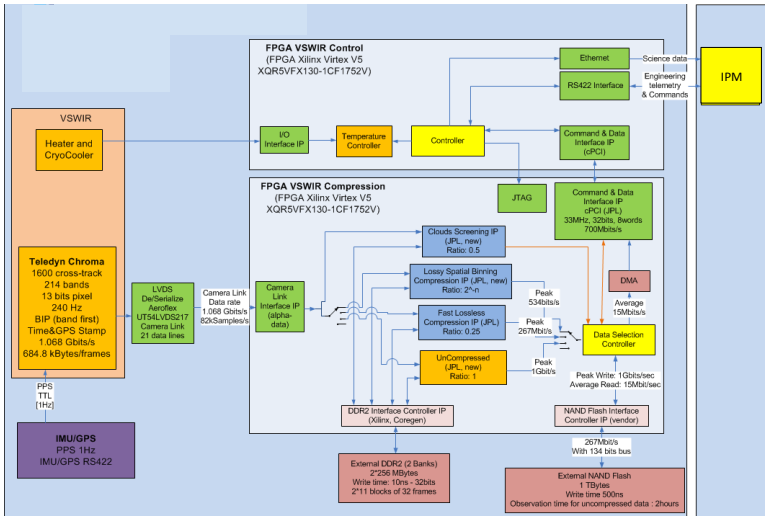
IGIS spectrometer with
4x mag telescope

MSS Pointing
Mirror System

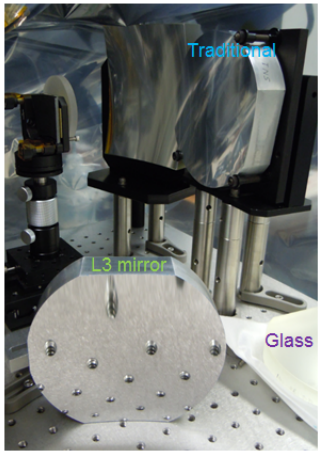


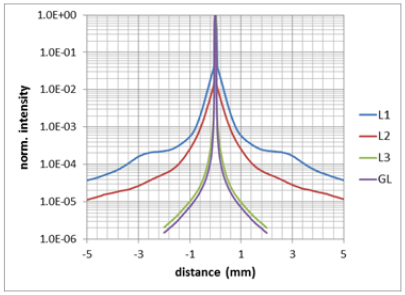
MSS

4X Lossless Data Compression



HyspIRI mirror performance demonstrated





Data to be handled and archived like AVIRIS airborne instrument. Direct search and download site for public to access.

Technology Demonstration

- Bring the HyspIRI VSWIR instrument optical, detector, slit, thermal, electronics, compression/cloud, and on-board calibration to TRL 9.

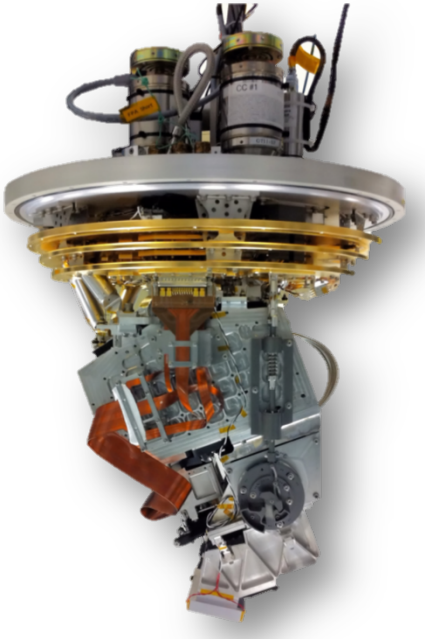
Components*	Entrance TRL**	Exit TRL
Detector	6	9
Focal Plane Electronics	5	9
Thales Cryocooler	6	9
Iris Technology Electronics	6	9
Spectrometer Slit	6	9
Spectrometer Grating	6	9
Intelligent Payload Module (IPM)	5-6	9
Vertex 5	6	9
4x lossless data compression	6	9
Cloud screening algorithm	6	9
On board storage	6	9

Comparison of DS Mission vs Tech Demo

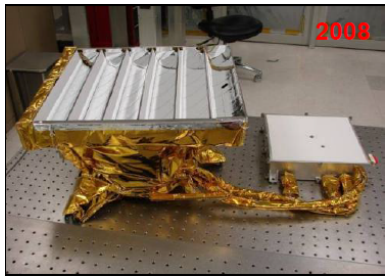
	DS Mission Flight Instrument	ISS Tech Demo Instrument
Orbit	LEO, Sun Sync.	51.6 north and south latitude
Mission Duration	3 years with goal of 5 years	6 months with goal of 2 years
FOV	12 degrees	5.67 degrees
Data rate	300 mbps	9.1 mbps
Coverage	Global and shallow coastal	25% of land mass
Revisit	19 days	~6 months
Parts	Class C	COTS
Swath	145 km	30 km
Resolution	60m	30 m
Spatial	2400 pixels	~1000 pixels

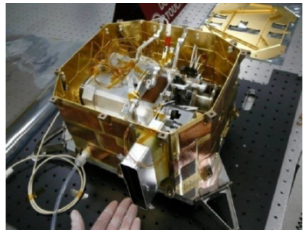
Tech Readiness

NGIS / MSS

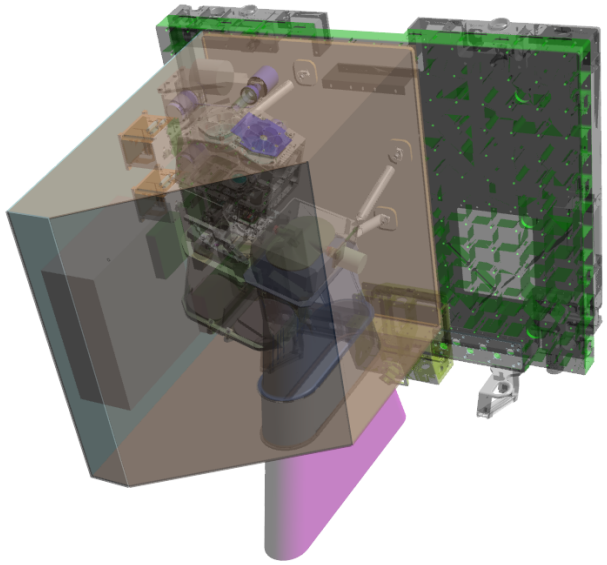


MMM





ISS VSWIR IS



- Heritage:
  - MSS super polished all aluminum telescope manufacturing, protected Ag coatings and alignment methodology
  - NGIS/MSS spectrometer alignment methodology and slit/grating mounts
  - NGIS OBC mechanism and actuator
  - NGIS PZT actuator alignment mechanism
  - JPL (MDL) e-beam grating and micro-machined slit
  - White painted radiators for 300K heat rejection similar to OCO radiators and Cryogenic flexible thermal straps from SDL
  - Calibration: TBIP, Laser and Integration Spheres, NST panel for radiometric

- Technology Readiness:
  - Thales CC flown on ARTMIS and is being qualified along with electronics at JPL
  - V5 flown on Cubesat and used on OCO3
  - Storage memory being used on SMAP
  - Fast lossless 4x data compression demonstrated on airborne AVIRIS-NG flights
  - Clouds screening algorithm was demonstrated in software on equivalent AVIRIS airborne data set

Command & Data Handling

- Intelligent Payload Module (IPM) by GSFC is Xilinx V5 based and will provide interface to FRAM or JEM-EF
- Communication is through 1553 Interface and data is sent using Ethernet
- IPM will perform data processing, selection, and formatting for downlink
- IPM has 1 Tbit of storage, and can send data when bandwidth is available on ISS
- 4x lossless data compression and cloud screening will be performed

Concept of Deployment & Operations

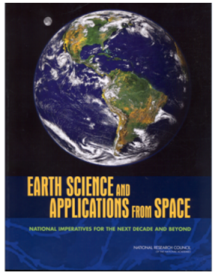
- Payload
  - FRAM mounted Instrument for ELC/Columbus or PIU for JEM-EF
- Launch
  - Space X Dragon Trunk
  - Falcon-9 LV or HTV
- Installation
  - Retrieved from Dragon Trunk by SPDM
  - Translated to ELC location and attached by FRAM
- Operations
  - On-orbit check out for 2 months with six month data collection
  - Two month checkout phase is for sensor calibration, orthorectification and sensor
    - Calibration is performed using an On-board Calibrator (OBC) that has an internal target that can be illuminated
    - The OBC will be used extensively during calibration and checkout phase, but during regular operations only once a week or less.

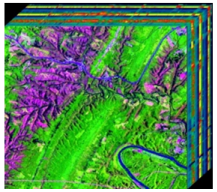
Concept of Deployment & Operations (cont)

- Operations (cont.)
  - Timed based pointing table
  - During rendezvous and proximity operations of visiting spacecraft close calibration shutter (to prevent contamination)
  - Weekly uplinks of pointing changes for targets of interest and discontinuous data collect
    - The Earth clouds cause all optical surface imagers to accommodate discontinuous data collection.
    - To account for discontinuous data and increase global coverage as well as collect targets of opportunities a pointing mirror system like the one developed for MaRSplus Sensor System (MSS) is included
  - GDS provides data storage, retrieval and backup
- Removal and Disposal
  - Payload removed from ELC reverse order
  - Payload placed in Dragon Trunk for atmosphere burn-up

Science

VSWIR Imaging Spectroscopy Science Tipping Point and Adaptation Relevant





- Ecosystem Measurement for Climate Feedback
- Pattern and Spatial Distribution of Ecosystems and their Components
- Ecosystem Function, Physiology, Diversity and Seasonal Activity
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- Coastal habitats, and inland aquatic environments

Full Spectrum 380 to 2510 @ 10 nm
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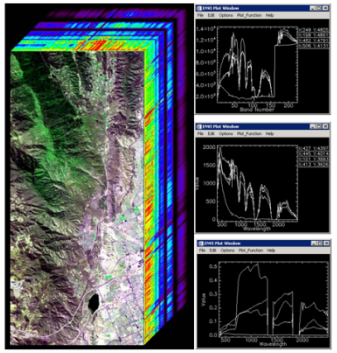
NASA HyspIRI Preparatory Science 2013-15 (Ecosystems, Seasonal, Climate, Coastal, Urban, Resources)

6 zones, 3 seasons, 2 years

AVIRIS VSWIR

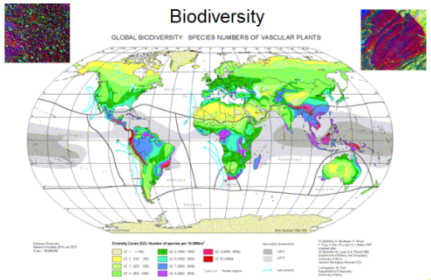


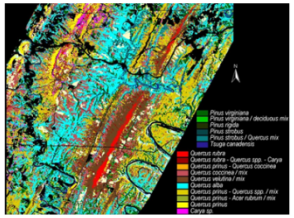
Ecosystem composition, function, biochemistry, seasonality, structure, and modeling
Coastal ocean phytoplankton functional types, habitat
Urban land cover, temperature, transpiration
Surface energy balance
Atmospheric characterization and local methane sources
Surface geology, resources, soils, hazards

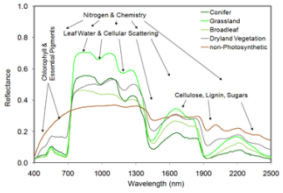
AVIRIS image cube and Level 1a, 1b and 2 spectra. The reflectance spectra (L2) will be used to address the full range of science objectives including ecosystems and climate.

Urgent and Unique Earth Science Enabled with ISS VSWIR Imaging Spectrometer

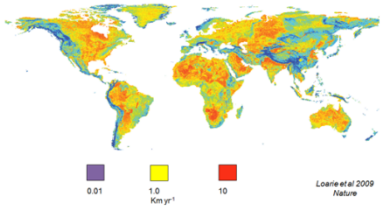
Biodiversity







Velocity of Climate Change



VSWIR Oil Spill Response

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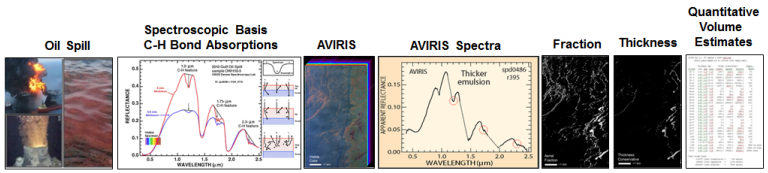

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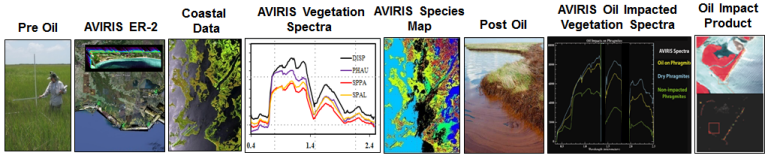

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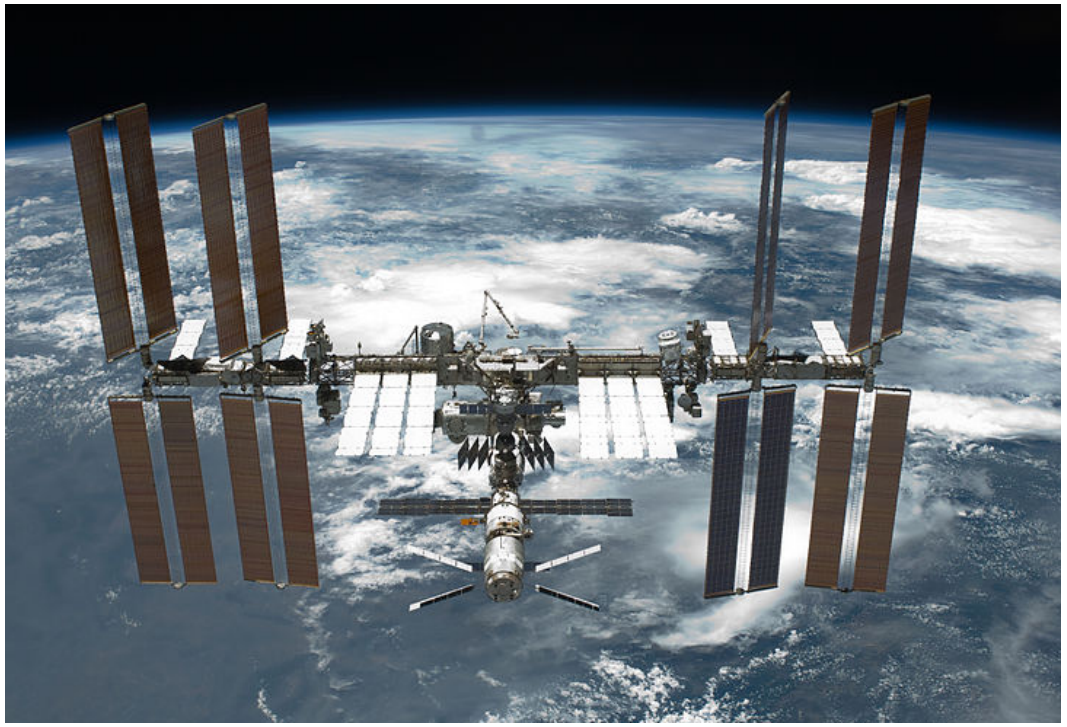
Science Objective

- HyspIRI VSWIR spectroscopy: terrestrial ecosystem function, metabolism, composition; coastal ocean habitats and coral reefs; natural hazards; etc.

- Early HyspIRI VSWIR Science results for 25% of the terrestrial surface & coasts at ±52 degrees latitude
  - Objective is to provide data collation for > 6 months operation with a goal of 2 years

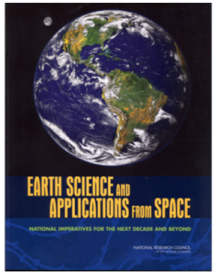


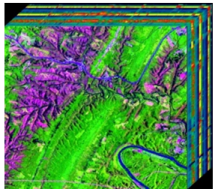
Summary

- The ISS VSWIR-IS instrument is compatible with multiple locations on the ISS, i.e., ELC, Columbus and JEM-EF
  - Some locations may be better for FOV, data rate or lower configuration costs but all are compatible
- The Instrument can be configured for either FALCON 9/ Dragon or JAXA HTV launch vehicle
- The technology demonstrations with ISS VSWIR-IS will benefit HyspIRI by reducing's its technical risk and saving cost
- The data returned from the mission will benefit the HyspIRI science community as well as giving a time dependent data set
- This is a fully feasible option for HyspIRI VSWIR early science and tech demonstration

HyspIRI VSWIR Early Science

VSWIR Imaging Spectroscopy Science Tipping Point and Adaptation Relevant





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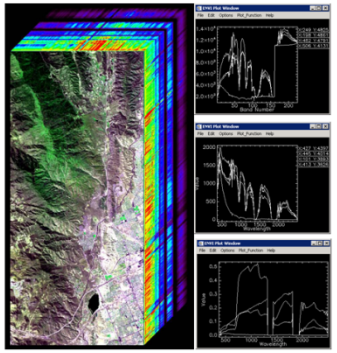

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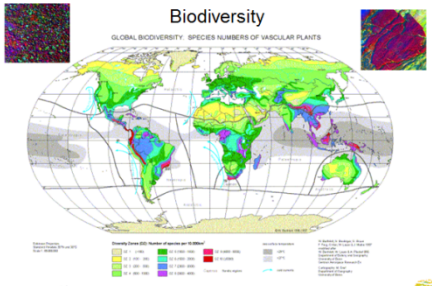

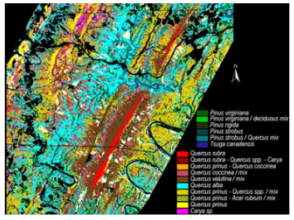

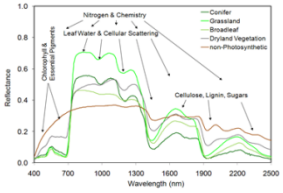

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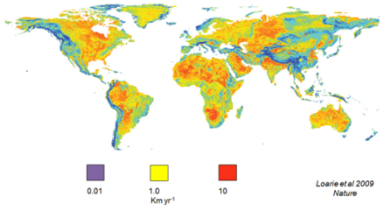

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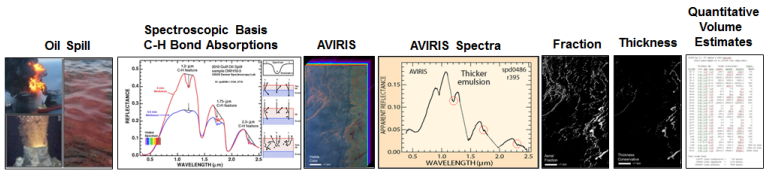

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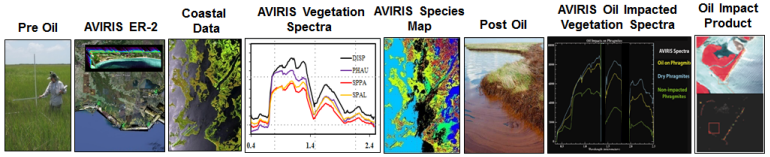

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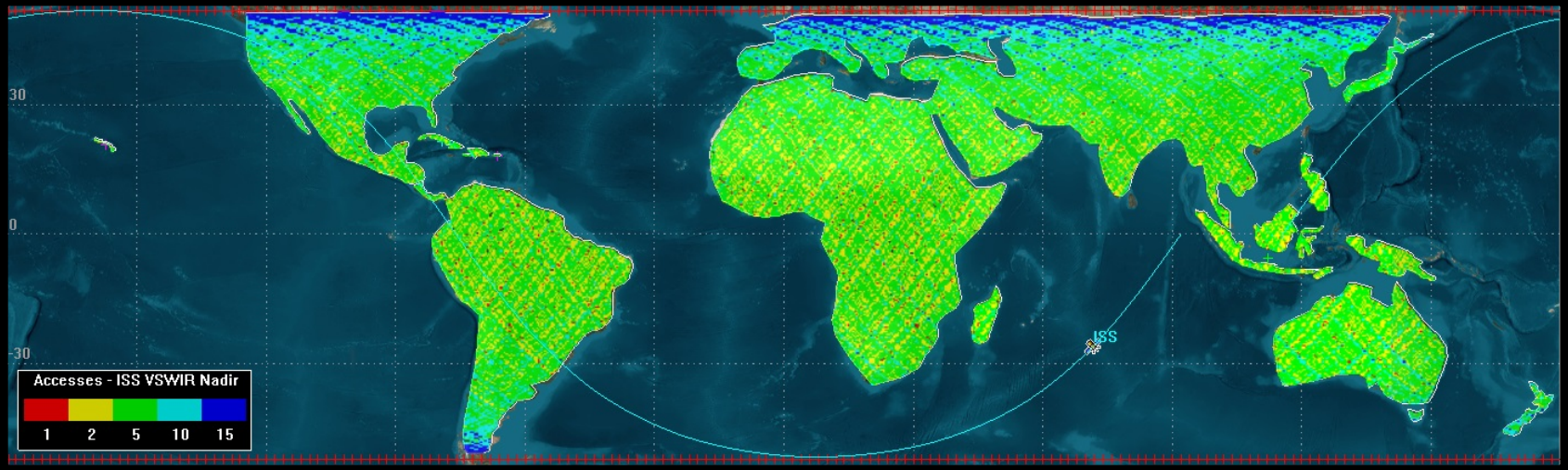
Thank you

Fixed Nadir Pointing Views in 1 Year



Maximum Target Views using Pointing
+2.5 Swath pointing in each direction (28.8° FOV)