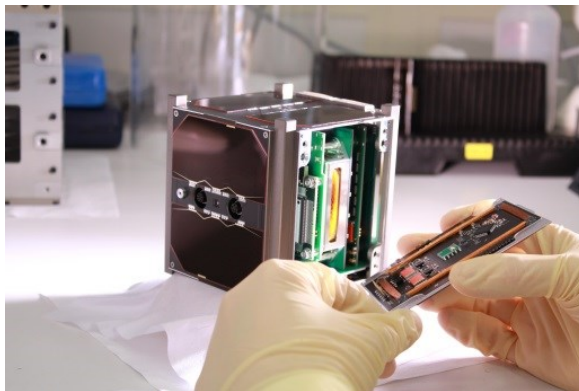


Prototypen-Mission für die Erstellung von 3D Wolkenhöhenkarten - Kleinstsatelliten für Erdbeobachtung

Anna Aumann, Iurii Motroniuk, Ilham Mammadov, Julian Scharnagl, Klaus Schilling





— 2020 | UWE-5

Relative Navigation

— 2018 | UWE-4

Orbit Control

— 2013 | UWE-3

Attitude Control

— 2009 | UWE-2

Attitude and Orbit Determination

— 2005 | UWE-1

Internet in Space

TOM | 2020

3 pico-satellite formation

- Cooperative observation
- Photogrammetric imaging

QUBE | 2020

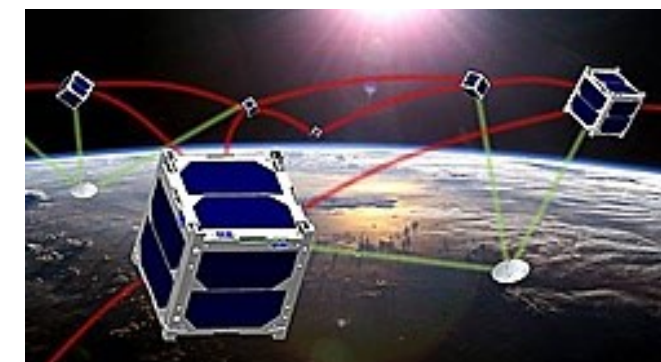
Quantum Encryption CubeSat

- Single 3-U Satellite
- Optical Downlink (OSIRIS)

NetSat 1-4 | 2019

Formation Flying Mission

- Distributed Computing
- Formation Control
- DTNs, MANets



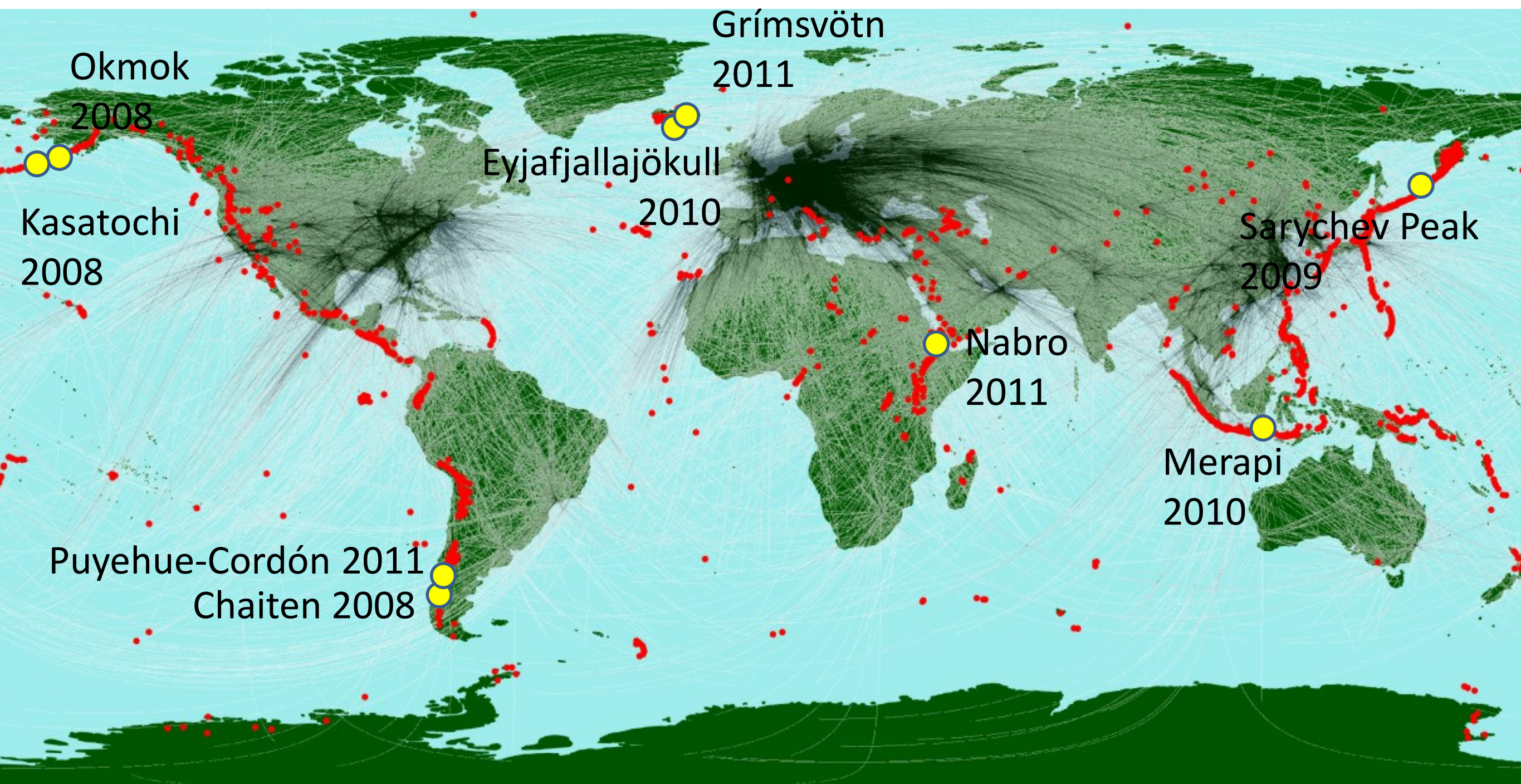


Eyjafjallajökull Eruption – April 2010

- 100.000 flights cancelled
- 10 million people affected
- **1.5 billion EUR** in 6 days



Major Eruptions in Last Years



● Active volcanoes in last 10,000 years

 Density of airline routes

Sarychev Peak eruption (12th June 2009)

Photogrammetric Ash Cloud Observations by Small Satellite Formations

Credit: Earth Science and Remote Sensing Unit, NASA Johnson Space Center

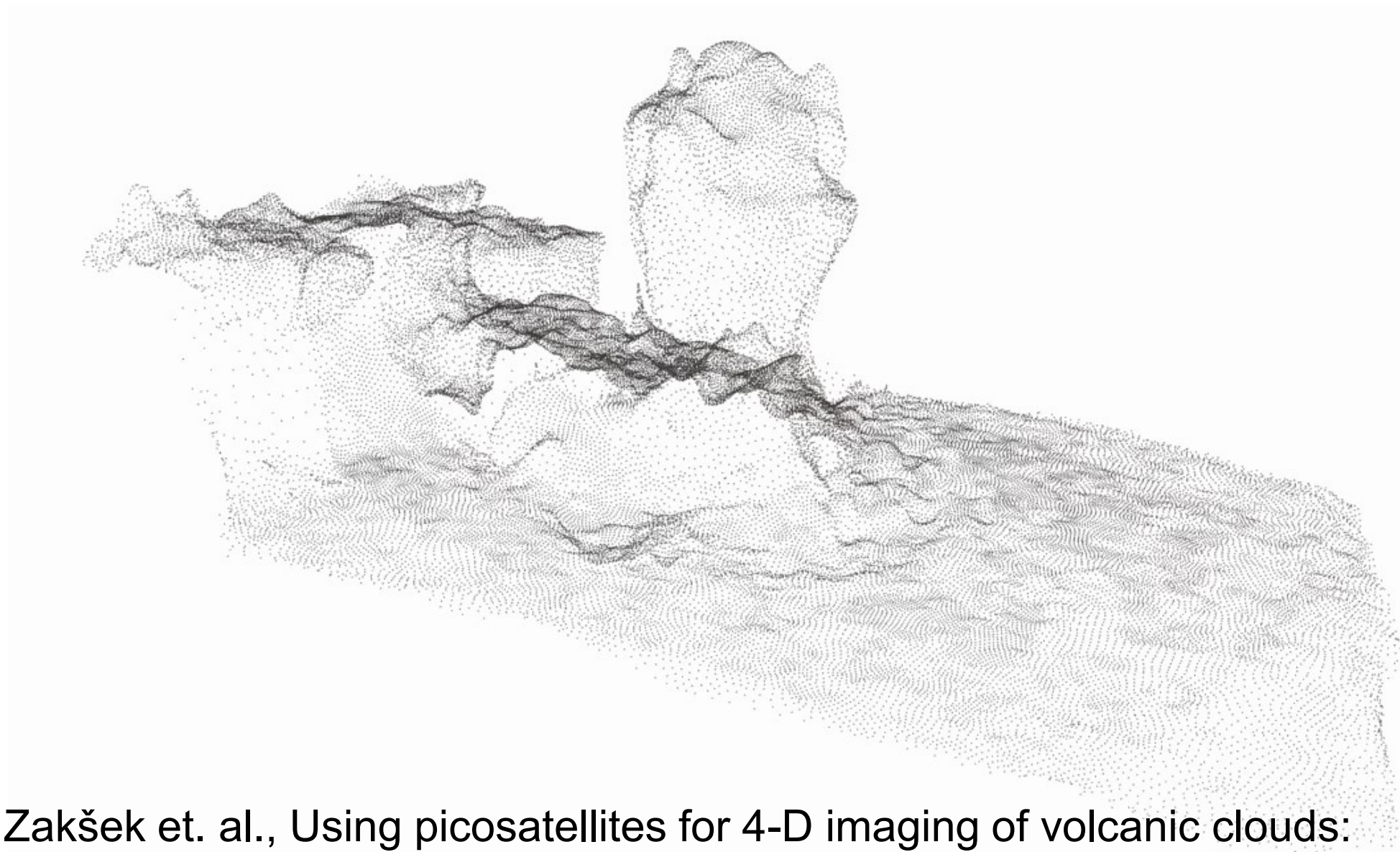
- Astronaut photo
- Nikon DsXs camera
- $H = 337 \text{ km}$
- 25 images
- 7 s between the selected 4 images

→ Algorithm proof of concept



3D-Pointcloud based on Photogrammetry

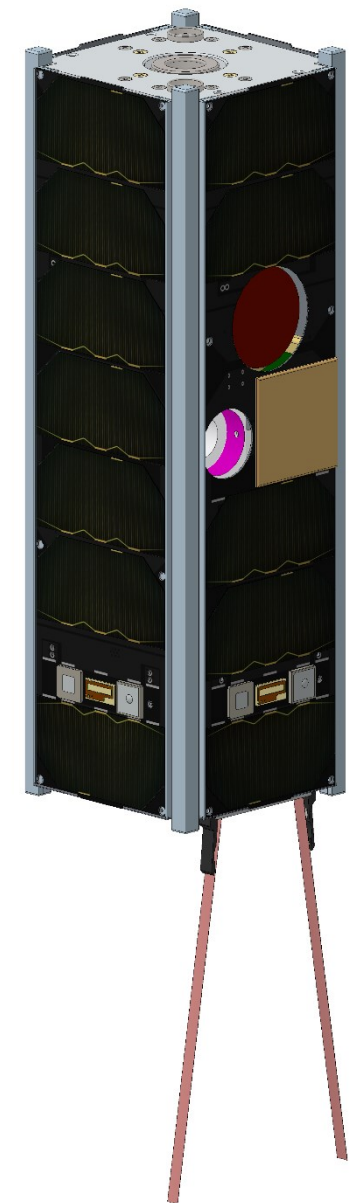
Proof of concept



[1] Zakšek et. al., Using picosatellites for 4-D imaging of volcanic clouds:
Proof of concept using ISS photography of the 2009 Sarychev Peak eruption

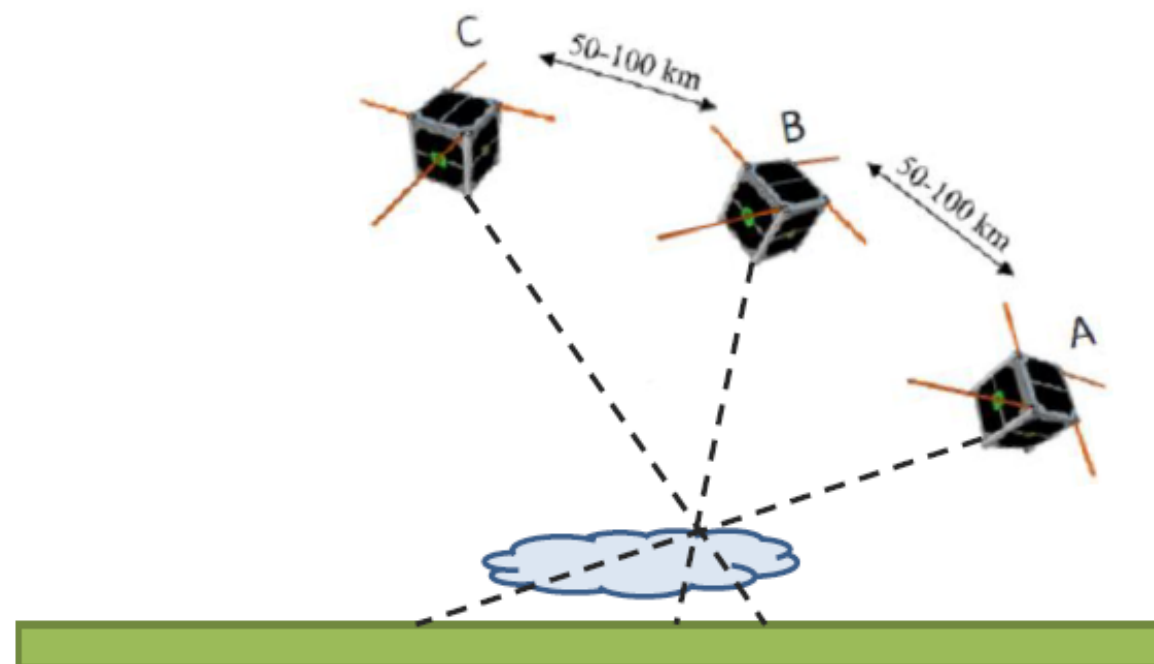
Mission Requirements

- The Earth observation objective for the TOM mission is to monitor volcanic eruptions
 - Observation of the distribution of clouds in space
 - Vertical extension of clouds
- Given the dynamics of this process, the satellite formation must:
 - be able to capture simultaneously high-resolution images of the same target in the visible area from at least two viewing directions
 - autonomously detect and track an ash cloud within a specific area of interest.



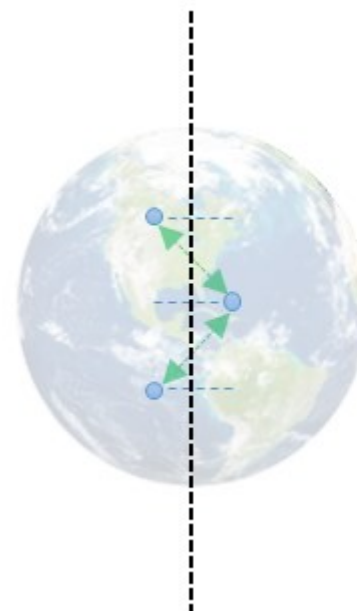
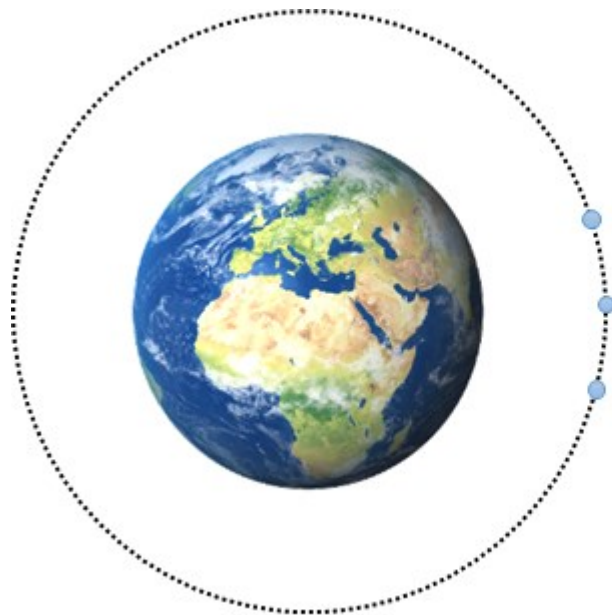
Mission Requirements

- The main requirements to be met by the mission are:
 - the Earth observation instrument must be a full-frame sensor;
 - the image resolution must not exceed 30 m;
 - the observed area must be at least 30 km wide;
 - the viewing angle difference between two satellites must be approx. 10° .

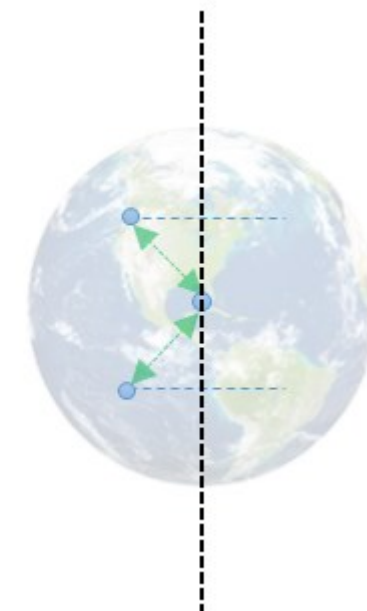


Formation Flying

Triple pendulum formation



balanced



unbalanced

- >5month mission life
- Baseline ~100km

- >100m/s Δv
- Out of plane separation ~ 50km

Concept Design

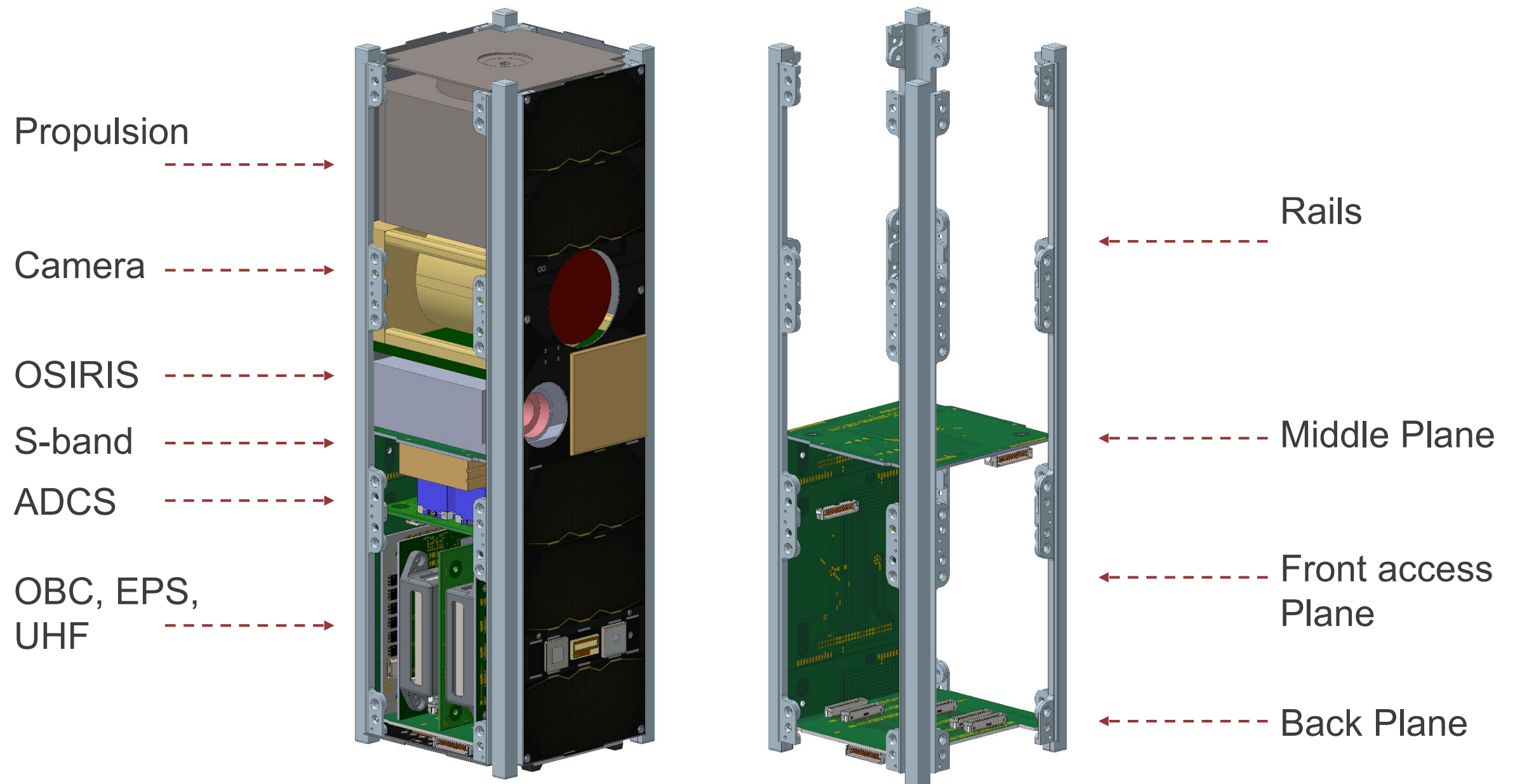
Single Spacecraft Concept

- **1U CubeSat:** 10×10×10 cm
- **3U CubeSat:** 10×10×30 cm



Concept Design

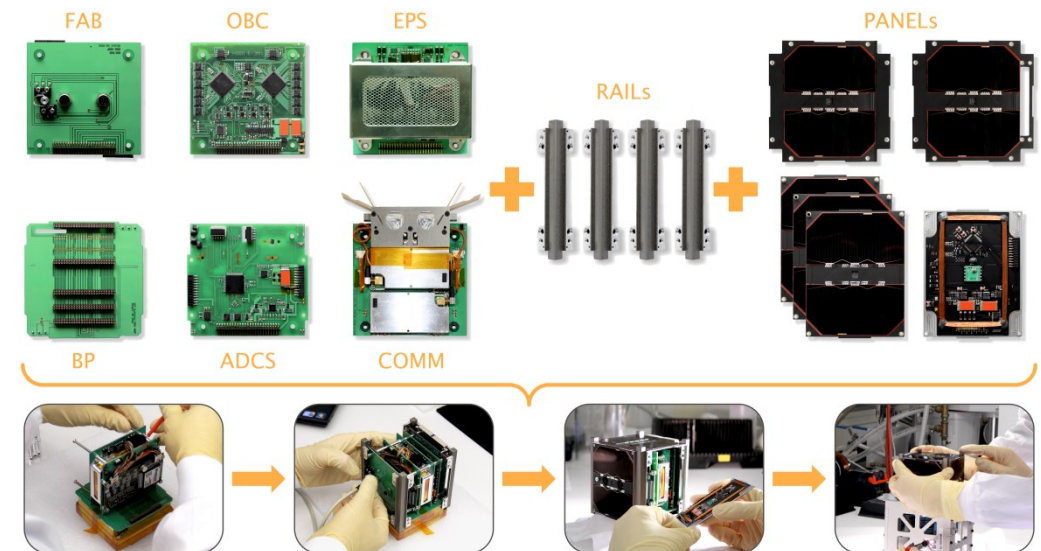
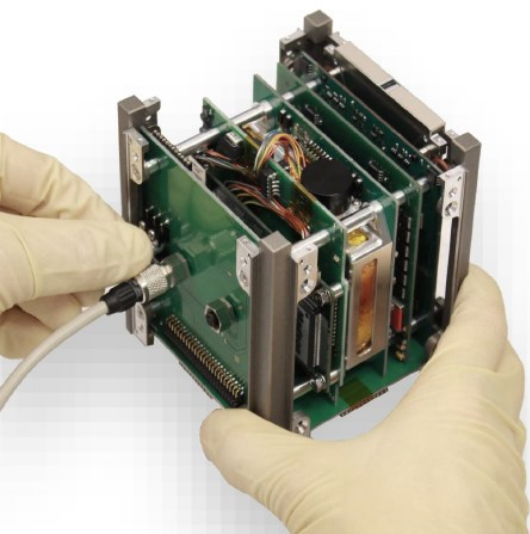
TOM Satellite with UNISEC standard



UNISEC Bus

CubeSat Interface Definition

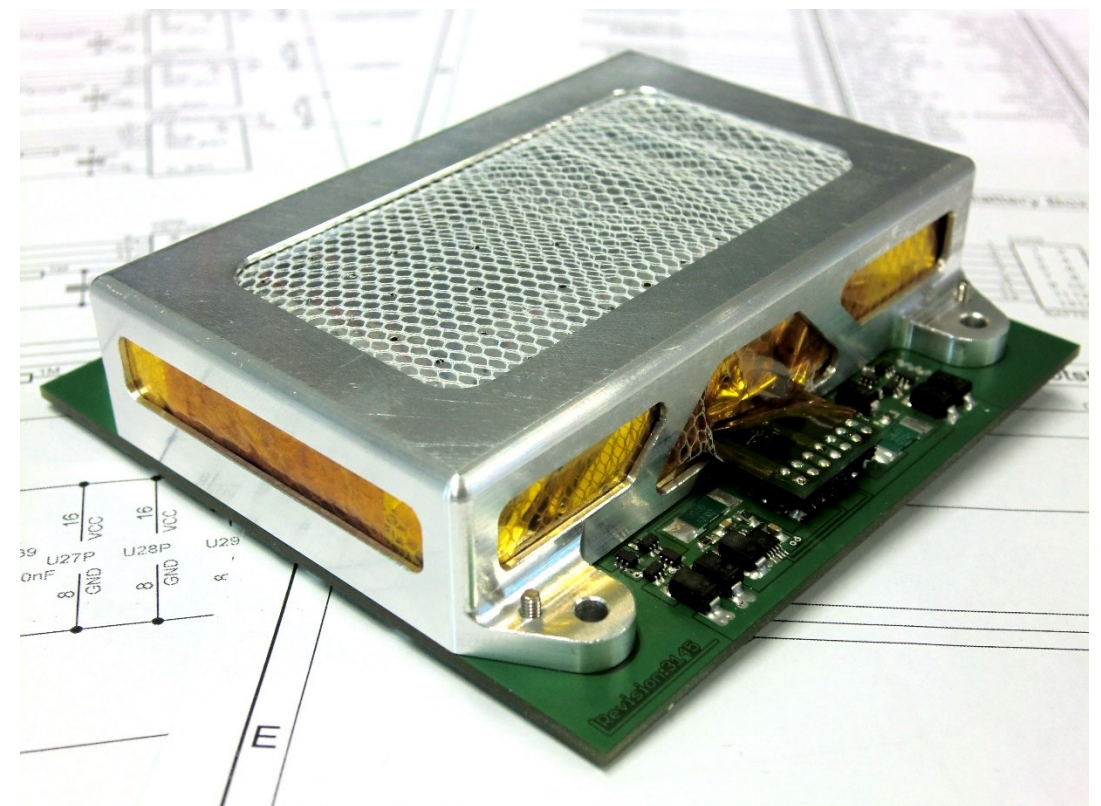
- modular architecture based on backplane
- debug support for ANY microcontrollers on ALL subsystems (via OBC)
- full access to each subsystem via umbilical even when satellite is completely / tightly integrated
- external debug interface (extra standardized interface for stand-alone operation) provided by USB-Interface



Power

Distribution

- Two EPS boards in parallel, ~85% efficiency
- 5V:
 - 2x1.2A total power w/ redundancy
 - 4x1.2A total power w/o redundancy
- 3V3
 - 2x6A total power w/ redundancy
 - 4x6A total power w/o redundancy
- UnREG:
 - 3.6V-4.2V
 - 4A per EPS Board limited with switches



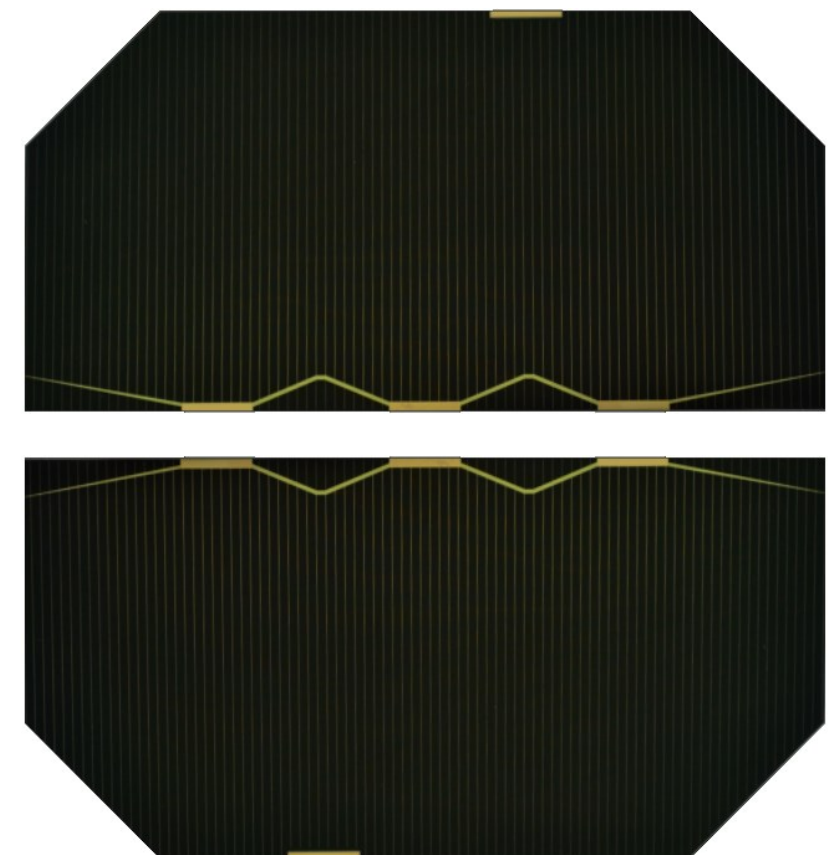
Power

Generation & Storage

- Solar cells: serial in pair, parallel among pairs
→ Even # of Solar cells
- 6 Solar cells per 3U side
→ 5.5W, 60min → **5.5Wh** restore per orbit
- Battery: Each board has two SAFT batteries in redundant configuration
- Both batteries can be used if necessary



Storage: 3.65V, 2x2.6Ah = 5.2Ah → 18.8Wh

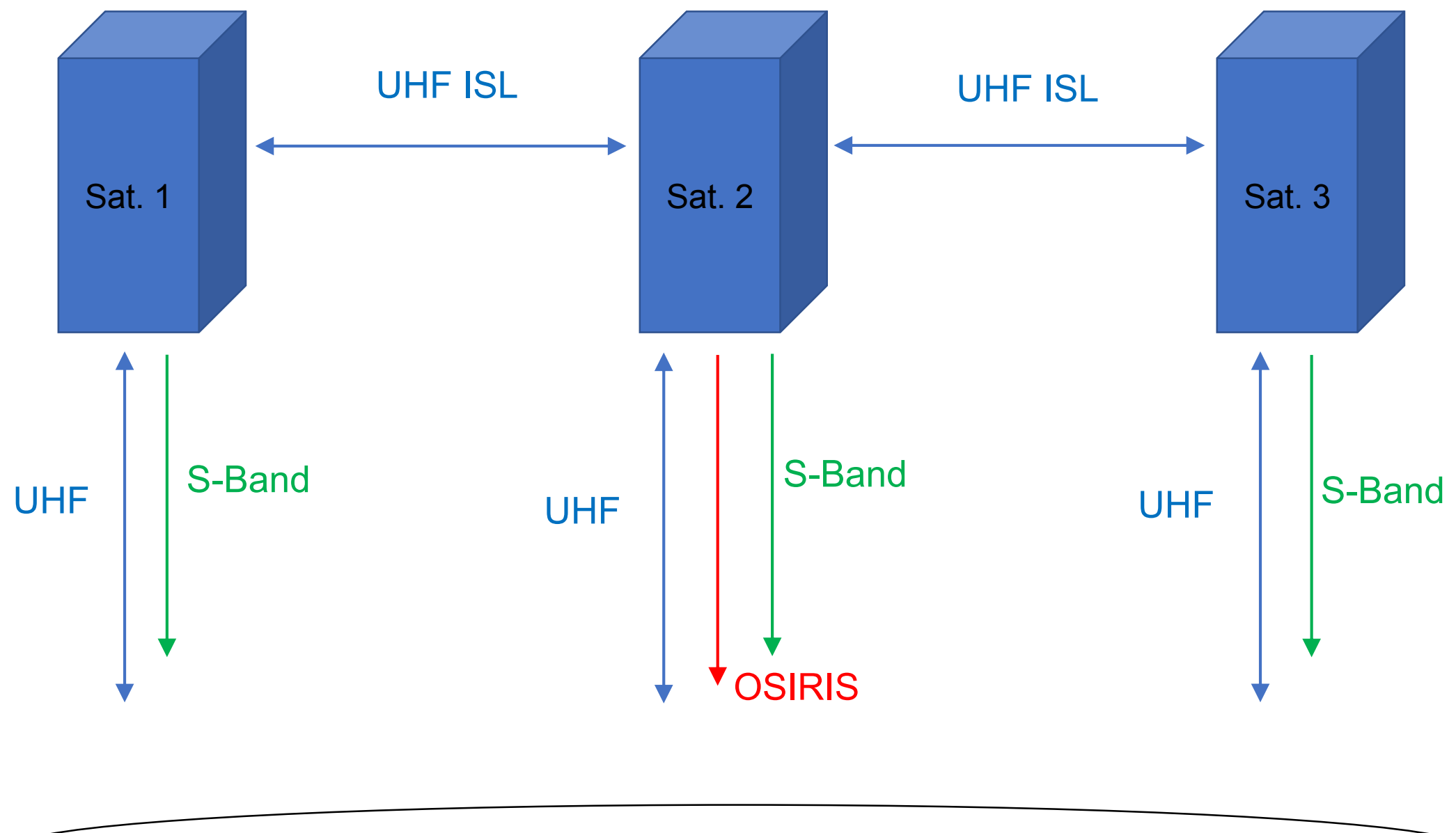


$V_{mpp}=4.8V$, $I_{mpp}=0.5A$, $P_{mpp}=2.4W$
Azur Space, 28%

Solar cell to battery efficiency: ~**80%**

Communications

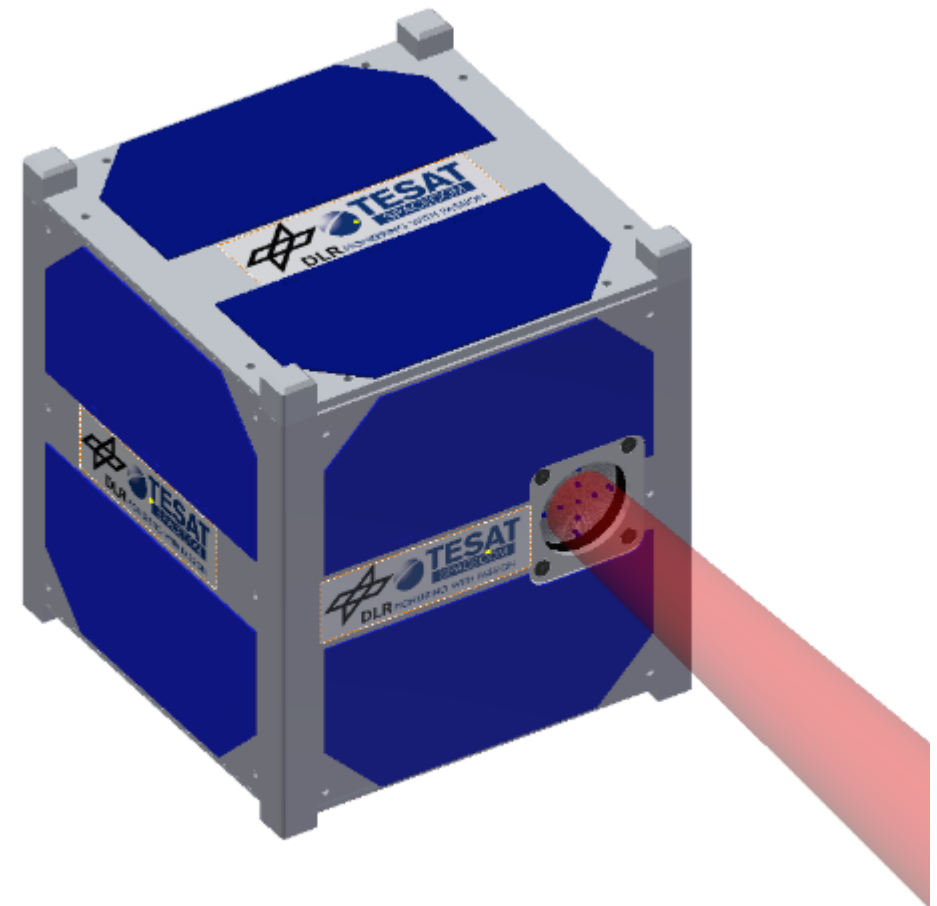
Concept



Optical Communication

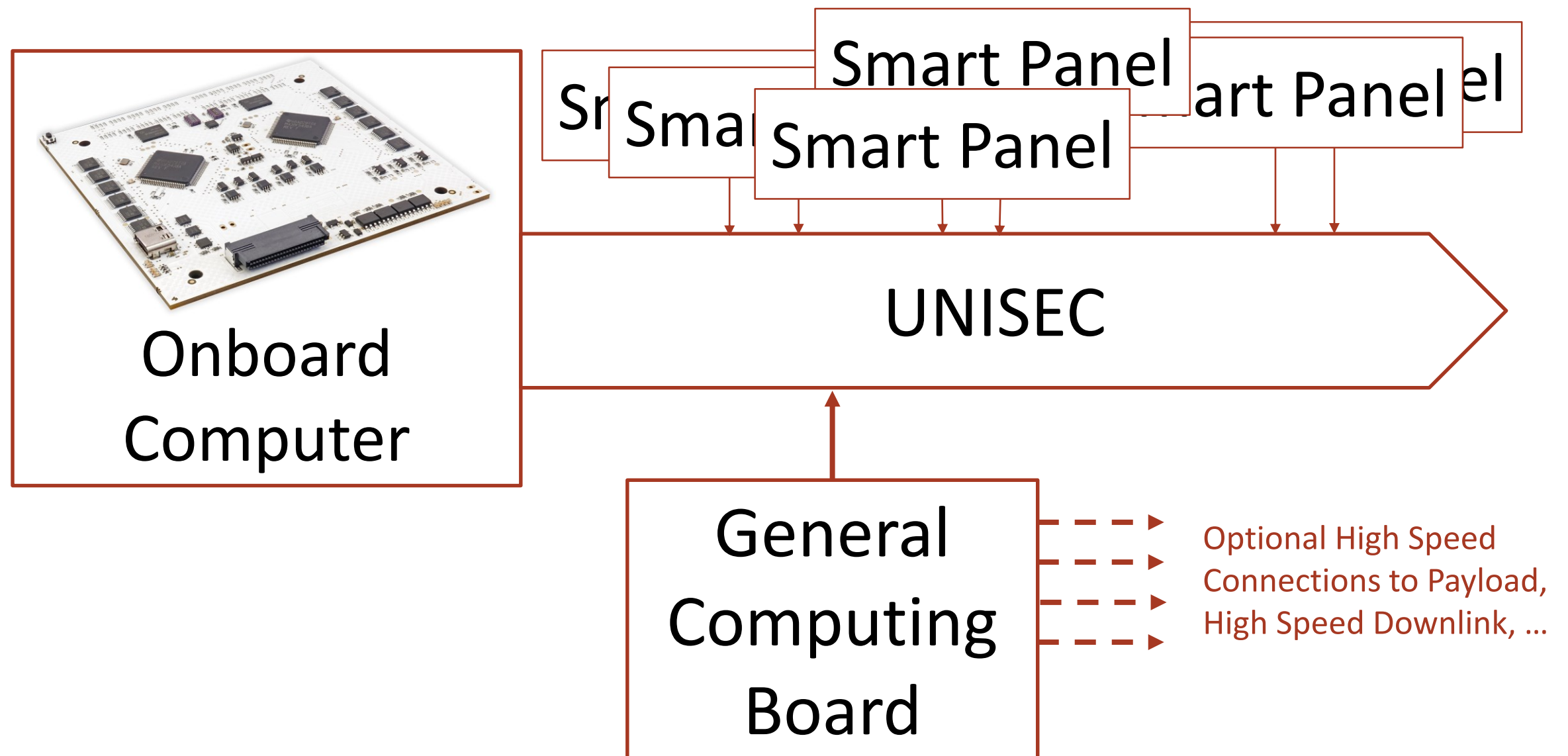
OSIRIS

- Optical Space Infrared Downlink System
- Developed by German Space Agency DLR, Institute of Communications and Navigation
- OSIRIS4CubeSat weighs less than 300 g and occupies approx. 0.3 U



A Distributed Approach to Data Handling

On-Board Data Handling System

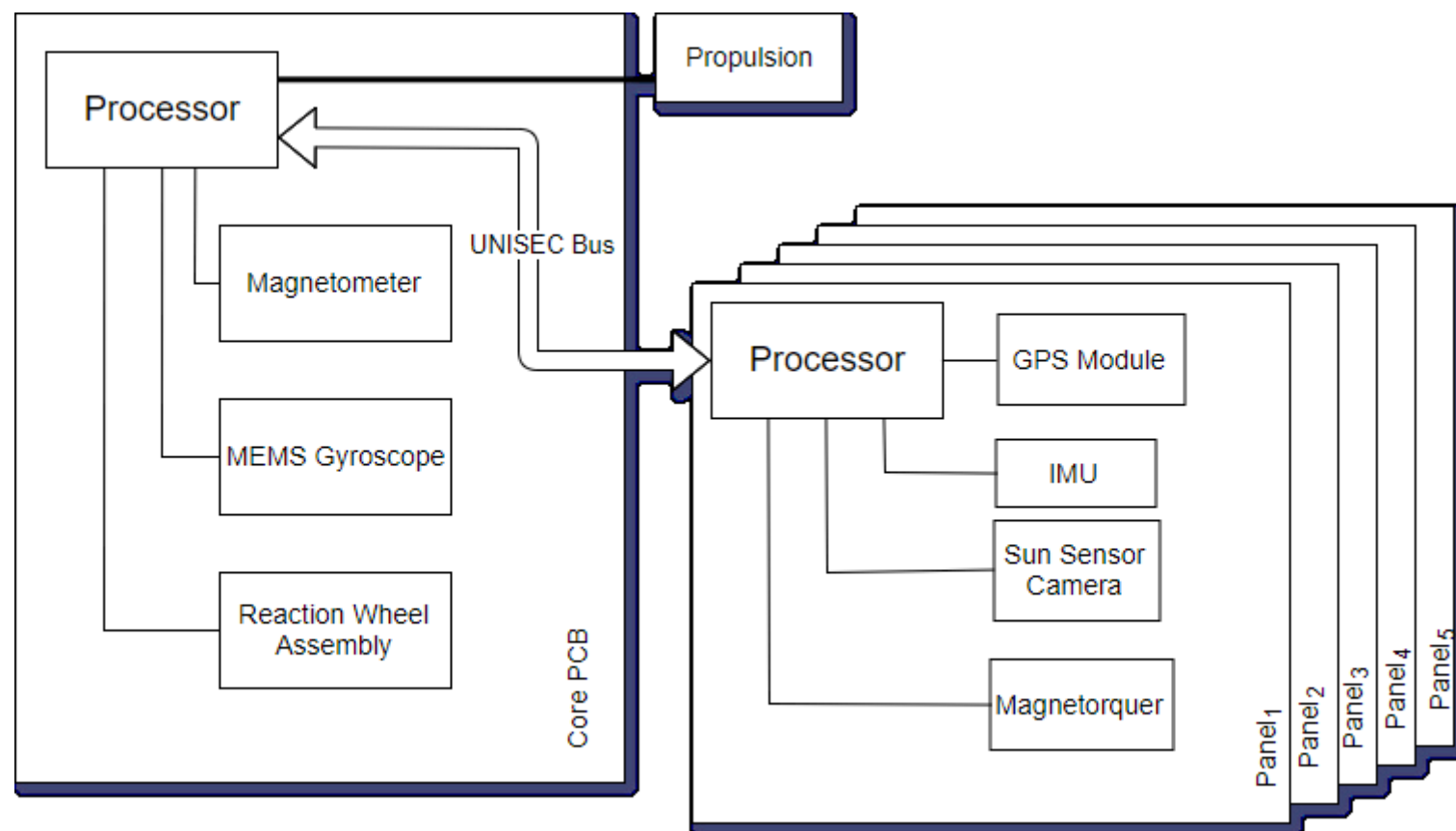


Precise Pointing for Common Observations

Attitude and Orbit Control System

Core PCB

- Interface to Reaction Wheel Assembly
- Processor for Determination and Control Algorithms
- Precise Sensors



Panel

- Interface to Magnetorquer
- Processor for Sensor Processing
- Very precise Sun Sensors
- Redundant Sensors

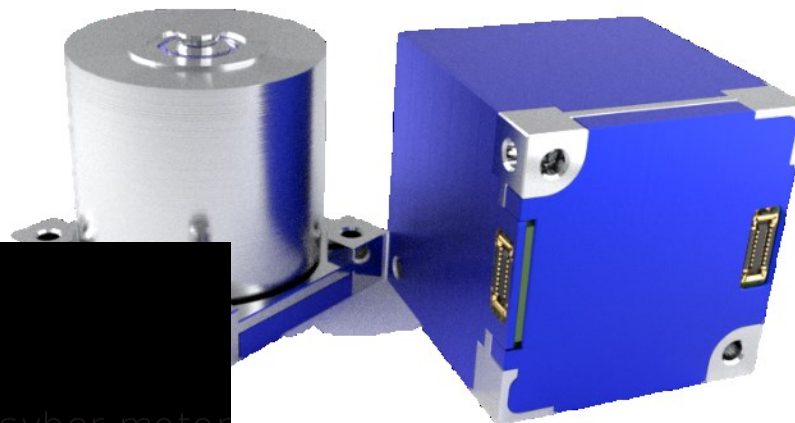
ADCS Components

Reaction Wheels

- Wittenstein / ZfT Development
- 20 x 20 x 20 mm, 20g
- 2 mNms Momentum Storage,
0.1 mNm maximal torque

Magnetic Coils

- One-off production (e.g. hrelectronic)
- 0.2 Am²/ axis



Optical Observation

Payloads

Optical Camera

- Creation of 3D Maps - Photogrammetry method based on Earth images
- Basic Requirement:
Ground Resolution of 30 m
- Twofold image processing:
 - On-board for Visual Servoing
 - On ground for creation of 3D maps

Example

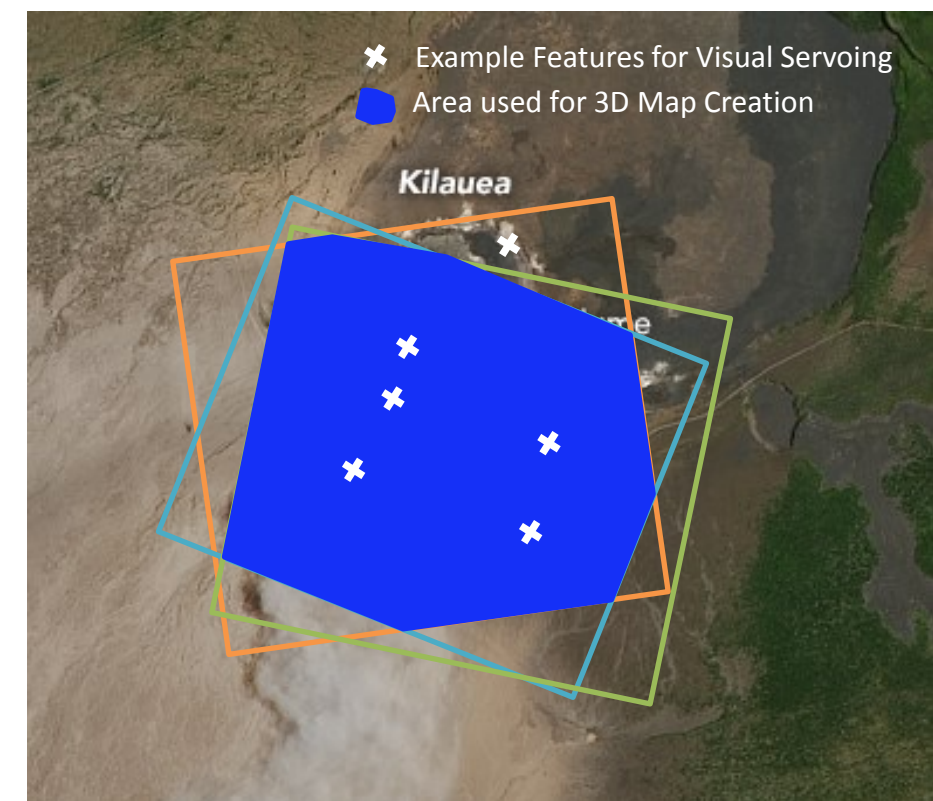
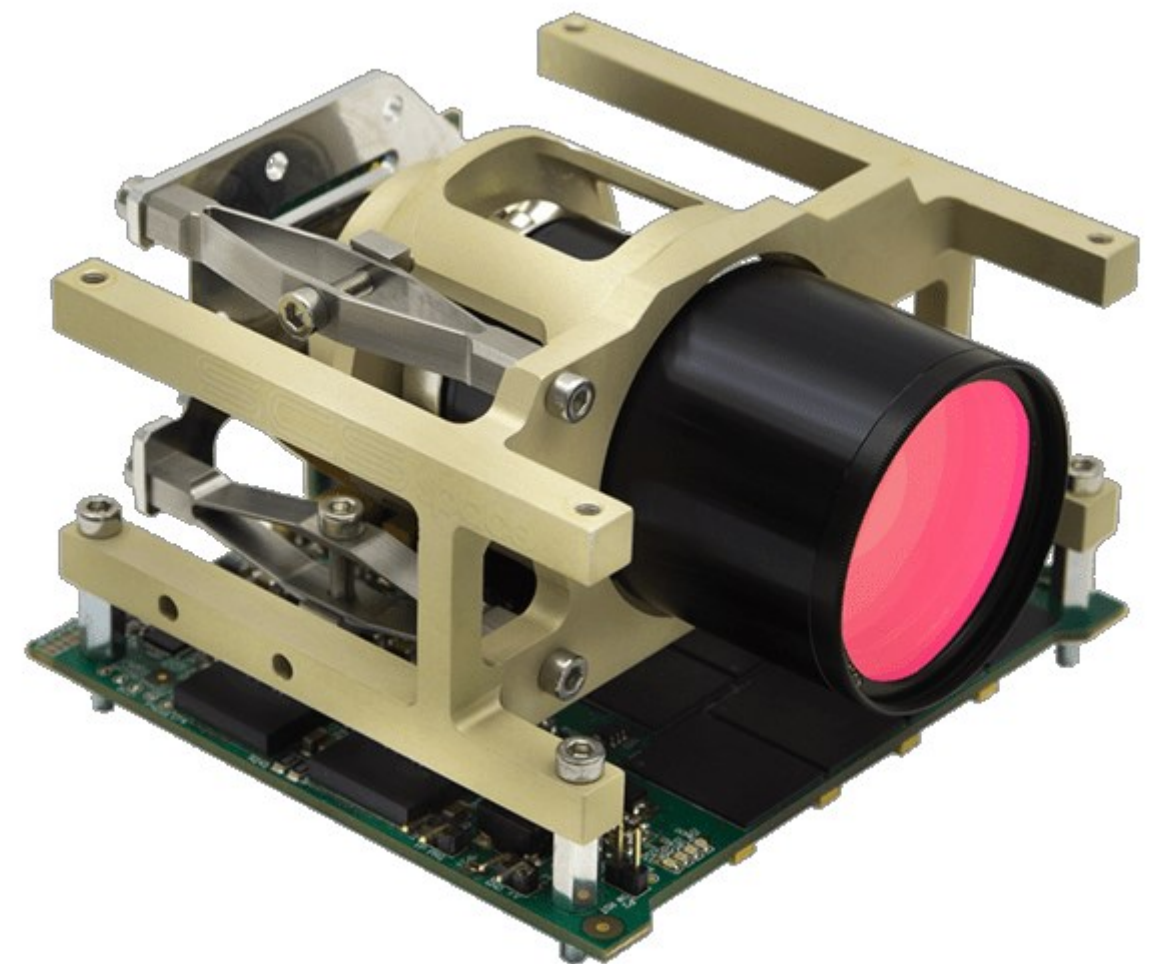


Image from LandSat 8 – OLI, May 14, 2018,
Kilauea Eruption

Camera

SCS Gecko Imager

Parameter	Value
Resolution	29.5 m
Swath width	72 km
Image Sensor	2.2 Megapixel RGB matrix
Shutter	Global
Radiation tolerance	30 krad
Data interfaces	LVDS, SPI and I2C
Image format	JPEG / RAW



Source: <https://www.cubesatshop.com/product/scs-gecko-imager/>

Vision Based Attitude Control

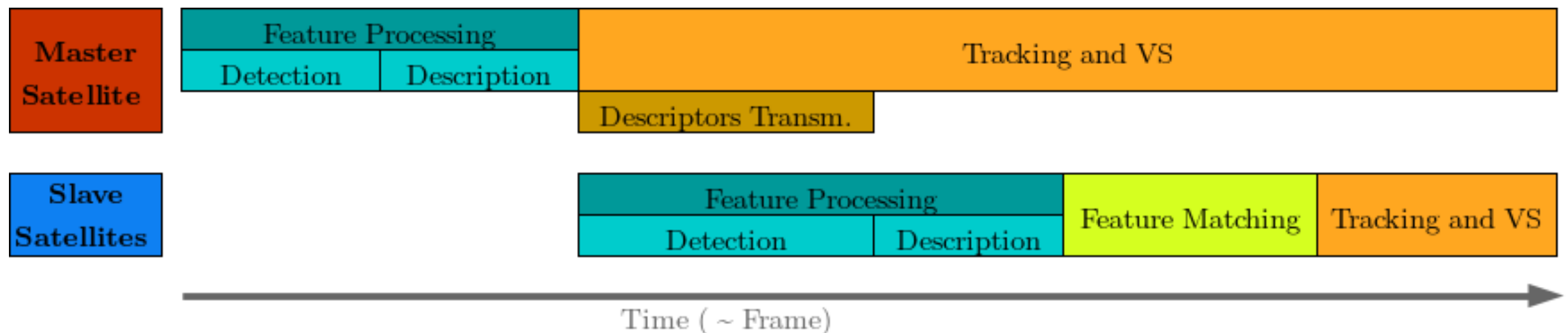
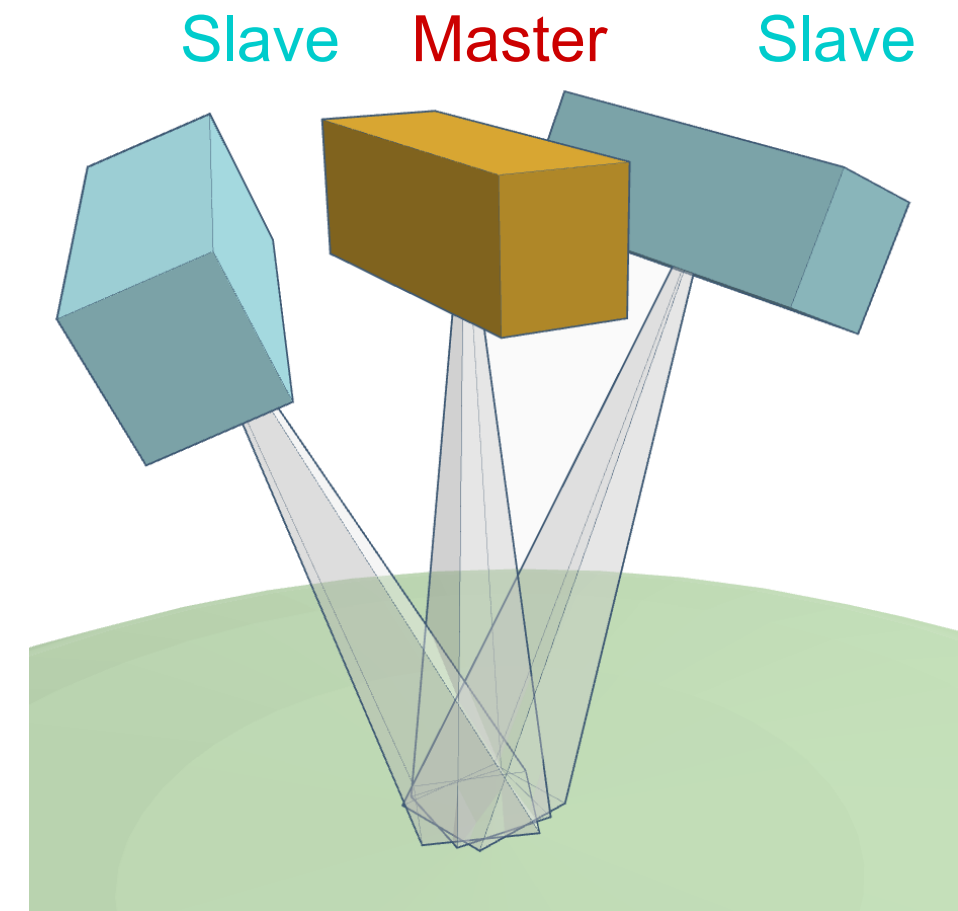
Mission Timeline

- **Master Satellite**

- Detect + Describe + Continuously Tracks Features
- Transmit Descriptors

- **Slave Satellites**

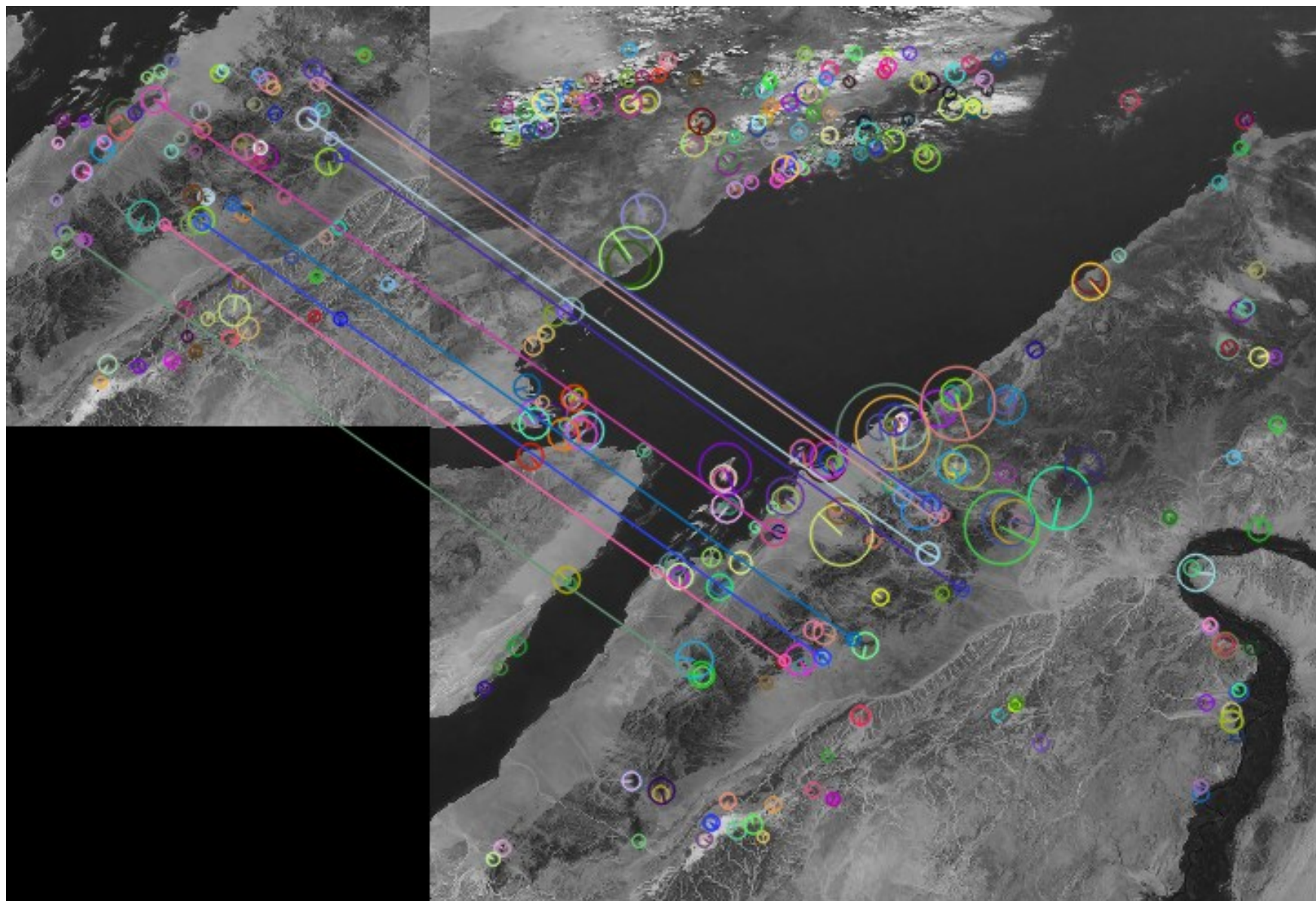
- Receives Descriptors
- Detect + Describe Features
- Match the Slave ↔ Master Descriptors
- Track matched Features



Feature Matching

- Binary descriptors from Slave + Master Sat. are matched based on the Hamming distance
- Matching Based on Brute Force Search Algorithm
- Outlier rejection methods Investigated
- Redundancy required due to outliers → +4 matched distinctive features sufficient for VS

Master Sat.
Camera image



Slave Sat.
Camera image

the original unprocessed data is found at <https://goo.gl/5oYMxV>

TOM / TIM

Telematics International Mission

- enhances TOM
- 7 project partners, 5 continents involved
- satellites based on UNISEC Standard
- 9 pico-satellites are planned suitable for 3D monitoring of
 - environment pollution,
 - harvesting status,
 - critical infrastructures,
 - natural disasters (like forest fires, volcano activities, earthquakes)
 - ...

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A satellite image of Earth showing a vast expanse of white clouds over a dark blue ocean. A prominent, long, straight, light-colored landmass or ice shelf is visible in the lower-left quadrant. The text "Thank you!" is overlaid in a white, sans-serif font within a semi-transparent grey rectangular box on the right side of the image.

Thank you!