HyspIRI Thermal Infrared Radiometer (TIR) ISS Technology Demonstration

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and Marc Foote

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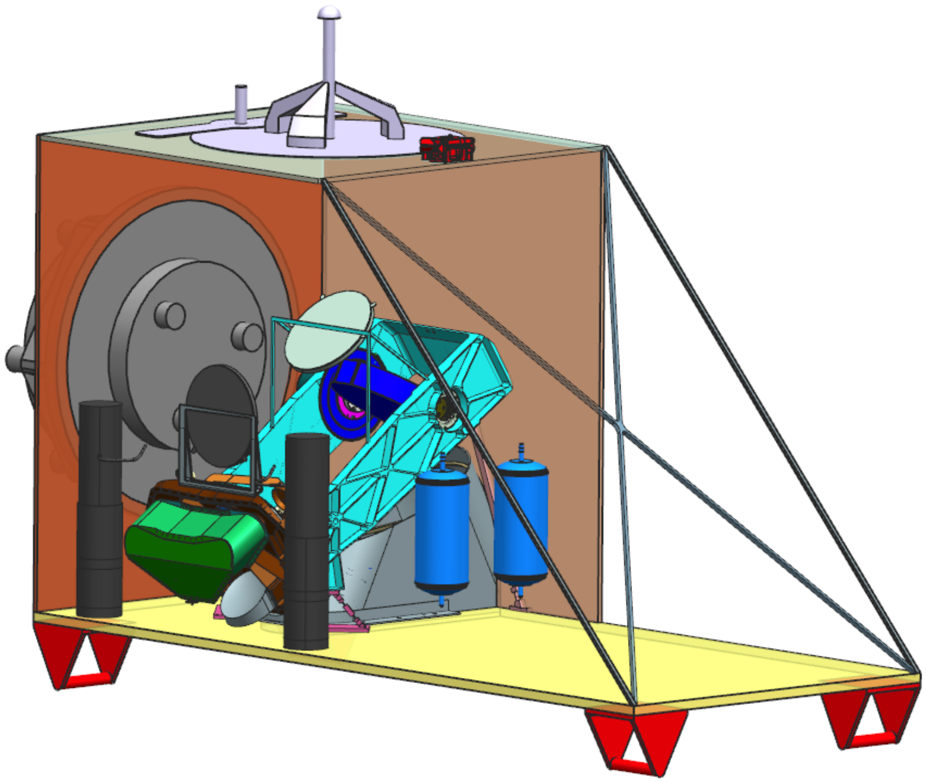
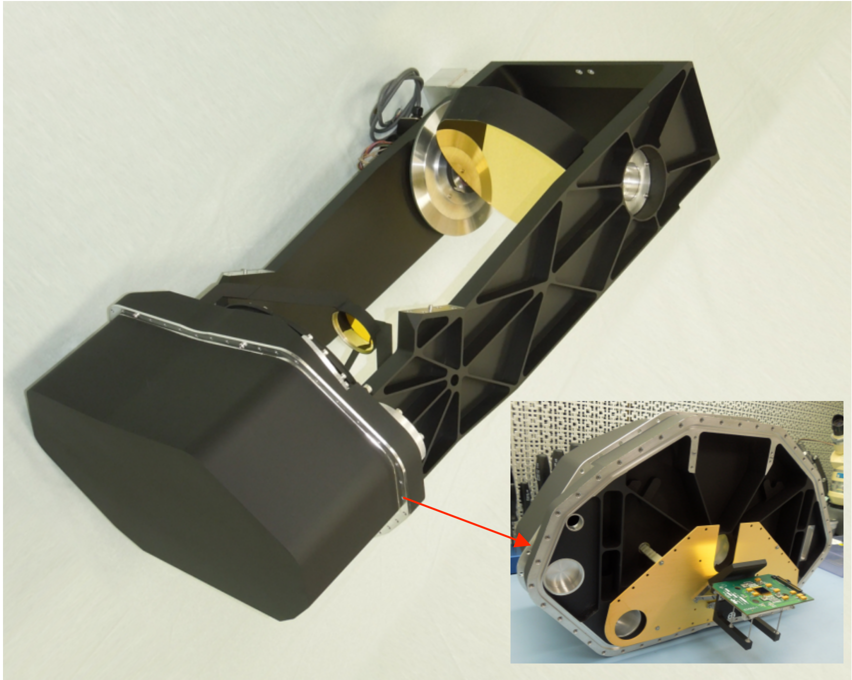




Fly ESTO-funded laboratory Prototype HyspIRI-TIR (PHyTIR) on ISS

Summary Quad Chart (1)

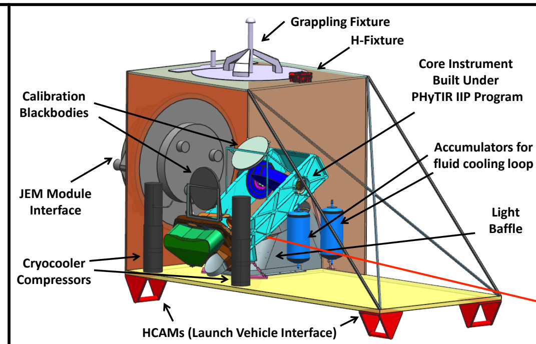
HyspIRI Thermal Infrared Radiometer (TIR)

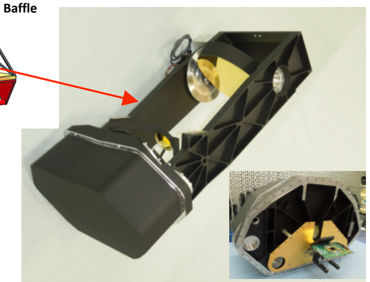
Marc Foote: Study Lead   Simon Hook: Science Lead

Objectives:

Demonstrate the HyspIRI-TIR instrument concept in space:

- Fast readout of a custom 60 K detector array
- Push-whisk approach for wide swath and high spatial resolution





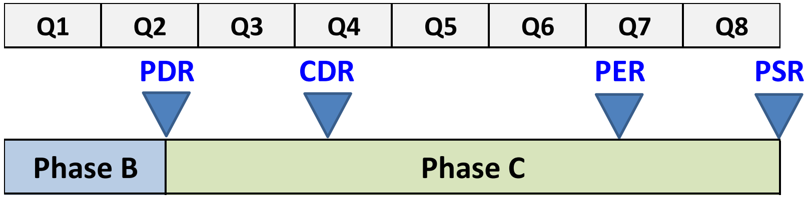
The core PHyTIR hardware assembly is shown to the right. Full system testing will commence in late 2013.

Approach:

- Use Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR) as core instrument currently being built under the IIP program
- Build interface to ISS JEM Module
- JEM Module used to accommodate Cryocooler heat rejection using fluid cooling loop
- Use GSFC Intelligent Payload Module for data processing and interface to ISS

Milestones:

24-month development period, made possible by existing PHyTIR core instrument



Summary Quad Chart (2)

HyspIRI Thermal Infrared Radiometer (TIR)

Marc Foote: Study Lead   Simon Hook: Science Lead

TRL Maturation:

- HyspIRI-TIR measurement concept currently at TRL 5-6 based on PHyTIR laboratory prototype
- ISS Tech Demo will increase TRL of system to TRL 9
- Focal-plane detector, scan mirror, optical design, pulse-tube cryocoolers, and Intelligent Payload Module will be advanced to TRL-9

Key Parameters:

Mass	115 kg
Volume	1 m x 1 m x 0.8 m
Power	350 W
Data Rate	3 Mbps
ISS Location	JEM Module
Operational Lifetime	6 mo (Req'd), 1yr (Goal)

Science:

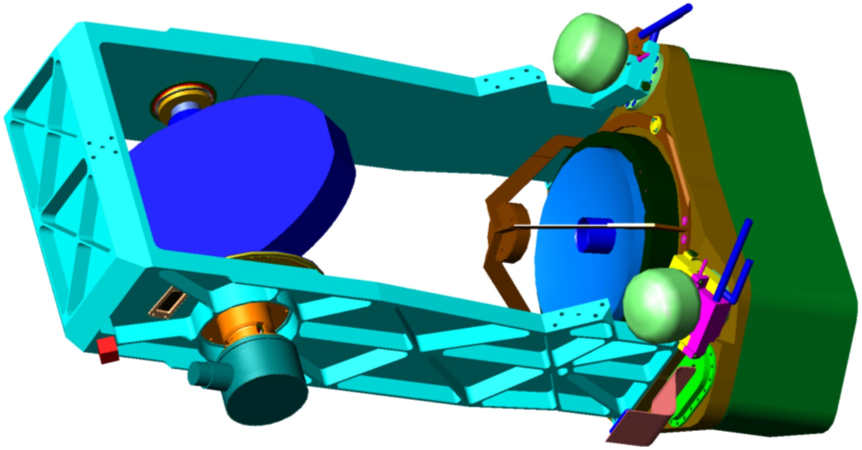
Same measurements as HyspIRI-TIR but targeted rather than global

- Volcanos
- Wildfires
- Water use and availability
- Urbanization
- Earth surface composition and change

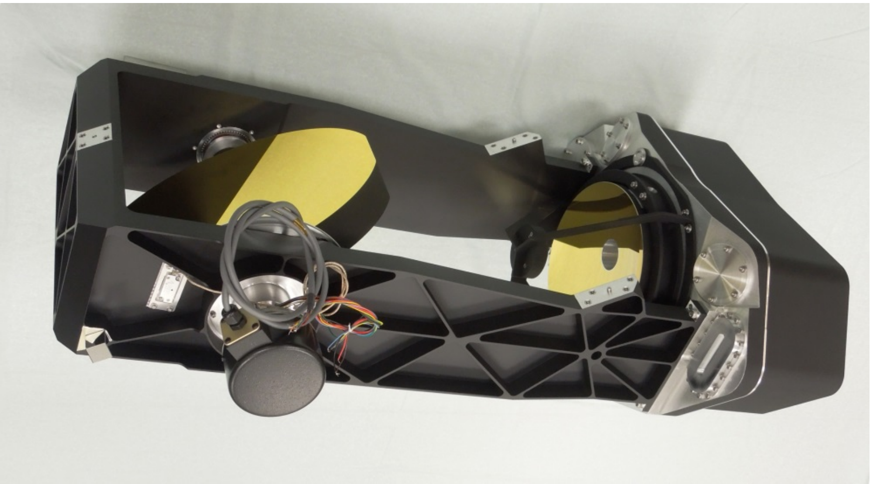
Benefits: ISS orbit enables 40m spatial resolution compared to 60m for HyspIRI-TIR. ISS orbit enables wildfire and evapotranspiration observations at all times of day allowing their diurnal behavior to be characterized

TIR ISS Technology Demo Concept

- Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR) is being developed with IIP contract (ESTO funded).
- Use core of PHyTIR (optical and scan system, focal plane, cryocoolers, focal-plane interface electronics), with minor changes, as core of technology demonstration.
- Interface PHyTIR core to ISS (mechanical, thermal, electrical)
- Use JEM module cooling loop to reject heat from cryocoolers and electronics. Eliminate HyspIRI radiator and passive cooler. No other locations on ISS provide needed cryocooler heat rejection.
- Include Goddard's Intelligent Payload Module (IPM) as data interface to ISS.

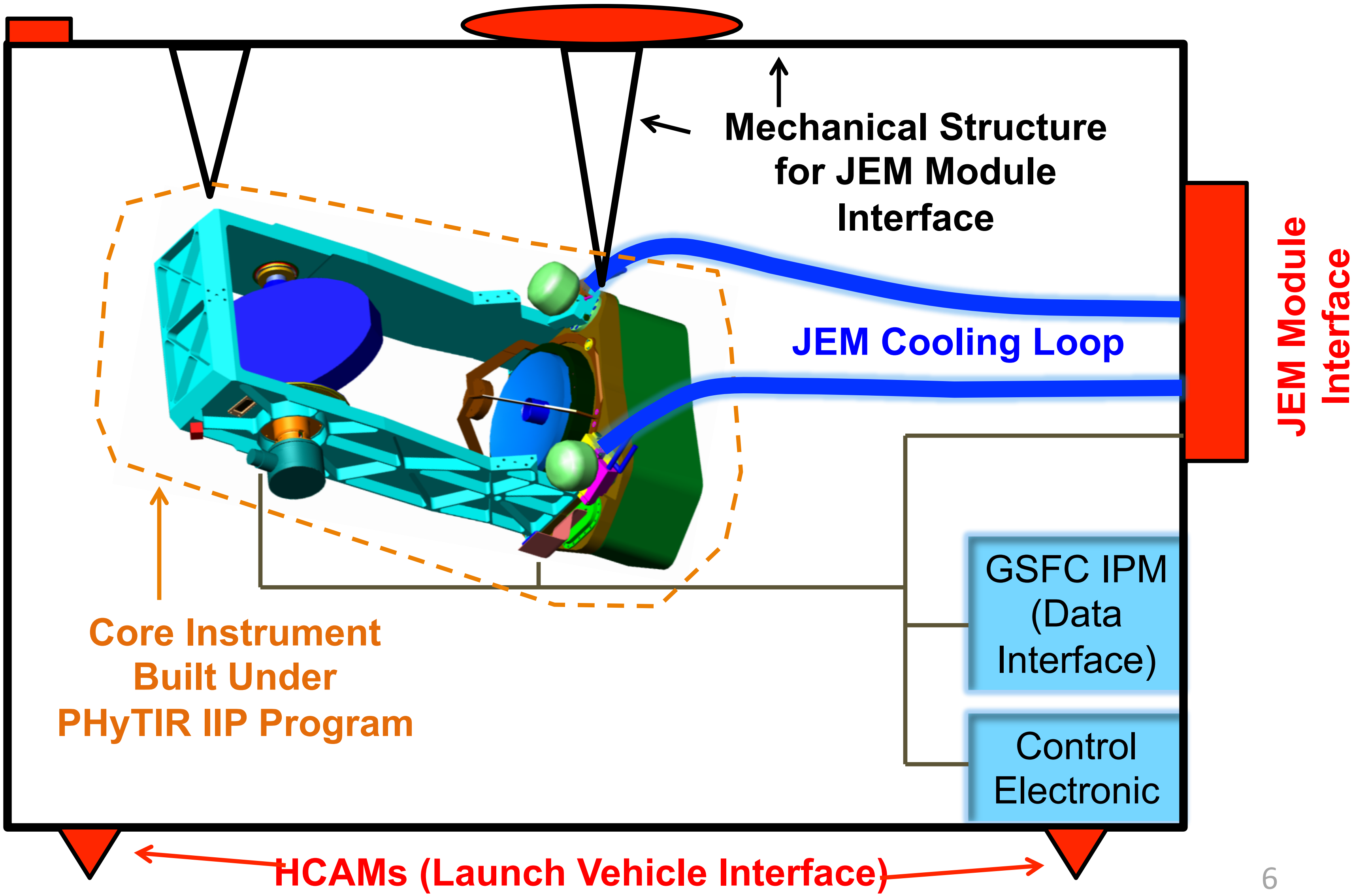


PHyTIR Core Instrument



Current PHyTIR hardware assembly

TIR Tech Demo Concept / Block Diagram

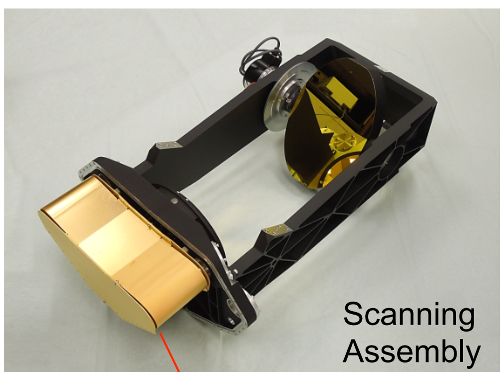


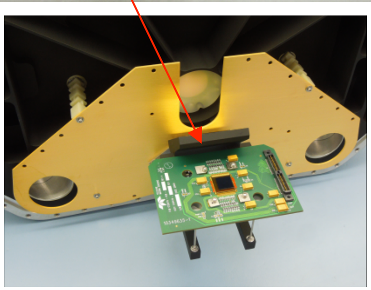
Programmatic Description

- The core PHyTIR instrument is currently being assembled with ESTO IIP funding. Assembly completion 10/1/2013. Completion of testing 4/1/2014
- Instrument candidate development
  - 24-month development schedule (core of instrument will already be complete)
  - Class D or below build. Extensive use of COTS parts.
  - No variations from NASA-provided ground rules
- Will be first thermal infrared instrument flown on ISS

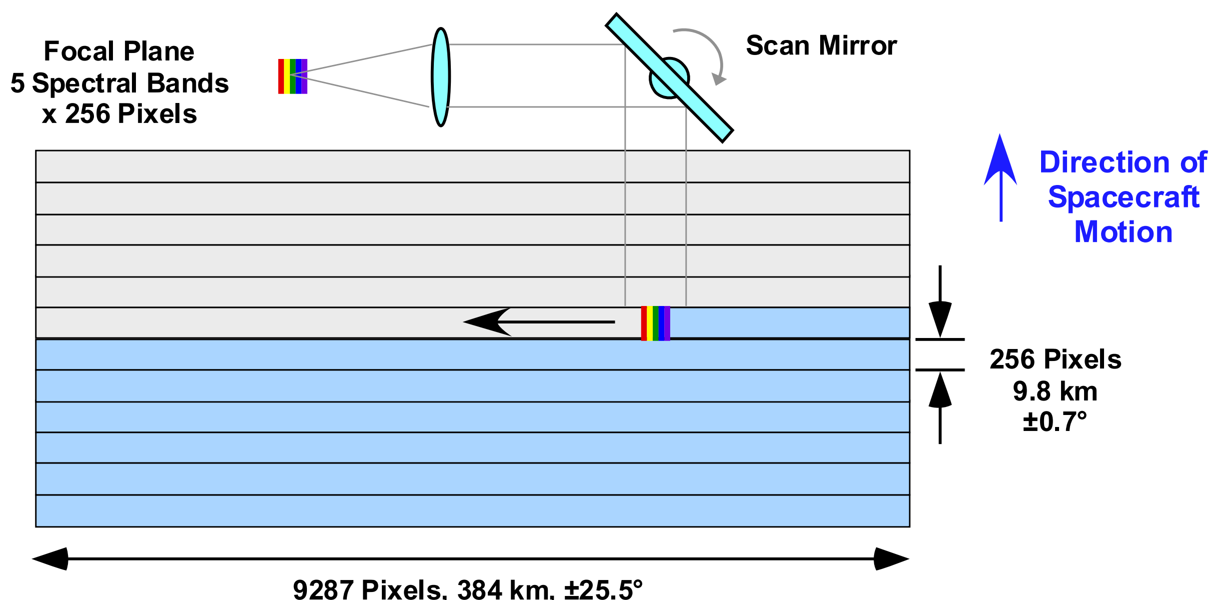
Functional Description

- The TIR instrument is a push-whisk scanning, multi-band filter radiometer for 4-12 μm
- Mercury-cadmium-telluride (MCT) array technology allows high spatial resolution (40 m at 400 km altitude) and large swath width (51°, 384 km at 400 km altitude).





Multi-band focal plane sensor chip assembly already developed



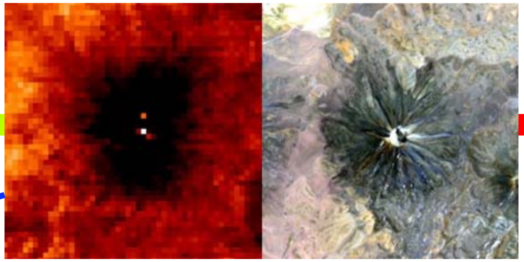
Technology Advancement

- Instrument currently exists as laboratory prototype: Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR)
- Current TRL 5-6. An ISS technology demo would advance key TIR instrument components and subsystems to TRL 7-9

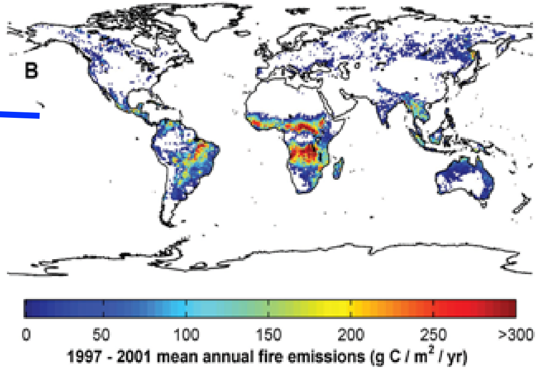
Component / Subsystem	TRL Level at Start	TRL Level at Completion
HyspIRI-TIR Measurement System	TRL 5-6	TRL 9: Full TIR capabilities demonstrated in space
Focal-Plane Array: Custom ROIC with 13µm MCT detectors	TRL 5-6: Tested in laboratory at maximum speed with same flux range. Radiation tested.	TRL 9: Fully flight qualified and flown in space.
Scan Mirror Assembly	TRL 5-6: Tested in laboratory as part of PHyTIR system.	TRL 7: Prototype Scan Mirror Assembly qualified and flown, but modifications needed to meet Class B instrument requirements.
PHyTIR Optical Subsystem	TRL 5-6: Tested in laboratory as part of PHyTIR system.	TRL 9: Fully flight qualified and flown in space.
Thales 9310 Pulse-Tube Cryocoolers	TRL 5-6: Tested in laboratory as part of PHyTIR system.	TRL 9: Fully flight qualified and flown in space.
Intelligent Payload Module (IPM) (GSFC)	TRL 5: Tested in laboratory	TRL 9: Fully flight qualified and flown in space.

Full HyspIRI TIR Science

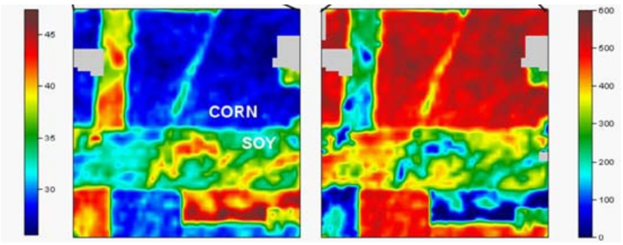
- Volcanoes/Earthquakes: How can we help predict and mitigate earthquake and volcanic hazards through detection of transient thermal phenomena?



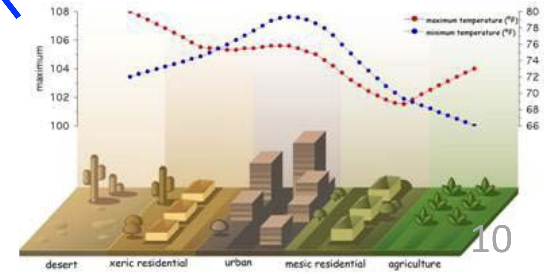
- Wildfires: What is the impact of global biomass burning on the terrestrial biosphere and atmosphere, and how is this impact changing over time?



- Water Use and Availability: How is consumptive use of global freshwater supplies responding to changes in climate and demand, and what are the implications for sustainable management of water resources?



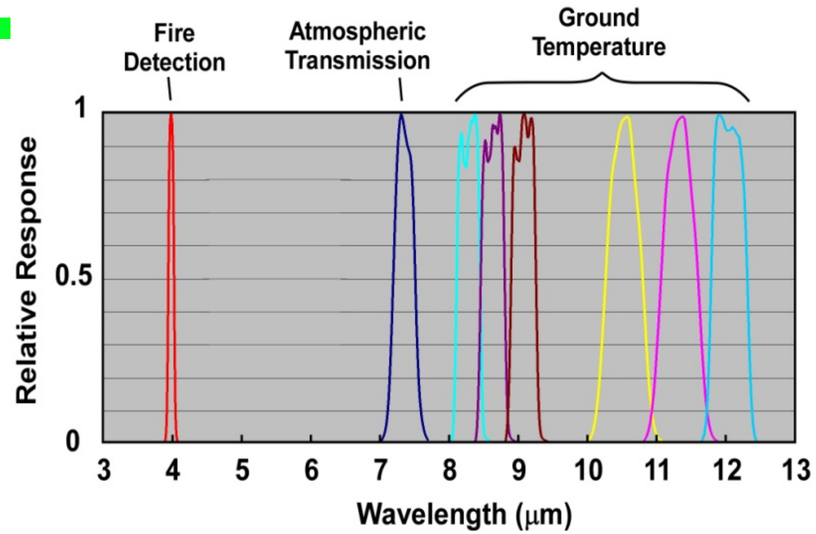
- Urbanization/Human Health: How does urbanization affect the local, regional and global environment? Can we characterize this effect to help mitigate its impact on human health and welfare?



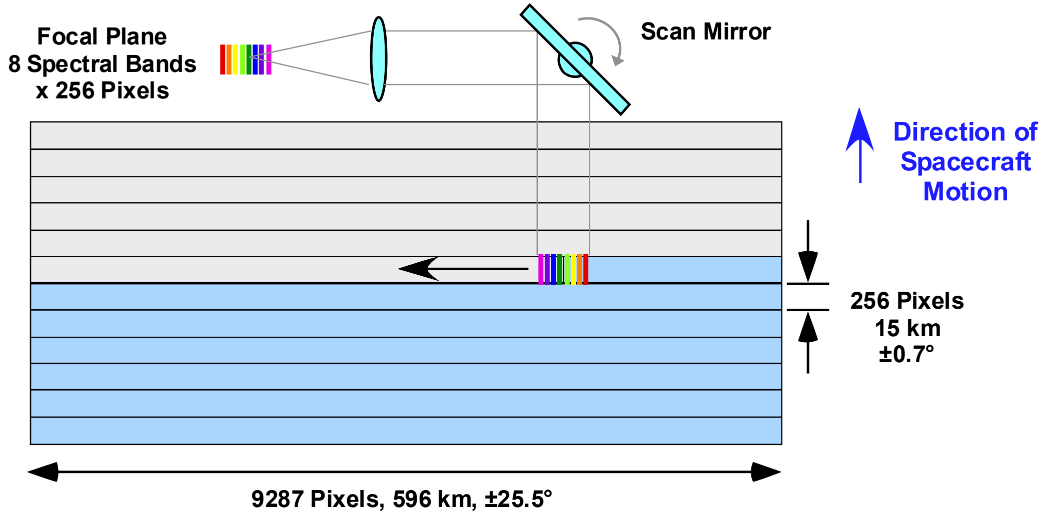
- Earth surface composition and change: What is the composition and temperature of the exposed surface of the Earth? How do these factors change over time and affect land use and habitability?

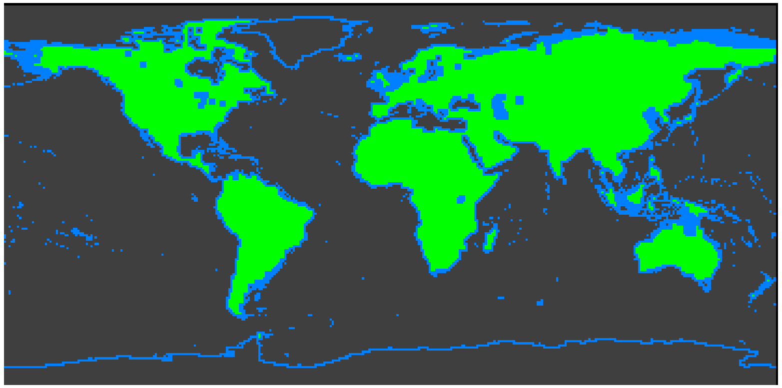
Full HyspIRI TIR Capabilities

- 8 spectral bands for wildfires, atmospheric transmission, and surface temperature
- 60 m spatial resolution
- Sun-synchronous orbit



- Push-whisk scanning approach provides global coverage with <5-day revisit (reduced resolution over deep oceans and ice sheets)





HypsIRI-TIR / ISS-Tech-Demo Comparison

Parameter	HyspIRI-TIR	ISS
Orbital Altitude	626 km	400 km
Ground Spatial Resolution	60 m	40 m
Land Surface Coverage	Full Earth <5-day revisit	±52° latitude with range of revisit periods. Subset of data downlinked.
Time-of-Day Coverage	10:30 AM and 10:30 PM	All times of day
Spectral Bands	8	5 (4 µm for fire detection; 8.3, 8.6, 9.1, and 11.3 µm for temperature measurement)
Average Data Downlink	24 Mbits/s	3 Mbits/s
Swath Width	51° 596 km	51°, 384 km; may be reduced based on ISS JEM accommodations
Mission Duration	3 years	1 year (goal)
In-Flight Calibration	Space and internal blackbody	2 internal blackbodies (reliable space view not available)

TIR Tech Demo Science (1/3)

- Volcanoes: Tech demo will demonstrate we can quantitatively measure hot spots and gas emissions and measure lava composition. Due to the limited duty cycle we will not be able to characterize the behavior of all active volcanoes. Reduced number of spectral bands will impact our ability to discriminate certain geological materials. Higher spatial resolution from the ISS of 40m will improve material discrimination compared with planned 60m spatial resolution for HyspIRI-TIR. (References – Volcanos, Slide 32)
- Wildfires: Tech demo will allow us to demonstrate that measurements of combined mid and thermal infrared active fire measurements can be used to calculate carbon emissions. ISS orbit will allow us to characterize burning over diurnal cycle. Due to limited duty cycle we will not be able to fully characterize each fire regime. (References – Wildfires, Slide 33)

TIR Tech Demo Science (2/3)

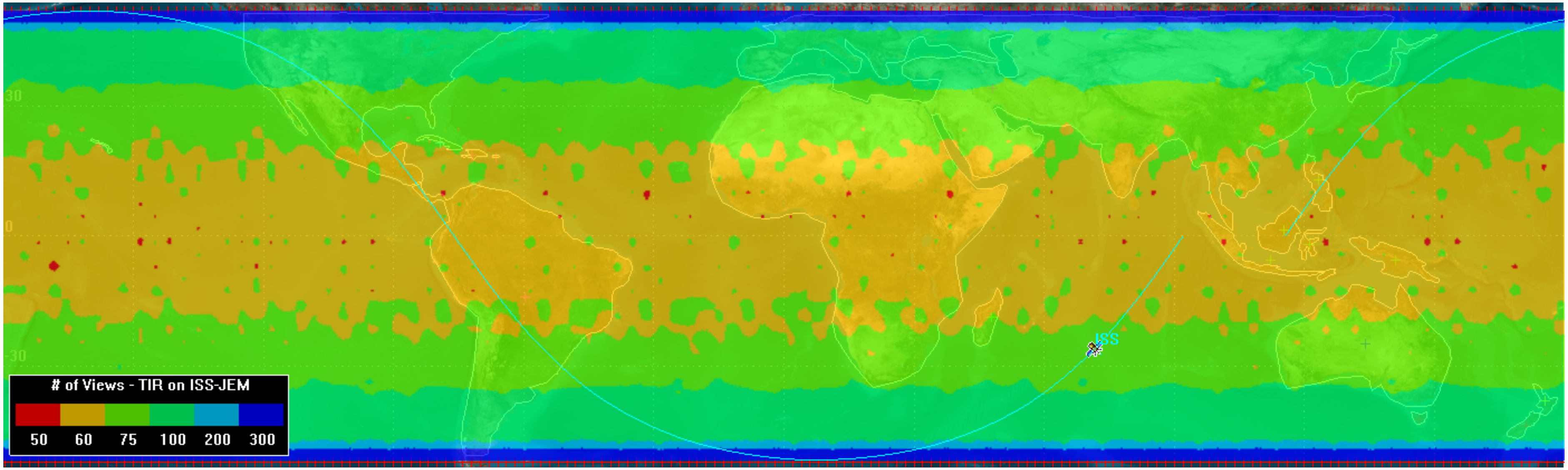
- Water Use and Availability: Tech demo will allow us to characterize ecosystem “hot spots” and quantify and understand variations in consumptive water use over irrigated systems. Tech demo will not allow continuous global coverage. Higher spatial resolution from the ISS (40m) will improve discrimination of evapotranspiration (ET) at the field scale. ISS orbit will enable ET to be studied over full diurnal cycle. (References – Water Use and Availability, Slide 34)

TIR Tech Demo Science (3/3)

- Urbanization/Human Health: Tech demo will allow us to characterize urban areas and urban heat islands. Reduced numbers of bands will limit our ability to discriminate urban materials and limited duty cycle will impact our ability to systematically characterize urban areas. Higher spatial resolution from the ISS (40m) will improve material discrimination compared with planned 60m for HyspIRI-TIR.
- Earth surface composition and change: For geological and soil mapping reduced number of bands will limit our ability to discriminate materials. Limited duty cycle will impact our ability to obtain cloud-free data. Higher spatial resolution on ISS will improve material discrimination as noted above.

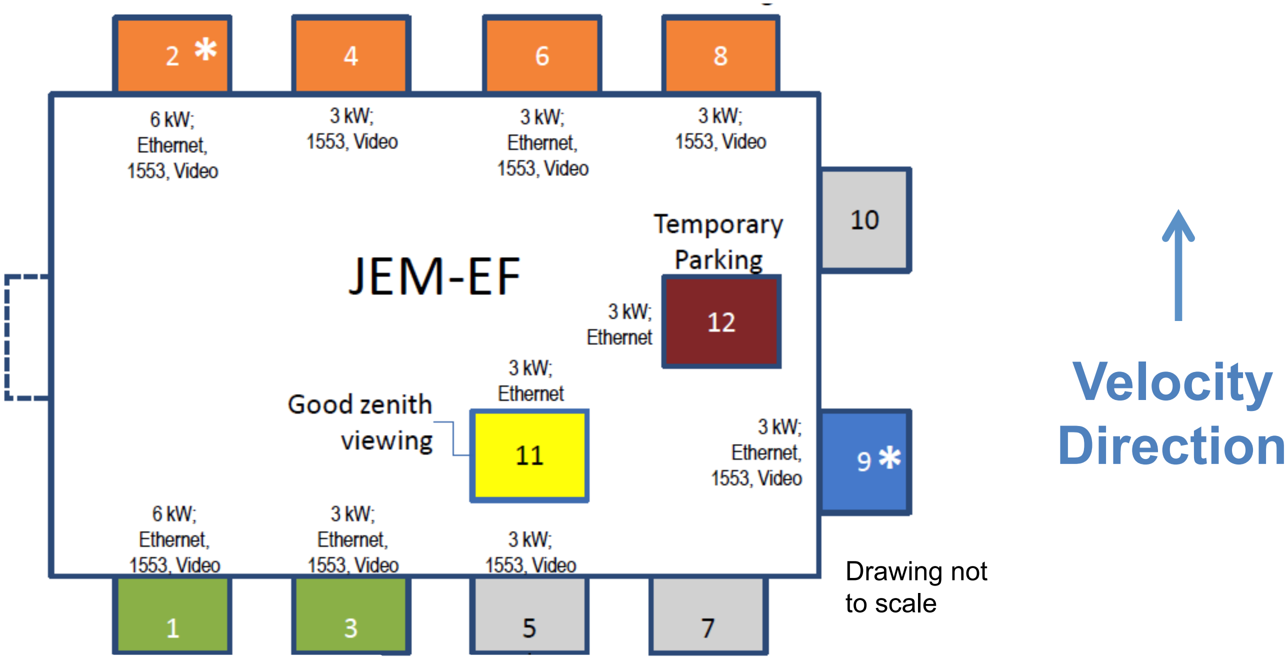
Available Coverage

- Diagram shows number of opportunities to view a point on the surface in 1 year.

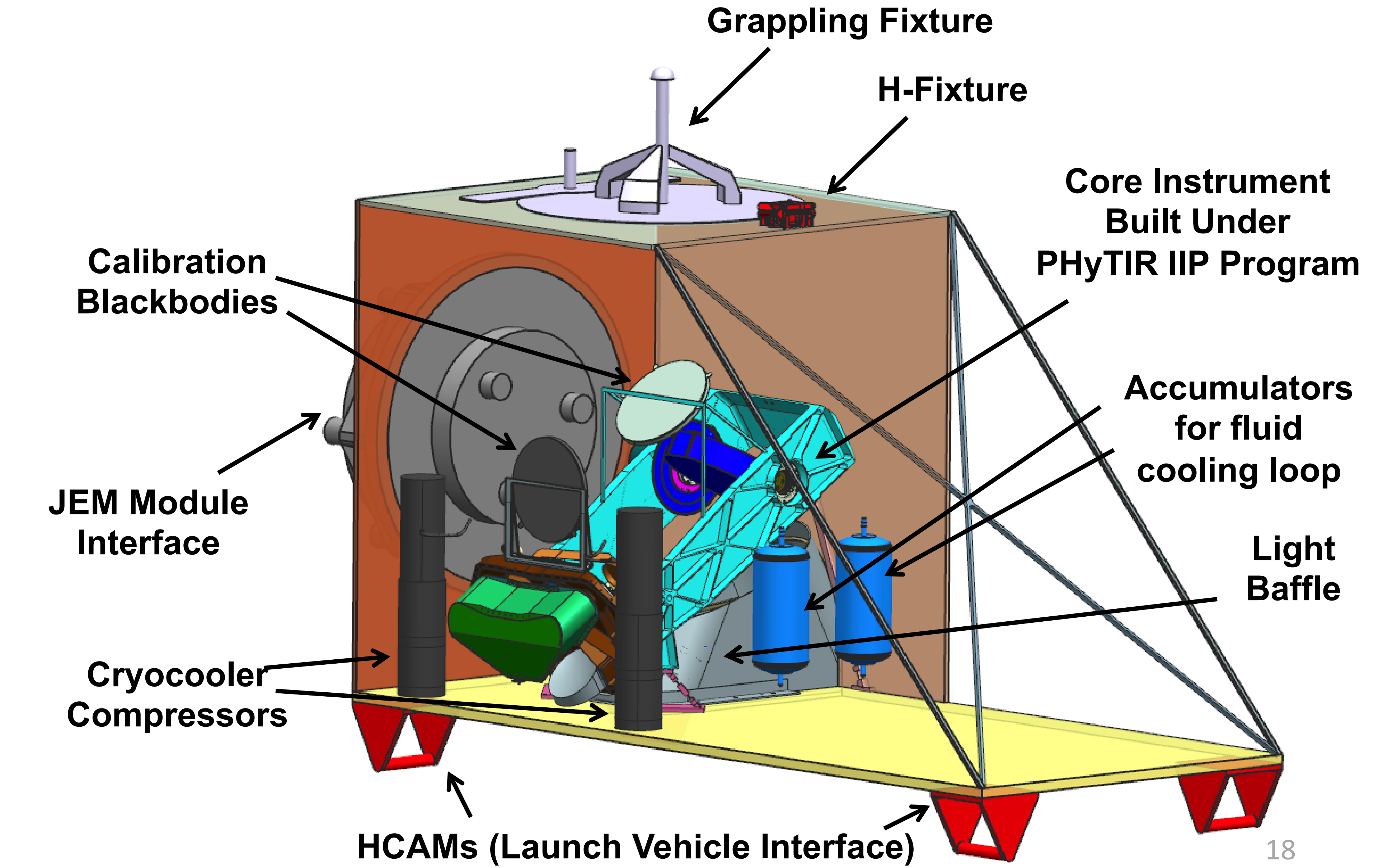


ISS Accommodations

- Cryocoolers for 60 K focal plane will require significant heat rejection. The JEM module must be used, as it provides closed-cycle cooling.
- ISS does not offer reliable space views. The instrument calibration will be performed using an additional blackbody target.
- Long direction of TIR instrument is perpendicular to velocity vector.
  - JEM locations #9-10 would allow straightforward mechanical accommodation.
  - JEM locations #1-8 provide a much tighter fit.
  - The mechanical configuration in this presentation uses the JEM location #1-8 geometry to show that any location #1-10 would be acceptable.



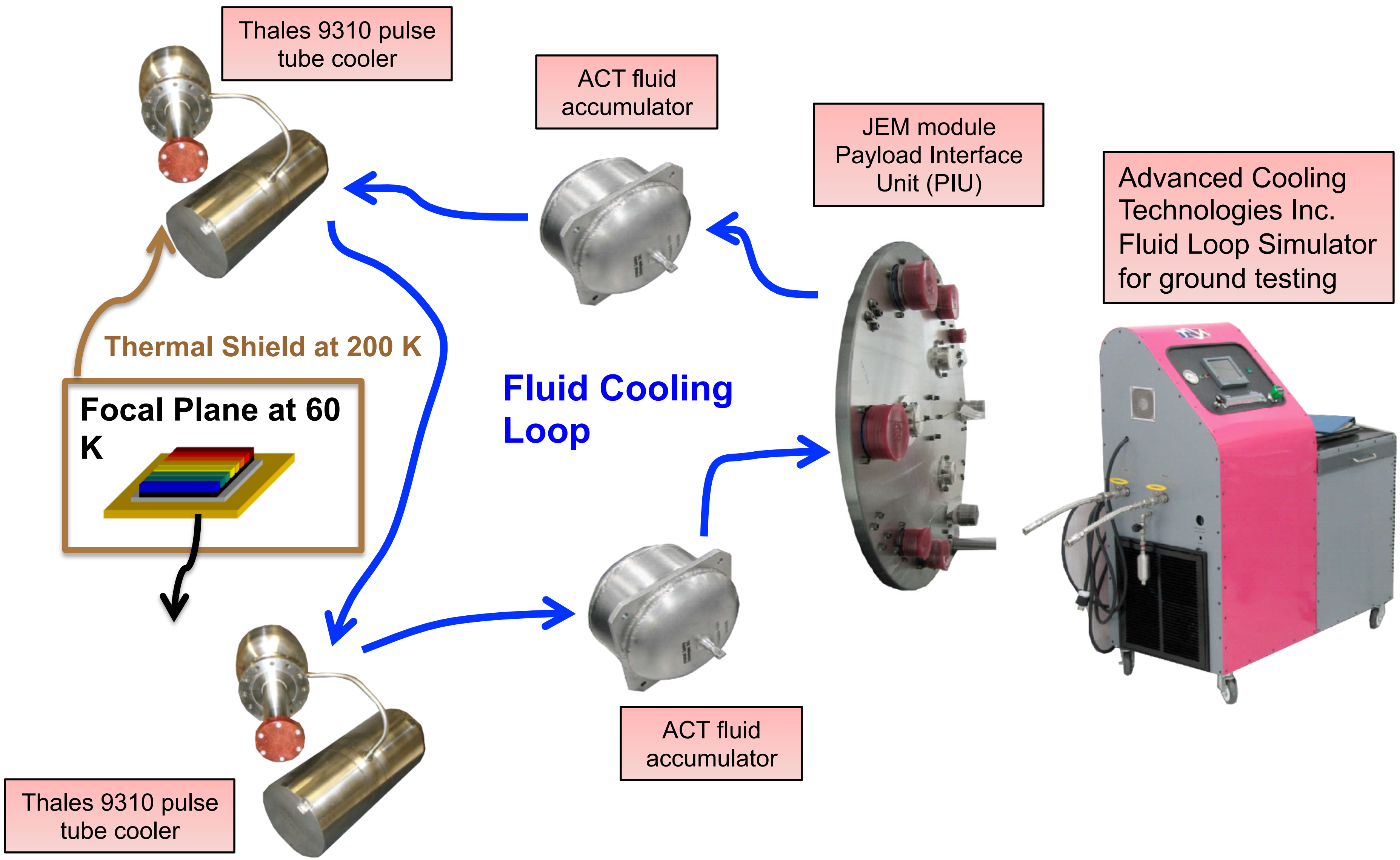
TIR Configuration on ISS JEM Module



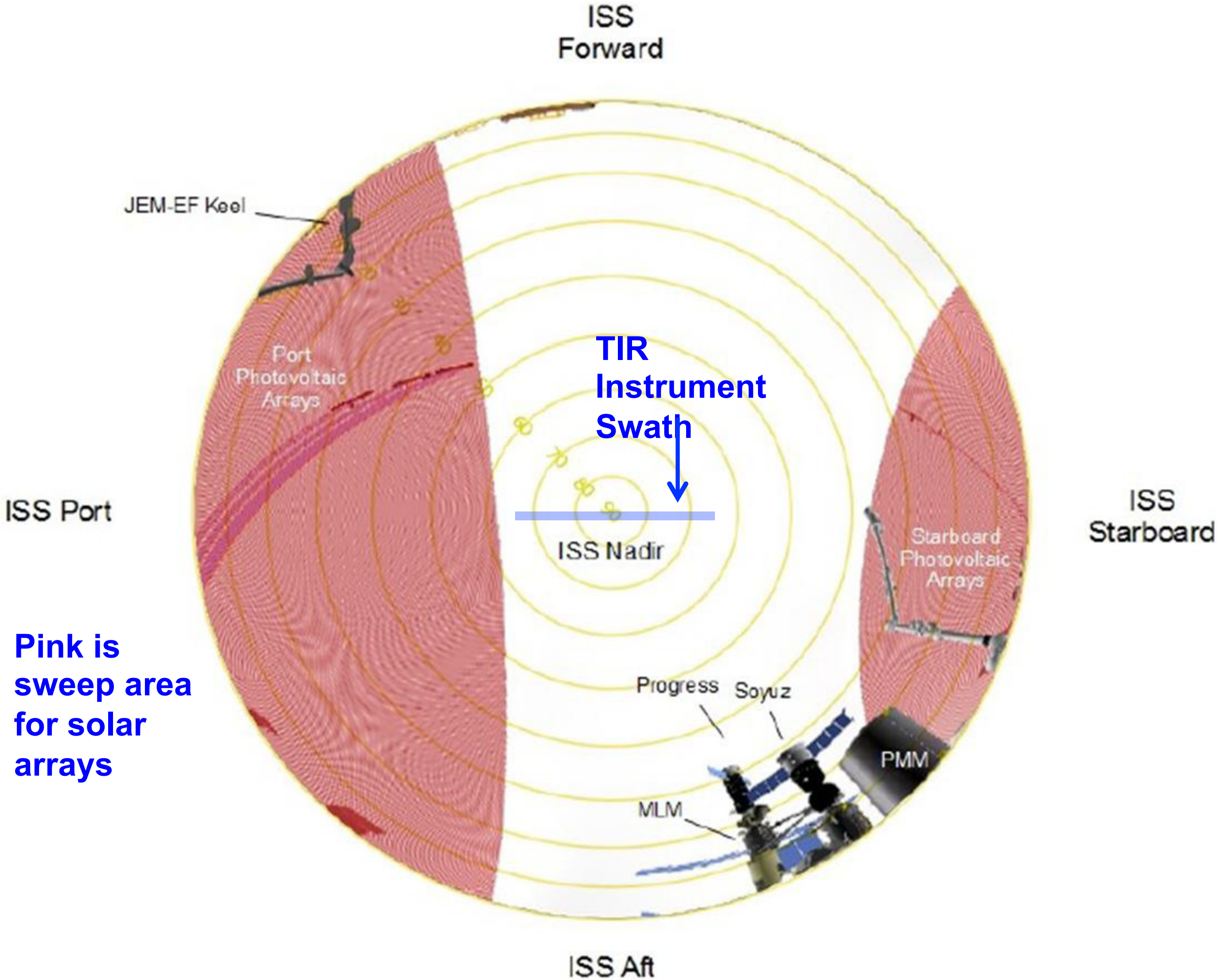
Position, Attitude & Pointing

- No requirement to point instrument, as instrument has 51° swath. The wide ISS attitude envelope is acceptable, although best mapping will be attained with Z near nadir and X near velocity direction.
- 1-3° ISS pointing knowledge acceptable. Better knowledge will be attained by image pattern matching with known ground features
- Required pointing stability 0.1° over 1 second
- On-ground post processing of position and attitude data is consistent with science data latency requirements

Thermal Diagram

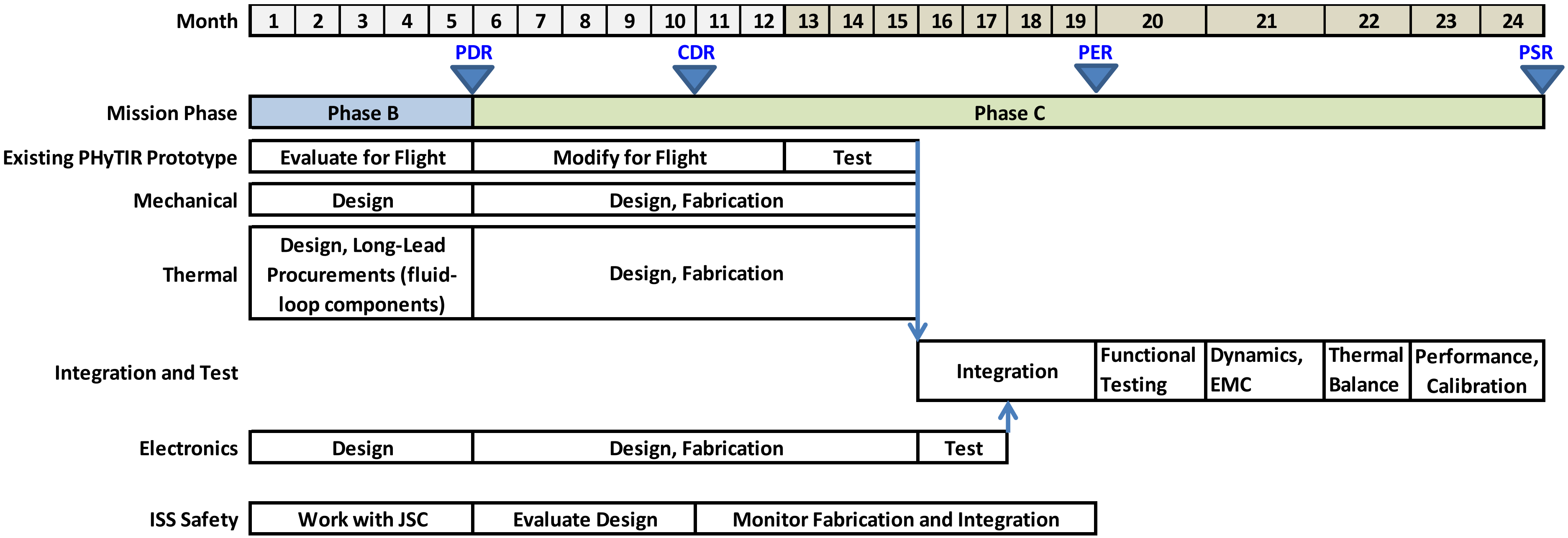


Example Field of View: JEM Position #2



Pink is sweep area for solar arrays

Schedule



PDR - Preliminary Design Review CDR = Critical Design Review PER = Pre-Environmental Review PSR = Pre-Ship Review

- A 24-month schedule is practical because core instrument has already been built as part of PHyTIR IIP program
- A start in January 2014 would allow instrument delivery in January 2016

Next Steps

- Evaluate PHyTIR core instrument for flight and for compliance with ISS safety requirements
- Upgrade filter assembly to contain 5-8 spectral filters (PHyTIR has 3)
- Define interfaces from IPM to TIR instrument and from IPM to ISS JEM module
- Advance the design to a preliminary detailed design for the ISS