Status of the Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR) for the HyspIRI TIR Instrument Concept

Presented at:

2012 HyspIRI Workshop
Washington, DC USA.

Simon Hook & The HyspIRI/HyTES/PHyTIR Team(s)
Organization: NASA/Jet Propulsion Laboratory

Outline

- Introduction
- Goals and Objectives
- Design Approach
    - Concept, Optical, Mechanical, Thermal, FPA, Testing
- Summary and Next Steps

HyspIRI-TIR Quad Chart

Science Questions:

TQ1. Volcanoes/Earthquakes

– *How can we help predict and mitigate earthquake and volcanic hazards through detection of transient thermal phenomena?*

- *TQ2. Wildfires*

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

- *TQ3. 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?*

- *TQ4. Urbanization/Human*

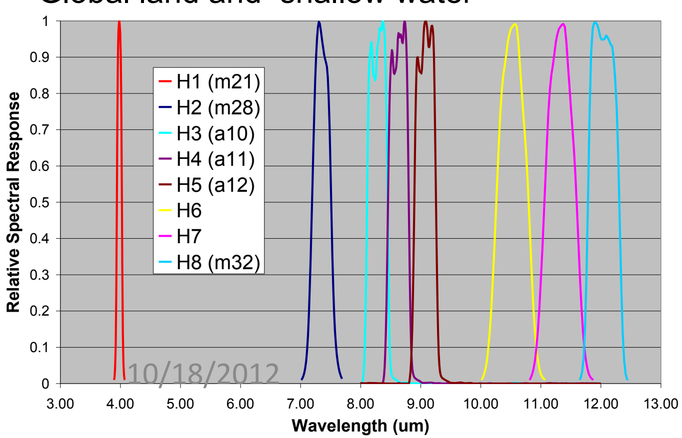
– *How does urbanization affect the local, regional and global environment? Can we characterize this effect to help mitigate its impact on human health and welfare?*

- *TQ5. Earth surface composition and change*

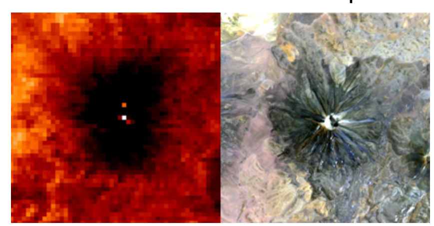
– *What is the composition and temperature of the exposed surface of the Earth? How do these factors change over time and affect land use and habitability?*

Measurement:

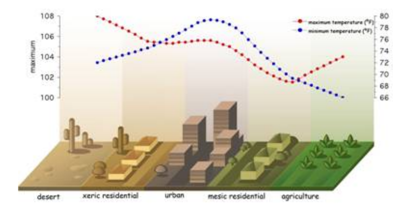
- 7 bands between 7.5-12 μm and 1 band at 4 μm
- 60 m resolution, 5 days revisit
- Global land and shallow water



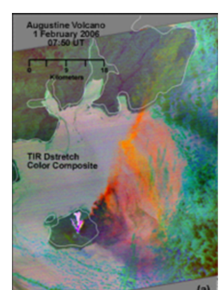
Andean volcano heats up



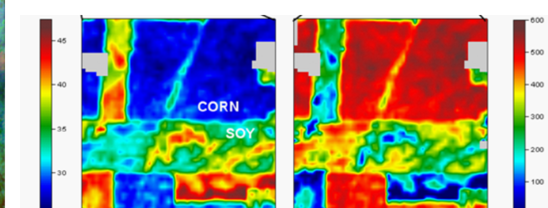
Urbanization



Volcanoes



Water Use and Availability



Surface Temperature

Evapotranspiration

HyspIRI, HyTES and PHyTIR

VSWIR

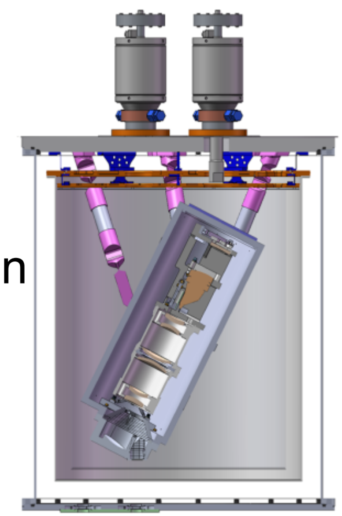
TIR

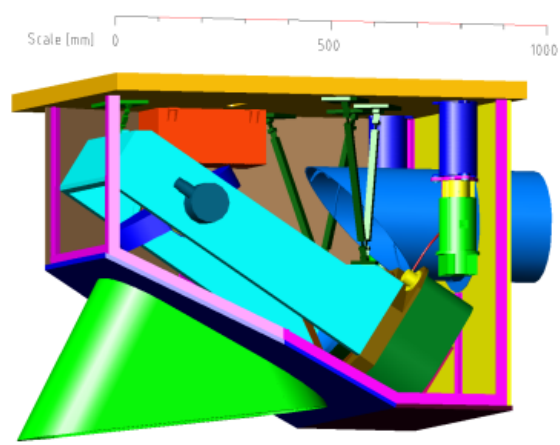
Hyperspectral Infrared Imager (HyspIRI)

Science Risk Reduction

Engineering Risk Reduction

Hyperspectral Thermal Emission Spectrometer (HyTES)

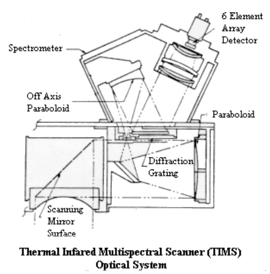


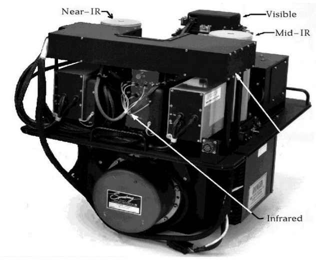


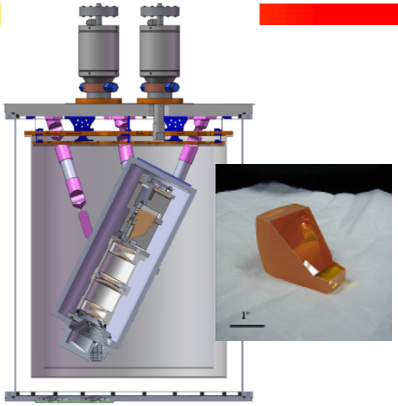
Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR)

HyspIRI, HyTES and PHyTIR

Airborne Instruments

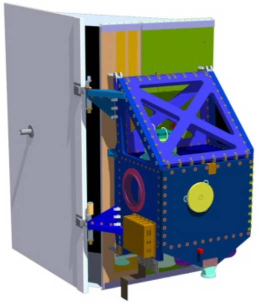


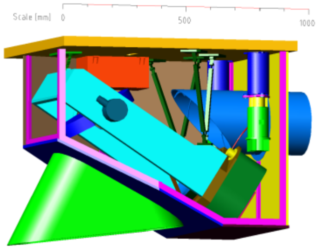




Airborne Name	TIMS	MASTER	QWEST	HyTES
First Year of Operation	1980	1998	2008	2012
Number of TIR Bands	6	10	56	256

Spaceborne Instruments (incl. lab prototypes)





Spaceborne Name	ASTER	Landsat 8 (LDCM)	PHyTIR	HyspIRI-TIR
First Year of Operation	1999	2013	2014	2020
Number of TIR Bands	5	2	8	8
Swath Width	60 km	185 km	600 km	600 km
Pixel Size	90m	100 m	60 m	60 m

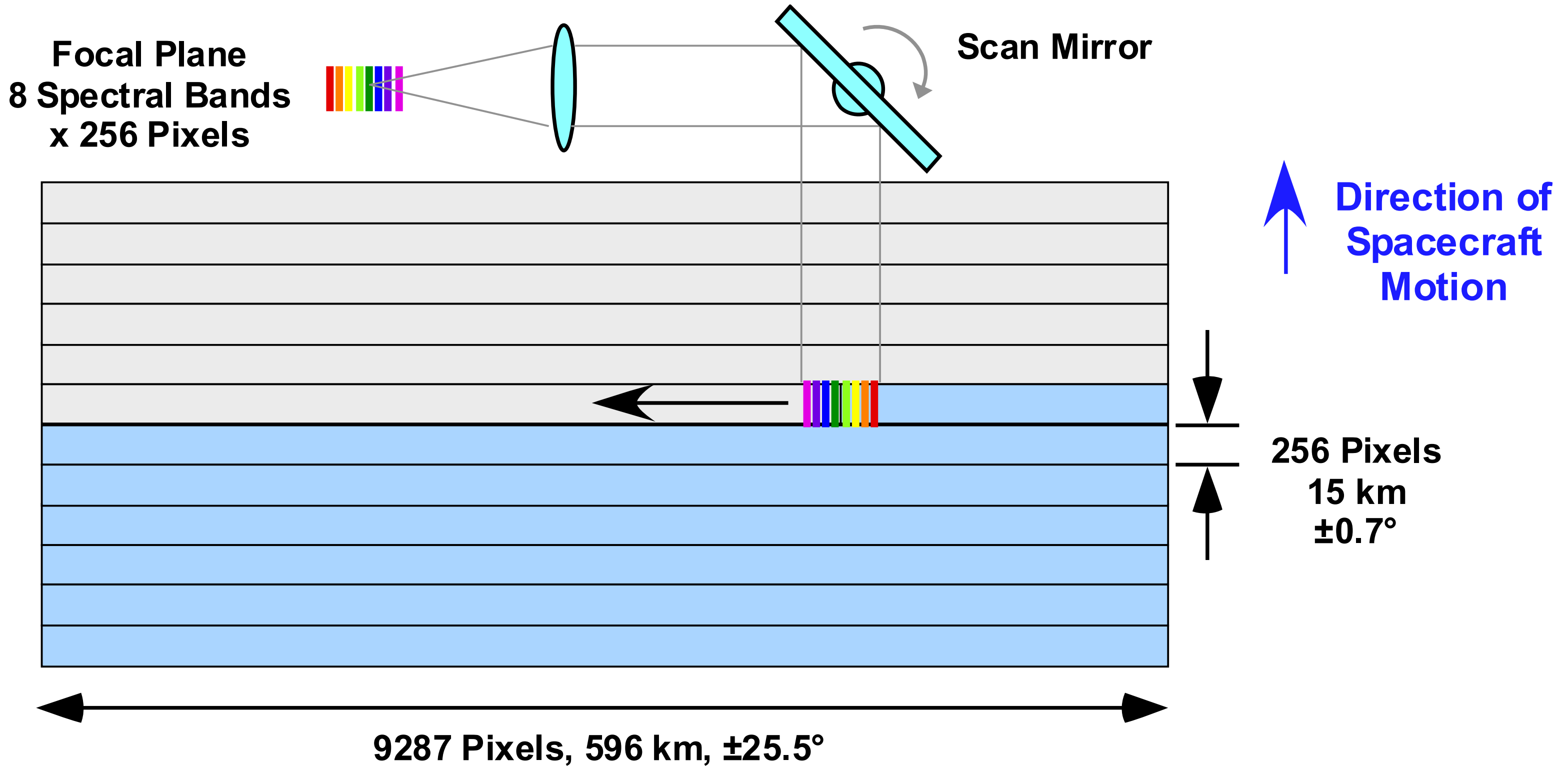
HyspIRI-TIR Science Measurement Requirements

PARAMETER	BASELINE	SCIENCE REQUIREMENT
Ground Resolution (m)	60	<100
Revisit (days)	5	<6
Noise equivalent delta temperature (K)	0.2	<0.3
Absolute accuracy (K)	0.5	<1
Saturation – low temperature bands (K)	500	>400
Saturation – high temperature band (K)	1200	>1100
Overpass time (hh:mm)	10:30am	10-3pm
Nighttime imaging	Yes	Required
Number of Bands (spectral range: 3 – 12 µm)	8	>=8
Coverage	Land and coastal regions	Land and coastal regions
Data latency	2 days	< 1 week

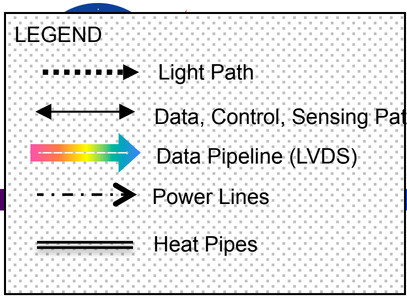
PHyTIR Overall Goal and Objective

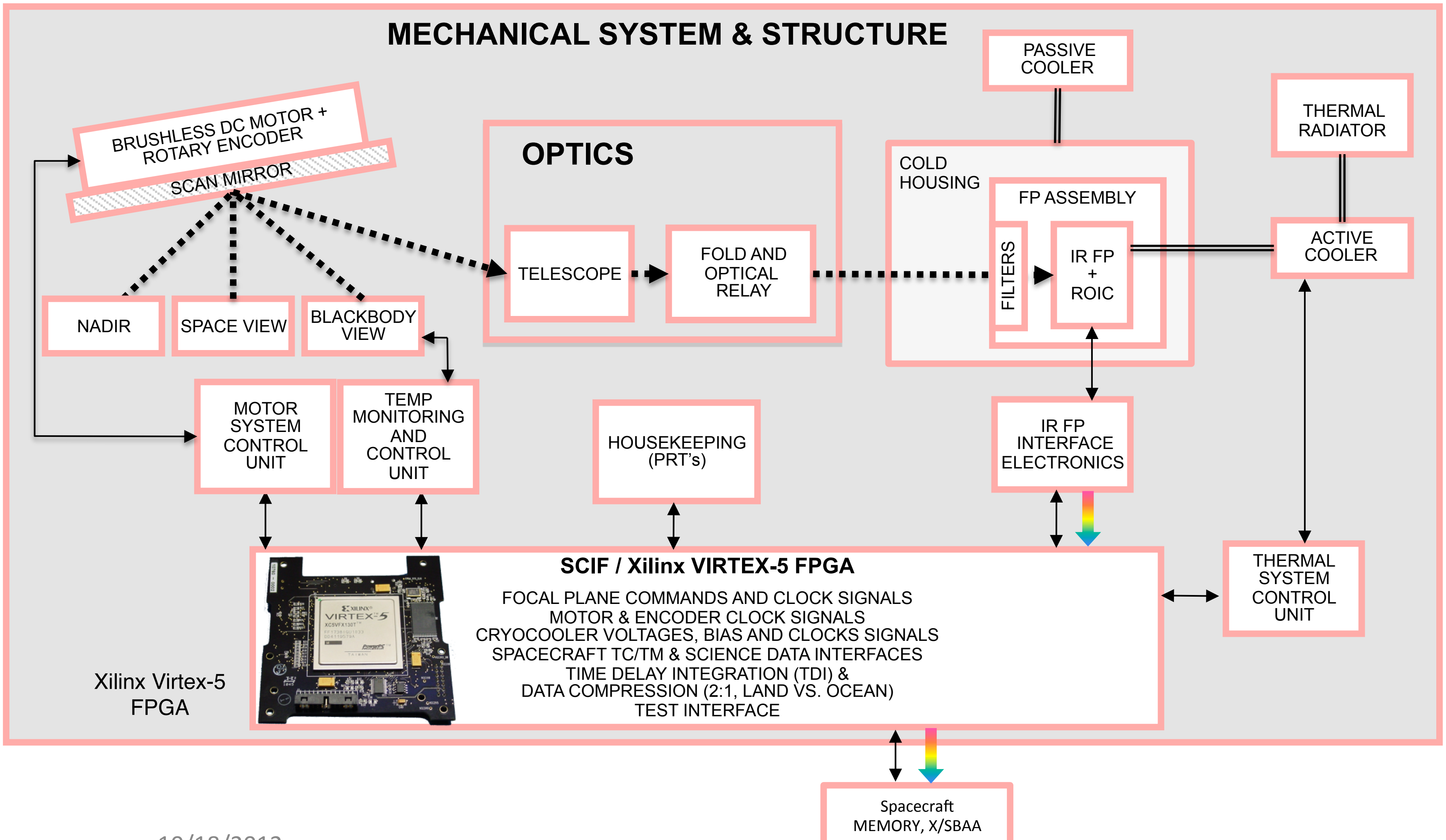
- Goal
  - Demonstrate for HyspIRI that:
    - The detectors and readouts meet all signal-to-noise and speed specification.
    - The scan mirror, together with the structural stability, meets the pointing knowledge requirements.
    - The long-wavelength channels do not saturate below 480 K.
    - The cold shielding allows the use of ambient temperature optics on HyspIRI without impacting instrument performance.
- Objective
  - Build the Prototype HyspIRI Thermal Infrared Radiometer. A laboratory demonstration of the performance of the key components HyspIRI.

HyspIRI Scan Concept

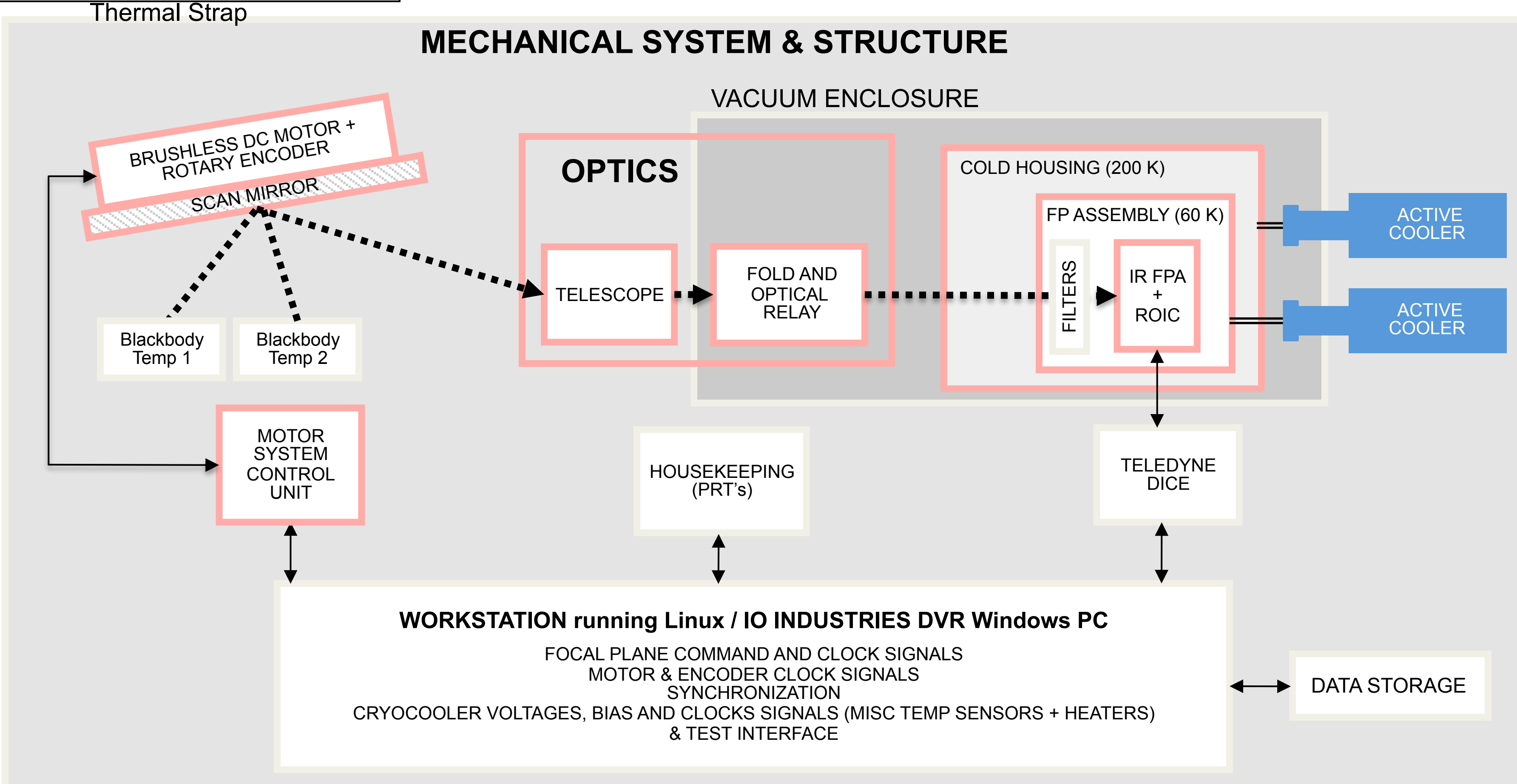


HysPIRI TIR Instrument Block Diagram



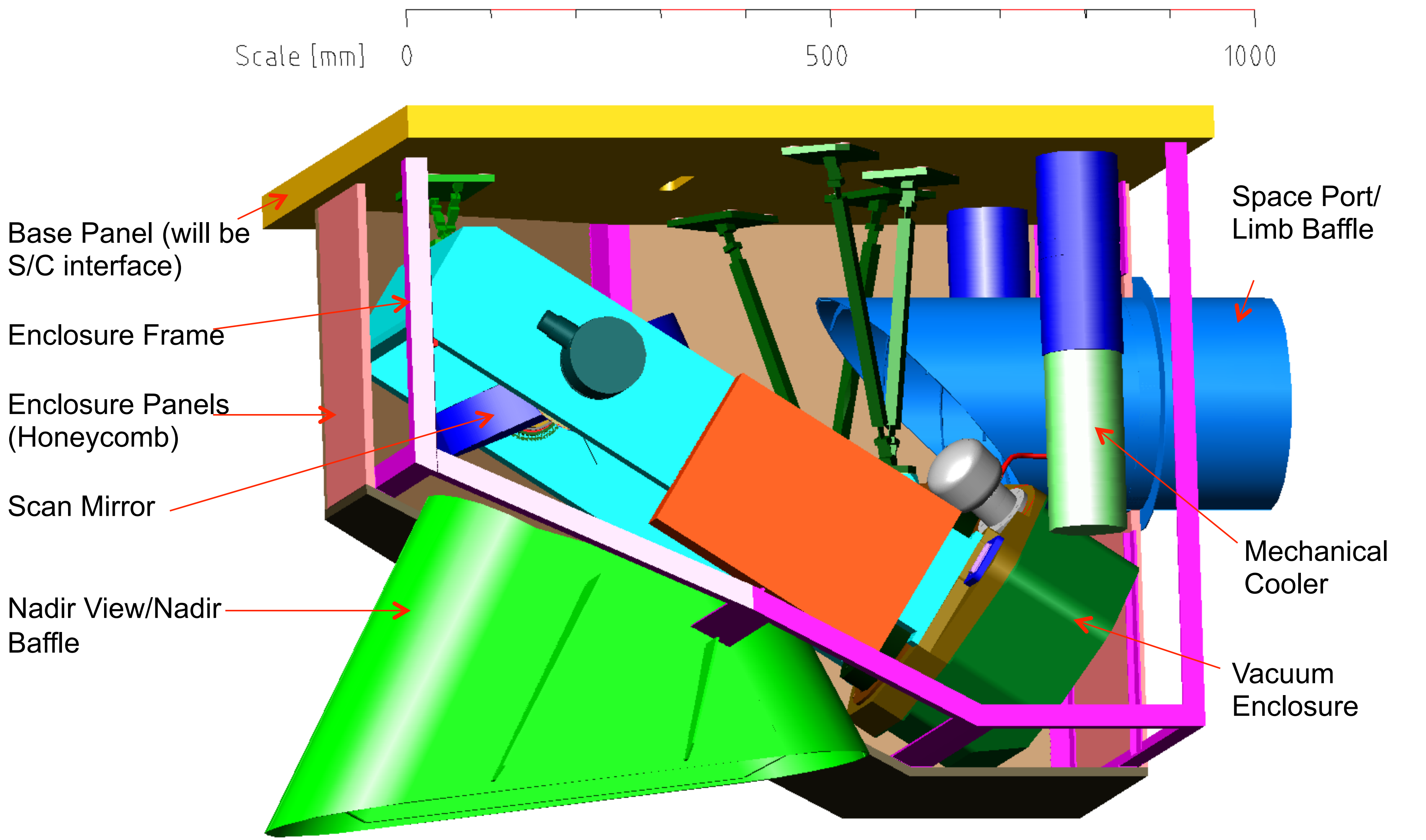


PHyTIR Instrument Block Diagram

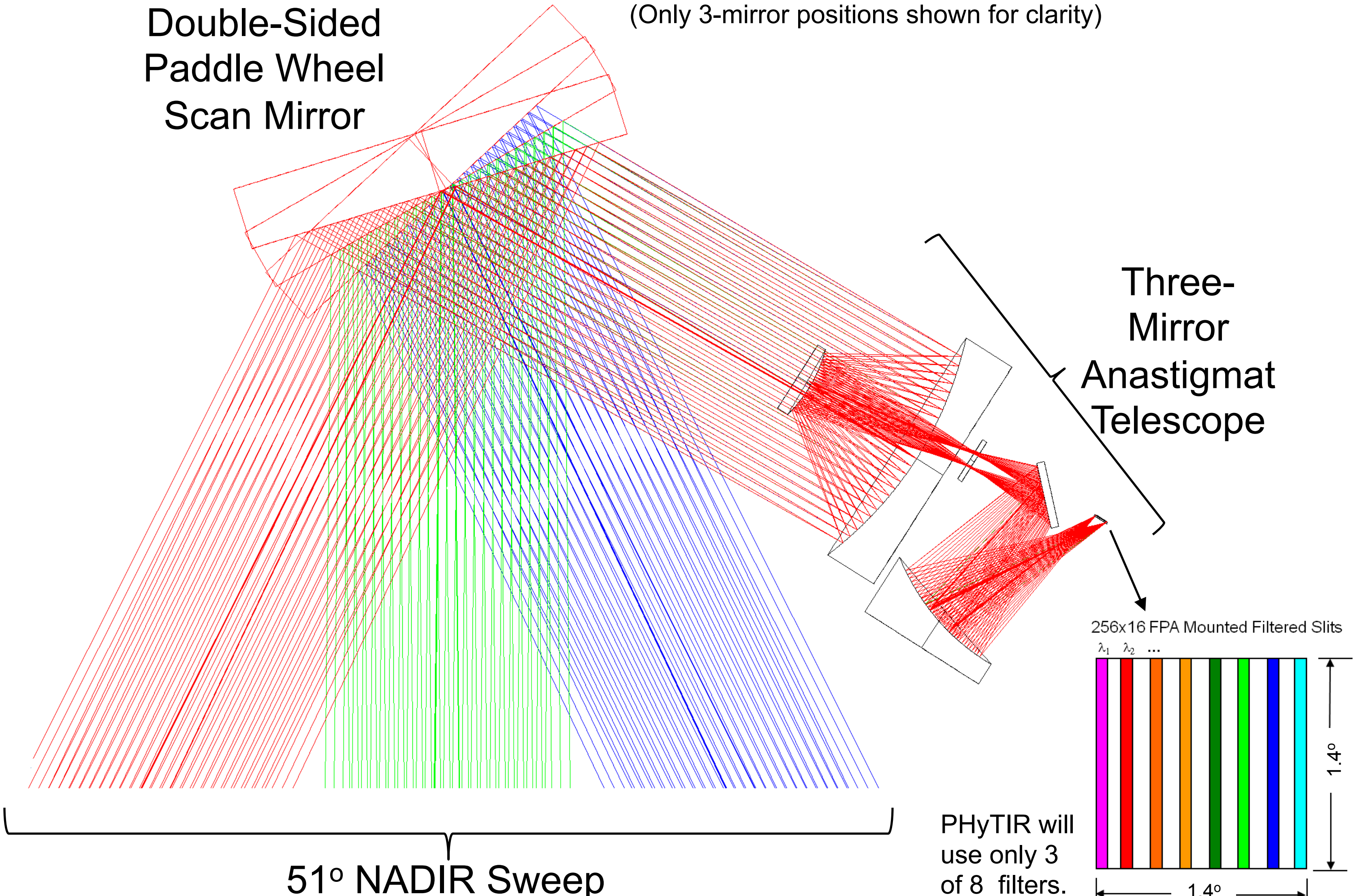


- PHyTIR will demonstrate prototypes of key HyspIRI components - optics, scan mirror, and focal-plane, stable structure
- Other components will be not be flight like – electronics outside of focal plane, cooling system
- Only 3 filter bands will be incorporated into filter assembly (4, 8, and 12 microns)

PHyTIR Mechanical Layout



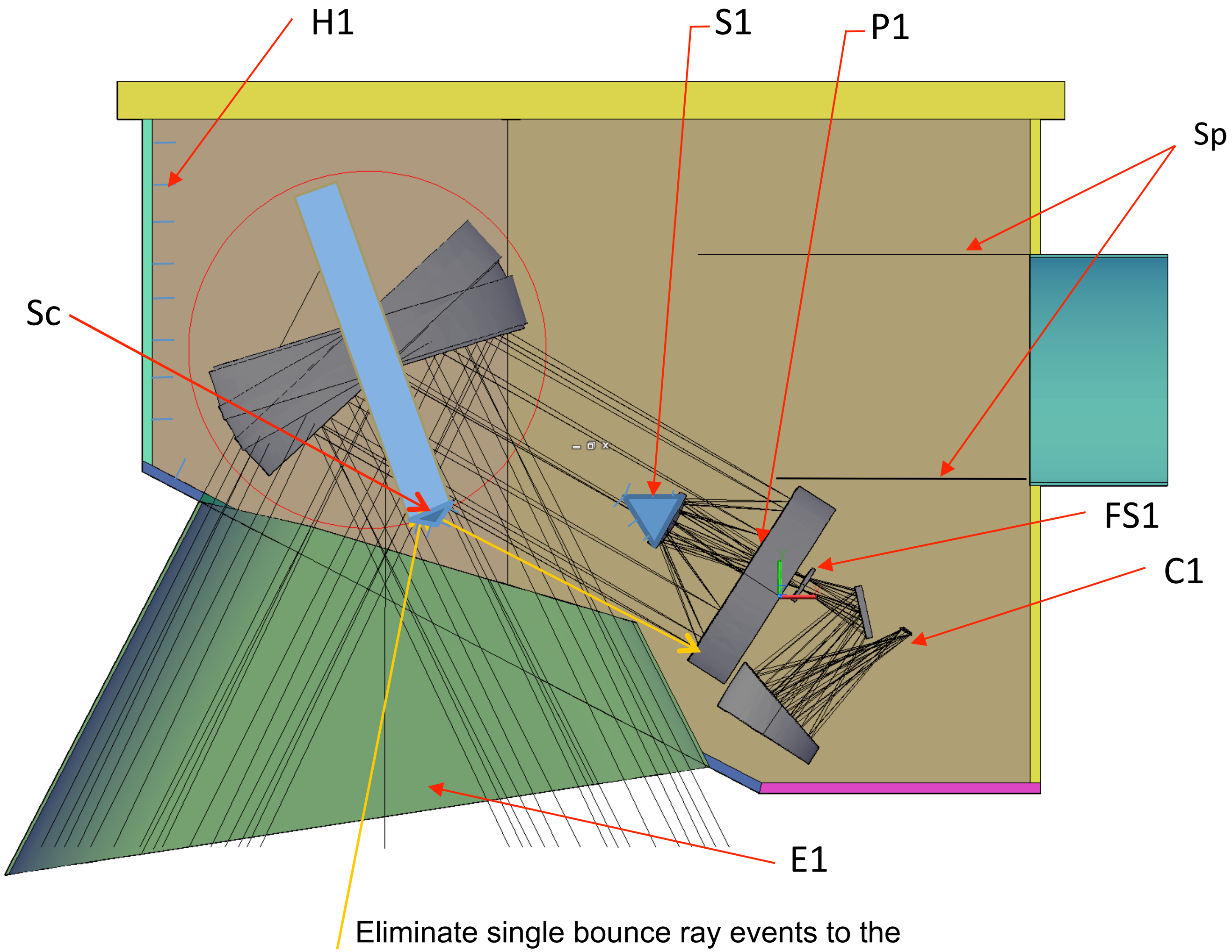
Optics



PHyTIR will use only 3 of 8 filters.

Optics

Design to best practices. Use non-sequential raytrace program as a verification.



Eliminate single bounce ray events to the focal plane (example shown in orange)

Main Baffles Used on PHyTIR
E1 (Earth baffle), 295K
P1 (Primary baffle), 295K
S1 (Secondary baffle), 295K
Sp (Space baffle), 295K
C1 (Cold baffle/stop), 60K
H1 (Housing baffle), 295K
FS1 (Field stop baffle), 295K
Sc(Scan mirror baffle), 295K

Optics

HyspIRI-TIR Bands

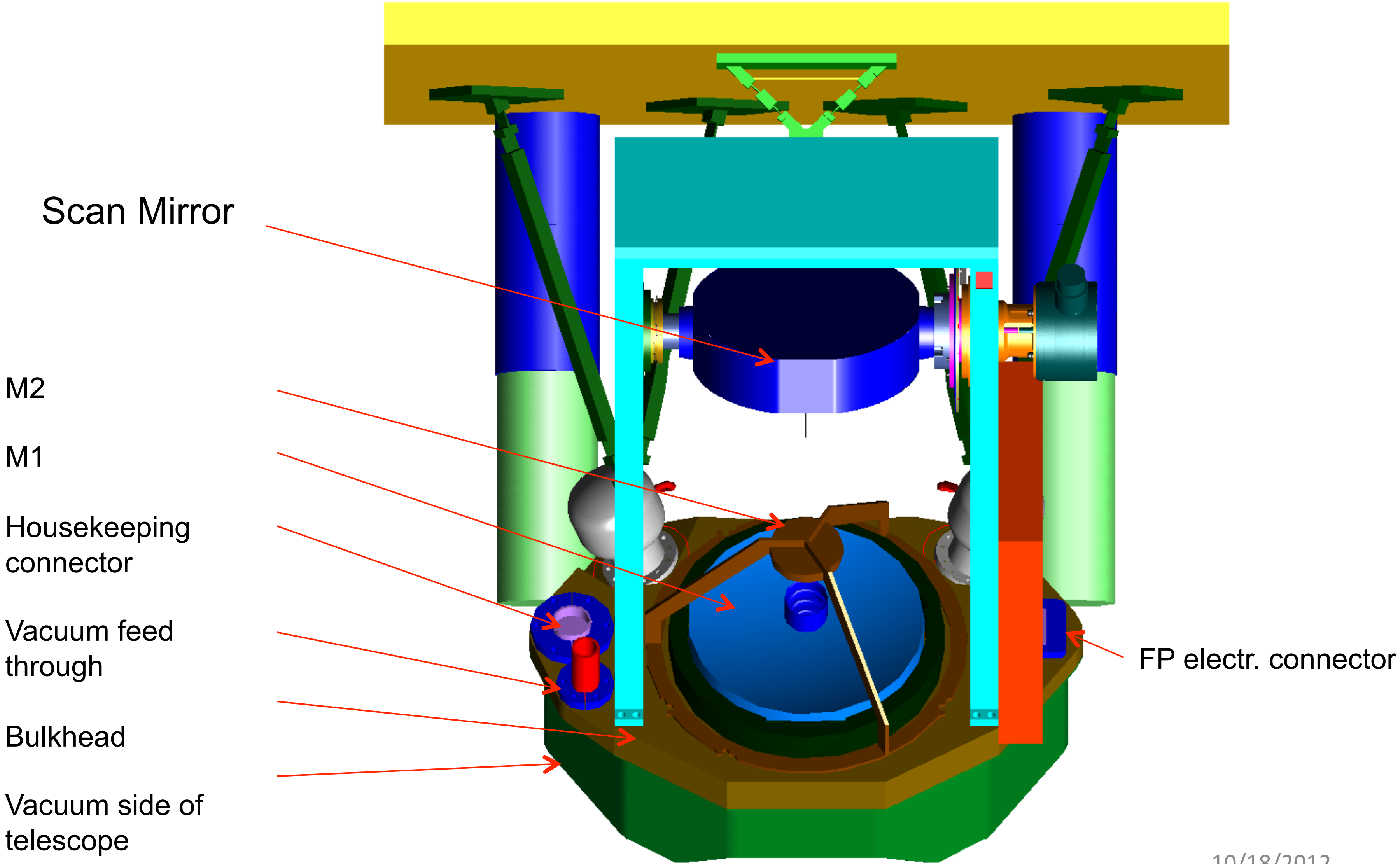
Filter #	center λo (μm)	SW10% (μm)	LW10% (μm)	BW (μm)
1	3.982	3.9745	3.9895	0.015
2	7.35	7.19	7.51	0.320
3	8.278	8.103	8.453	0.350
4	8.628	8.453	8.803	0.350
5	9.074	8.894	9.254	0.360
6	10.5284	10.2584	10.7984	0.540
7	11.3284	11.0584	11.5984	0.540
8	12.046	11.786	12.306	0.520

PHyTIR Focal Plane Filters

λ (μm)	Δλ
4	0.015
8	0.35
12	0.52

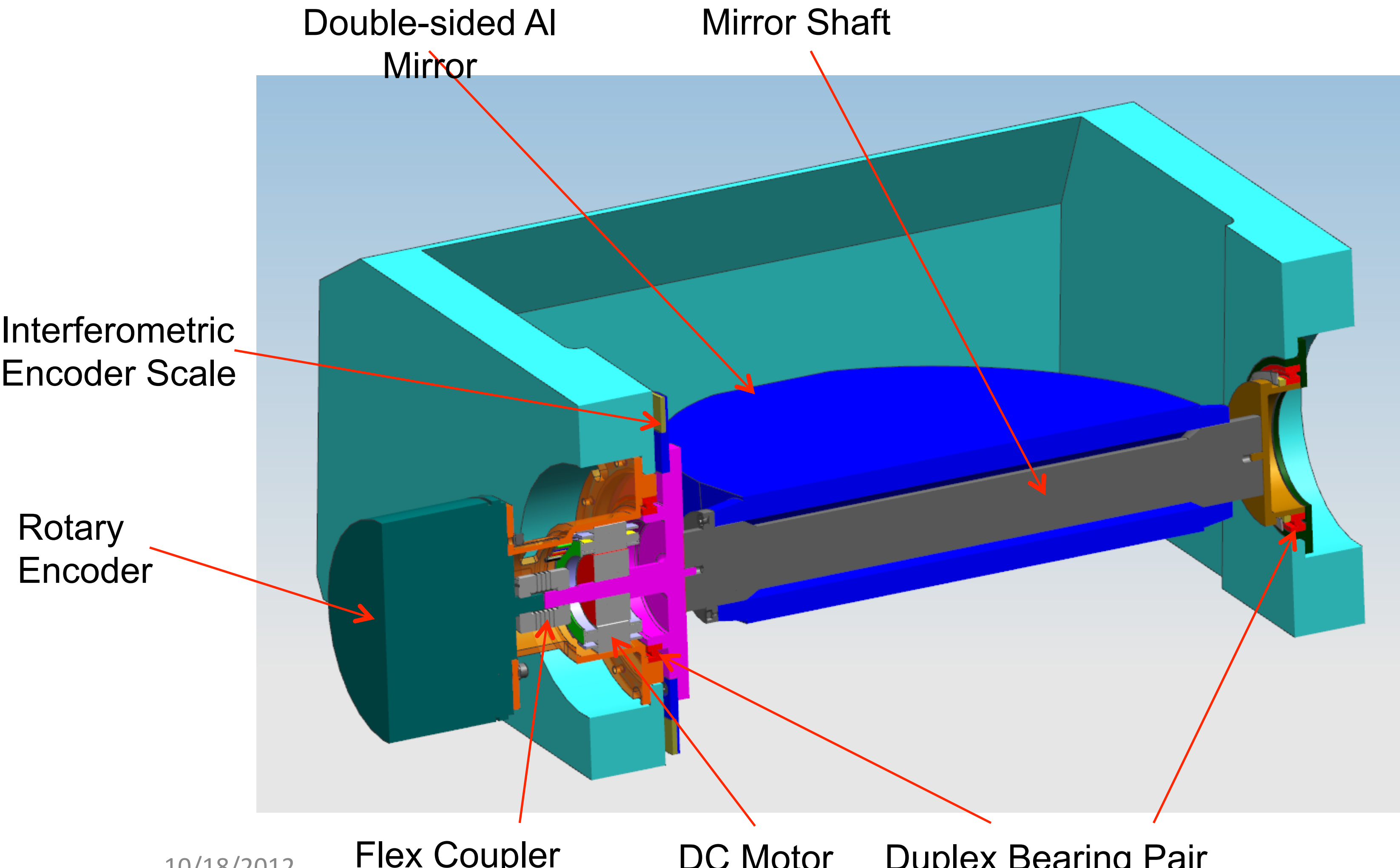
- Three custom filters will be deposited on a single ZnSe substrate. The filters should span the passband of HyspIRI-TIR but do not need to be exact matches to HyspIRI-TIR bands due to cost limitations.

Mechanical

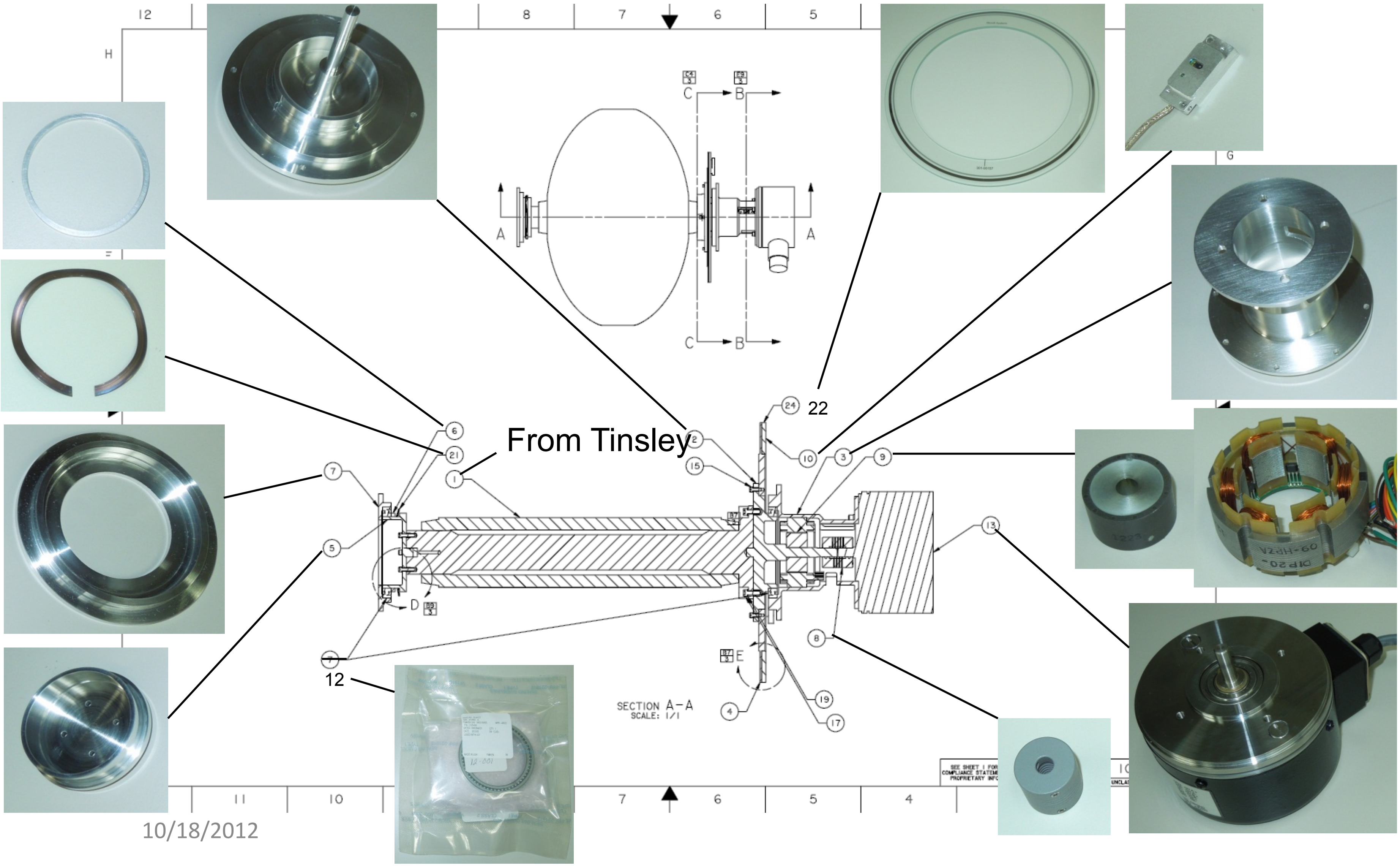

Scan Mirror
M2
M1
Housekeeping connector
Vacuum feed through
Bulkhead
Vacuum side of telescope
FP electr. connector

Mechanical

- Scan Mirror Assembly Cross Section



Mechanical

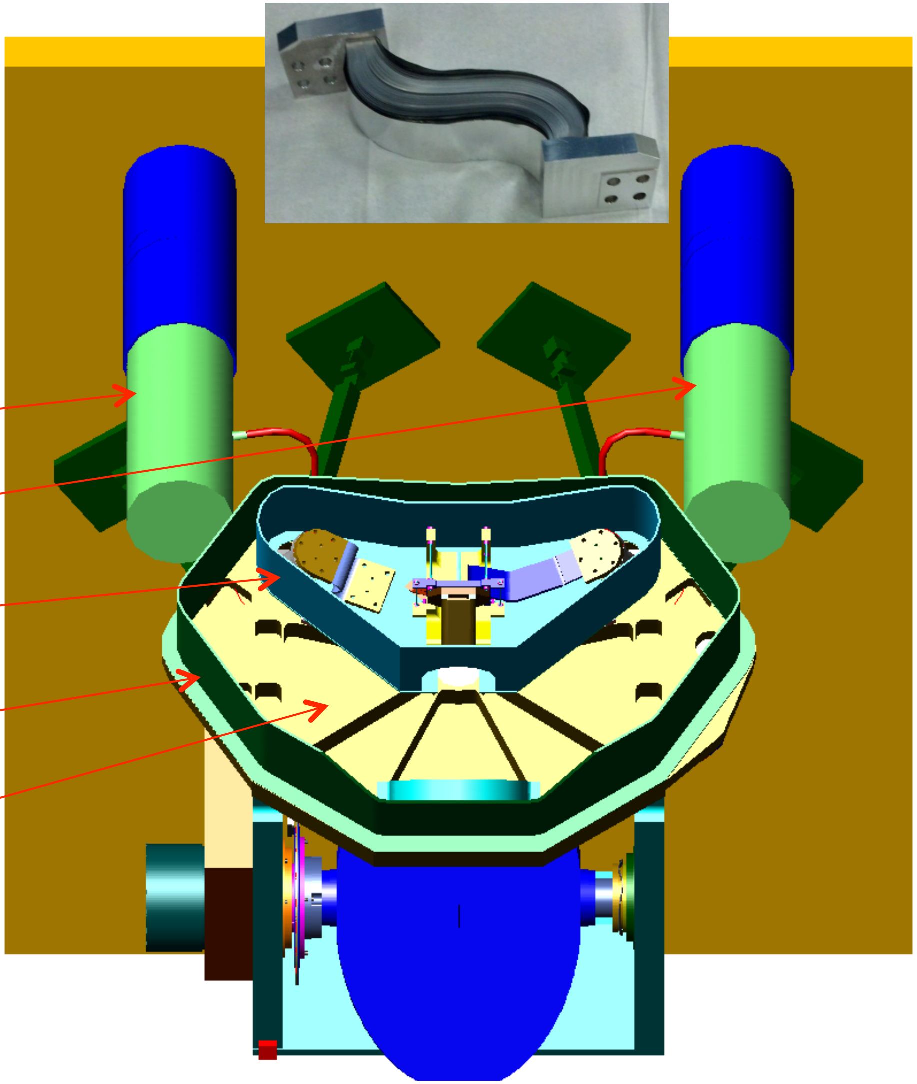


Mechanical

- The Cryocoolers

  Model: Thales Cooler LPT9310

Sample Thermal Strap:



Cryocooler (for 200degK)

Cryocooler (for 60degK)

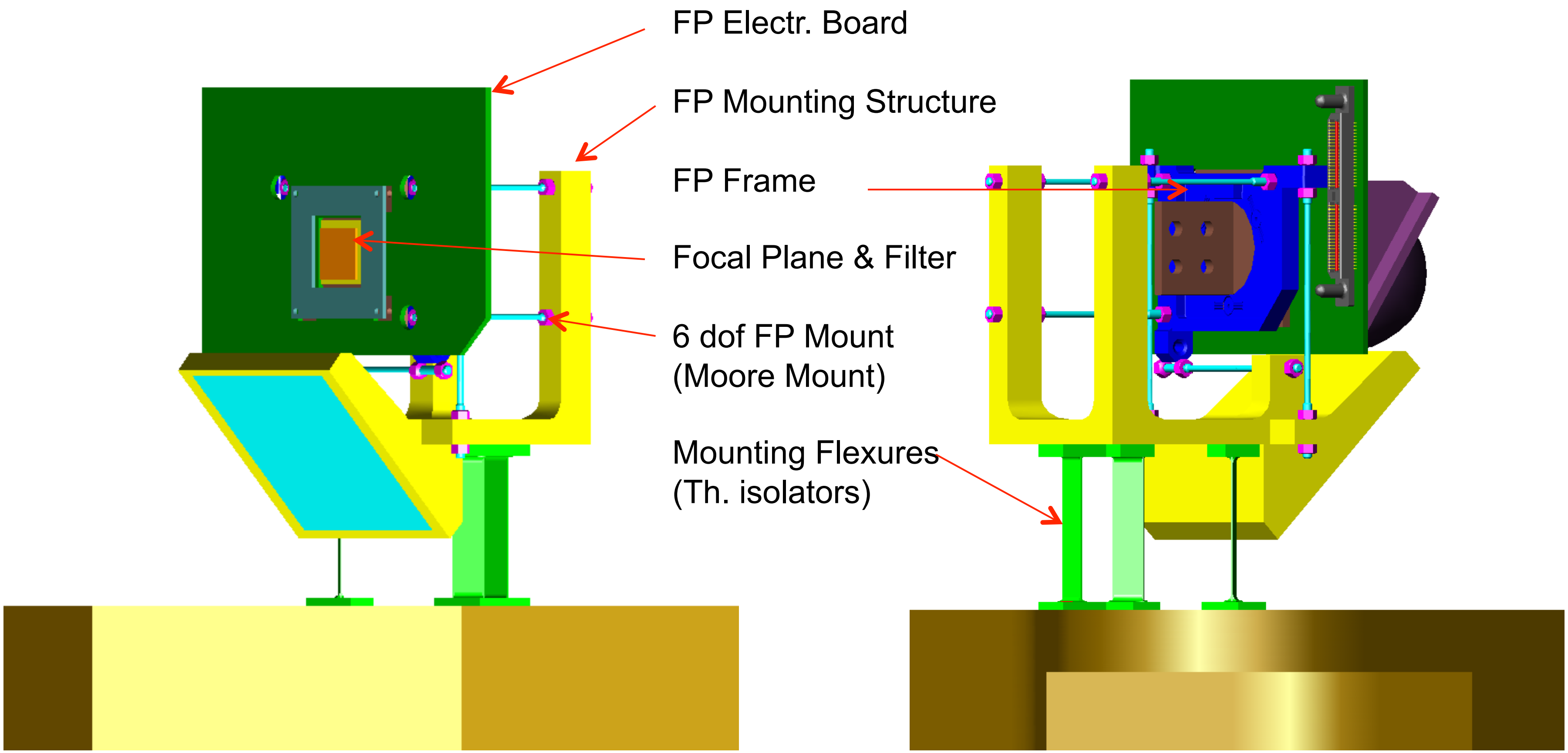
Cold Housing
(top removed to show inside)

Vacuum Housing
(top removed to show inside)

Bulkhead

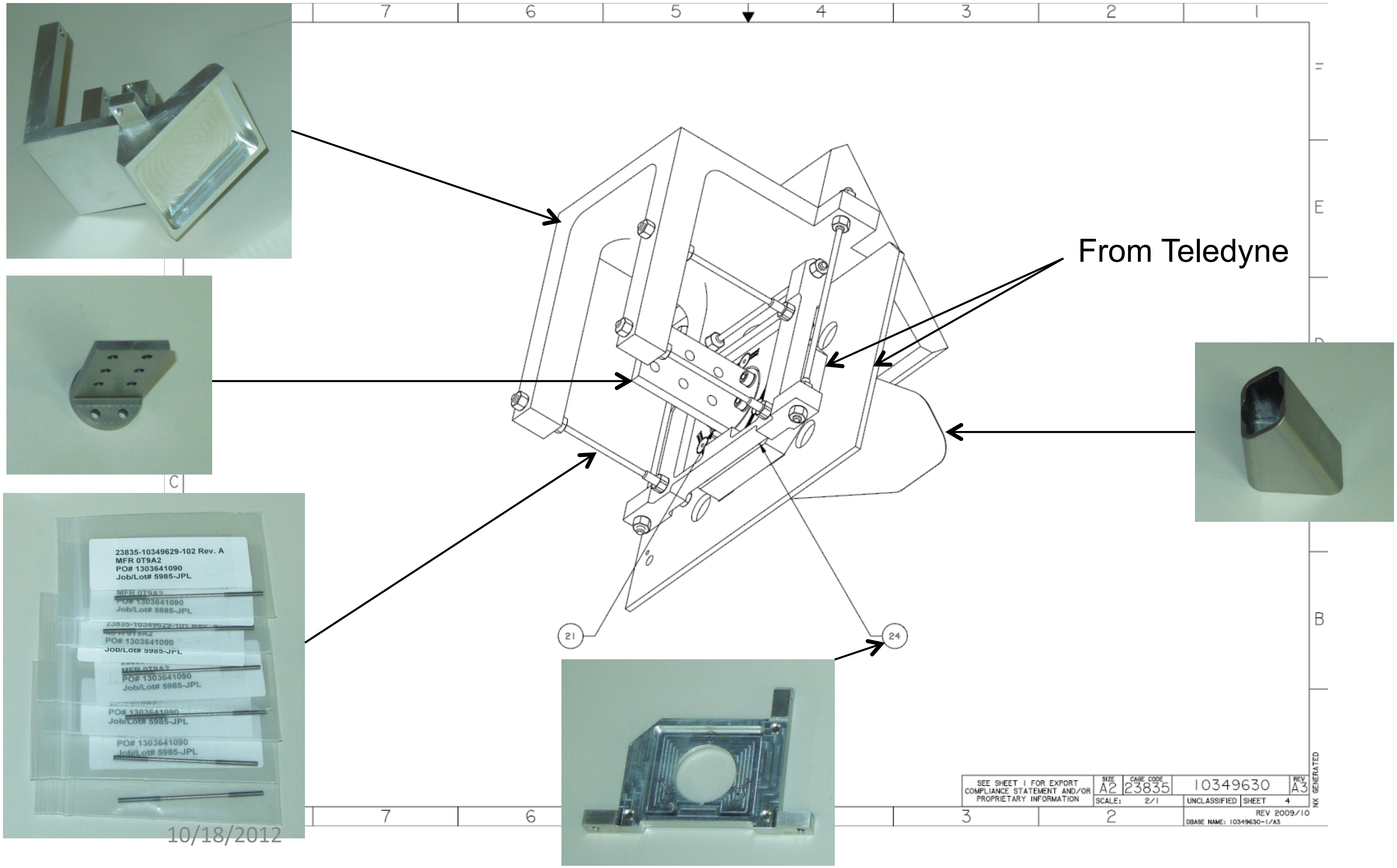
Mechanical

- The FP Assembly



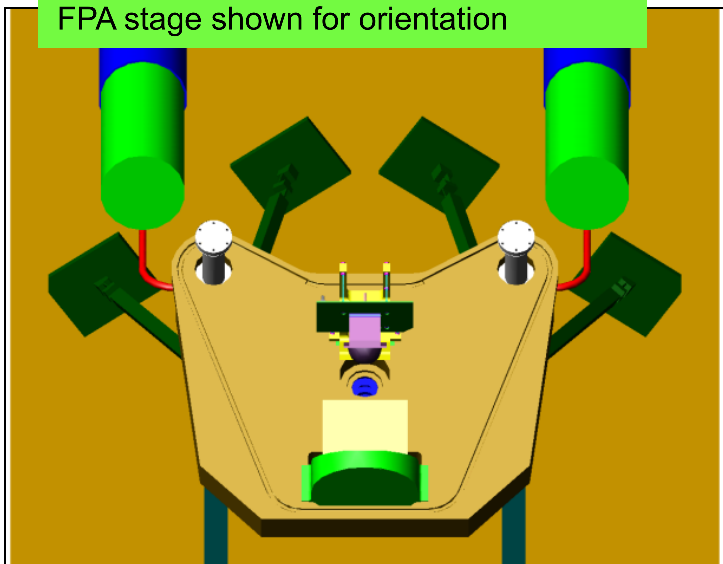
FP Front Side (FP Baffle not shown)   FP Backside (FP Baffle on Backside)

Mechanical

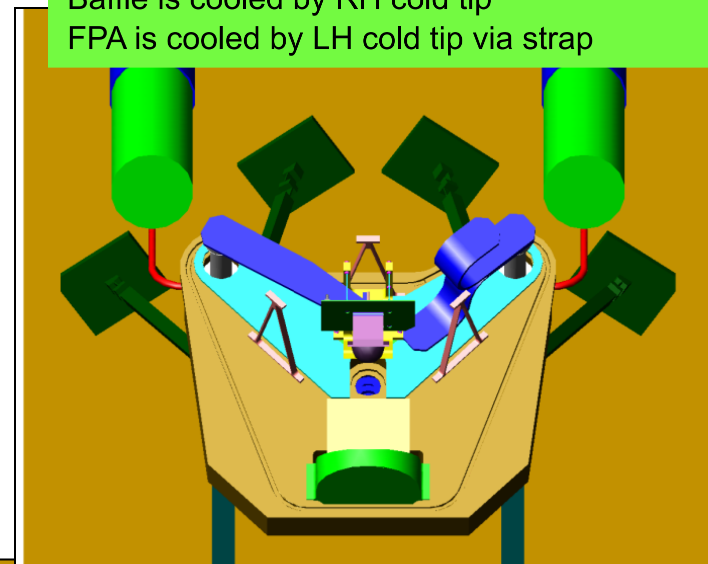

From Teledyne
23835-10349629-102 Rev. A
MFR 0T9A2
PO# 1303641090
Job/Lot# 5985-JPL
21
24
SEE SHEET 1 FOR EXPORT COMPLIANCE STATEMENT AND/OR PROPRIETARY INFORMATION
SIZE A2
CAGE CODE 23835
10349630
REV A3
SCALE: 2/1
UNCLASSIFIED
SHEET 4
REV 2009/10
DBASE NAME: 10349630-1/A3
NX GENERATED

Cooling

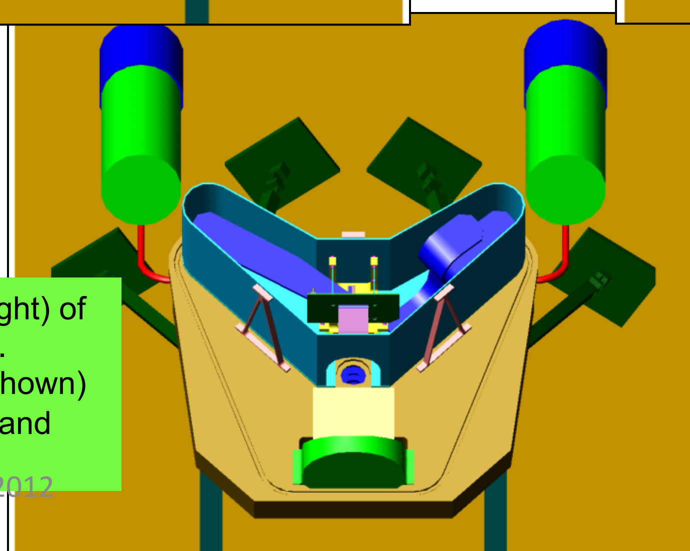
Bulkhead with cryocooler cold tips:
FPA stage shown for orientation

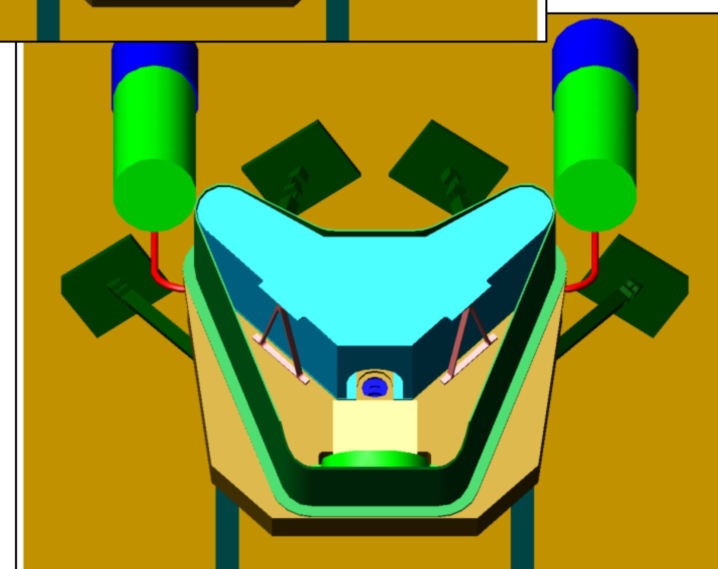


Lower stage of 200 K baffle supports FPA structure, intercepts conducted loads
Baffle is cooled by RH cold tip
FPA is cooled by LH cold tip via strap



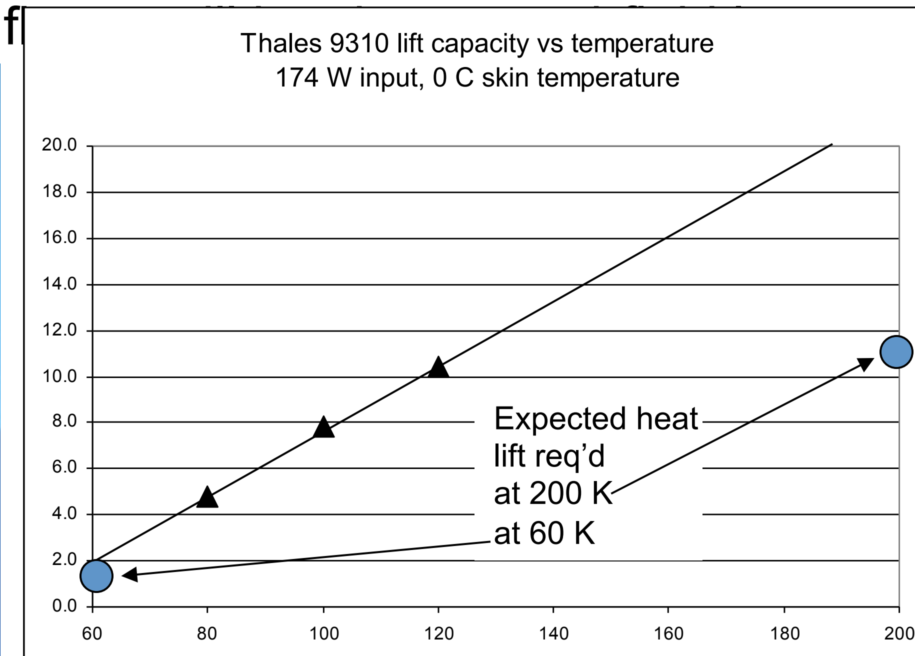
Wall (left) and top (right) of 200 K baffle in place. Vacuum cover (not shown) encloses cold stage and mirrors.



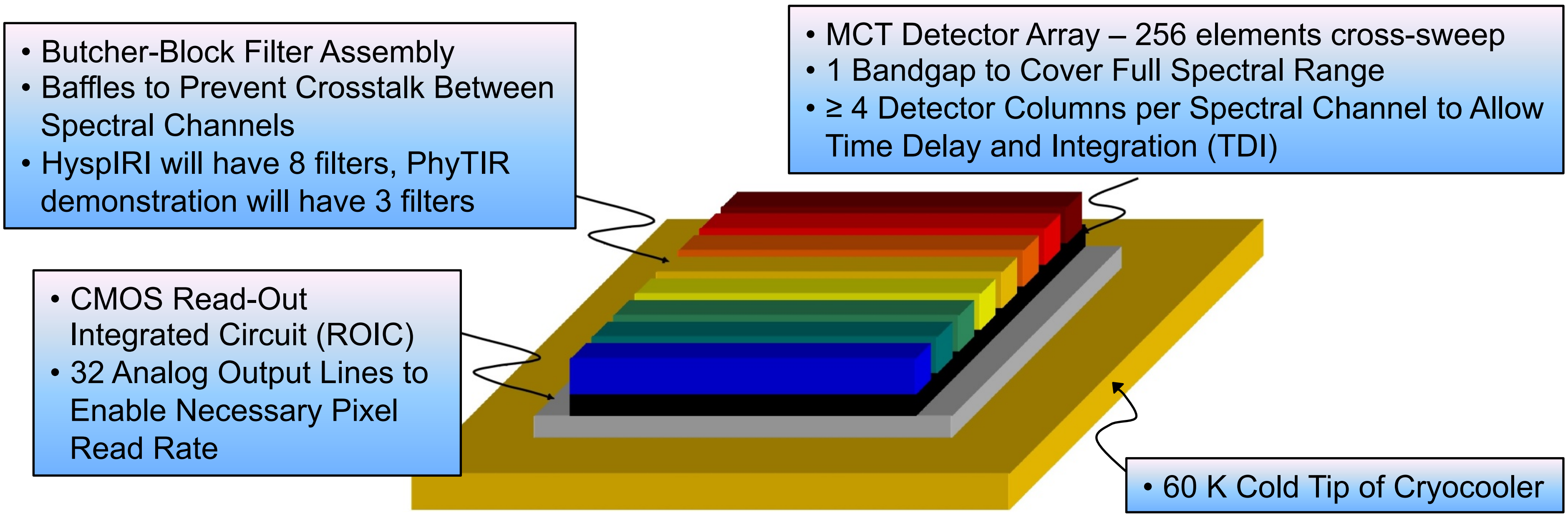


Cooling

- PHyTIR uses two identical Thales 9310 pulse tube coolers
  - 20,000 hour MTTF (2.3 years)
  - drive electronics will incorporate lab-level active vibration cancellation for the dual opposed pistons, enabling evaluation for future flight potential
- Cooler motor mounted to interface plate, may require vibration isolation (TBD)
- Cooling of motors and cold head f

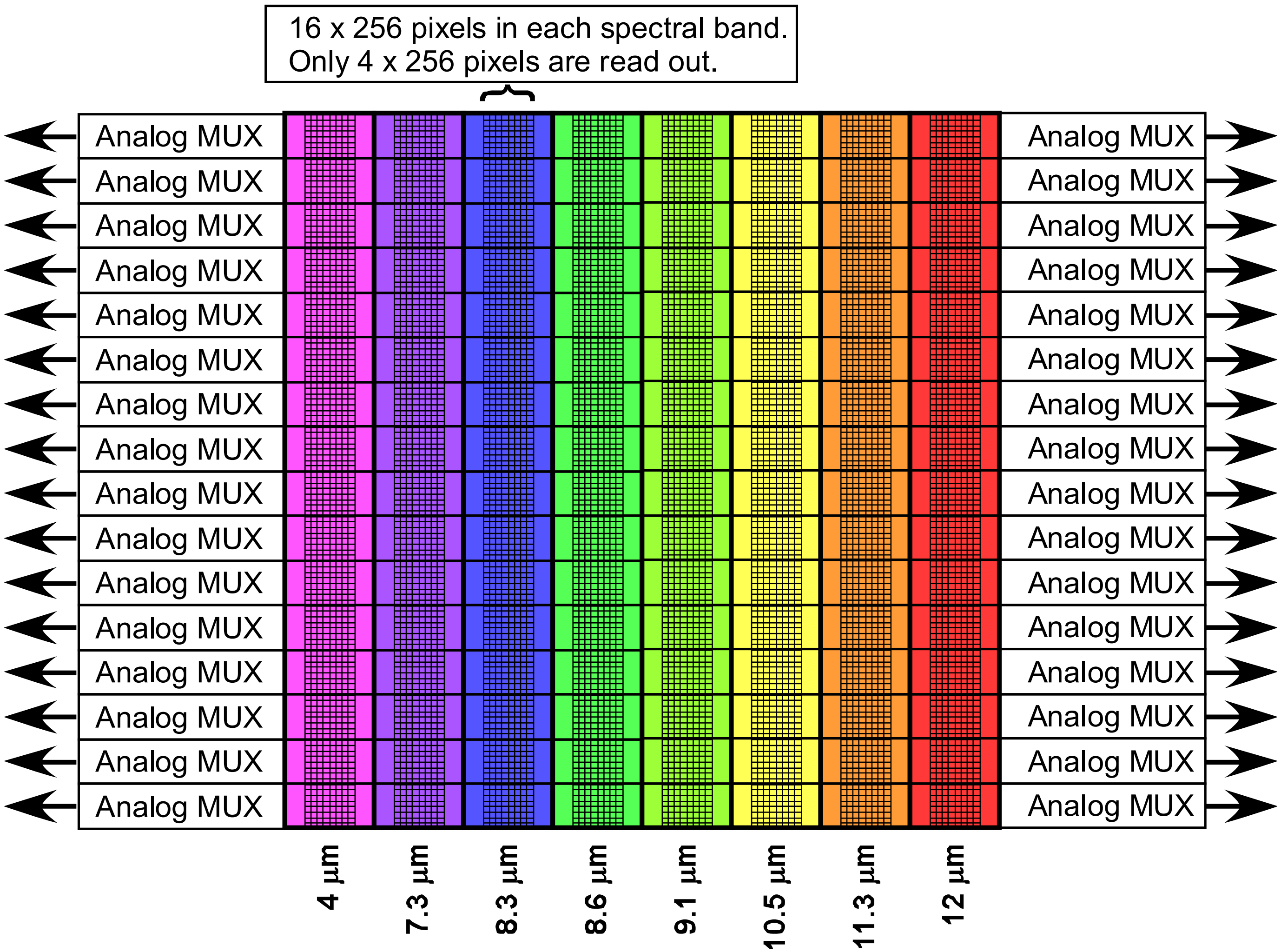


Focal Plane Concept

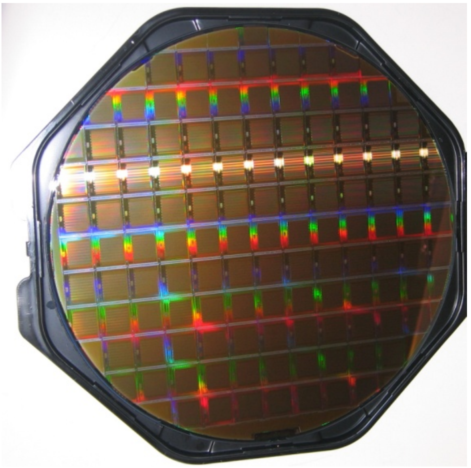


- Teledyne under contract to provide focal planes. Contract for external readout electronics in place.
- Digitization in off-chip ADCs
- TDI performed after digitization

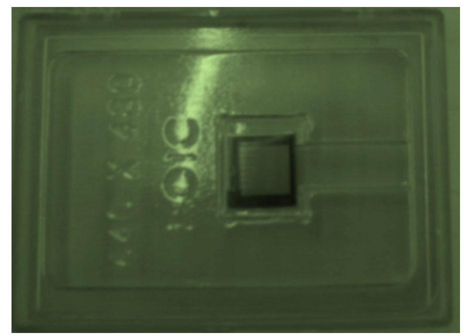
Focal Plane Readout Architecture

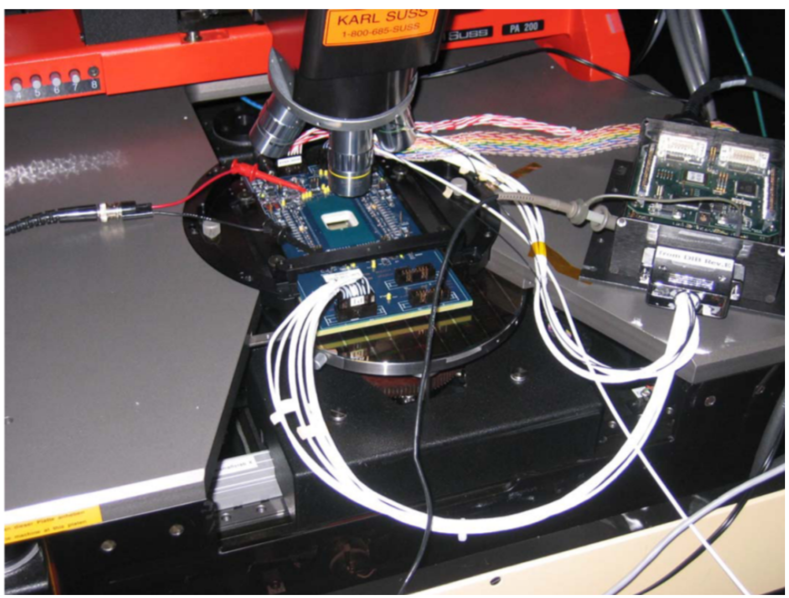


ROIC Status



6 eight-inch wafers have been fabricated and delivered to Teledyne with over 100 dies each. Diced ROICs are ready for hybridization.

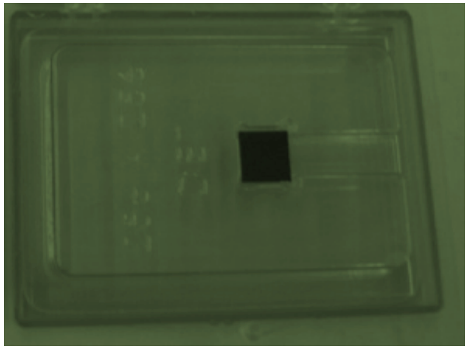


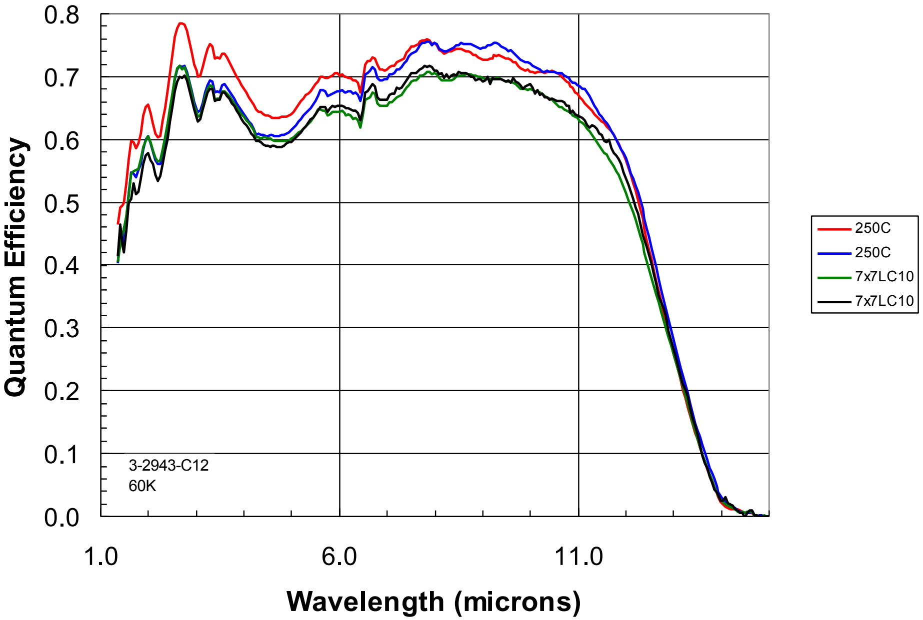


Wafer probe station. Wafer has been tested at room temperature and at nearly the required readout speed. Noise and power performance are as expected, as well as register functionality.

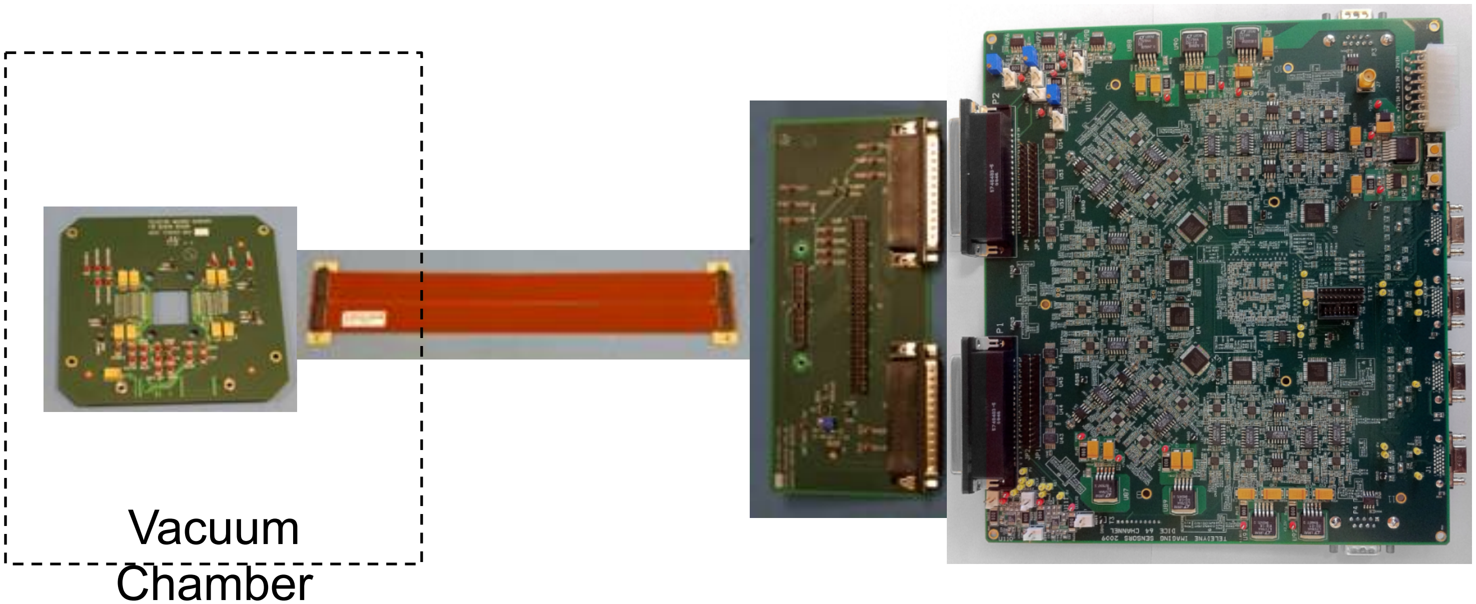
Detector Status

- Detectors wafers have been fabricated using ~13.2 micron cutoff MCT material.
- Diced detectors are ready to hybridize.
- Antireflective coating on a test detector shows adequate quantum efficiency.
- Detectors will be hybridized with readout chips in December 2012



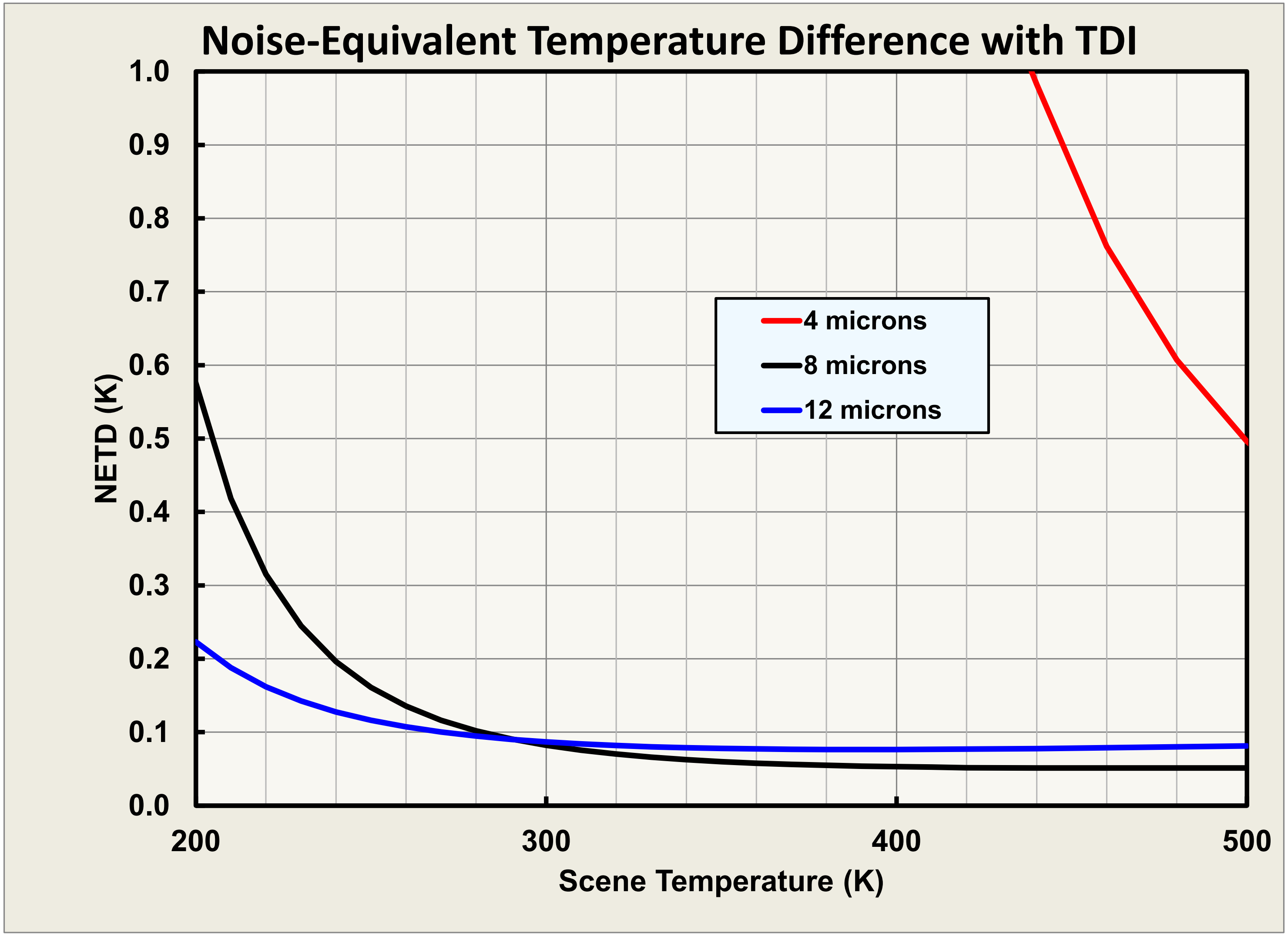


FPA Electronics

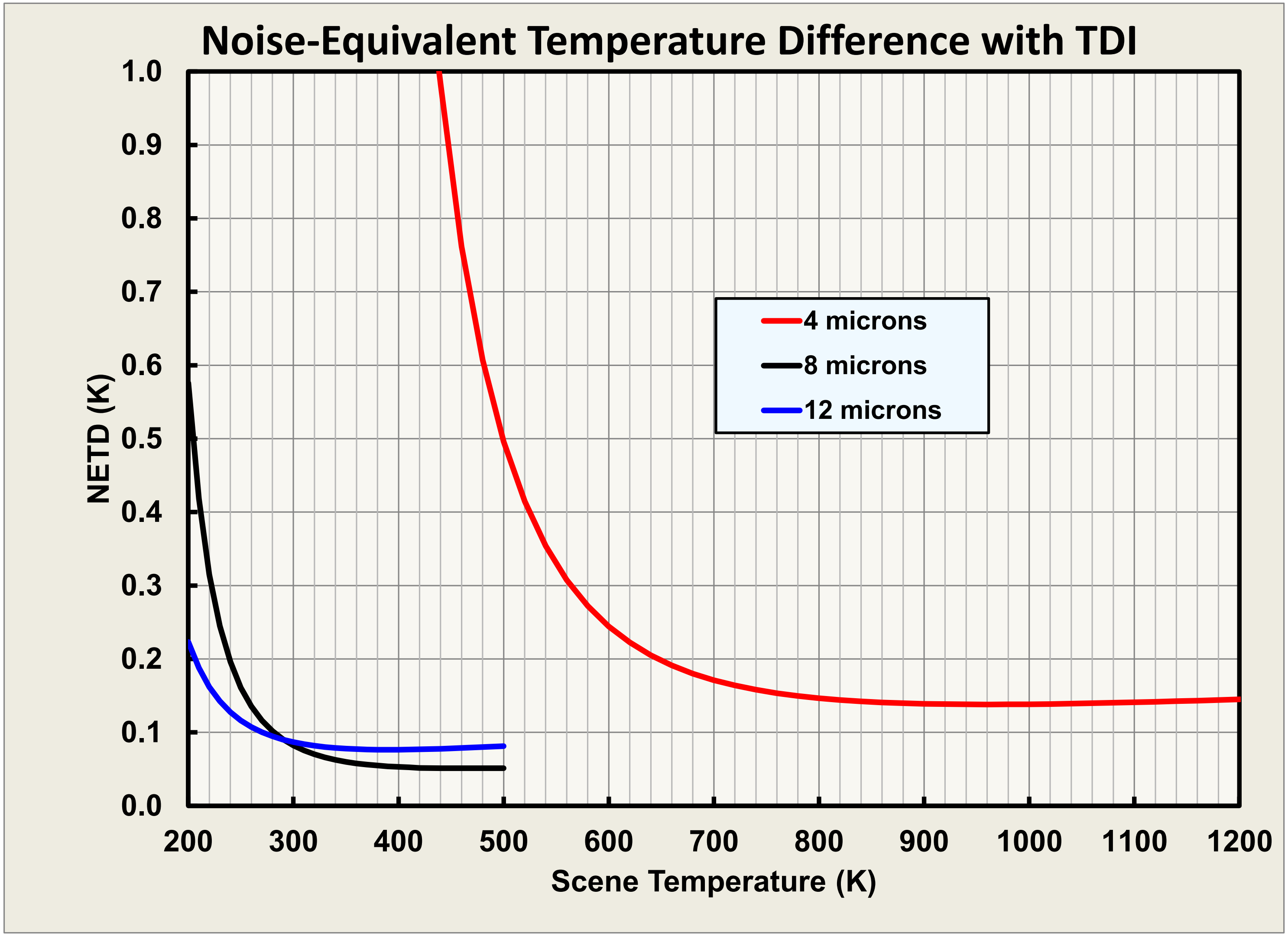


- Teledyne FPA board contains the ROIC, other passive devices, and SAMTEC connector to get data, control, and supply signals in and out.
- Flex cable is being designed to replicate the performance of an existing SAMTEC cable, but we must use a different conductor to meet thermal performance specifications.
- Teledyne interface board contains SAMTEC connector, test points, voltage regulation circuits, and two 78 pin DSUB connectors to interface with digitization board.
- Teledyne DICE board digitizes ROIC data and generates low-noise biases, clocks, and communication signals for the ROIC.

Performance



Performance – Full Temperature Range



PHyTIR Overall Goal and Objective

- Goal
  - Demonstrate for HyspIRI that:
    - The detectors and readouts meet all signal-to-noise and speed specification.
    - The scan mirror, together with the structural stability, meets the pointing knowledge requirements.
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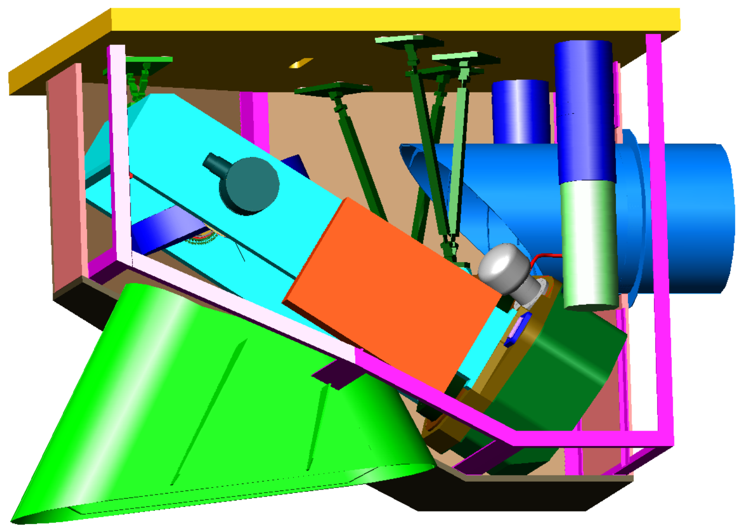
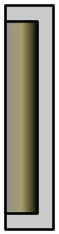
PHyTIR Test Configuration

- Instrument is in air. Vacuum enclosure around focal-plane is evacuated (to be described in detail in mechanical presentation). Scan mirror rotating.



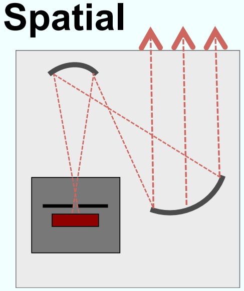


Room-temperature reference blackbody. Flat plate with corrugated, painted surface. Emissivity <1 acceptable.

Radiometric and Saturation

Variable-temperature blackbody: room temperature to 500 K. Flat plate with corrugated, blackened surface. Emissivity <1 acceptable.

Spatial



MCS Target Projector with slit source. Will underfill PHyTIR aperture.

<u>Test Sources Placed Within PhyTIR Scan Range</u>

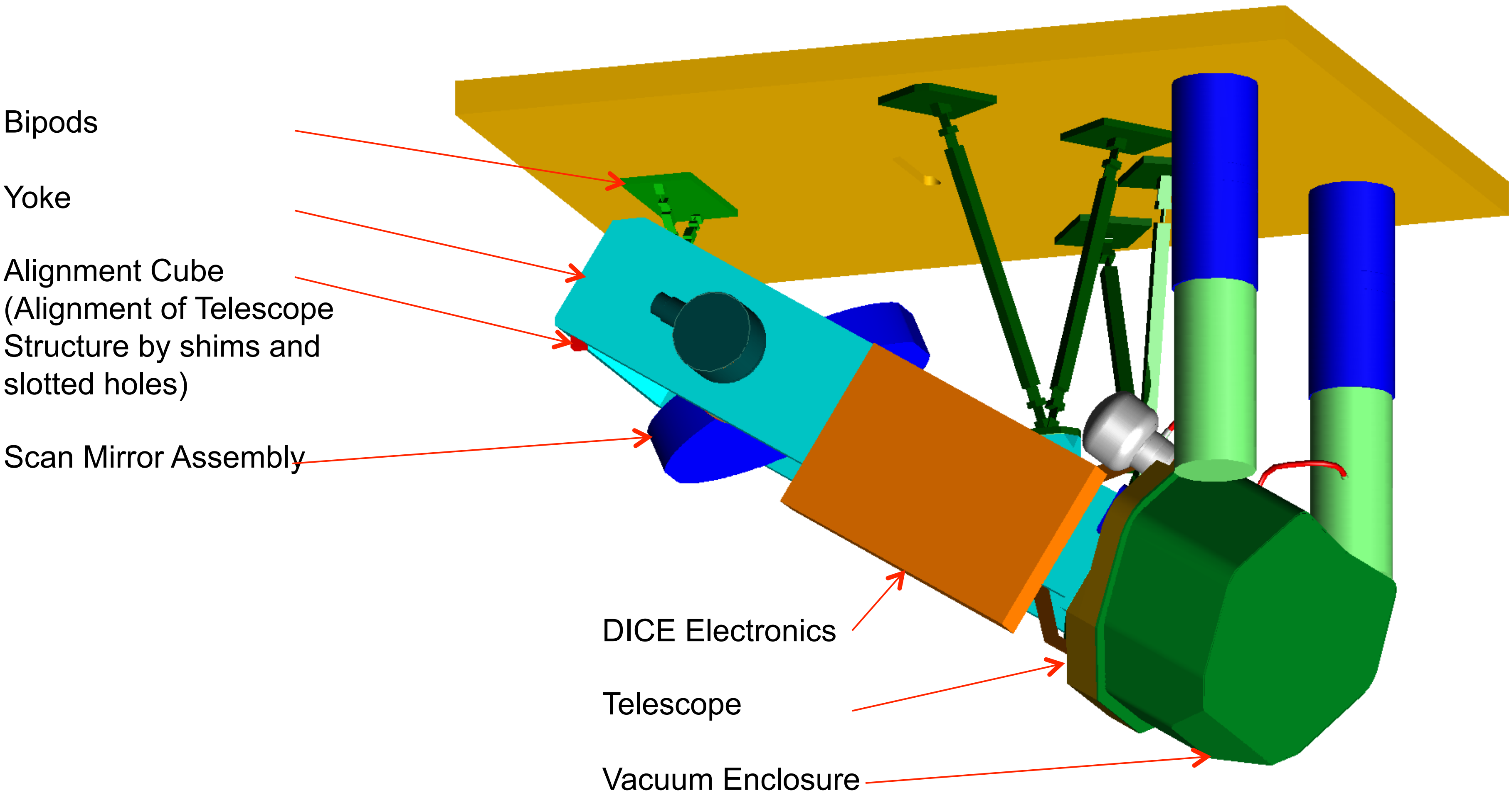
Summary and Next Steps

- PHyTIR will reduce the risk associated with key aspects of the HyspIRI-TIR performance (signal to noise, pointing, saturation, shielding
- PHyTIR is on track with all the large procurements in place and delivery of the first detectors expected in December. Key components are already being assembled e.g. scan mirror.
- Next steps will be to assemble the instrument and start testing in mid 2012

Backup

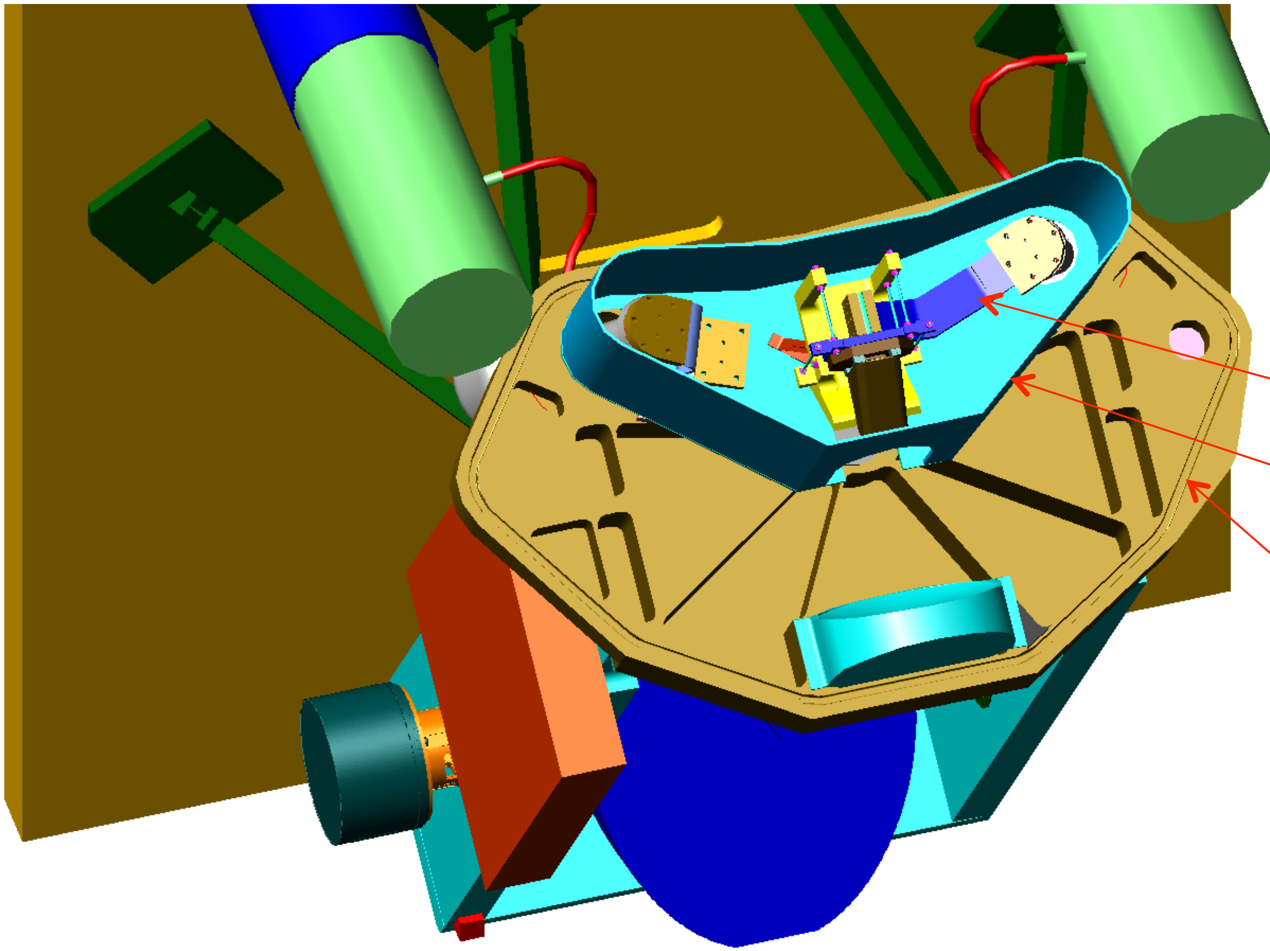
Mechanical

- Instrument w/o Enclosure

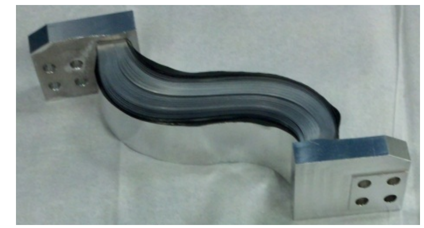


Mechanical

- Inside the Vacuum Enclosure



Sample Thermal Strap:



Thermal Straps

Cold Housing
(top removed to show
inside)

Vacuum seal O-Ring
groove