NASA Instrument Incubator Program (IIP) Multi-Band Uncooled Radiometer Instrument (MURI)

6/14/18

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DRS TECHNOLOGIES
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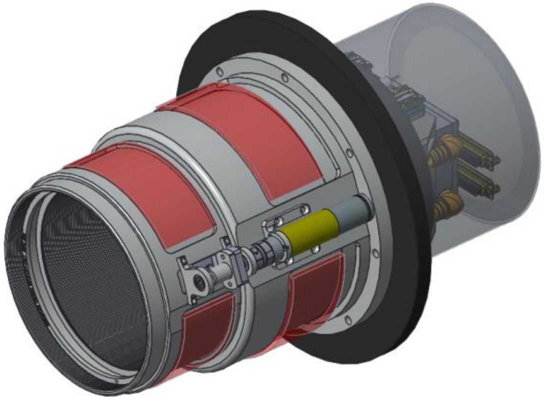
NASA

ESTF2018
Earth Science Technology Forum 2018

MURI Sensor Concept



MURI Airborne Sensor

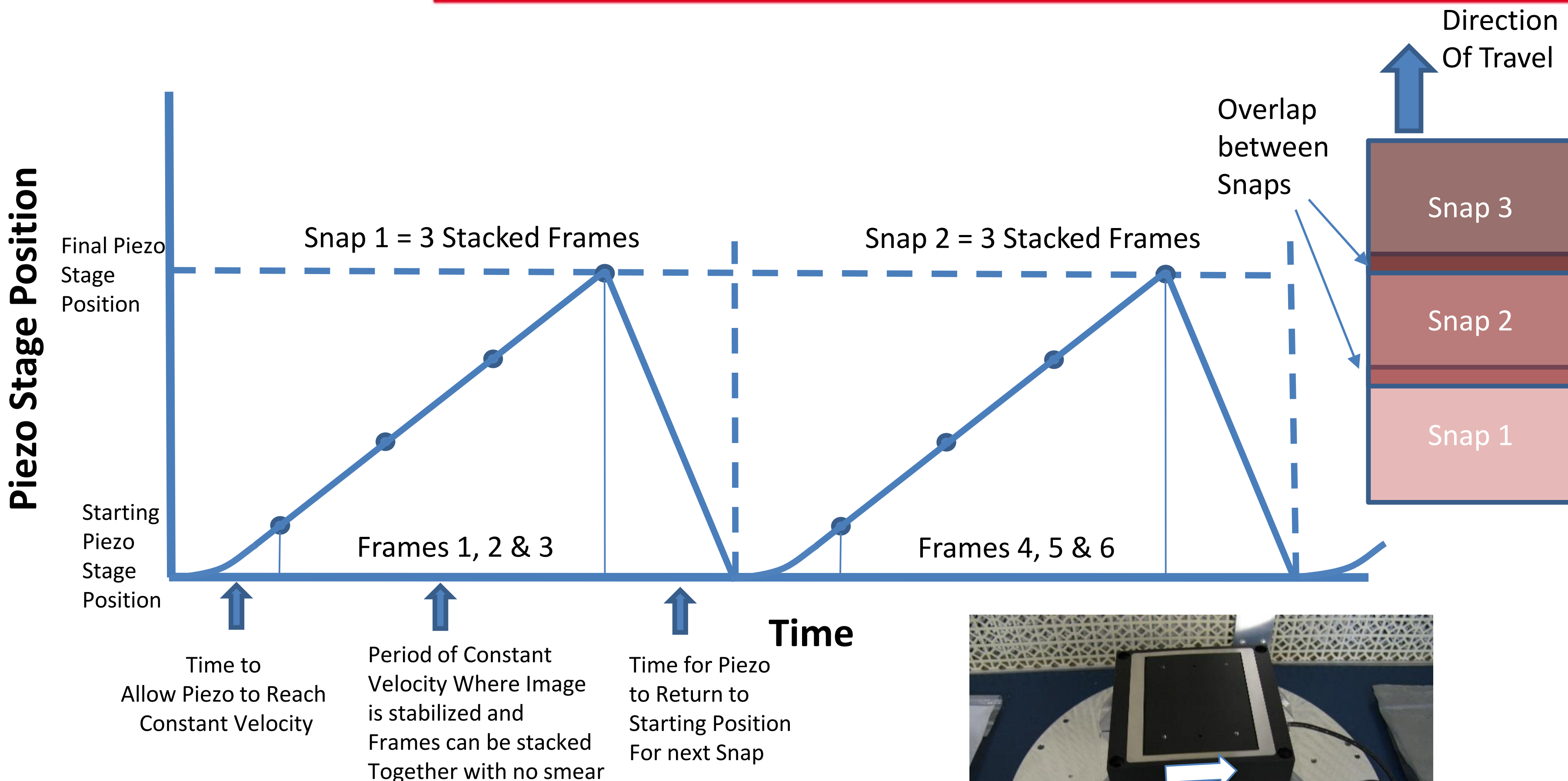
Band	Center Wavelength (um)	Spectral Bandwidth (um)	Application
1	7.68	0.10	Methane Monitoring
2	8.55	0.35	SO_2, cloud/volcanic ash properties
3	9.07	0.36	Minerals, SO_2
4	10.05	0.54	Surface temperature, vegetation, minerals
5	10.9	0.59	LANDSAT 8 TIRS 1
6	12.05	1.01	LANDSAT 8 TIRS 2

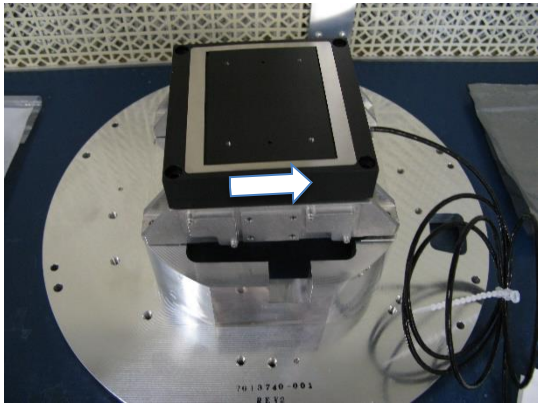
Six Spectral Bands Split Between Two Butcher Block Filters

TRL at Start of Program = 3
TRL at Completion of Year 3 of Program = 6

- DRS will use a Piezo Stage to Backscan a 6-Band Multispectral Uncooled Radiometer Imager (MURI) to achieve NETD and RER performance consistent with LANDSAT
- Absolute Radiometric Precision of <2% (260K to 330K Scene Temp) will be achieved by controlling FPA & Lens Temp and then monitoring the Lens and Camera Housing Temp and correcting the radiometry using DRS patented TCOMP algorithms
- Three Flight Data Collects Planned:
  1. The first will assess initial data quality and calibration with known targets deployed (Landsat Truth data)
  2. The second will demonstrate scientific products available over vegetative and urban environments
  3. The third will demonstrate methane and SO_2 detection capability

Example of Piezo Stage Movement

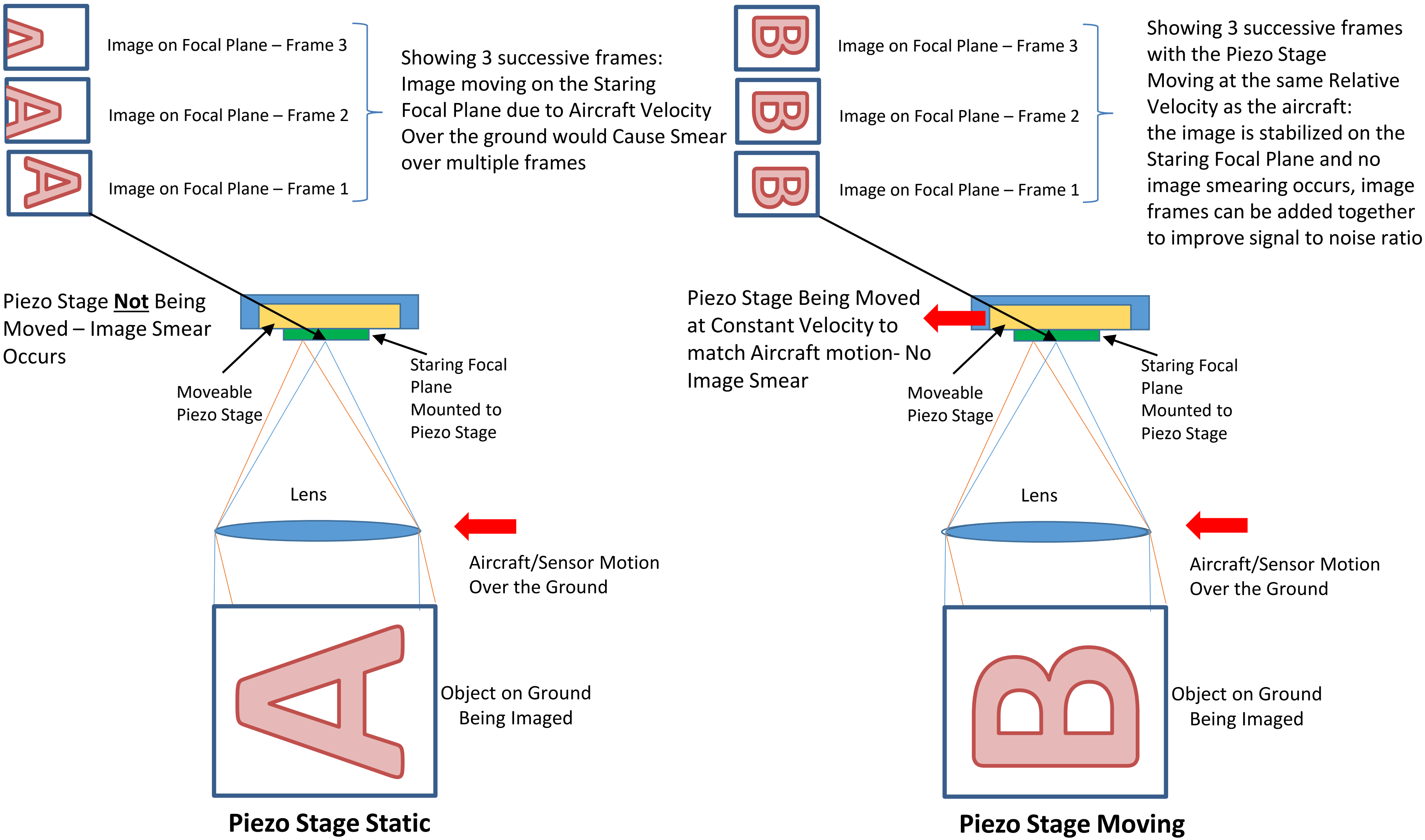




Piezo Stage Assembly

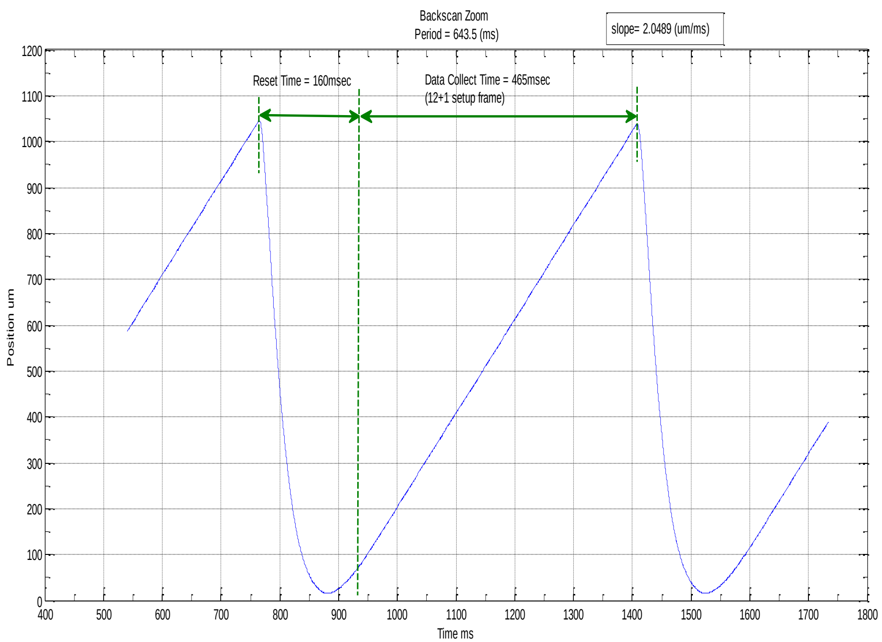
DRS Patent Pending for
Piezo Stabilization

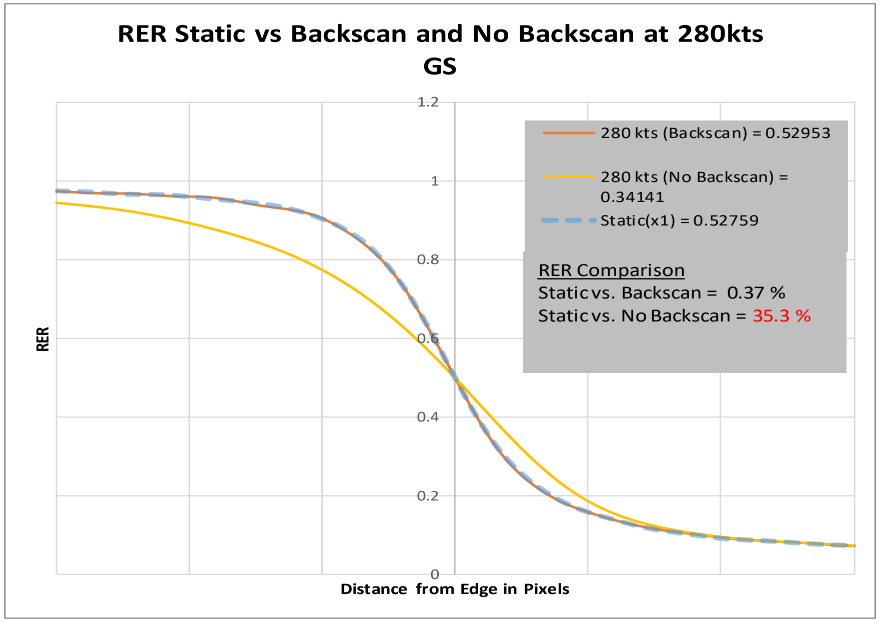
Pictoral Example of Piezo Stage Image Stabilization



For illustration Purposes. Without Piezo Stage, Image would Move ~4pixels per Frame in Airborne Instrument

Lab Demo Shows Piezo Backscan Works

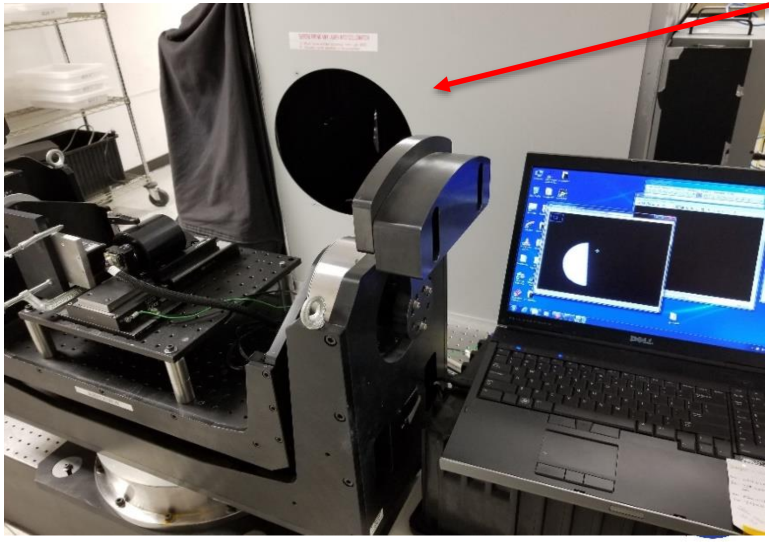




2deg FOV Collimator projecting a slanted edge for measuring RER

Rotary Stage moves in yaw (CCW) to simulate aircraft forward velocity

Control Loop measures yaw velocity and commands backscan of piezo at appropriate velocity to desmear image

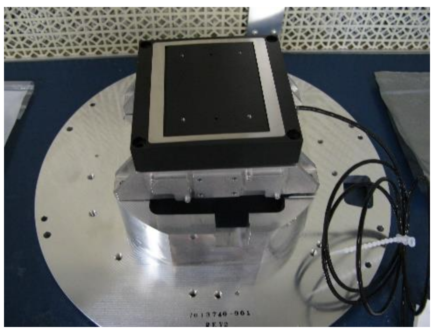


PC/Frame Grabber collects multiple stabilized frames for stacking

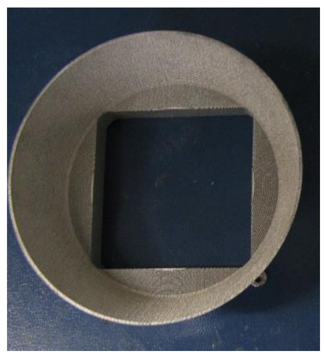
DRS Patent Pending for Piezo Stabilization

Program Status: Where we are Today

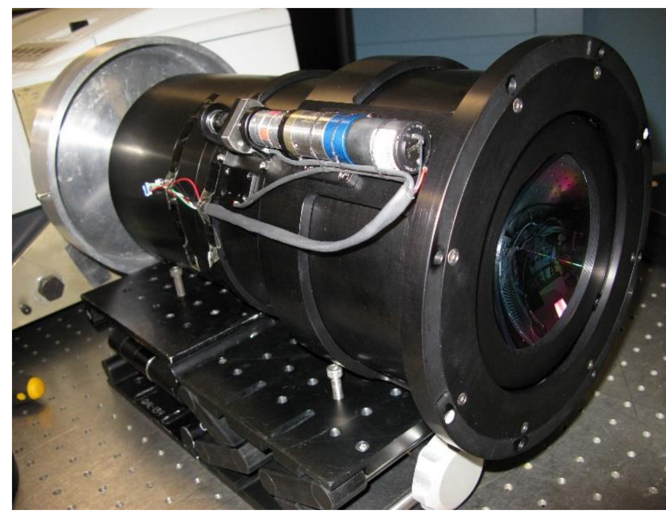
- DRS has completed the MURI Radiometer Instrument design (Year 1)
- With lab testing, DRS has demonstrated that the piezo backscan approach works and can provide a constant velocity to match the anticipated aircraft velocity
- We are in Year 2 and are receiving the instrument hardware from suppliers and are starting instrument Assembly; Sensor software is being completed
- In Year 3, we will complete instrument integration and laboratory testing followed by field testing on an airborne platform



Piezo Stage Assembly

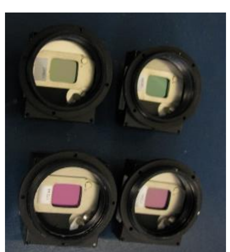


Thermal Radiation Shield

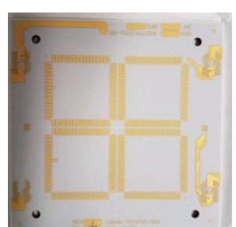


f/1, 120mm EFL LWIR Lens Assembly w/ Motor Focus

Piezo Controller



4 LWIR UFPAs & Camera Electronics



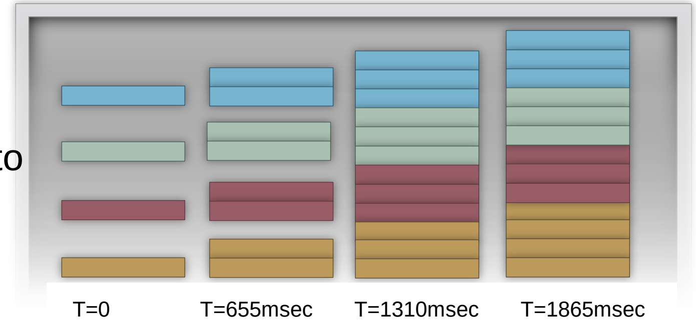
CMLB Bias Board

MURI Aircraft Demo For Earth Science Applications

The collection sequence consists of:

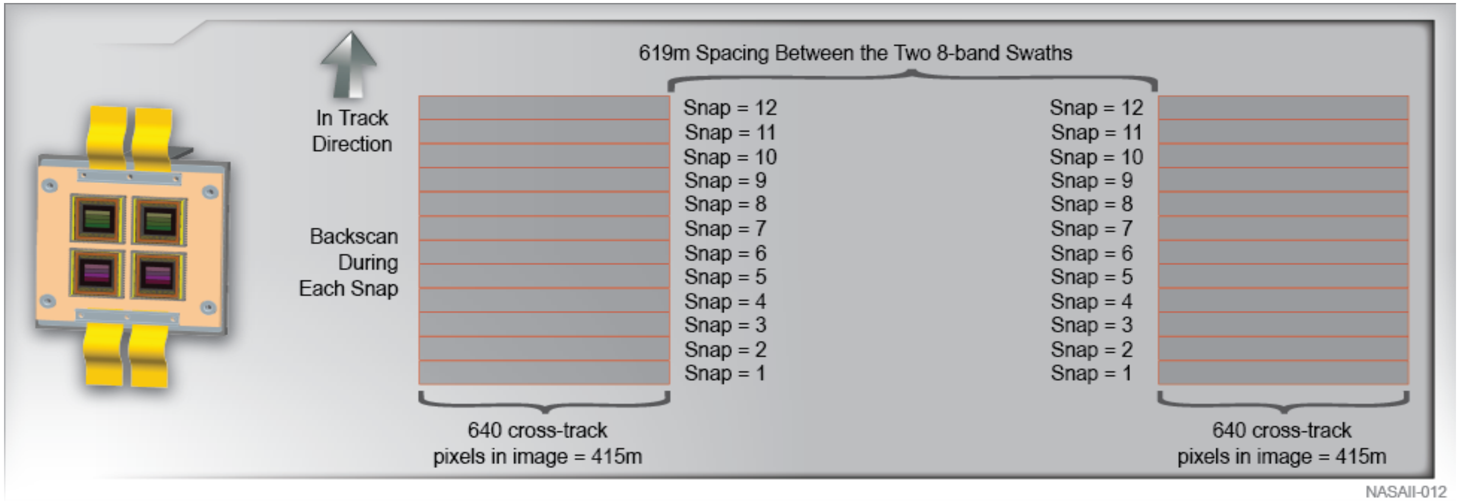
- Twin Otter aircraft typically flies at 15000ft and 120-150kts
- Collection during piezo-backscan
- Piezo returns to nadir position
- Aircraft motion carries nadir pointing LOS to next image position (with some overlap)
- This gives us a maximum of 6 colors with existing packaging

Only 4 bands shown for this illustration



Demonstration Data Collection In 6 LWIR Wavebands

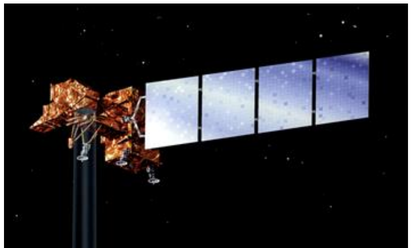
MURI Detector layout



MURI Sensor has 0.65m GSD @ 15,000 ft Altitude
IFOV is Equivalent to 100m GSD at 705Km Landsat Orbit

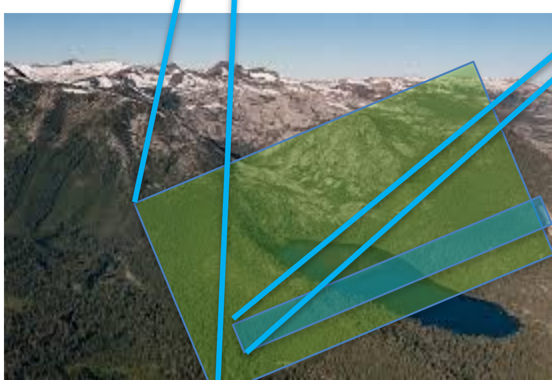
MURI CONOPS

MURI is an airborne instrument demonstration of a potential replacement of the Landsat TIRS Instrument.
It will be demonstrated against several Earth Science applications and its radiometric accuracy will be assessed by comparison to a coincident Landsat 8 overfly of a reference location such as Lake Tahoe



Landsat 8

MURI Mounted in
Twin Otter Aircraft



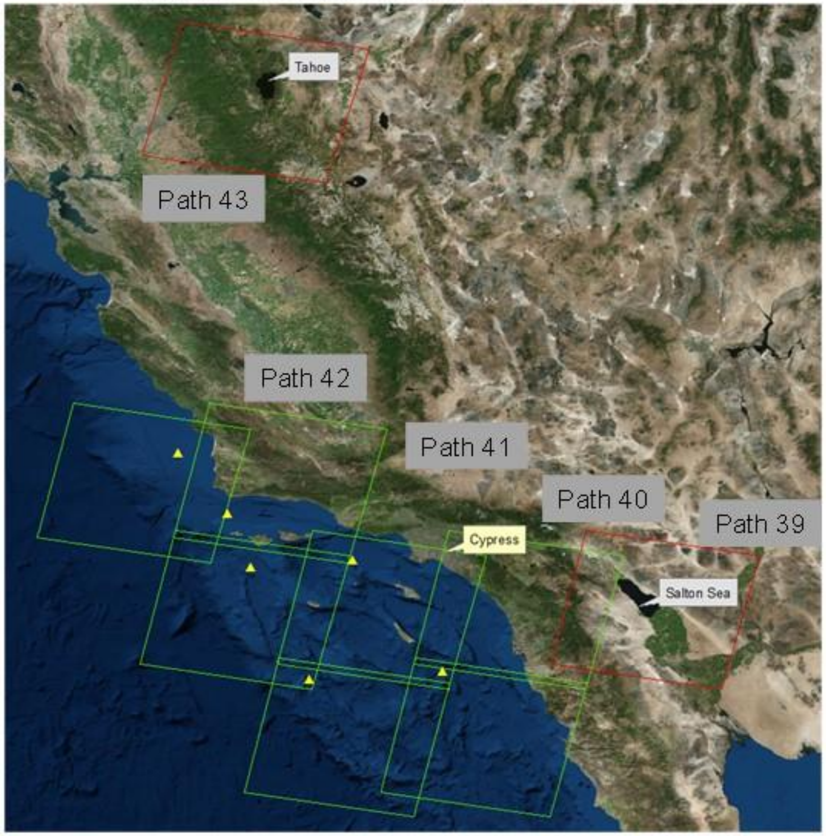
Lake Tahoe

California Central Valley

Calibrated Buoys off California Coast

2. Methane and Open Ocean Landsat Overpass

- Larger Thermal Targets for Landsat TIRS bands
- Image likely methane release sites



NOAA Buoy
RIT Cal Scene
JPL Cal Scene

Calibration and Comparison
-L8 TIRS
-MURI bands 10.9, 12.05
Large water bodies
stable temperature and known emissivity

Summer 2019 overpass dates

Path 42	Path 41	Path 40
4/3	4/12	4/5
4/19	4/28	4/21
5/5	5/14	5/7
5/21	5/30	5/23
6/6	6/15	6/8
6/22	7/1	6/24
7/8	7/17	7/10
7/24	8/2	7/26
8/9	8/18	8/11
8/25	9/3	8/27
9/10	9/19	9/12
9/26	10/5	9/28
10/12	10/21	10/14
10/28		10/30

3 Major Challenges Being Addressed on DRS' IIP MURI Program Using Microbolometers for Earth Imaging from Low Earth Orbit

Issue #1: Long time constant of microbolometers (typically ~ 12msec) make them susceptible to image smear when imaging from LEO satellites travelling @ ~7km/sec or aircraft flying at 125 Knots

Solution #1: Implement piezo backscan of FPA to precisely match the image velocity on the FPA and hence stabilize image (i.e. eliminate image smear)

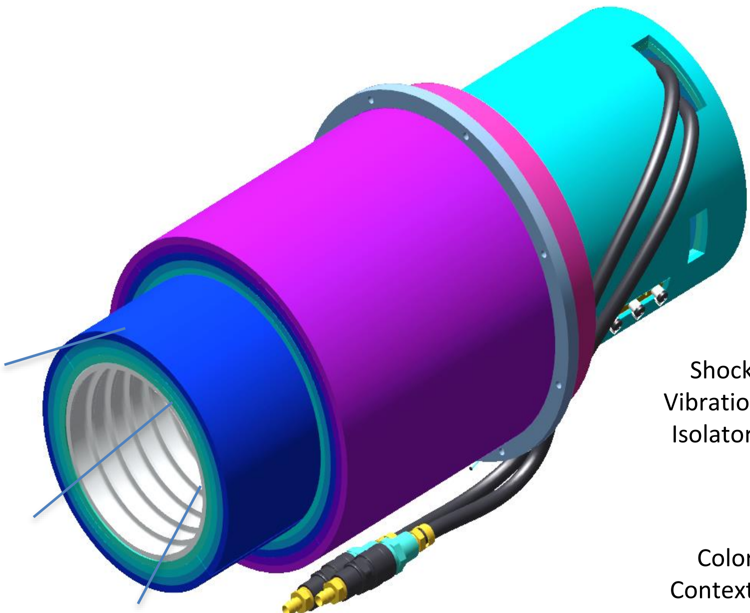
Issue #2: NETD of bolometers are significantly degraded when used with the narrow spectral band filters typically used for multi-band earth imaging

Solution # 2: Maintain use of f/1 optics, fabricate bolometers with an even longer time constant (~20msec) to get a 40% improvement in NETD and then frame stack 14 frames to improve NETD another sqrt(14)= ~3.7X

Issue #3: Bolometers' output signal are sensitive to temperature of objects in the scene but also their surrounding environment temperature (lens temp, camera housing temp, etc.) make achieving a radiometric accuracy of < 2% challenging.

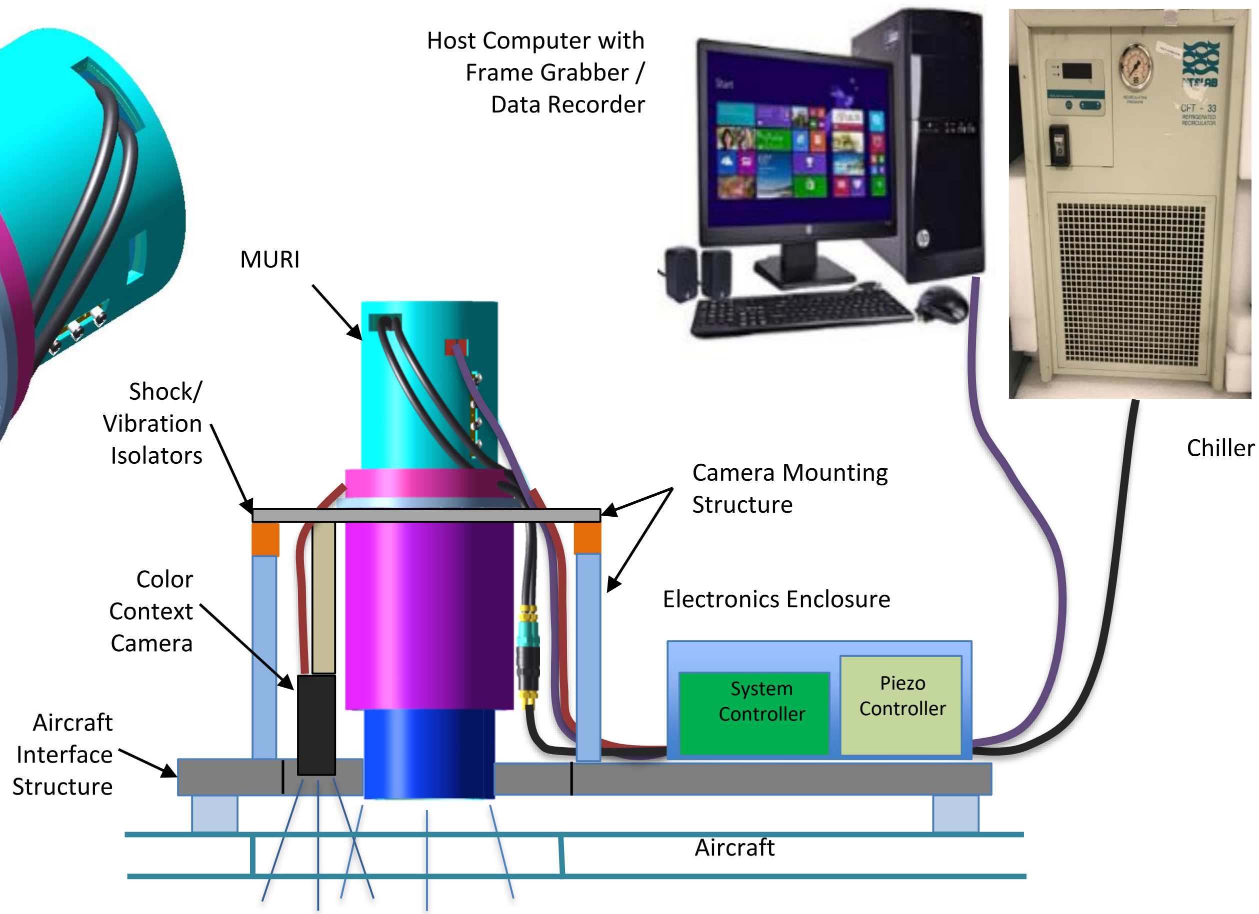
Solution #3: Stabilize and control the lens and focal plane assembly temperatures, and utilize DRS' proprietary TCOMP algorithms which perform a radiometric correction to the data from a laboratory calibration which accounts for FPA and lens temperature in a polynomial correction.

Overall MURI System Architecture



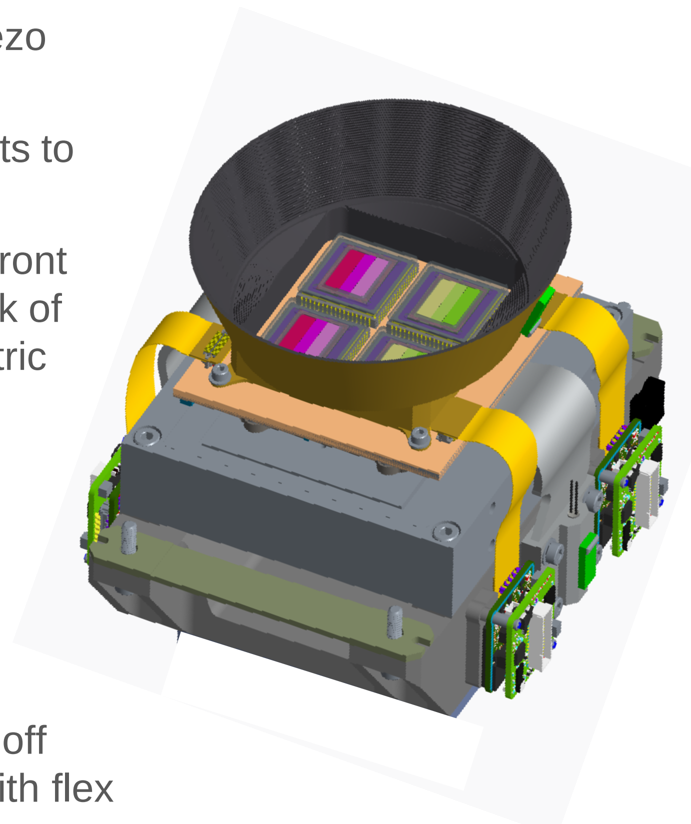
Multi-Band Uncooled Radiometer Imager (MURI)

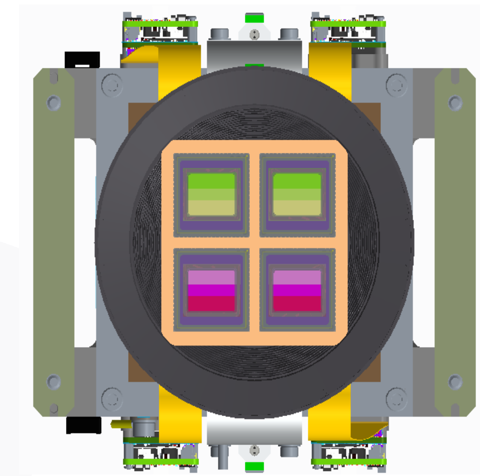
MURI Bench Test and Flight System Configuration

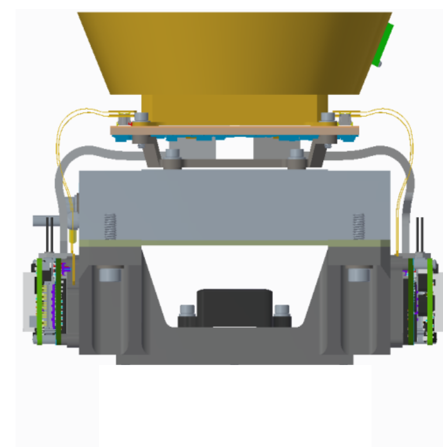


UFPAs / Piezo / Piezo Mount Subassembly

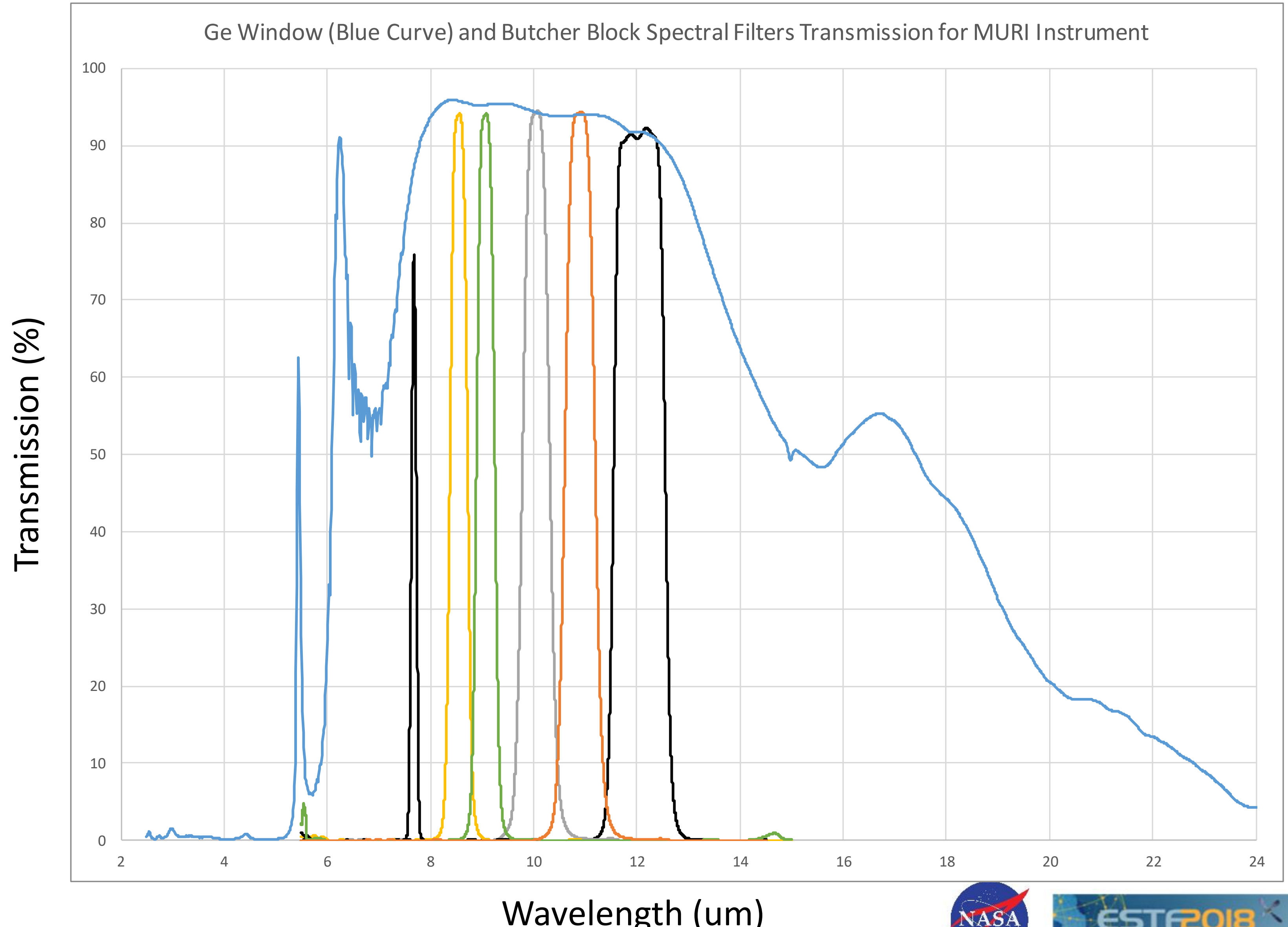
- Precision assembly alignments made with DRS precision alignment equipment and/or CMM, and tooling
  - Piezo stage is centered to piezo mount
  - UFPA/CMLB assembly mounts to piezo stage
  - Radiation shield mounted to front and thermal straps to the back of CMLB, help achieve radiometric accuracy
    - Radiation shield helps to control incident flux
    - Thermal Straps and heater help control UFPA temperature
  - Camera electronics mounted off piezo stage and connected with flex cables
- 4 UFPAs (each with a butcher block filter in front of it) mounted with precision machined shims and optimized epoxy thickness for final planarity adjustment to lens image plane





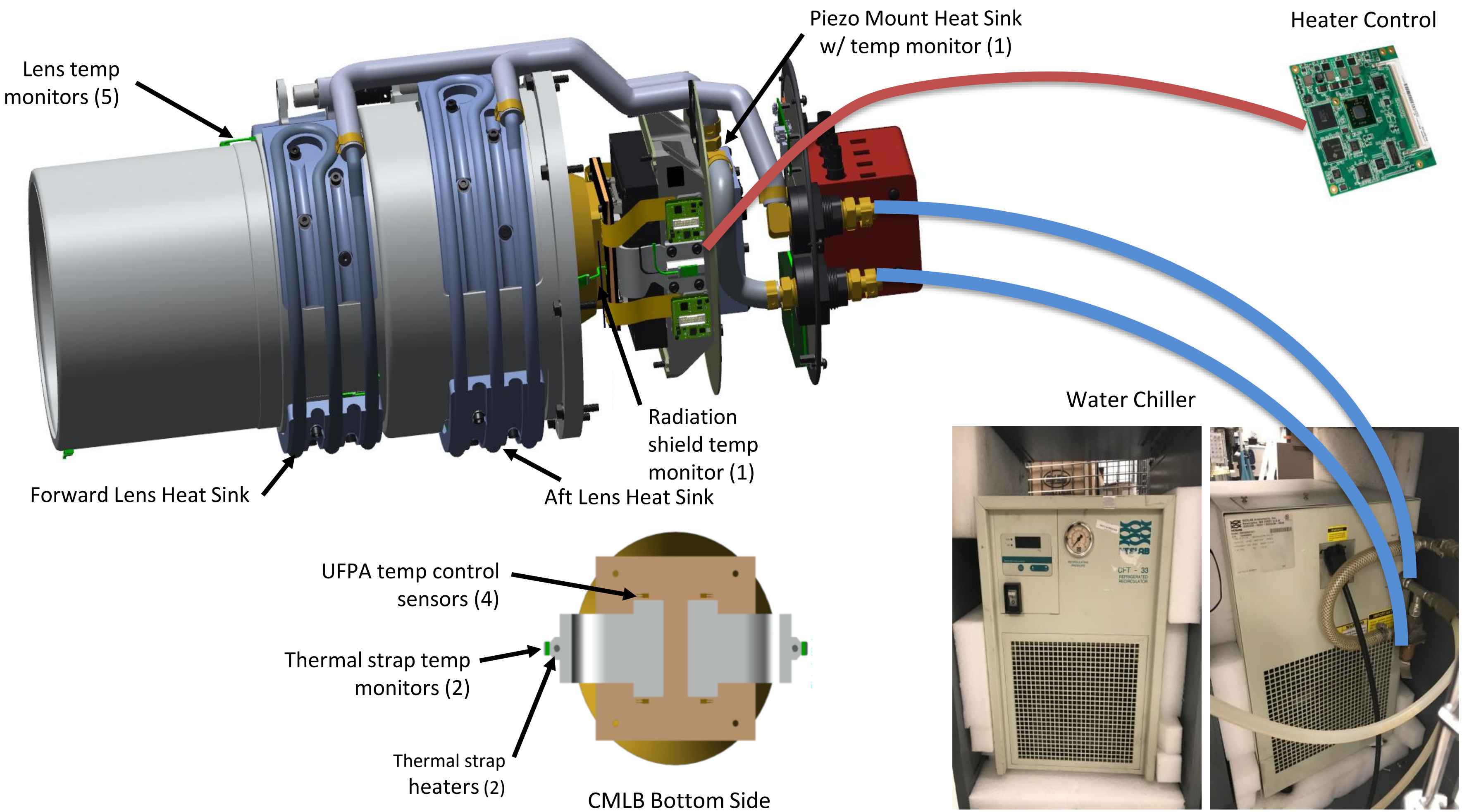


UFPA Package Ge Window and MURI Spectral Filters



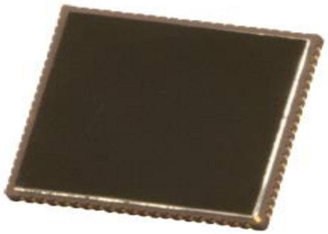
Thermal Control and Monitoring

Thermal Control and Monitoring is Critical to Achieve Desired Radiometric Accuracy. DRS will also Employ TCOMP Algorithms for the Necessary Radiometric Precision.

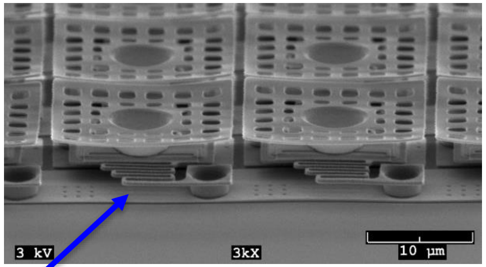


U6160 640x480 UFPA Tailored for MURI

- U6160 640x480 UFPA is in production at DRS
- For MURI thermal time constant is being tailored (lengthened to 20msec) to improve NETD for narrow band operation
- Spectral response adequately covers the spectrum for MURI, but can be extended into the MWIR with a customized AR coated window (Bolometer response with Si window shown below)
- Projected instrument level NETD @300K of <100mK and <60mK projected for LANDSAT TIRS 1 (CWL=10.9um) & TIRS 2 (CWL = 12.05um) bands respectively

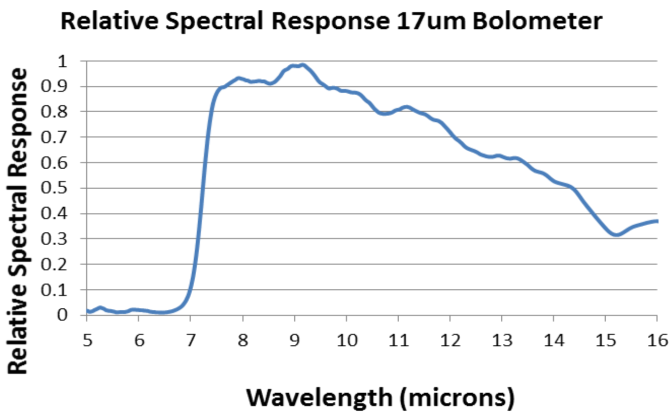


640x480 U6160 Microbolometer Array Package



SEM of 17um Bolometer Pixel

Aspect Ratio of Bolometer's
Serpentine Legs
Determine Time Constant



MURI IIP Program Summary

- All Hardware is On Order for MURI Radiometer Integration
- DRS has received some Hardware and is Making Progress on Integration of Radiometer
- Incremental Testing of Instrument Will Take Place as we wait on Delivery of Longest Lead Items (i.e. Butcher Block Filters) which are due in 4th Qtr of 2018; Final Instrument Checkout & Calibration in Q1 & Q2 2019
- Making Arrangements for Twin Otter Flight Testing in Summer/Fall of 2019
- On Track for Successful Demonstration of MURI Instrument for Earth Science Applications in 2019

DRS Thanks NASA ESTO for the Opportunity to Build and Demonstrate a Prototype Uncooled Multi Band Radiometer Imager for Future Earth Imaging Applications