

Teledyne's DESIS Spectrometer on the ISS-based MUSES Platform

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Multi-User System for Earth Sensing (MUSES)

- ▶ MUSES Platform launches to the ISS on SpaceX-11, Q1 2017
- ▶ Inertially stabilized, 2-axis gimbal for pointing and Earth surface target tracking
- ▶ Robotically installed on EXPRESS Logistics Carrier (ELC) 4
- ▶ Hosts up to 4 robotically installed instruments
- ▶ Instruments launched in “soft stowage”
- ▶ Total data downlink ~225 GB/day
- ▶ Teledyne owns the platform, determines pointing schedules, and retains data rights in cooperation with partners



Major Agreements, Partnerships, and Teaming

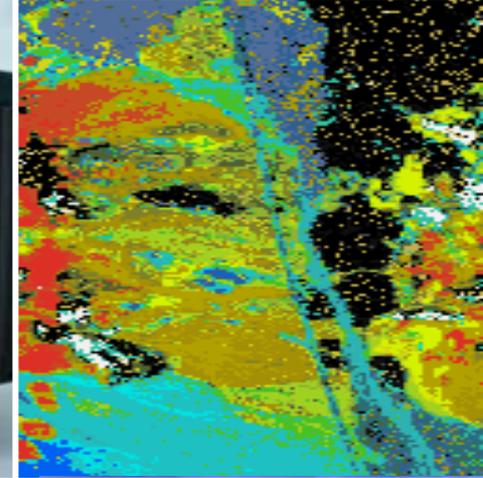
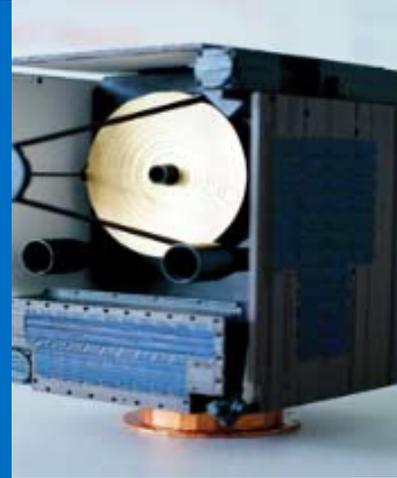
Name	Type	Summary
	Enabling, Science	<ul style="list-style-type: none"> Cooperative Agreement (NNJ12GA21A) with the ISS Program Office for MUSES \$15M data purchase agreement POC: Steve Neeck, steven.neeck@nasa.gov, (202) 358-0832
NOAA	Enabling	<ul style="list-style-type: none"> License to Operate a Private Remote Sensing Space System
	Enabling, Science, Humanitarian	<p>Implementing agreement for the DLR Earth Sensing Imaging Spectrometer (DESIS)</p> <ul style="list-style-type: none"> Covers the design, development, and operation of the DESIS instrument Provision of imagery to DLR for scientific and humanitarian purposes Bi-lateral cooperation and sharing of all DESIS calibration data TBE licensing of DESIS image processing algorithms and software
UNESCO	Humanitarian	<ul style="list-style-type: none"> Provision of imagery for world heritage site monitoring
SERVIR	Humanitarian	<ul style="list-style-type: none"> Provision of imagery to aid developing countries manage climate risks and land use
	Science	<p>Alabama Remote Sensing Consortium (ARSC)</p> <ul style="list-style-type: none"> UA Huntsville, Alabama A&M University, Auburn University Provision of imagery for research & instruction ARSC will support periodic vicarious calibration activities
	Commercial	<ul style="list-style-type: none"> Cloud-based image processing and archive distribution systems
	Commercial	<ul style="list-style-type: none"> Calibration planning & execution Image processing independent QA/QC



Teledyne MUSES Commercial Products/Services

▶ Turn-Key Instrument Missions

- Development, integration, and operations.
- TRL maturation, prove-out of instrument design, early data products prior to free-flyer missions.



▶ Commercial Data Sales

- Archive, tasking, subscription
- From one image to the whole data pipeline
- Non-exclusive and limited exclusivity options



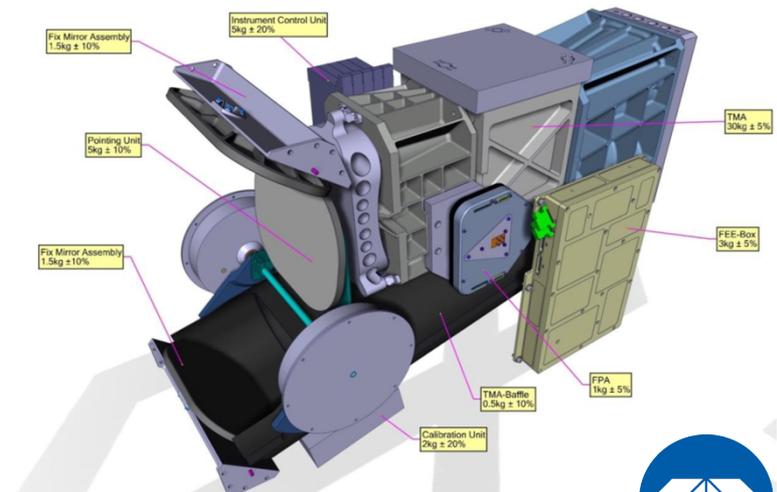
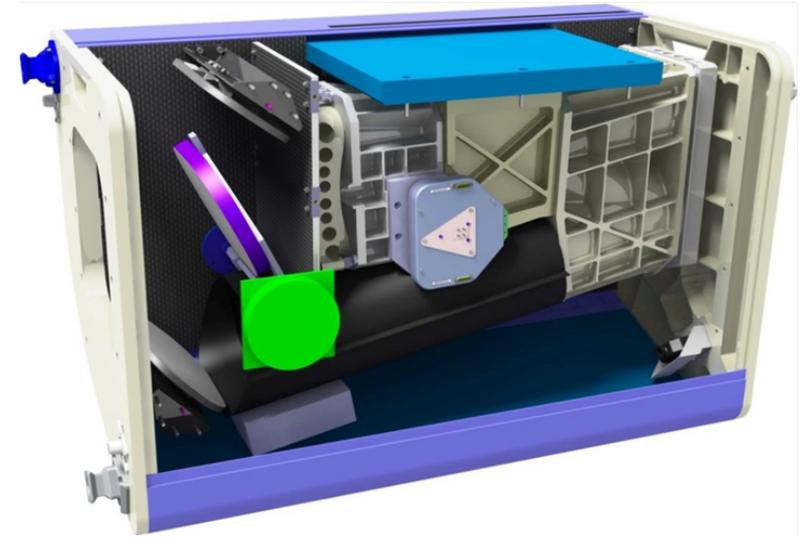
▶ Analytics and Decision Information Products

- Commercial, scientific, humanitarian value
- Collaborative Research and Development
- Partnership and mutually-beneficial capacity building, to address new markets and new opportunities



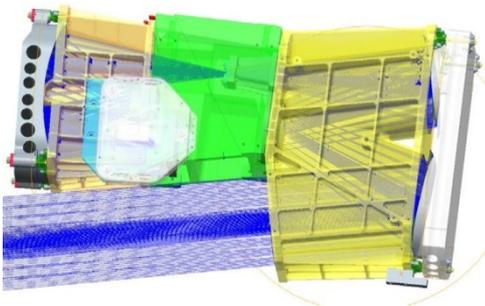
Teledyne & DLR Partnership

- ▶ Teledyne and DLR have partnered to build, integrate, & operate the DLR Earth Sensing Imaging Spectrometer (DESIS) from the Teledyne-owned MUSES Platform on the ISS
- ▶ The DESIS Instrument will be used to
 - Enable scientific RESEARCH
 - Expand HUMANITARIAN response
 - Provide COMMERCIAL value



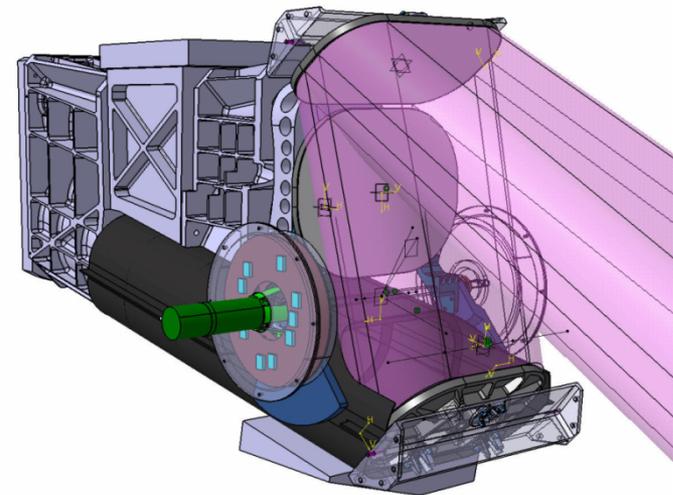
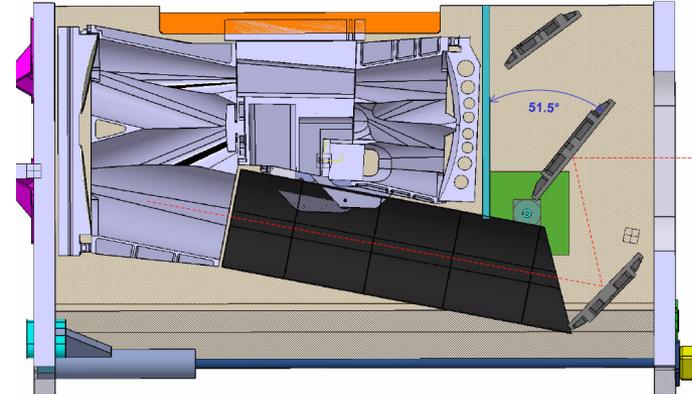
DLR Earth Sensing Imaging Spectrometer (DESI)

- ▶ Partnership between Teledyne and DLR
- ▶ Teledyne is responsible for payload integration and operations
- ▶ Teledyne retains rights for commercial use
- ▶ DLR retains rights for scientific use
- ▶ Launch planned for Q2, 2017



Parameter	Value
Focal length	320 mm, telecentric
F#	2.8
Field of view	4.4 °
Pixel IFOV	0.0043 °
GSD @ Nadir	30 m @ 400 km
Swath @ Nadir	30 km @ 400 km
Spectral Range	400 nm to 1000 nm
Spectral Channels	235 channels @ 2.55 nm
Spatial Pixels	1024
Radiometric Linearity	> 95% (10%-90% FWC)
MTF @ Nyquist (no smearing)	< 3 nm
Independent Pointing	± 15° along track
Pixel Size	24 x 24 μm
FPA Size	1056 (spatial) x 256 (spectral)
Pixel Quantization	12 bits
Design Lifetime	5 years
Operational Mode	Pushbroom
Instrument Developer	DLR Adlershof/Berlin

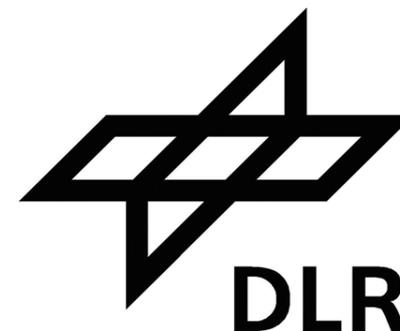
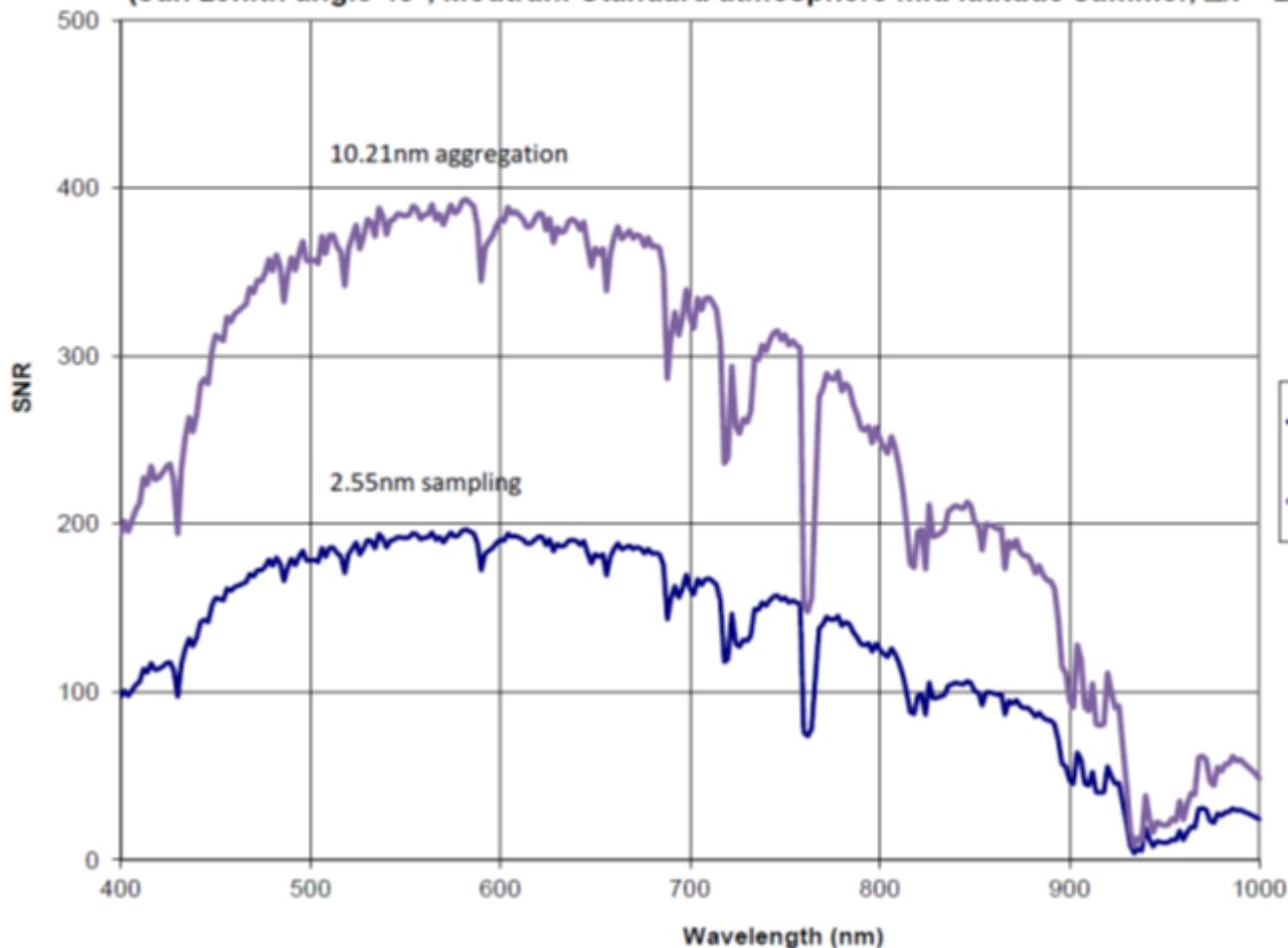
- ▶ Closes light path for DNSU & PRNU calibration
- ▶ Redirects the light path $\pm 15^\circ$ in the along-track direction
- ▶ Allows acquisition of up to 3 image tiles under different angles: $+15^\circ$, 0° , -15°



DESIS Signal to Noise (SNR)

10.06.2015

DESIS : Offner with TMA, Ag mirror, CIS2001 (BAE), trapeze grating: SNR
(sun zenith angle 45°, Modtran: Standard atmosphere mid latitude summer, $\Delta\lambda = 2\text{nm} / \text{H. Witt}$)

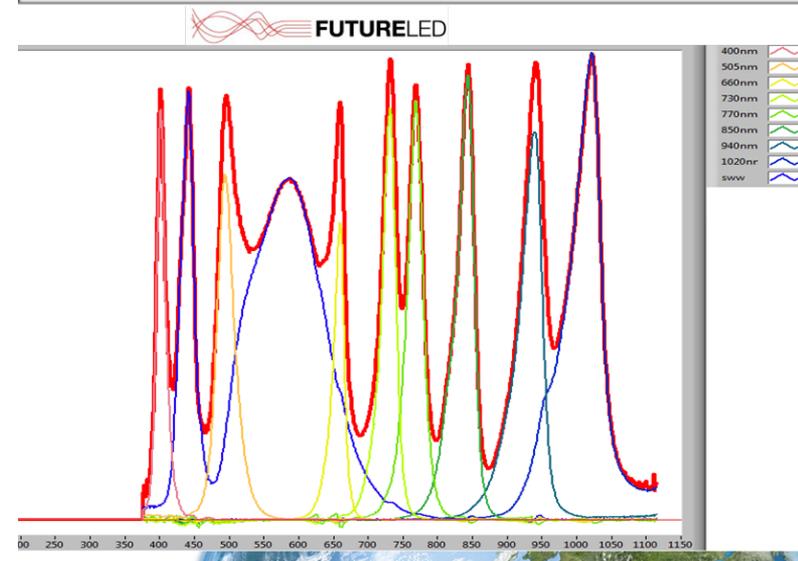
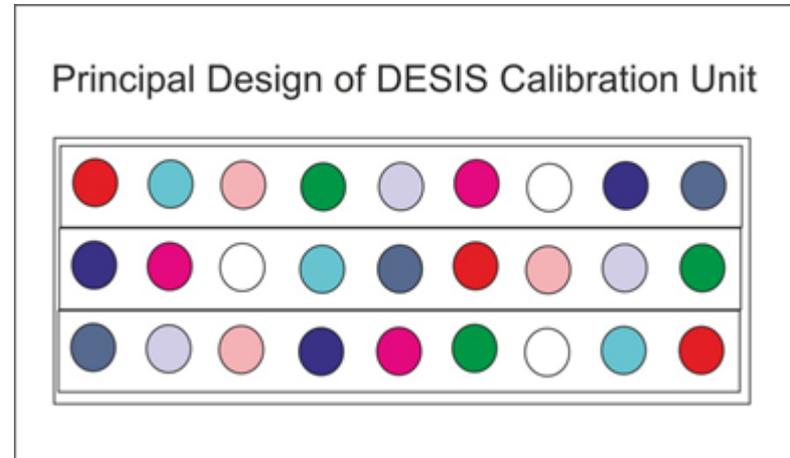


SNR for 2.55 nm sampling distance and spectral binning by factor 4



DESIS Calibration

- ▶ **Rigorous pre-launch geometric & radiometric calibration**
- ▶ **On-board calibration unit**
 - DSNU calibration before/after each collected scene
 - Periodic PRNU calibration
 - Geometry Calibration using Single LEDs
- ▶ **Vicarious Calibration**
 - Planned every 30 – 60 days
 - CEOS sites, RadCalNet autonomous instrumented sites
 - Spectral diversity using ARSC research fields and forests



DESIS Mission

Enable Scientific Research

- ▶ Basic Research
 - Spectral unmixing
 - De-noising
 - classification
 - Geophysical parameters
 - Fusion
- ▶ Applied Research
 - Environ. Monitoring
 - Soil degradation
 - Vegetation monitoring
 - Inland water quality
- ▶ Academic Research
 - Alabama Remote Sensing Consortium (ARSC)

Expand Humanitarian Response

- ▶ Support the International Disaster Charter – Teledyne & DLR
- ▶ Environmental monitoring of refugee camps
- ▶ Change detection
- ▶ Habitat monitoring
- ▶ Flood area mapping & characterization
- ▶ World heritage site monitoring (UNESCO)
- ▶ Aid to developing countries (SERVIR)

Provide Commercial Value

- ▶ Commercial source of moderate spatial, high spectral resolution data
 - On-demand tasking
 - Archive data
 - Direct & VAR/VAS channels
- ▶ Registered & cross-calibrated with Landsat 8
- ▶ Analytic Products
 - Commercial agriculture & forestry
 - Ocean & inland water quality assessments
 - Multi-sensor fusion products



Current MUSES/DESI Status

▶ MUSES

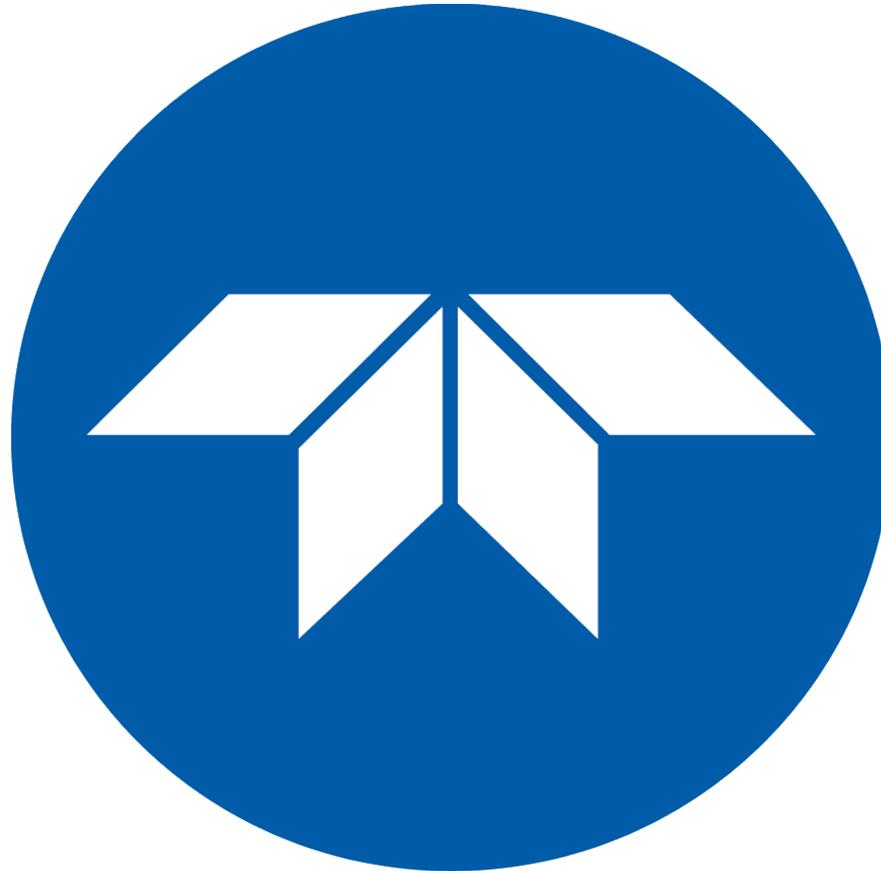
- Final closeout of pre-launch verifications
- Performing ground testing and performance characterizations
- Manifested for launch on SpaceX-11
- Expect SpaceX-11 launch by Q1, 2017

▶ DESIS

- Critical Design Review in Berlin, 27-29 June, 2016
- Planned launch in Q2, 2017

▶ Commission MUSES and DESIS during Q2-Q3, 2017





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