

# Miniaturize hyperspectral imager for short-wave infrared (SWIR) operating on-board the Hello World- small satellite mission

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24.04.2019

CubeSat Developer Workshop, San Luis Obispo

# VTT Microspectrometers team



## Team expertise:

- MEMS process design
- Optics, electronics and mechanics design
- Assembly, testing & characterization
- Software and UI development



## Key research topics

- Space CubeSat instruments
- Environmental sensing
  - Stand-off detection
- Medical and diagnostics
- MEMS sensors for automotive, mobile and process industry
  - Gas sensors
  - Optical readers

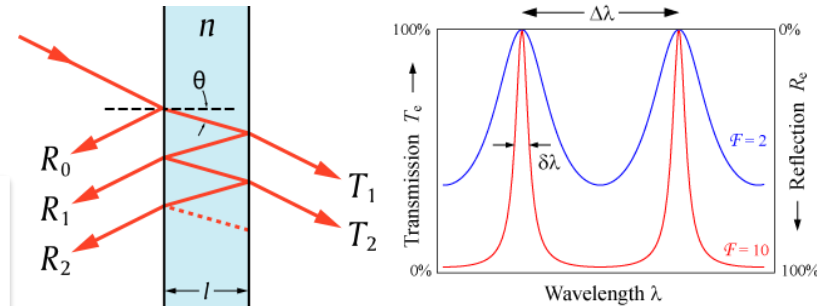
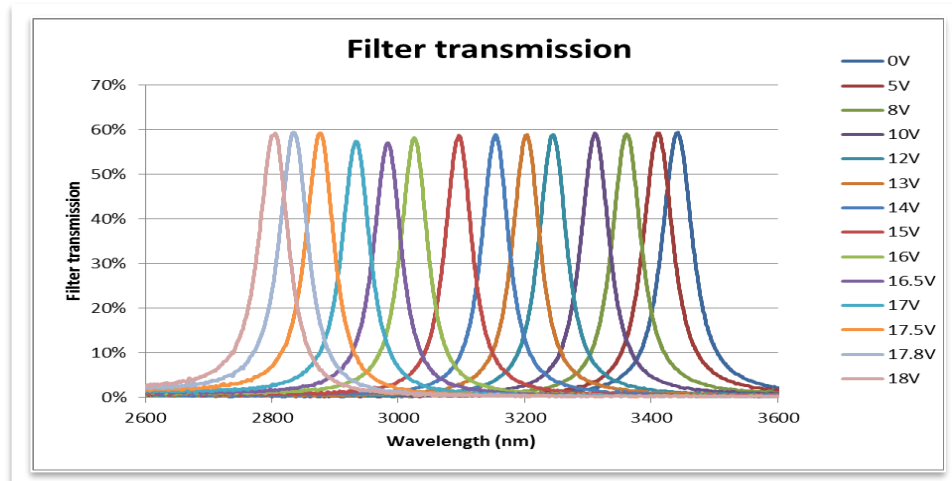


## Our offering:

- Contract R&D
- Product prototyping
- Pilot MEMS production
- IPR out-licensing and sales

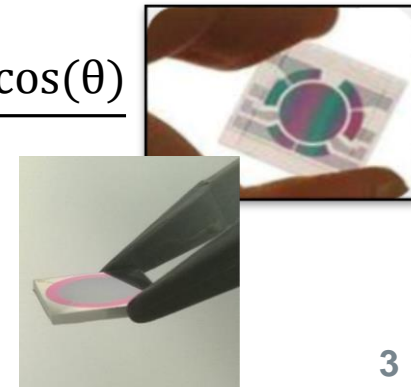
# Tunable Fabry-Perot interferometer

- Two parallel mirrors separated by a cavity
- Acts as an optical resonator
- Can be used as a tunable passband filter

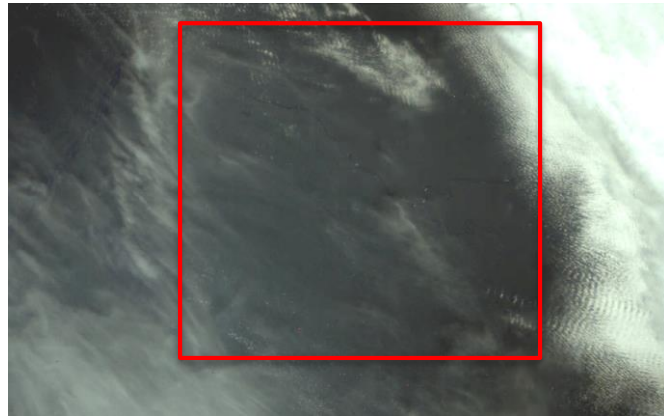


$$\lambda_n = \frac{2 * n * l * \cos(\theta)}{m}$$

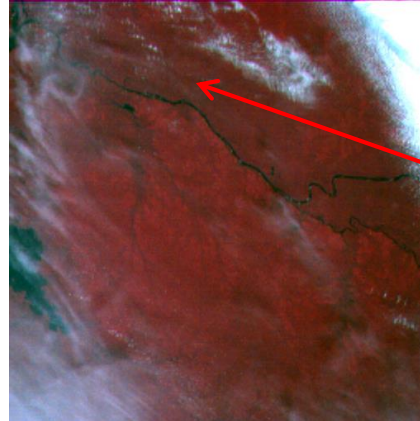
$m=1,2,3,\dots$



# Aalto-1 satellite

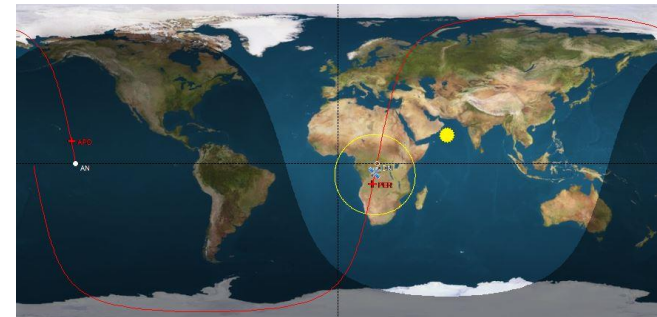
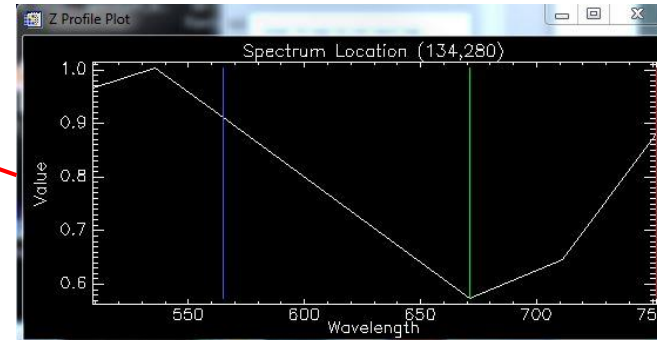


Normal image



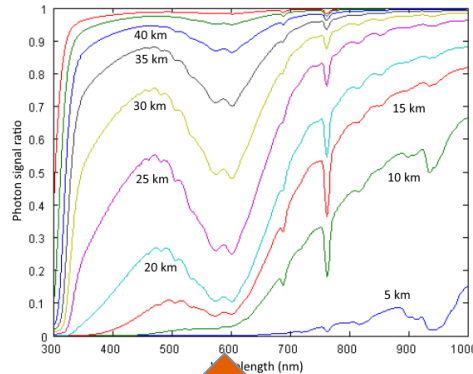
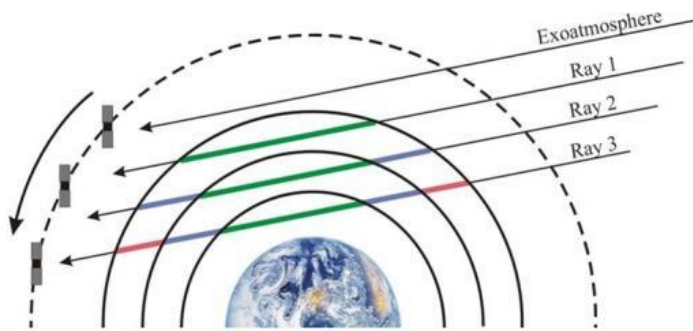
Spectral image

- Satellite finally de-tumbled in June 2018.
- First cloud-free images taken in August 2018.
- No visible degradation in images after 1 year in orbit
- PoC successful



# Picasso VISION

- VTT's second nanosatellite spectral imager
- Project started in 2014
- FM delivered in May 2017

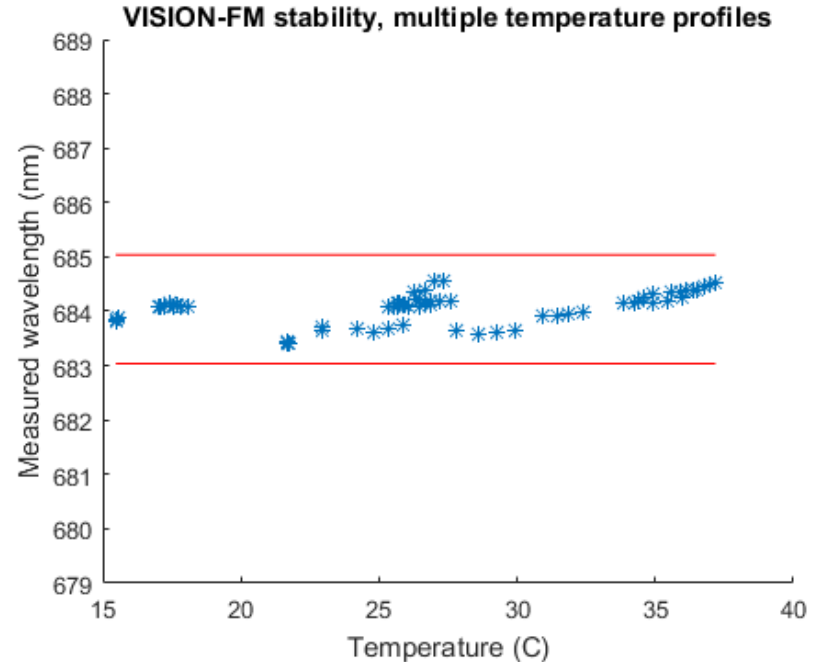
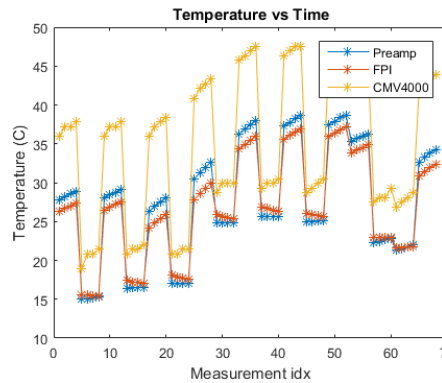
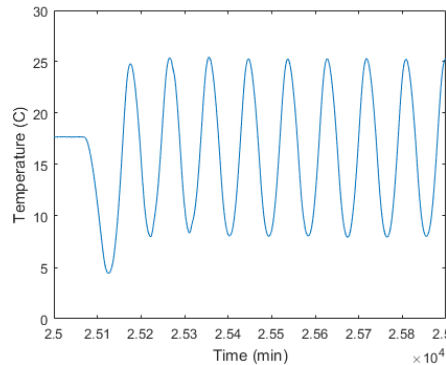


$O_3$



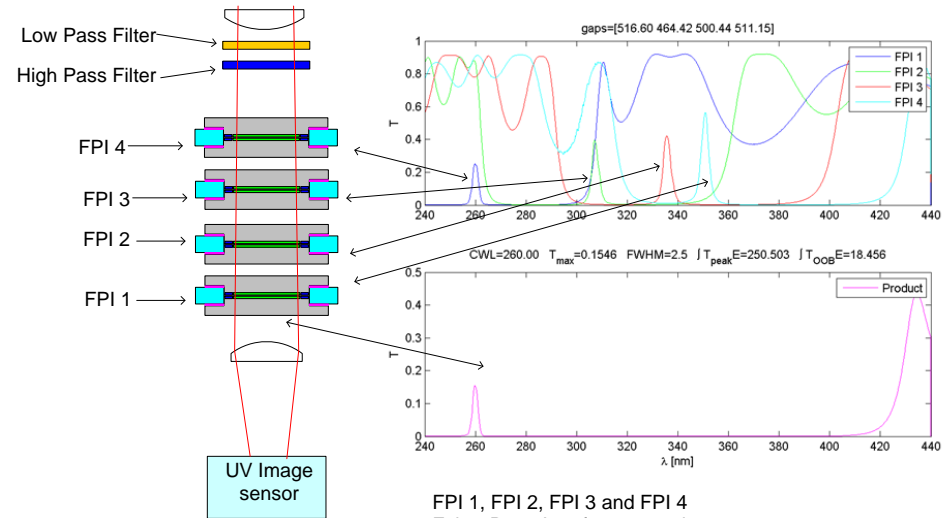
# Thermal stability

- Tested with different temperature profiles
- The observed wavelength drift is  $<1\text{nm}$



# ALTIUS

- Space mission by ESA
- Tunable filters for the UV channel
- Spectral resolution < 2 nm
- EQM delivery in 2019
- Filter modules qualified to 75  $G_{rms}$ 
  - General NASA levels are 14  $G_{rms}$



FPI 1, FPI 2, FPI 3 and FPI 4 Fabry-Perot Interferometers in series. Total transmission contains only one spectral band.



## Hello World satellite

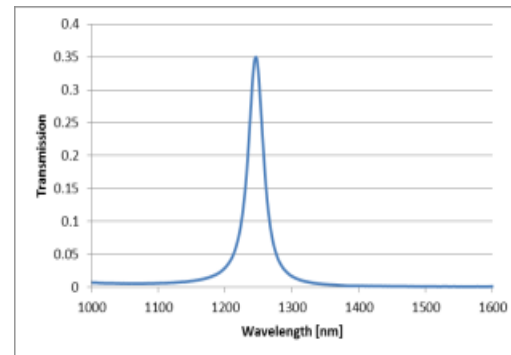
- Developed by Reaktor Space Lab
- Spearhead project in the field of future space services
- First ever miniature infrared hyperspectral imager payload



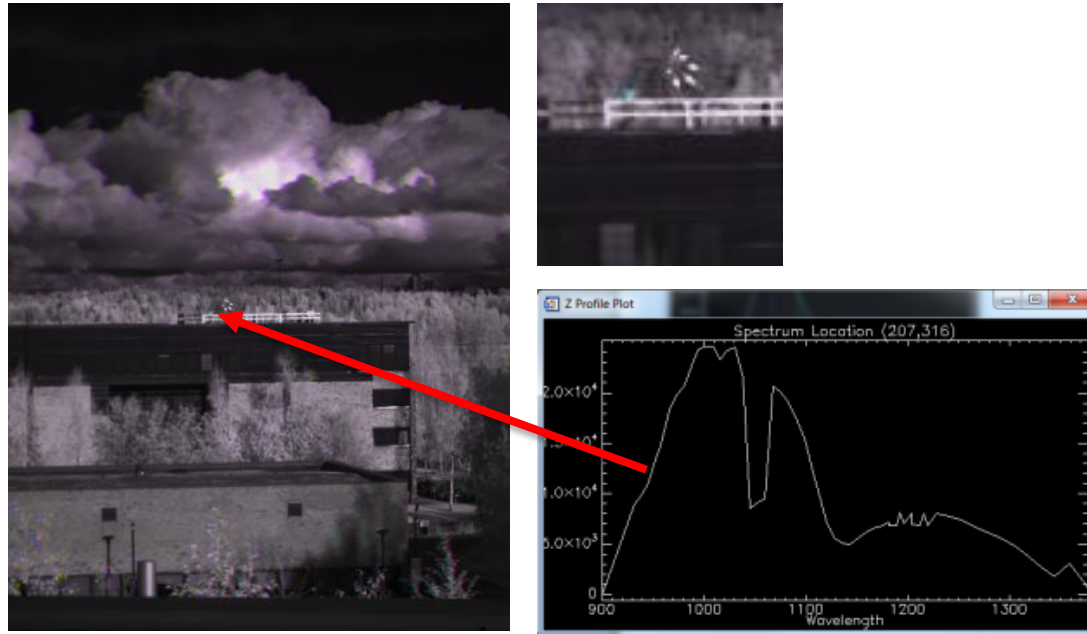


# Hello World hyperspectral payload

- 0.5U SWIR-1 spectral imager
- 925 - 1400 nm
- Can be adapted to 1000-1600 nm
- FWHM 20 - 45 nm
- FOV of  $10^\circ \times 10^\circ$
- InGaAs sensor
- 640 x 512 pixels @ 15-bits
- Mass <600g
- Power consumption < 2W

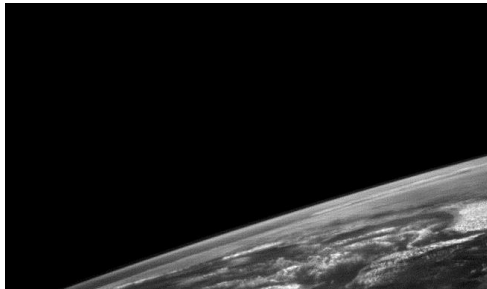


# Hello World hyperspectral payload

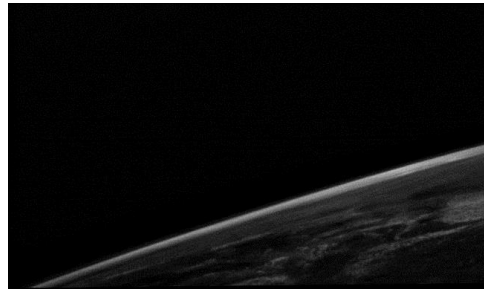


# Hello World results

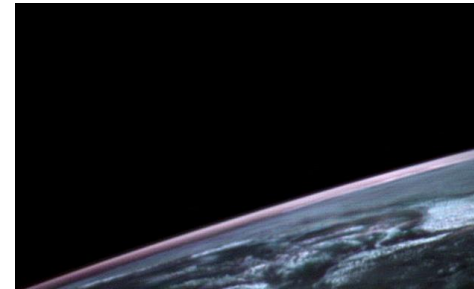
- Successful launch on November 29th 2018
- First images on December 2nd



1050 nm



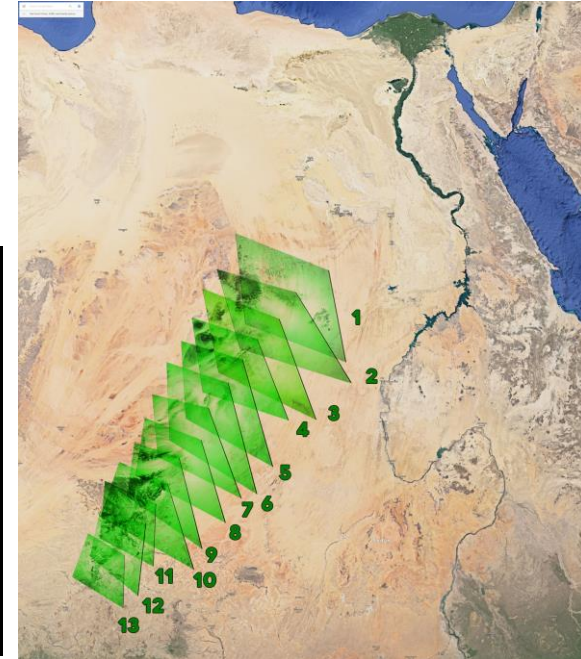
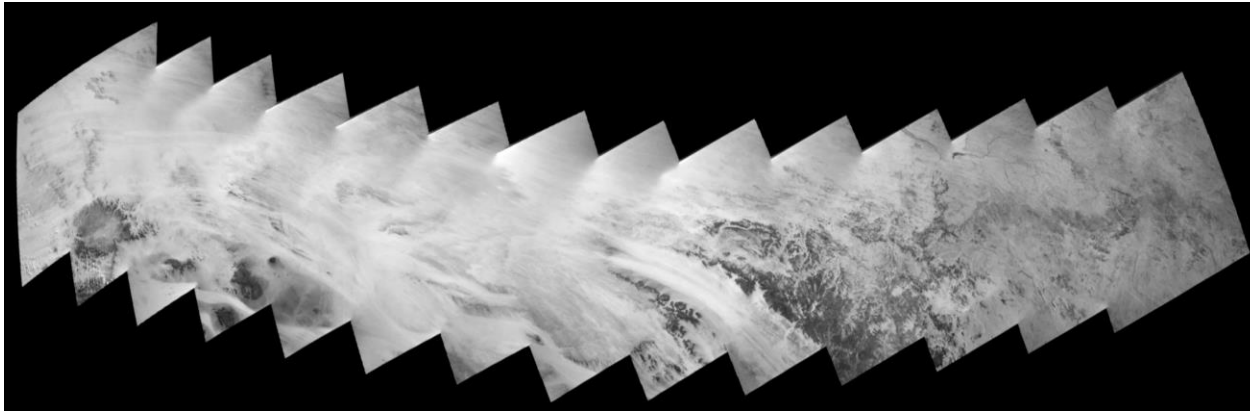
1150 nm (H<sub>2</sub>O absorption)



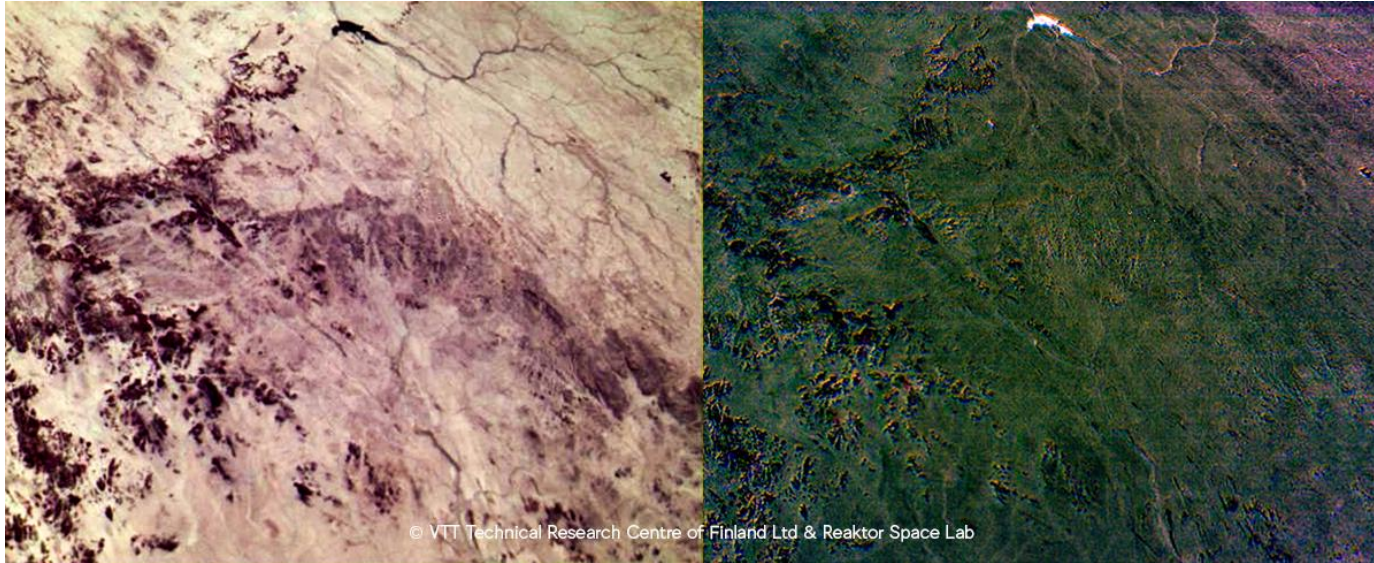
False color composite

# Hello World results

- First land images on December 4th
- Series of images of Egypt and Sudan

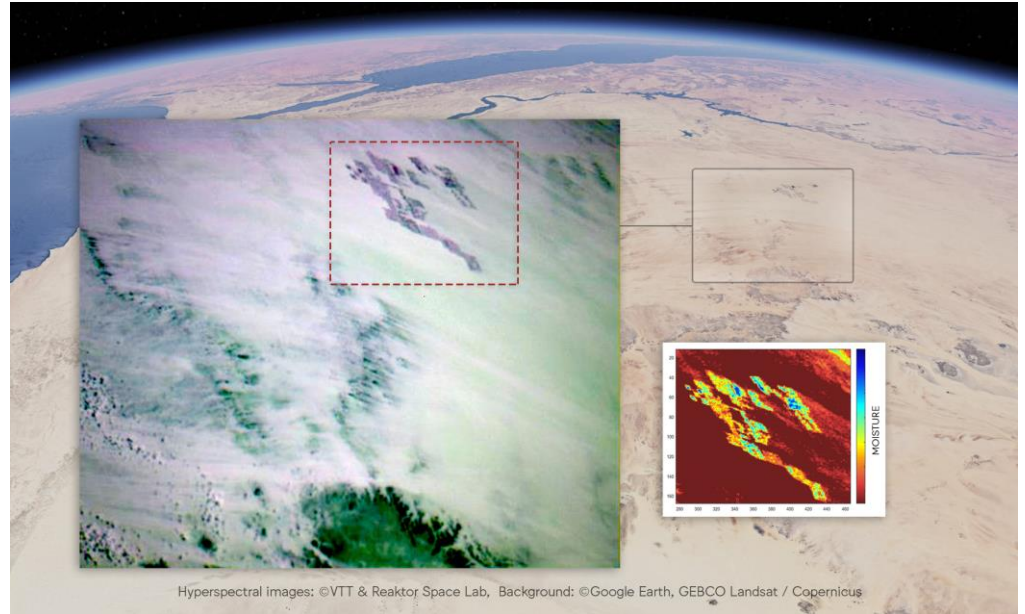
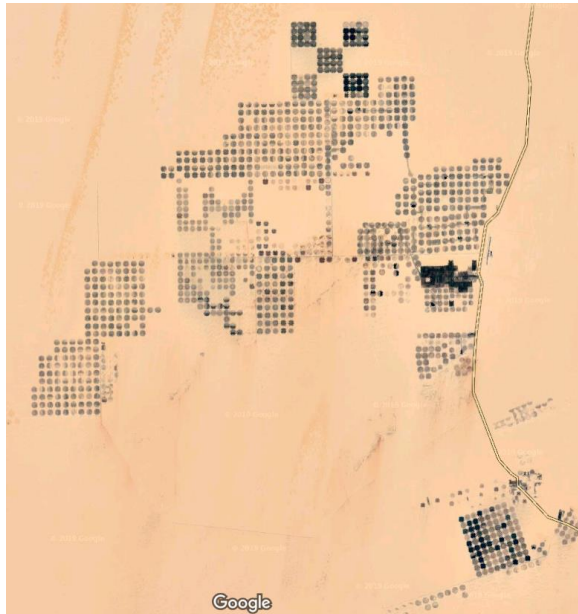


# Moisture variation in Sahara



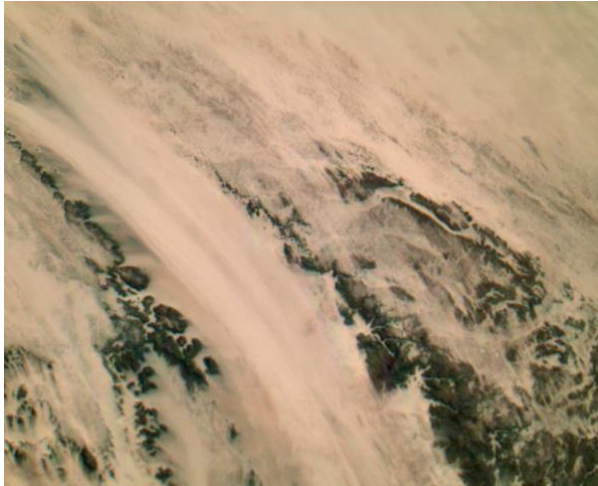


# Moisture variation in Sahara

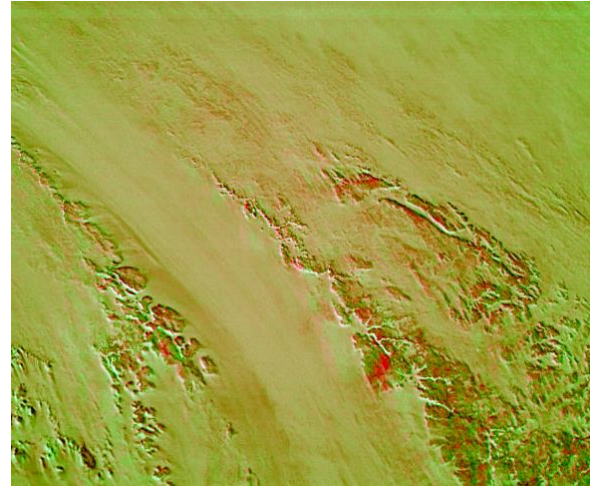


# Hello World results

- Rock species differentiation



False color composite  
(R=1250 nm, G=1100 nm, B=1000 nm)

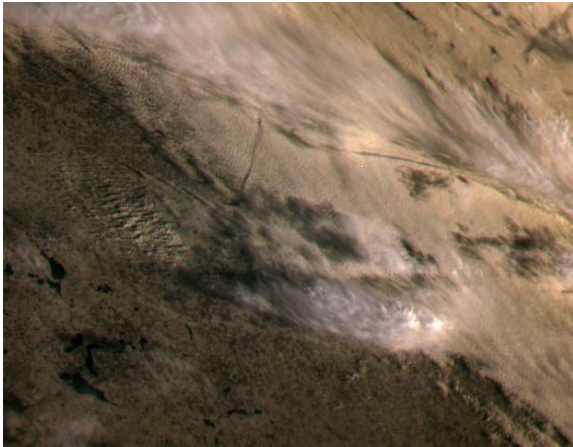


False color composite, wavelength  
ratios

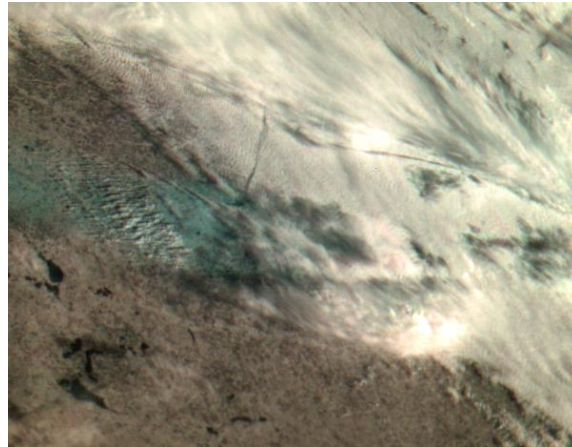


# Hello World results

- Cloud height separation
- Frost/snow detection(?)

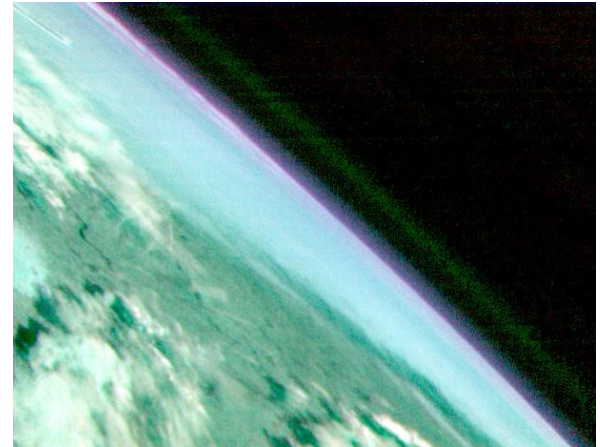


False color composite  
(R=1050 nm, G=1000 nm, B=970 nm)



False color composite  
(R=1310 nm, G=1100 nm, B=1000 nm)

Bonus: Atmospheric emission (airglow)



O2/OH Air glow emission at 1270 nm

# Hello World results

- Land classification (Pakistan, January 9th 2019)



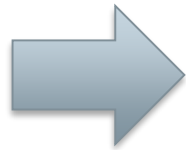
False color composites  
(R=1310 nm, G=1075 nm, B=1025 nm)

# What have we learned?

- We've found **water** on Earth
- We've found **oxygen** on Earth
  
- We can separate different **rock species / minerals**
- We can see changes in **vegetation**
  - All this with 2U/3U CubeSat(!)

# Technology development, scaling up

- Optical aperture diameter has been increased to **25 mm**
  - AaSI, Hello World and VISION all have 15 mm aperture
- Filter transmission has increased to ca. **40%**
  - Aalto-1 Spectral Imager transmission is ca. **15%**



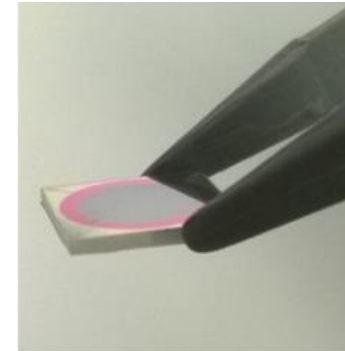
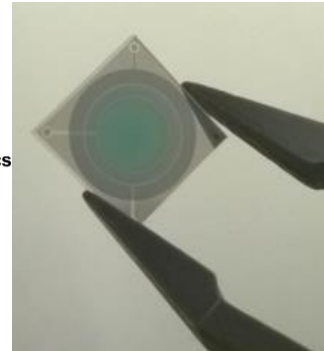
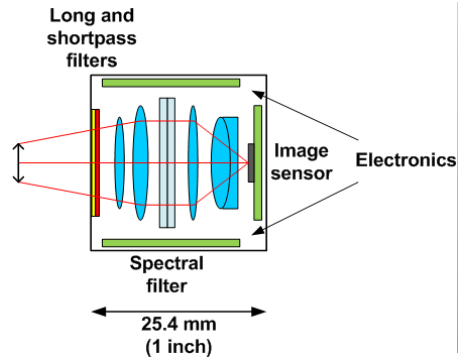
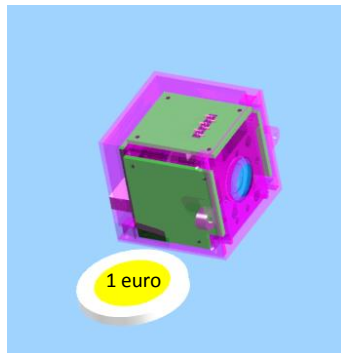
These upgrades alone increase the optical throughput by over **600%**



Higher ground resolution becomes a reality

# Technology development

- Cubic-Inch imager
- Mass < 40g
- Based on large aperture optical MEMS filters
- Wavelength range ca. **600-950 nm**
- Example: Hyperspectral microscope for a lander/rover!



# Summary

- VTT's spectral imaging technology has been flight proven on two different missions
  - Excellent results from Aalto-1 and Hello World missions
- The flexibility and scalability of the technology have enabled miniturized instrumentation for several new space missions
  - Interplanetary missions are behind the corner
- The field of applications is very broad and still rather unexplored
  - Many new opportunities to come!

**Thank you for your  
attention!**