Mission Design Review Summary

Conclusions

- Mission is primarily a **tech demonstrator** and will give **scientific products** secondarily
  - Need to demonstrate **autonomous coordination of agents** for observation and in-situ validation
- **Q4 2019 or Q1 2020 launch** opportunities are expected
- **Orbit Configuration 2** (see slides) is most scientifically viable but less available in terms of launchers.
- Payload is 1/2 U, i.e. **we push for a 3U CubeSat** regardless of performance. 3U good enough, 6U better (will include SDR)
  - 3U baseline
  - More of a cost question
- If 6U is more feasible and cheaper, then **SDR** is proposed to be implemented. Would like a cost estimate here. **SDR is proposed only if we should go for a 6U**.
- Relax pointing requirements for cheaper cost
- Want to push development + launch + operations cost down to **8 MNOK for 2 missions (4-5 MNOK for first mission)**
- S-band for both downlink and uplink proposed **- KSAT only has S-band -** however TBD.
- Add another **RGB camera** to validate HSI images, only if it fits with the HSI in 1U
- **Level 2 and Level 4** are nominal processed data products
- **Start testing the HIS prototypes asap.**
  - **Need to manufacture electronics in parallel to testing the optics**
  - **There are two things to understand: 1) how optics work (all versions) and 2) how electronics shall accommodate flight-ready version**
- Coordinate with the **AUV group(s)** at NTNU and UPorto
- Payload **flight-ready HSI by Q1 2019** (incl. change in optics and data processing to meet requirements)
- Next mission in pipeline: **SDR or Hyperspectral Imager no. 2**
- Would like to be given **access to SDK** (+ source code) as much as possible for **academic research purposes (PhDs)**
- Will follow the **IOD CubeSat standard** – stay competitive
- **NTNU needs full control of downlinking/uplinking**
- Make overview table of how we perform compared to Sentinel, HICO and other CubeSats (Hawkeye, Hyperscout, SPOC and MOCI). **What is our selling point**.

Detailed

Mission Motivation:

- Mission is both a technology demonstration and science driven
  - Pushing the requirements to stay competitive in terms of optics & performance is necessary. Need to show novelty in terms of technology (optics + processing)
- Communicate with UAVs, USVs and AUV for direct coordination during campaigns necessary
  - Communications through mission control for now
  - UHF comms./SDR with USVs directly

- Need to support NTNU Field Campaigns with AUVs firmly (Frøya, Svalbard, potentially Lofoten). Also want to map the Baltic, Barents Sea, Iceland, Faroe Islands and Greenland.
- Spring time observations are sought more than summer time (fall and winter are "useless")
- PhD goals, requirements and objectives need to be integrated into the mission design – research shall be done on these platforms. Useful data from satellite labelled also as firm success criteria for mission. Need a survey on this from each PhD student.

Orbits:

- 2 Launch opportunities are sought
  - 1) 10:00-11:00 AM orbit that fulfils RAAN = 80-85 deg. This one is most available
  - 2) 8:00 – 9:00 PM orbit that fulfils RAAN = 230-235 deg
- This enables two sun-synchronous orbit configurations:
  - 1) covers one dedicated target at Norwegian coast per day. 450-550 km altitude.
  - 2) covers whole coast of Norway per day. 450-550 km altitude. This configuration is most desirable due to science.
  - Analysis should be done on both cases
  - April and May and morning-time observations are priority due to higher chance of detection
- Q4 2019 or Q1 2020 launch are goals, earlier is not feasible.
- Very low chance of detection – no. 2) enables higher chance of detection
- 1) needs downlink at Svalbard & uplink in Trondheim, 2) needs uplink at Svalbard and downlink in Trondheim. Access times between Ground Stations and satellite are satisfied.

Remote Sensing:

- Performance threshold for nadir-looking satellite is set to SNR=80:1 at all wavelengths (incl. 800 nm).
- Performance threshold for side-looking satellite is set to SNR=40:1 at all wavelengths (incl. 800 nm).
- Baseline frames per second is FPS = 30
- Baseline viewing angle at slewing is 20 degrees
- Pointing precision should be less than 0.01 degrees
- Mapping Error should be less than 100 m
  - Attitude determination error, instrument mounting error, stability over exposure time matters

Data Processing:

- Need to meet 3 firm requirements: data size, timeliness (processing time) and data quality (operational & scientific types)
- JPEG2000 will be used for lossless spatial compression
- TBD on algorithms for spectral and radiometric processing
- Deconvolution shall ideally be used frame by frame real-time (to avoid large data size)
- Level 2 (scientific, radiometrically calibrated) and Level 4 (operational, fully compressed, calibrated data) are baseline data products. Level 1a, 1b and 3 are upon request. Level 0 may be reconstructed from Level 1a. Definitions: https://science.nasa.gov/earth-science/earth-science-data/data-processing-levels-for-eosdis-data-products
- Operational and Raw data that is deconvoluted and spatially compressed meets the downlinking time requirements.
- Raw data that has not been undergone deconvolution cannot be downlinked. Suggestion: only 1 frame can be downlinked if this is the case (Level 1a or Level 0)

- Level 0 is only useful for characterizing the raw performance of camera (not scientifically useful) – i.e. one frame is enough.
- Response time, i.e. time between detection and end user, shall be no more than 30 min
- Processing time, i.e. end of image acquisition and downlink start, shall be no more than 1 min.
- Downlink time available is 6 min

<u>Communications:</u>

- KSAT and NTNU Trondheim are baseline Ground Stations, but keeping options fully open.
- S-band communications fulfil all requirements for downlink.
- Proposed to use S-band communications also for uplink.
- Relaxed pointing requirements for downlink (patch antenna has good directivity & performance even at off-angles).

<u>Hyperspectral Imager (Payload):</u>

- Proposed redesign of optics – larger front lens
- Open to other types of designs (see Svalbird proposal/concept)
- Proposed is to add another RGB camera to the PCB to validate HSI images
- Testing pipeline shall be of two segments:
    - Q1 2018 - UAV flights in Portugal (Feb); Balloon flight test at Mountain View High School (Feb/March); Learn calibration and testing at UNIS (Jan); Test across fjord (March/April). Prototype designs.
    - Q2/3 2018 - UAV flights in Norway (Summer); Independent calibration and testing (May); Test across fjord (Summer). Near-final designs.
    - Q1 2019 – Complete flight-ready hyperspectral imager and electronics for space

<u>Calibration of optics:</u>

- Monochromatic light source (550 nm); sky (blue); Black body type source of light; Diffuse source of light – even illumination (not focused); Closing lid; Source of light (clean room) and subtract the noise to see signal response
- Characterize Quantization Error, spectrum shifts and noise
- In-Orbit: lunar and solar light calibration for radiometric stability in on-board processing

<u>Spacecraft systems design:</u>

- Estimated mass is 4 kg for 3U and 6.3 kg for 6U
- Power consumption of HSI is 4 W in avg and estimated 10 W for peak
- Approx. 12 Wh in consumed in pass that have full operations (uplink+imaging operations+ downlink)
    - Motivates for 6U if more imaging flexibility is sought
    - 3U is sufficient for 3 fully operational passes per day; 6U may have much more flexibility
    - Need 36 Wh in total per day.
- Cost Estimates (hardware, software, launch, operations, training)
    - 3U: 6.2 – 8.3 MNOK
    - 6U: 9.5 – 13 MNOK
- 6U enables SDR as secondary payload, 3U does not.