

Imaging Spectroscopy Applications Using the DESIS Hyperspectral Instrument on MUSES

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Ray Perkins¹, Rupert Mueller², Emiliano Carmona², Robert Griffin³, Randy Miller¹

¹Teledyne Brown Engineering, ²DLR, ³ARSC

Introduction

- ▶ Teledyne and DLR have partnered to build and operate the DLR Earth Sensing Imaging Spectrometer (DESI) 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



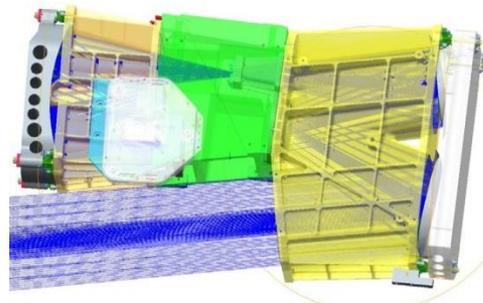
DLR Earth Sensing Imaging Spectrometer (DEISIS-30)

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

Parameter	Value
Focal length	320 mm, telecentric
F#	2.8
Field of view	4.4 °
Pixel IFOV	0.004 °
GSD @ Nadir	30 m @ 400 km
Swath @ Nadir	30 km @ 400 km
Spectral Channels	235 measured
Spatial Pixels	1024
SNR	205:1 sampled at 2.55 nm @ 550 nm 406:1 binned to 10.2 nm @ 550 nm
Radiometric Linearity	> 95% (10%-90% FWC)
MTF @ Nyquist (no smearing)	< 3 nm
Instrument 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



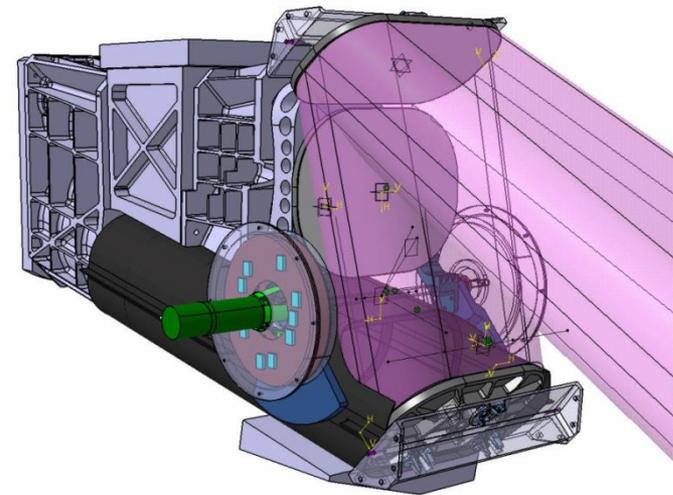
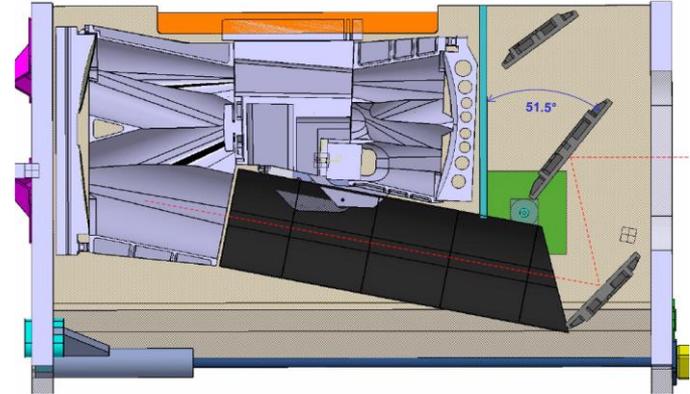
DLR



DESIS Pointing Unit



- ▶ Changes sight $\pm 15^\circ$ in the along-track direction
- ▶ Allows acquisition of up to 3 image tiles under different angles
- ▶ ES-Mode
 - 11 measurement positions $\pm 15^\circ$ (every 3°)
 - Repeatability / accuracy 20 arc minutes
 - Target replacement time ≤ 0.5 seconds
- ▶ FMC-Mode
 - Speed 0.6 deg/sec and 1.5 deg/sec
 - Accuracy 0.06 degrees (1/10 GSD)
 - Range of rotation $\pm 15^\circ$



- ▶ Spectral unmixing techniques (linear & non-linear methods)
- ▶ De-noising techniques (especially at wavelengths close to 400 nm for water applications)
- ▶ Improvements of hyperspectral data classification methods (deep learning, compressive sensing / sparse reconstruction, synergetics)
- ▶ Derivation of geophysical parameters employing bidirectional reflectances
- ▶ Fusion of hyperspectral (DESI) and multispectral (WV-2/3, Sentinel-2,...) for resolution enhancement keeping the spectral integrity (*not only pan-sharpening*)

see next slide (based on *Joint Sparsity Model for Multilook Hyperspectral Image Unmixing*)

- ▶ *and many more...*



Example

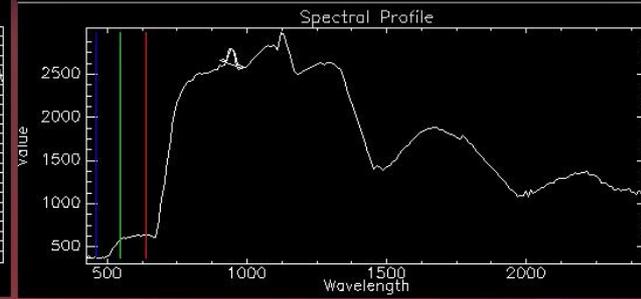
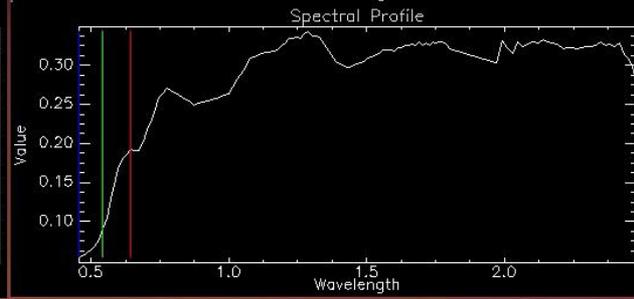
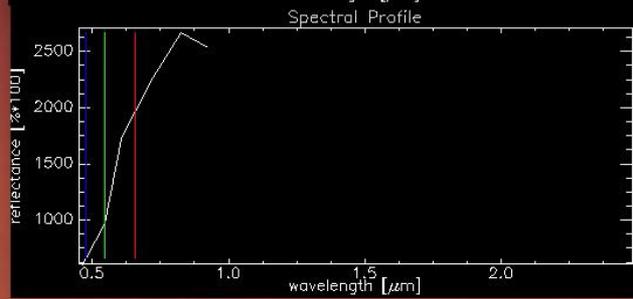
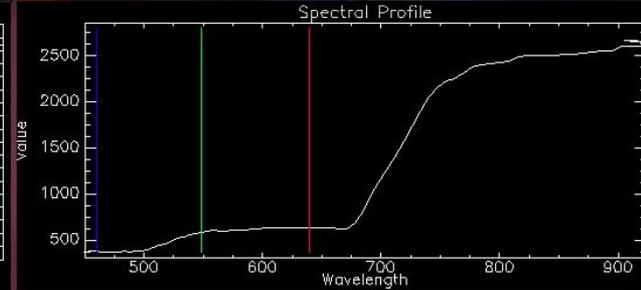
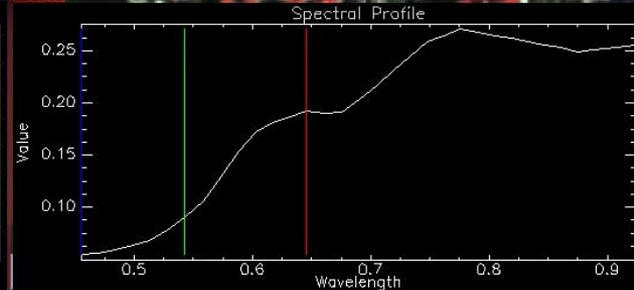
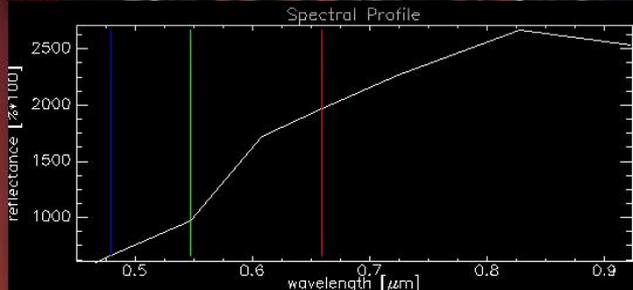
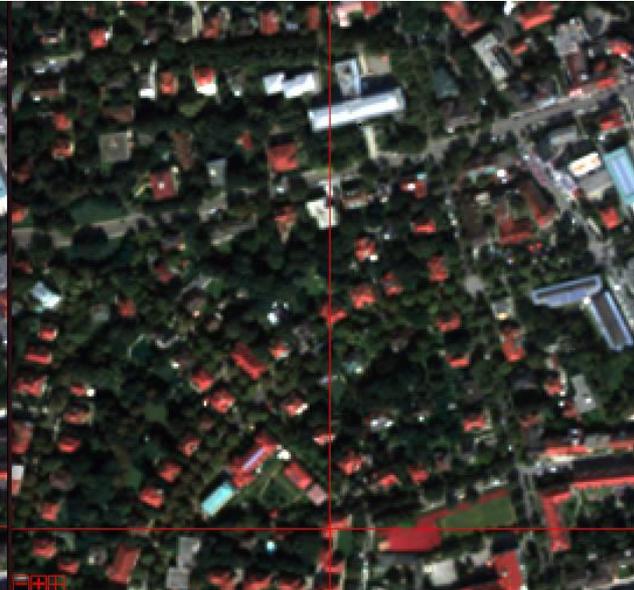
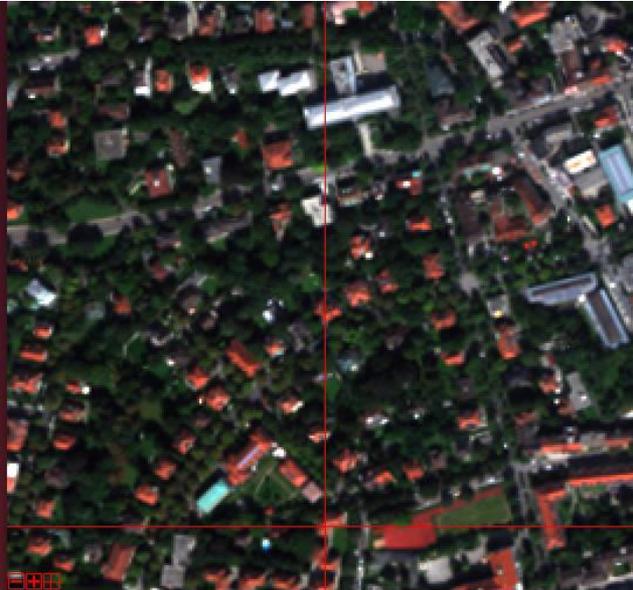
Fusion of Multispectral and Hyperspectral Data



WV-2 (~2 m, MS 8 bands)

Fusion

DESIS (30 m, HSI)

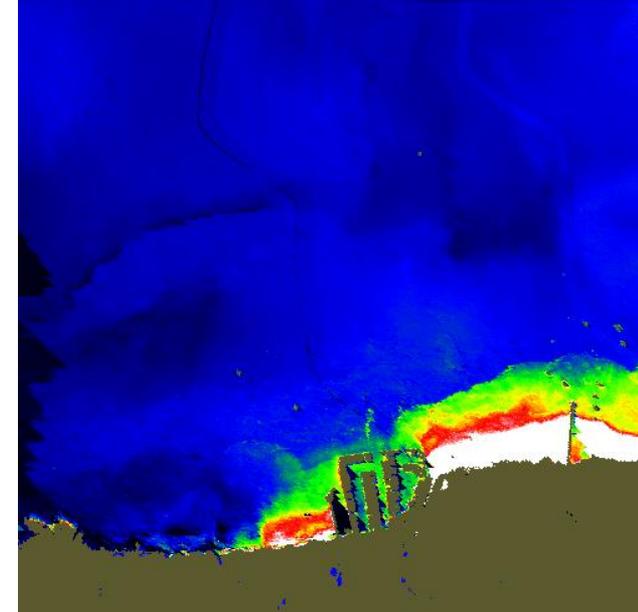
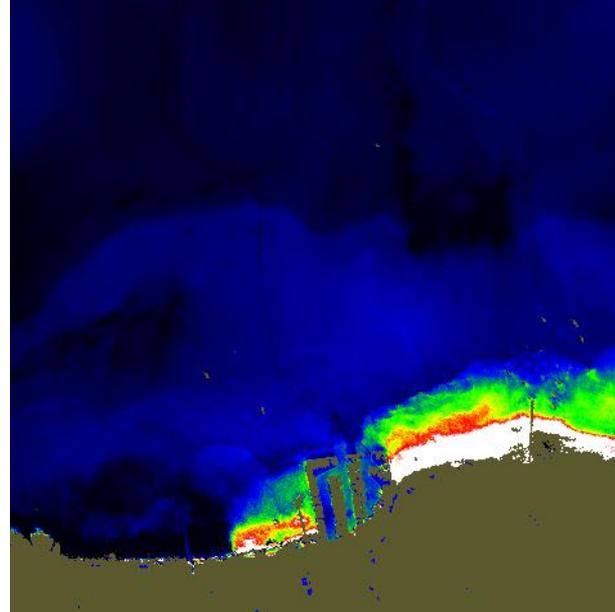


Example Denoising of Hyperspectral Data (HySpex)



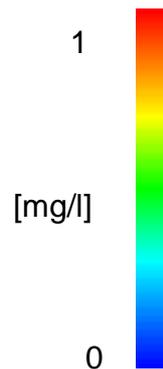
Before Denoising

After Denoising



Starnberger See,
Germany

Noisy & 'clean' bands



Absorption Estimation (WASI Tool) of
Coloured Dissolved Organic Matter

(Error in model fit drops down 50% after denoising)



DESI Data Utilization (2)

Application Oriented Applications



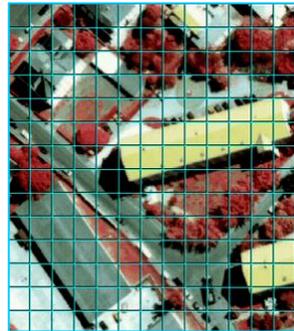
- ▶ Mid- and long-term environmental monitoring of mining resource districts (environmental acidification, monitoring, restoration assessment)
- ▶ Soil degradation (indicators, pollution, salinization)
- ▶ Vegetation monitoring (stress parameters, monitoring)
- ▶ Inland waters (chlorophyll, pollution, bathymetry, water content models)



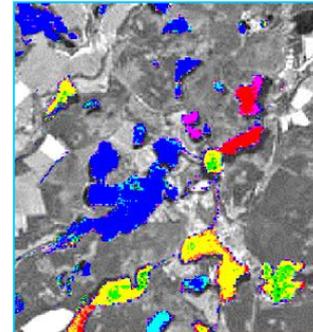
management of agricultural and forest ecosystems



hazard assessment



urban development



inland water



dryland degradation



- ▶ Analysis for the utilisation of HSI data for rapid provision, processing and analysis of satellite imagery during natural and environmental disasters, for humanitarian relief activities and civil security issues worldwide
- ▶ Development of algorithms (mapping of damages before/after e.g. floodings, natural resources, change detection, burned areas,...)
- ▶ Operational service also in the context of the International Charter 'Space and Major Disasters'



Example Natural Disasters and Humanitarian Aid

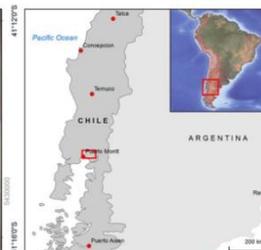
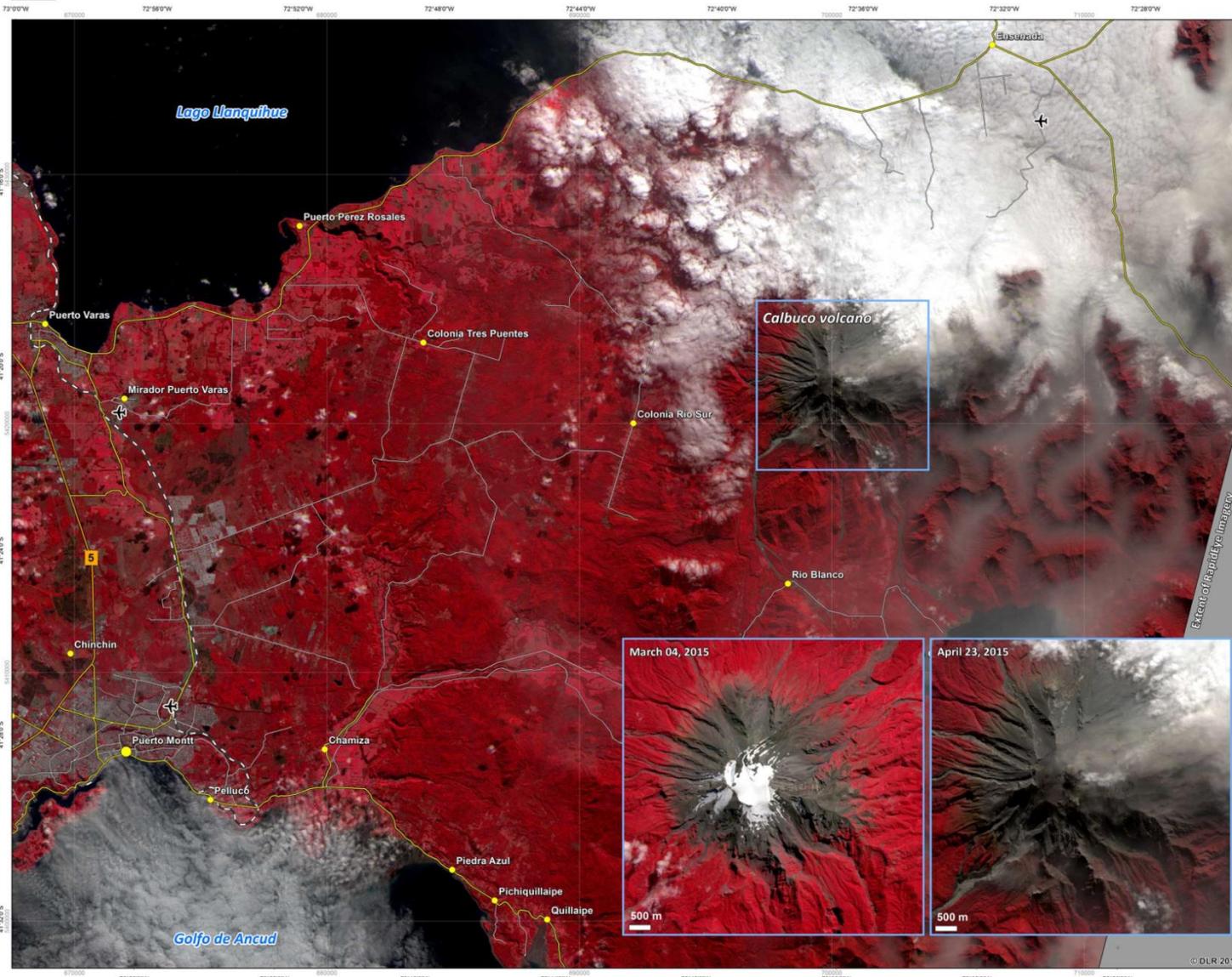


CHILE - Calbuco volcano eruption

Situation as of April 23, 2015 - Overview Map

1:70,000

Charter Call 528
Product No. 01
Version No. 01



Legend

Infrastructure

- City
- Town / Village
- Airport
- Highway
- Primary road
- Secondary road / Track
- Railway

Interpretation

The map shows the Calbuco volcano in southern Chile and its surroundings. The volcano erupted on April 22, 2015 for the first time in over 42 years sending a plume of ash up to an altitude of about 10 km into the sky. A second eruption occurred seven hours later on the following morning and early reports indicate that it was on the same scale as the first one. The event triggered a Red Alert in the Los Lagos Region of Chile. Thousands of people within a 20 km radius of the volcano have been evacuated.

RapidEye satellite imagery (false colour composite NIR/Red/Green, red colour indicating vegetation) acquired on April 23, 2015 (15:47 UTC) is used as backdrop. Note: The transport network is not complete. The map shows predominantly major roads.

Cartographic Information

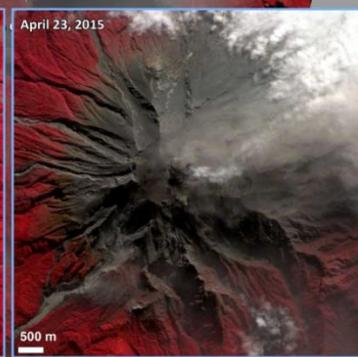
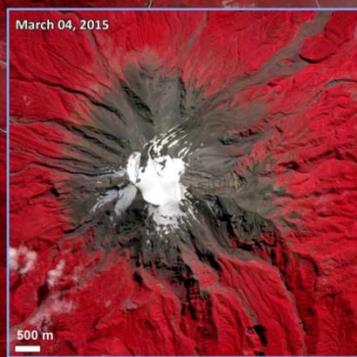
0 1 2 3 4 5 km
Local projection: UTM Zone 18S, Datum: WGS 1984
Geographic projection: Lat/Lon (DMS), Datum: WGS 84
Scale: 1:70,000 for A1 prints.

Data Sources

RapidEye (5 m) © 2015 BlackBridge AG. All rights reserved.
Vector data © OpenStreetMap contributors 2015 © DLR 2015

Framework

The products elaborated for this Rapid Mapping Activity are realised to the best of our ability, within a very short time frame, optimising the material available. All geographic information has limitations due to the scale, resolution, date and interpretation of the original source materials. No liability concerning the content of the use thereof is assumed by the producer. The ZKI crisis maps are constantly updated. Please make sure to visit <http://www.zki.dlr.de> for the latest version of this product. Map produced April 24, 2015 by ZKI © DLR 2015 zki@dlr.de <http://www.zki.dlr.de>



Extent of RapidEye imagery

© DLR 2015



ARSC Research & Instruction



- ▶ Unique research/instruction collaboration between private industry and regional educational institutions
- ▶ Data tasking for research topics as defined by member institution PIs





University of Alabama in Huntsville, Auburn University, Alabama A&M University (current member institutions)

- ▶ **Agricultural applications: plant stress, soil physics, agricultural extension applications, *precision agriculture* and integrated UAS solutions**
- ▶ ***Cubesat* simultaneous data collection, multisensor investigations**
- ▶ **Data *compression* for enhanced downlinking**
- ▶ **Natural hazards and *disaster response*: Gulf of Mexico oil spill evaluation, hydrometeorological and associated disasters**
- ▶ ***Forest* health and timber industry**
- ▶ **Integrated research and instruction (field data collection and associated *calibration activities* between TBE and ARSC member institutions) for undergraduate and graduate students**



Humanitarian Response

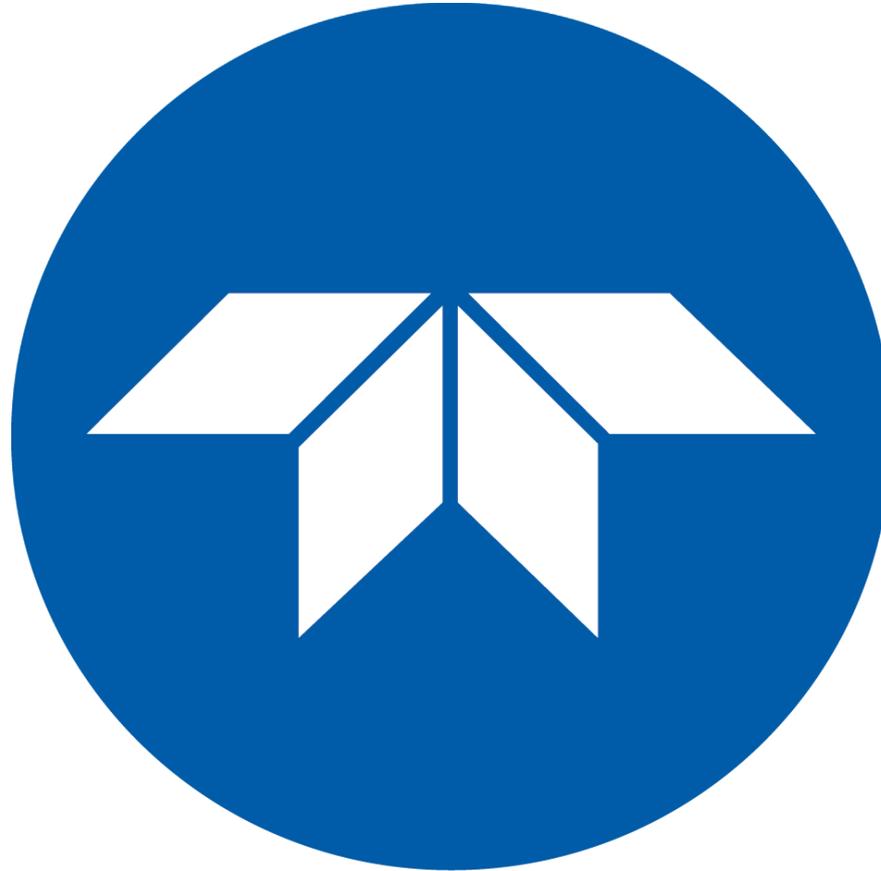
- ▶ **Environmental impact assessments of refugee camps**
- ▶ **Wetland monitoring for water shortages**
- ▶ **Change detection under near-real time conditions**
- ▶ **Vegetation mapping for habitat characterization**
- ▶ **Flood area mapping and characterization**
- ▶ **World Heritage Site monitoring**
- ▶ **Aid developing countries manage climate risks and land use**
- ▶ **International Disaster Charter support**



Commercial Value

- ▶ **Provide a commercial source of near-global, production quality, moderate spatial, high spectral resolution data**
 - On-demand tasking services
 - Hyperspectral data archive
 - Utilize both direct sales and distributor / value added reseller market access
- ▶ **Orthorectified, atmospherically corrected hyperspectral data**
 - Registered and cross-calibrated to Landsat 8
- ▶ **Hyperspectral Analytic Products for**
 - Vegetation classification
 - Crop and forest health assessments and stress indications
 - Ocean, estuary, and inland water monitoring
- ▶ **Multi-sensor Fusion Products**
 - Spatial Enhancement with Panchromatic and/or Multi-spectral data
 - Radar/Lidar Fusion
- ▶ **Migrate validated research applications into production applications**





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