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Experiences and data collected from HYPSO-1's second year in orbit

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Outline

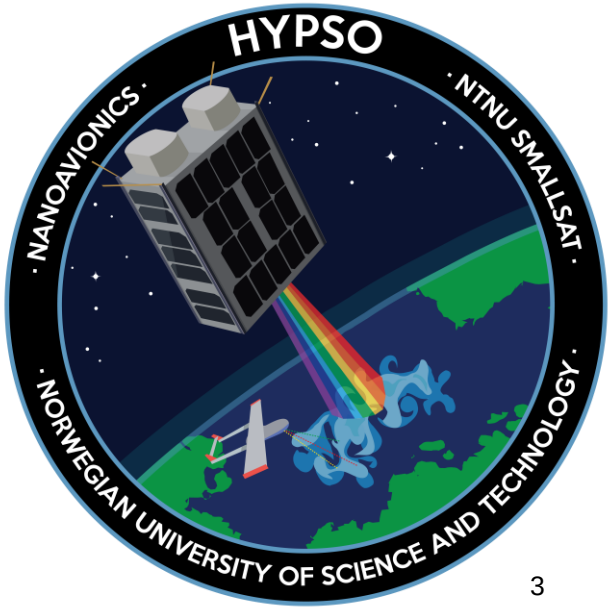
- Introduction to the HYPSO project
- Agile maneuvers
- Processing & scheduling software
- Issues and resolutions
- (HYPSO-2 status)

The HYPSO project

HYPerspectral Smallsat for Ocean observation (HYPSO)

- Maritime research and monitoring
  - Harmful algal blooms
  - Novel hyperspectral imaging payload

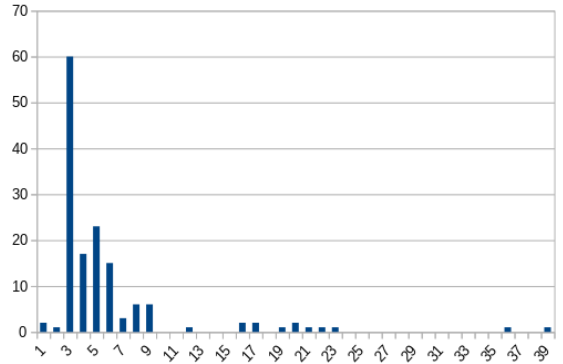
- HYPSO-1 launched
- HYPSO-2 scheduled for launch in 2024



- **Size: 6U CubeSat, ~7 kg**
- **Injection Orbit: 540 km, ~94 min, SSO**
- **Payload: Hyperspectral Imager**
- **Power: Solar**
- **Control: Magnetorquers & Reactions Wheels**
- **Data Processing: on-board, ground**
- **Communication: S-band, UHF**
- **Launched: 13. January 2022**

In-flight results

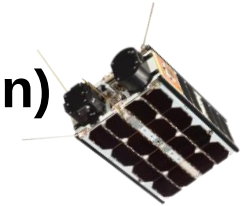
- 1700+ images
- 2500+ boot sequences
- Backup Linux operating system used once (on purpose)
- Of the 150(-4) most recent images (as of 14.12.2023):
  - Average recording to downlink time: 5.67 hours
  - Fastest: 1.38 hours



Agility of the satellites

- Reaction wheels + magnetorquer

- Maneuver examples:
  - **Slew (forward movement correction)**
  - Quaternion (off-nadir pointing)
  - Stereo imaging (extra wide)
  - Dual imaging
  - Quaternion sequence



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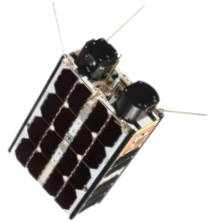

Slew

- Blurriness due to overlap between pixels
+ increase in SNR

Non-slew

Slew

Kristiansen, Bjørn Andreas; Langer, Dennis David; Garrett, Joseph Landon; Berg, Simen; Gravdahl, Jan Tommy; Johansen, Tor Arne. (2023) Accuracy of a slew maneuver for the HYPSO-1 hyperspectral imaging satellite — in-orbit results. Workshop on Hyperspectral Image and Signal Processing, Evolution in Remote Sensing

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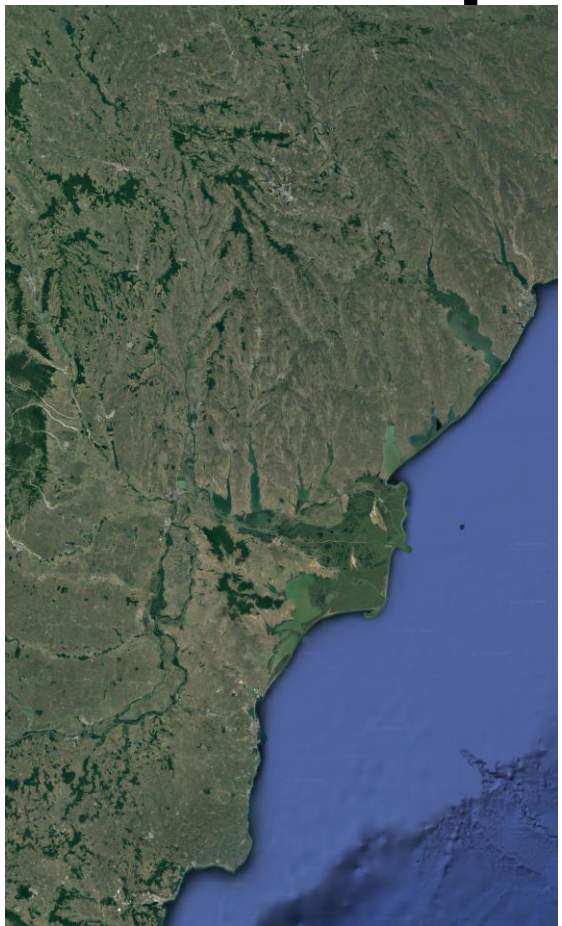
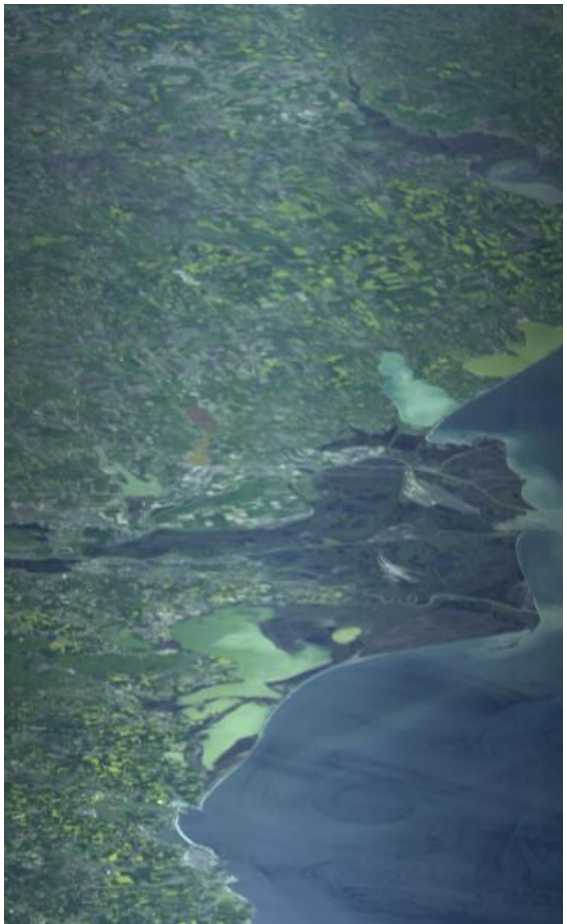
Quaternion capture





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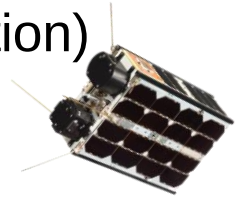

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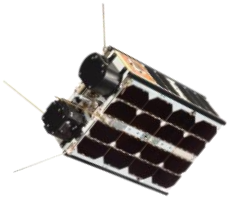

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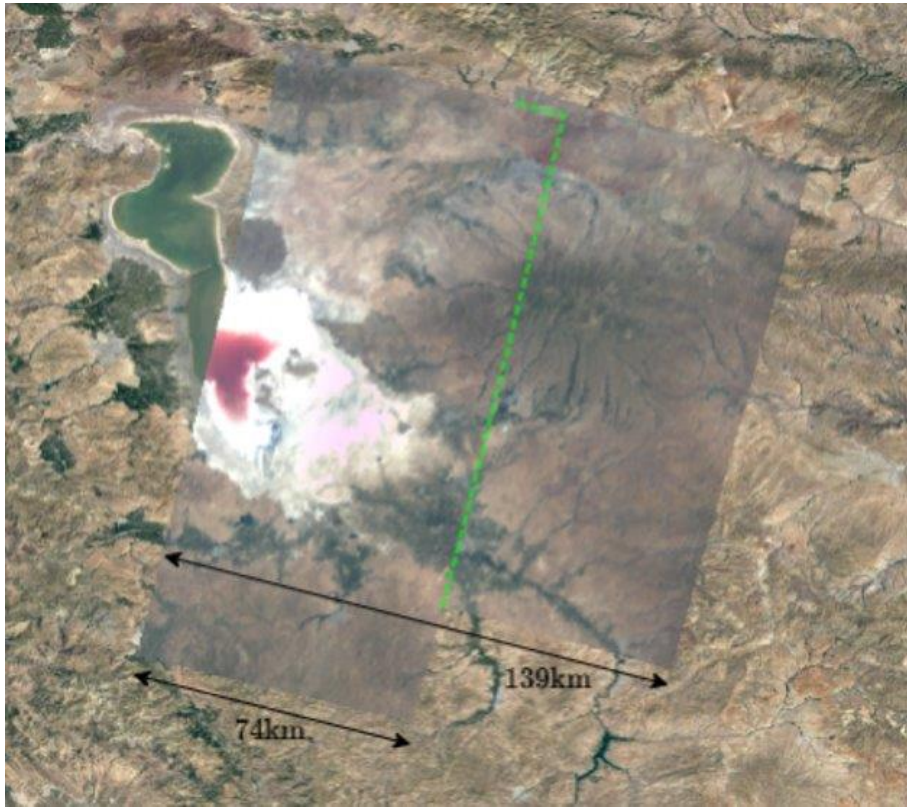
Extra wide capture

- Nearly doubled the width



Dennis D. Langer, Joseph L. Garrett, Bjørn A. Kristiansen, Sivert Bakken, Simen Berg, Roger Birkeland, J. Tommy Gravdahl, Tor A. Johansen, and Asgeir J. Sørensen, “Agile Maneuvers for Push-Broom Imaging Satellites” Submitted to IEEE Transactions on Geoscience and Remote Sensing.

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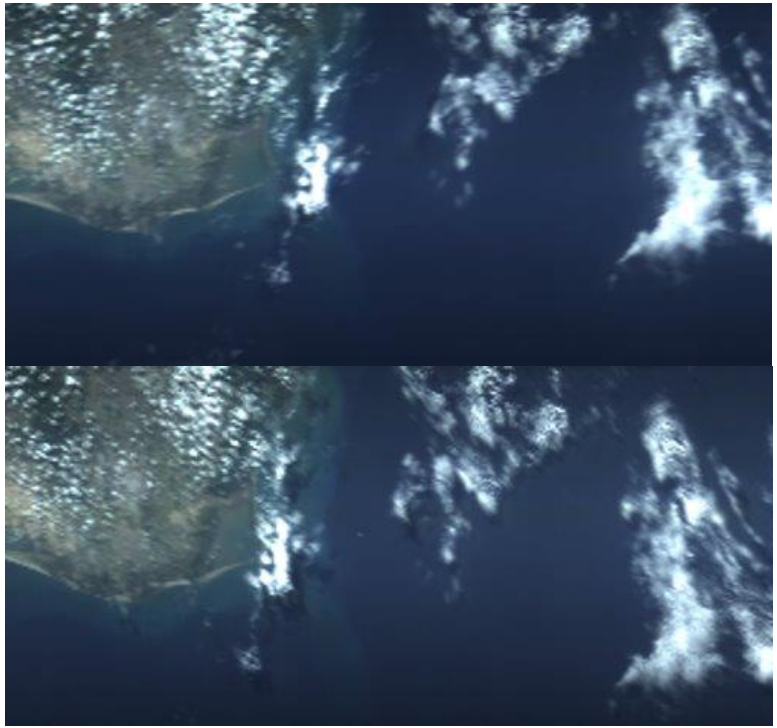
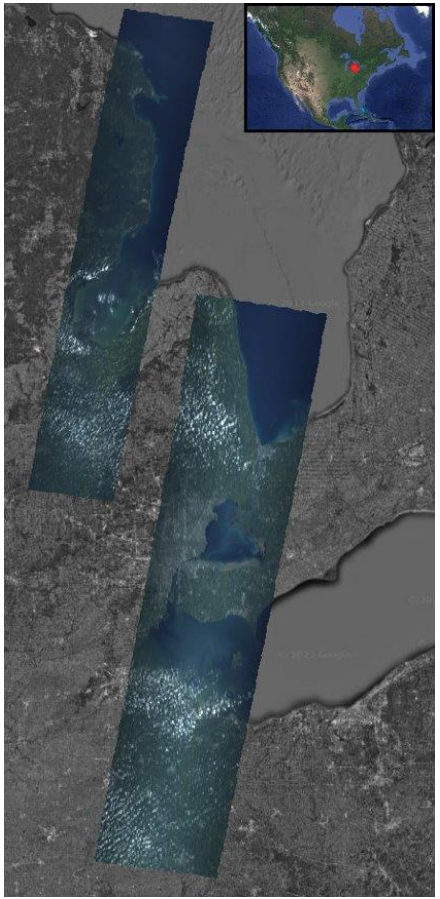
Dual imaging

Spatial stacking for increased SNR

Different locations in case of multiple targets in close geographical vicinity





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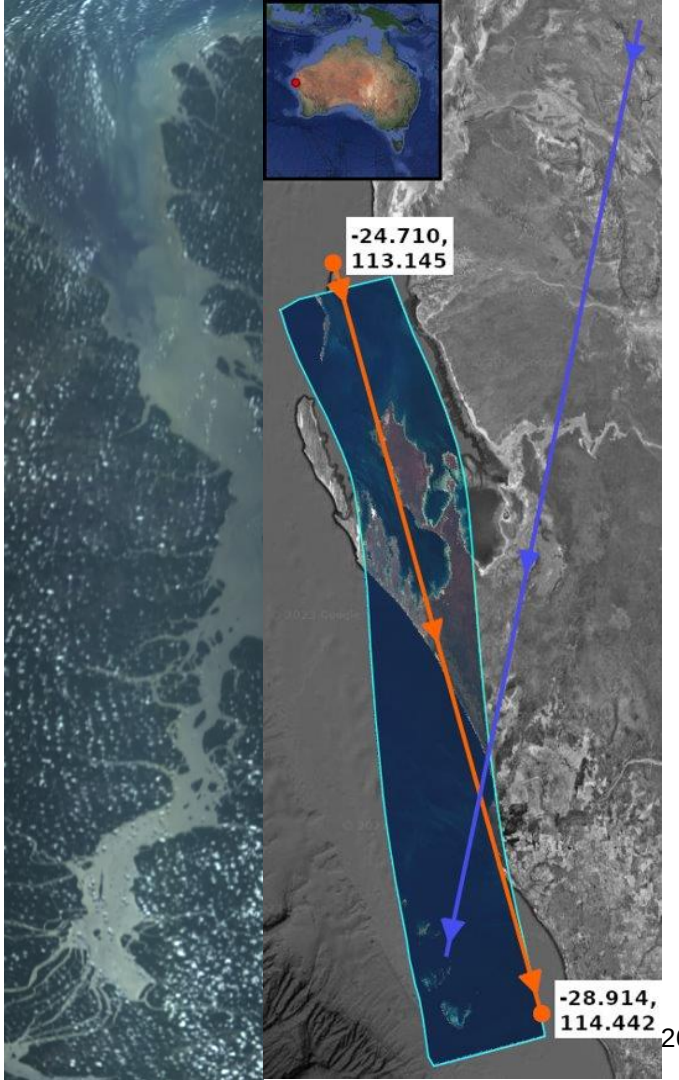

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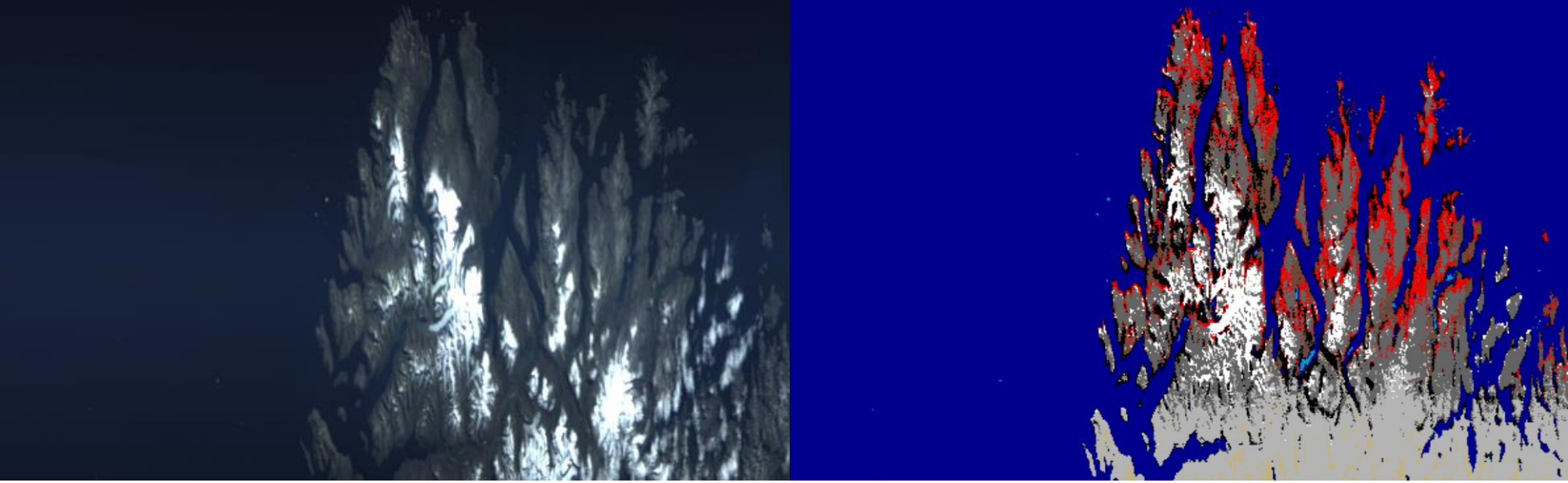
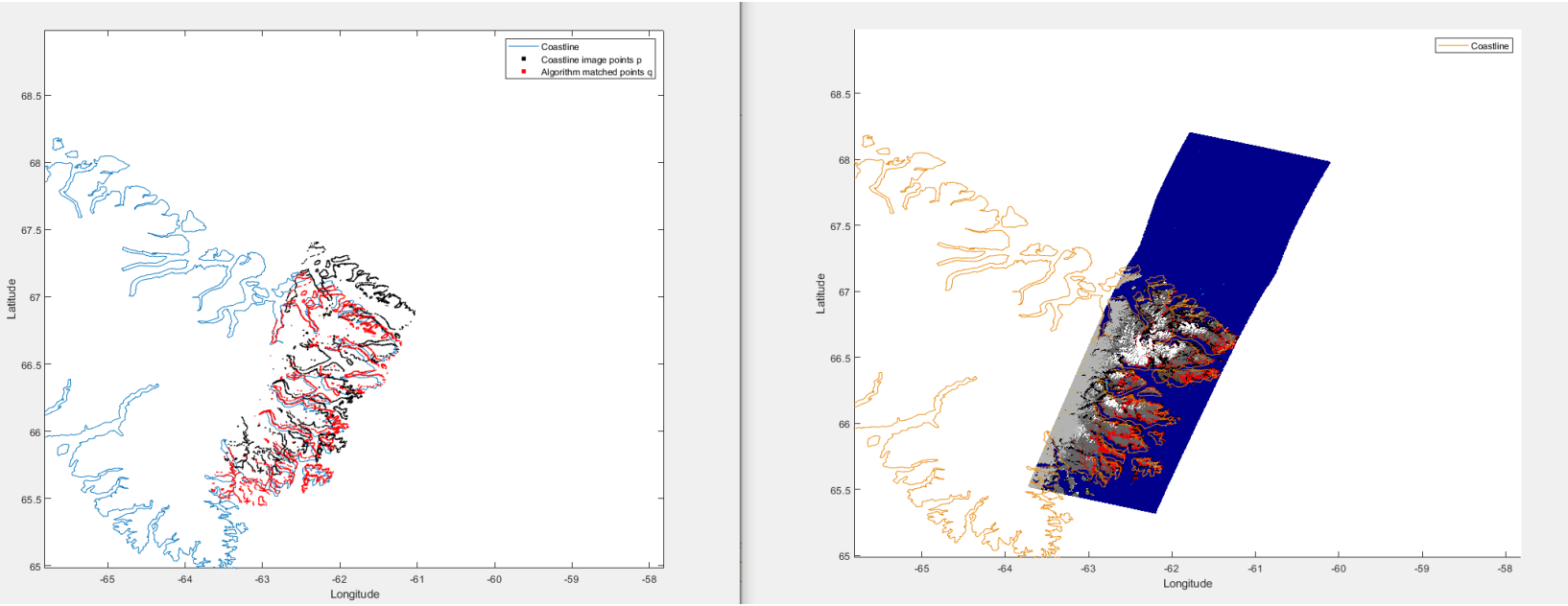
PROCESSING & SCHEDULING SOFTWARE



Jonas Røysland's work on onboard classification. **Ran on-board the satellite**

Røysland, Jonas; Langer, Dennis David; Berg, Simen; Orlandic, Milica; Garrett, Joseph Landon. (2023)
Hyperspectral classification onboard the HYPSO-1 cubesat. Workshop on Hyperspectral Image and
Signal Processing, Evolution in Remote Sensing

Direct georeferencing (not yet on-board)



Corrado Chiatante,
Currently only been run on ground

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Chiatante, Corrado; Langer, Dennis David; Garrett, Joseph Landon; Birkeland, Roger; Berg, Simen;
Orlandic, Milica. (2023) ONBOARD HYPERSPECTRAL CLASSIFICATION ENABLES GEOREFER-
ENCING. Workshop on Hyperspectral Image and Signal Processing, Evolution in Remote Sensing

Rapid response

Labels downlinked ~1 minute after image acquisition

Note: Incorrectly labeled

Scheduling software

Short version:

- Input a list of target areas with a priority
- Outputs scripts ready to be uploaded to the satellite

Accounts for

- Predicted cloud cover
- Elevation angle
- Sunlight
- Estimated downlink time
- Removes acquisitions that cannot be downlinked due to scheduling conflict

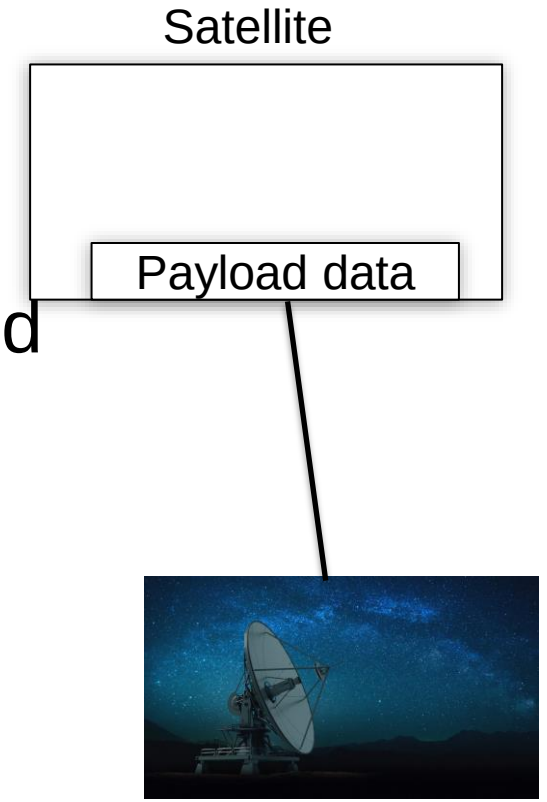
More in:
Berg, Simen; Bakken, Sivert; Birkeland, Roger; Chiatante, Corrado; Garrett, Joseph Landon; Johansen, Tor Arne. (2023) Ground systems software for automatic operation of the HYPSO-2 hyperspectral imaging satellite. Proceedings of SPIE, the International Society for Optical Engineering

ISSUES AND RESOLUTIONS

On-board storage

Problem

- SD-card for bulk storage
- One got corrupted/cannot be used



On-board storage

Resolution

- Tried locating corrupt parts of the storage and locking them off
  - It was unsuccessful
- Reconfigured system to use embedded memory chip instead
  - Less storage in total => less backlog to downlink payload data
  - Went from ~5-6 captures per day down to 3-4
  - With improved scheduling software: 5-6 captures per day again

Pointing issues

- Star tracker was sometimes blinded

Pointing issues

Solution:

- Calculate angle to sun in the scheduling software
- Rotate the satellite to point away from the sun & further away from the Earth

HYPSO-2

Improvements on the HYPSO-2 satellite

HYPSO-1

- S-Band for payload data downlink
- CAN bus for on-board data buffering

Capture & downlink capacity:
Data handling bottlenecked
~6 captures per day

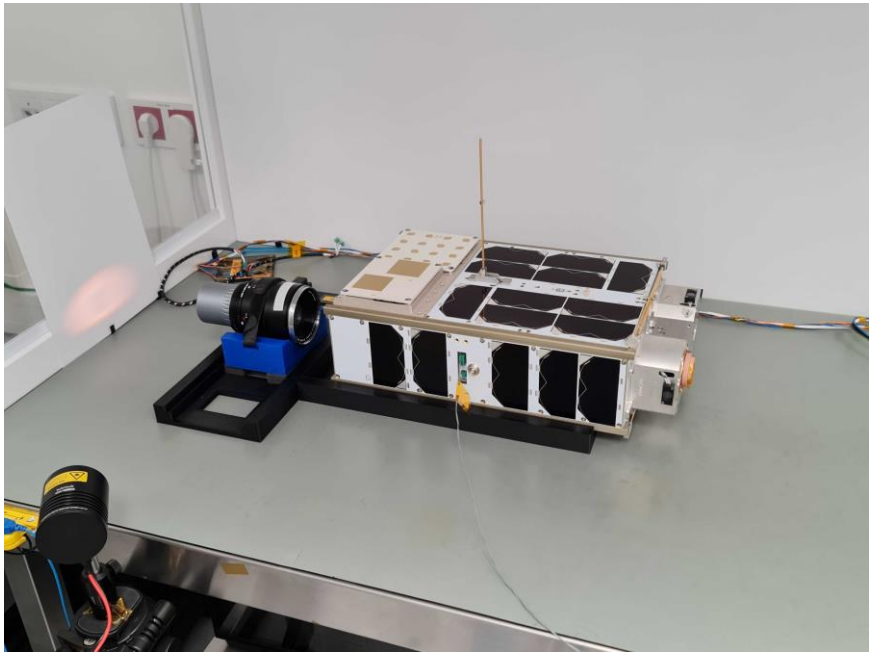
HYPSO-2

- X-Band for payload data downlink
- RS-422 for on-board data buffering
- Deployable solar panels
- Increased data storage

Capture & downlink capacity:
~50 captures per day

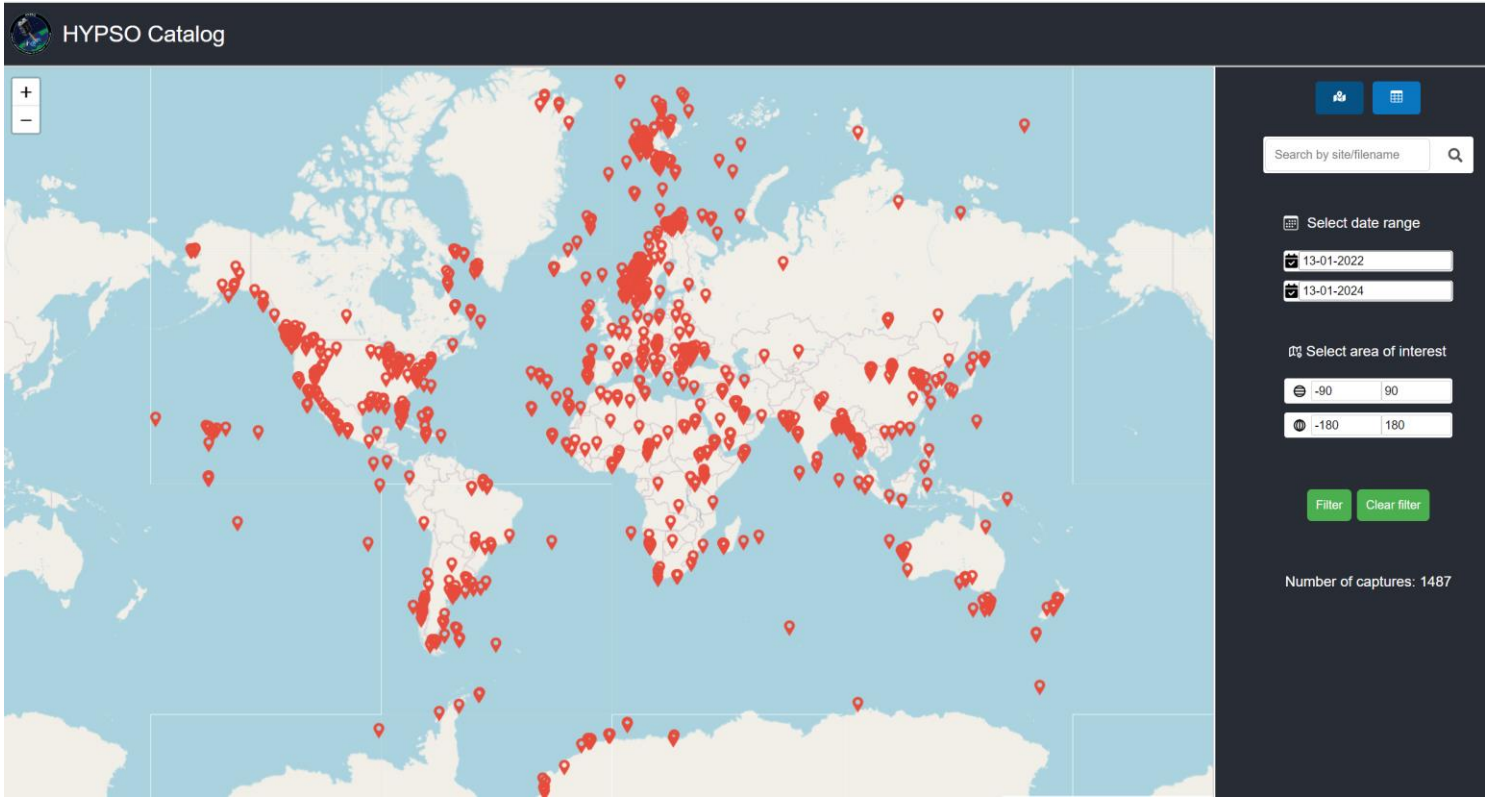
Current status

- Last touch by NTNU: December 2023
- Scheduled for launch in 2024



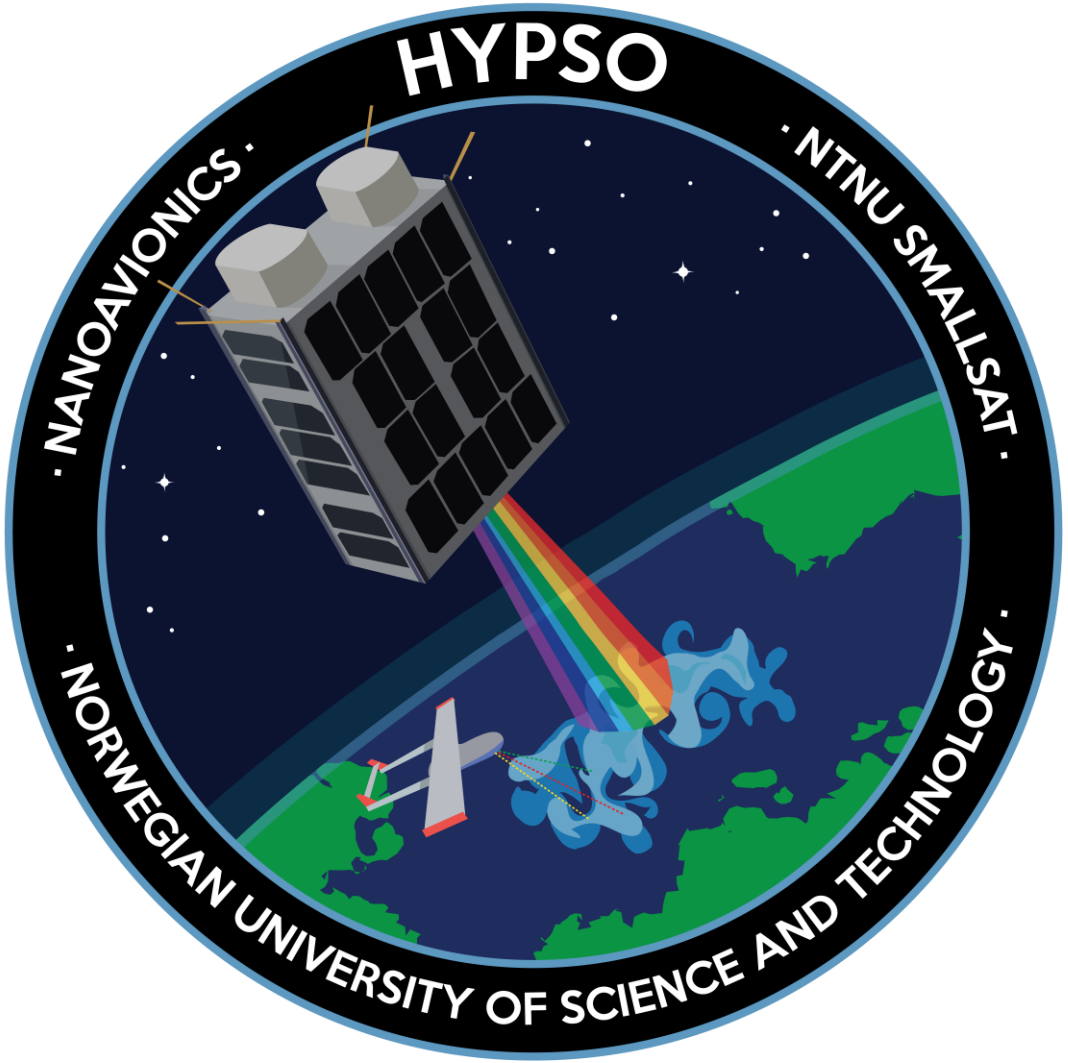
Final note - Data distribution

Work in progress



Thank you!

Simen Berg
simen.berg@ntnu.no



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