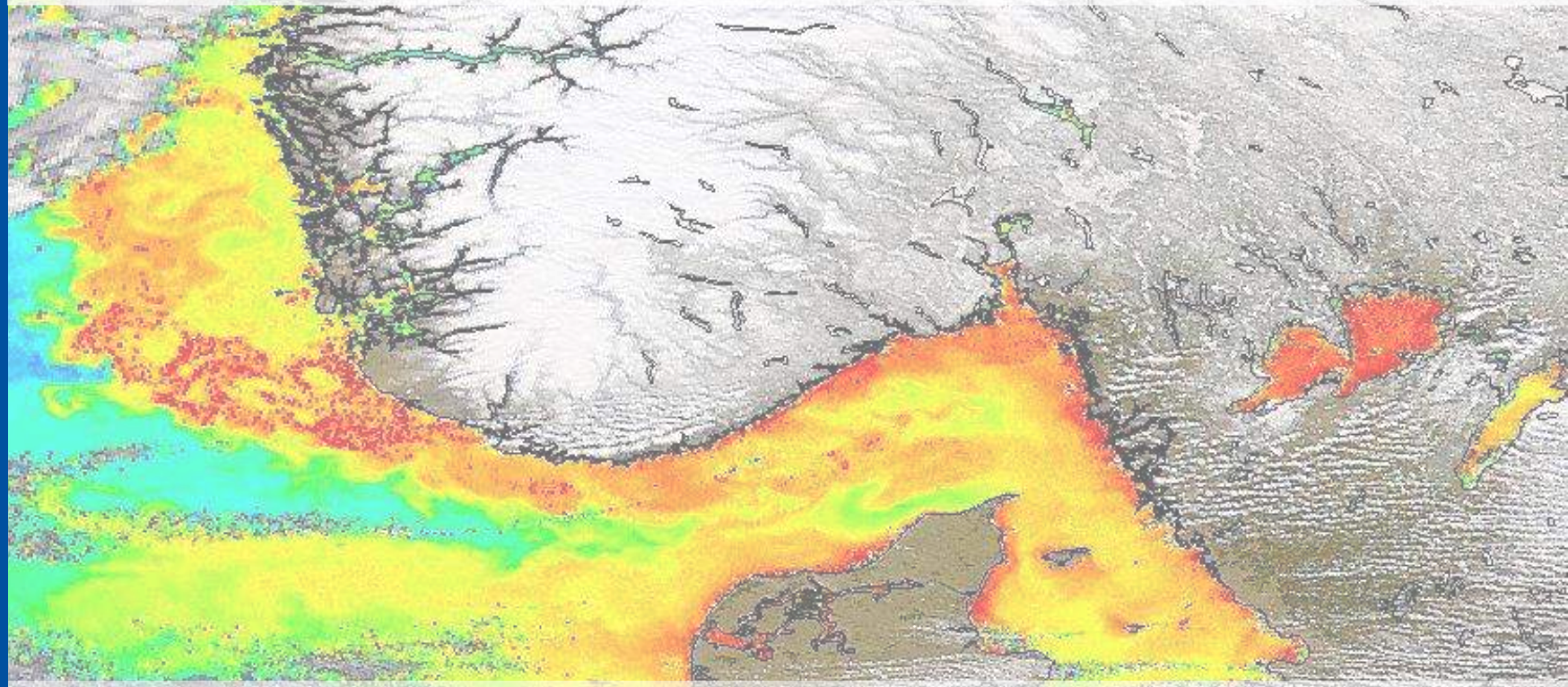
Mission design for NTNU SmallSat — a Hyper-spectral imaging mission

Mariusz E. Grøtte[1], Roger Birkeland[2], Joao Fortuna[1], Kanna Rajan[1;3], Tor A. Johansen[1], J. Tommy Gravdahl[1]



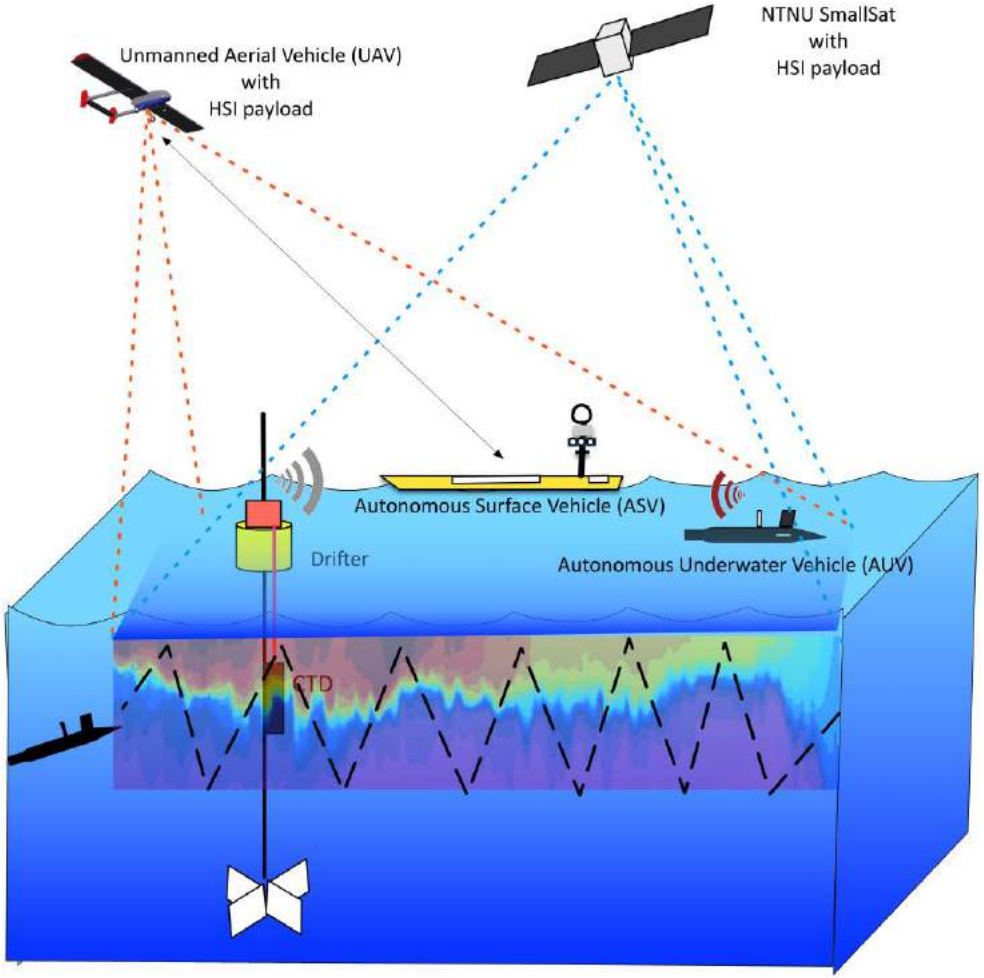
[1] Center for Autonomous Marine Operations and Systems (AMOS), Department of Engineering Cybernetics, Norwegian University of Science and Technology, Trondheim, Norway

[2] Department of Electronic Systems, Norwegian University of Science and Technology, Trondheim, Norway

[3] Faculty of Engineering, University of Porto, Portugal.

Image: Toxic Bloom off the Coast of Norway. Credit: NASA

Vision: the Robotic Platform Architecture



- High spatio-temporal resolution for oceanographic observations
- De-conflicting time and space is critical
- Observations in hours not days → space segment

Oceanography off Norway's coast

- Study of dynamic oceanographic processes (fronts, anoxic zones, plumes, blooms...)
- Maritime Surveillance

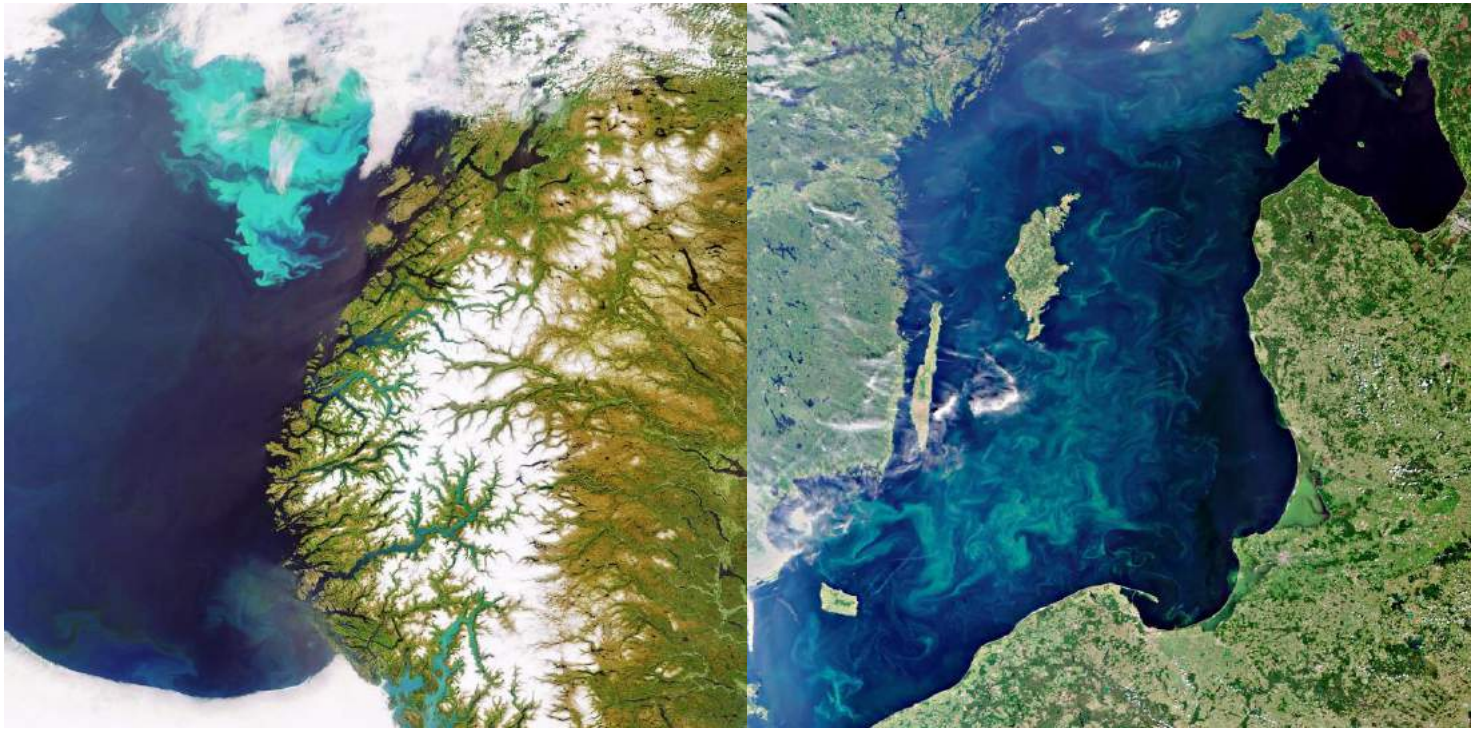


Fig.: Phytoplankton blooms observed from space. Left: bloom observed 10 th June 2006 by Envisat's MERIS instrument off the coast of Norway. Right: bloom observed in the Baltic Sea acquired by MERIS on 11 th July 2010.
Credit: ESA

Concept of Operations

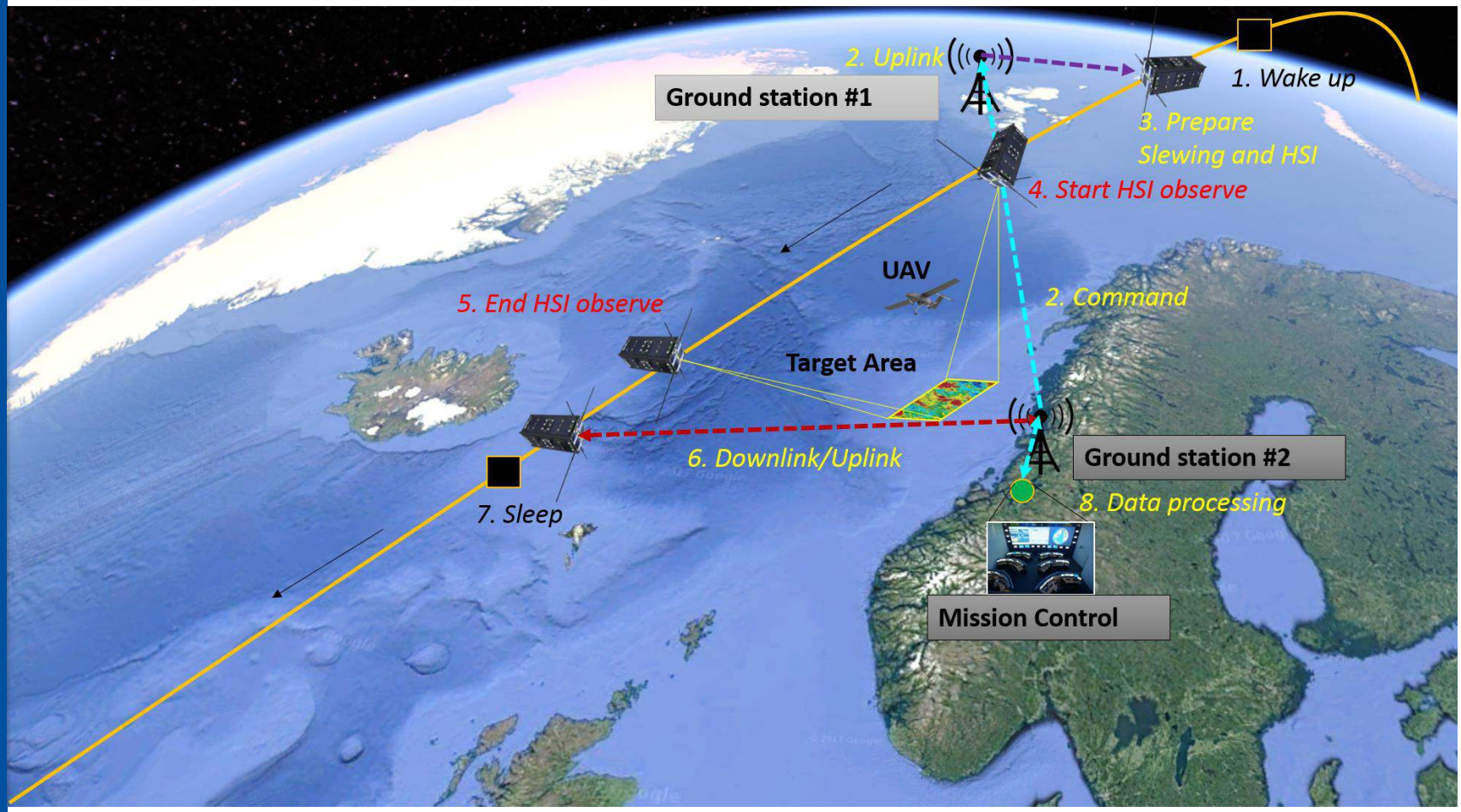
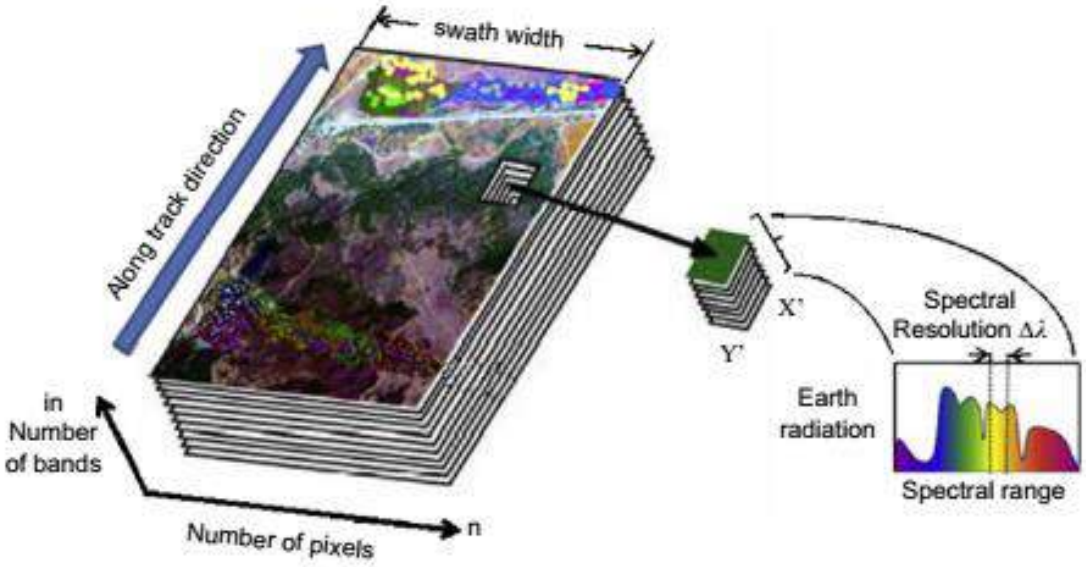


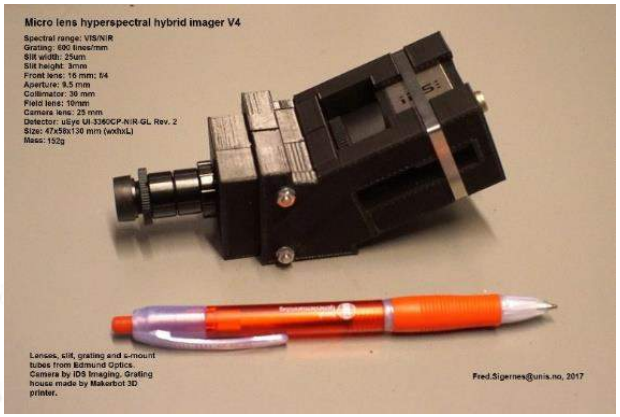
Fig.4 Concept of Operations. Satellite is in retrograde near-polar orbit and is operational about 5 min during one pass per day. Constellation is designed with baseline 3 revisits per day. Preliminary suggestions aim at a sun-synchronous orbit.

HSI Payload

- Spectral resolution of 5 nm
- Spectral range: 400 – 900 nm (VIS-NIR), usable: 100 bands
- Size of 1/3 U, and mass of <300 g
- Ground sampling distance (GSD) 100 meter/pixel



Credit: M. Guelman, F. Ortenberg / Acta Astronautica 64 (2009) 1252 –1263



Micro lens HSI
Credit: Fred Sigernes
http://fred.unis.no

NTNU

Mission Design

Mission Objectives

1) **Provide and support oceanography through**
   - **Hyper-Spectral Imaging**
   - **Autonomous communications in an concert of robotic agents in Atlantic Ocean**

2) To collect statistical data and detect and characterize:
   - spatial extant extent of **algal blooms**
   - emittance from **fluorescence** generating microorganisms
   - other substances resulting from **aquatic habitats and pollution**

3) Investigate analytical reduced-order sizing relationships for
   - identified **performance** characteristics
   - constituent SmallSat properties as related to oceanography

4) Build strong competence and strengthen prospect of SmallSats as supporting intelligent agents in integrated **autonomous** robotic systems for dedicated **marine** and **maritime** applications

Mission Requirements

Level 0 mission statement

NTNU SmallSat mission shall, through targeting high-resolution Hyperspectral Imaging, demonstrate proof-of-concept oceanographic observations.

Level 0 – minimum mission success criteria

- S/C shall successfully launch, deploy and initialize operations in LEO at 400-700 km altitude
- Shall enable HSI operations over target area in the Atlantic Ocean
- Shall identify and track a target ocean area with precise tracking
- Shall take 10 HS images with required spectral bands in 400-900 nm range that will include at least 1 particular signature of scientific target
- Ground user shall be able to download at least 10 on-board spatially compressed images and on-board telemetry data for direct/indirect interpretation
- *Shall be operational for 30 days and enable mission updates during peak-season and target localization*

Level 1 mission requirements

- Shall detumble with full mission operations support during 10 orbits
- Must enable initial mission plan update to start space segment operations
- Shall enable sleep on/ off during on/ off HSI demands autonomously and on command
- Target area shall be at least FoV of 50x50 km ground
- Target area shall be observed at least 3 min per pass with 3 passes per day
- Target shall be observed at approx. 60 deg N and 10 deg E
- Shall operational at least 10 min/day, during brightest time of the day in peak season
- Target area shall be observable and imaged by S/C given max. 1250 km movement (westwards) cross-track on previous /subsequent pass
- Must enable GSD < 100 m
- Target area shall be observed with max. 100 m precision discrepancy
- Slew maneuver shall be prepared for and enabled prior to observing operations
- Processed images shall have 500 x 500 pixels resolution where each pixel has at max. 100 m x 100 m resolution
- Detections on signatures from 100 spectral bands must be made during observation
- Faintest signature that is set to observe must be at ? SNR
- Raw images shall have Δx = 400 m and Δy = 83 m spatial resolution
- Radiometric, spectral, spatio-temporal, geometric data processing must happen in-orbit
- Model update of mission data shall happen in-orbit
- Space segment agent shall be coordinated with other robotic agents indirectly
- Shall downlink data at least 200 kbit/s to at least 1 ground station
- Must adhere to Space Debris Policy and enable de-orbit upon end-of-life within 25 years
- Space segment shall enable updates on mission planning
- Space segment shall support re-scheduling of planned events by ground command.

Detailed Success Criteria in Initial-Operations

Success Criteria	Min	Full
Launch of `SmallSat`	✓	
Deployment of `SmallSat` in LEO	✓	
Identification after 1 orbit `SmallSat`	✓	
Tracking of `SmallSat` over 1 orbit		✓
Power systems ON	✓	
Communications achieved	✓	
Enable slew maneuver to target area		✓
HSI operations over target area (10 img)	✓	
Acquire images with required spectral bands		✓
Downlink on-board processed data		✓
Enable sleep off/on		✓
Repeat in 4 consecutive passes giving 4 images	✓	
Repeat until end-of-life		✓

Architectures

A. Mission Concept	HSI mapping of the ocean with autonomous on-board processing of mission data, then transmitted after pass. Ground commands on mission plan.
B. Controllable Subjects	None
C. Passive Subject	Oceanography through Hyperspectral light
D. Payload	Small aperture HSI
E. Spacecraft Bus	2-6U size; 3-axis stabilization; spacecraft pointing; body-mounted solar panels; onboard GPS; onboard orbit control; possibly micro-propulsion
F. Orbit	SSO; 1-satellite
G. Launch System	PSLV (depends on orbit)
H. Ground System	Dedicated: NTNU; Commercial (e.g. KSAT)
I. Communications Architecture	Store & dump data; TM/TC-transceiver; >2 ground stations; UHF-band uplink, X-band downlink; SDR
J. Mission Operations	Fully automated ground stations; part-time operations on demand; Indirect updates on mission to/from other robotic agents

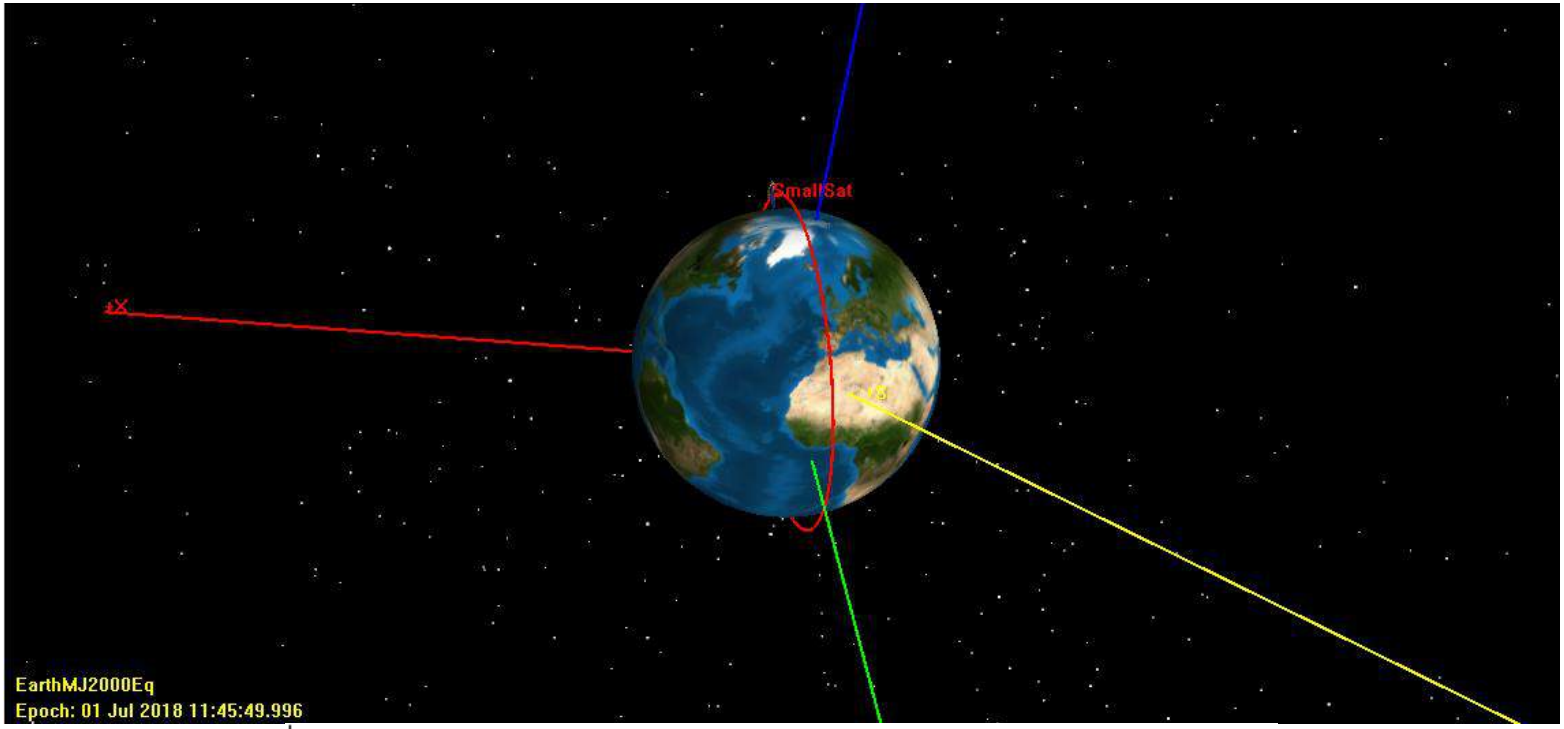
Rank	Mission Architecture
1	A3-B1-C1-D1-E1-F1-G1-H1-I1-J1
2	A1-B1-C1-D1-E1-F2-G1-H1-I2-J1
3	A3-B1-C1-D1-E1-F2-G1-H1-I1-J1
4	A3-B1-C1-D1-E1-F1-G1-H1-I2-J1
5	A2-B2-C1-D1-E1-F1-G1-H1-I6-J2

Alternative trade-offs

- A
  - Send raw data
  - Autonomous platform
  - Detect signatures
- B
  - Track UAVs on Earth
- F
  - LEO (i=75-90 deg)
  - 2 satellites
- I
  - S-band uplink
  - S-band downlink
- J
  - Direct updates on mission

- Have now 40 architectures to choose from
- TOPSIS evaluation

Orbit – SSO or LEO



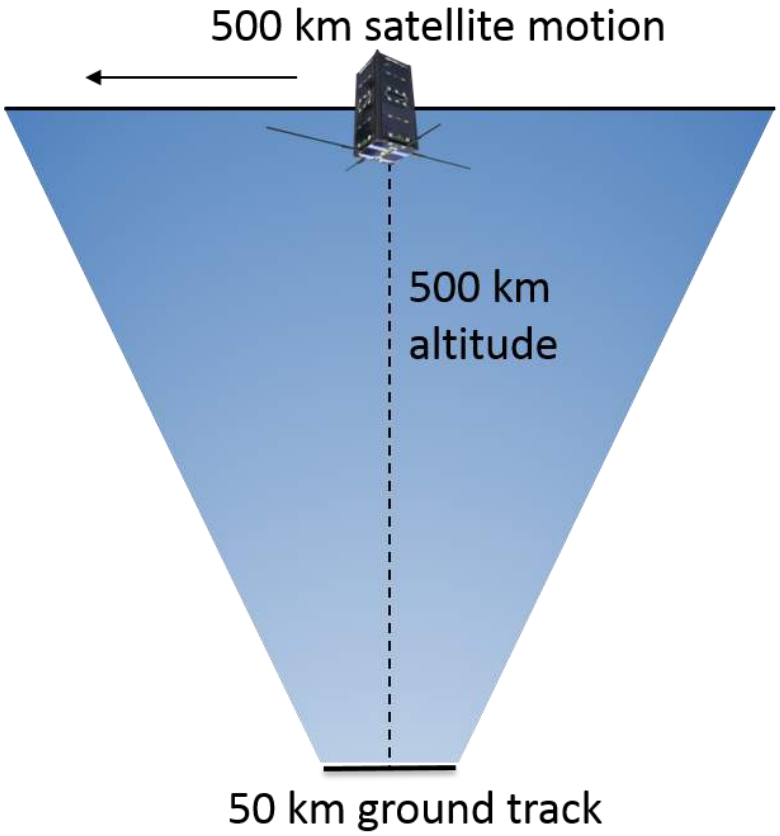
Target: SmallSat

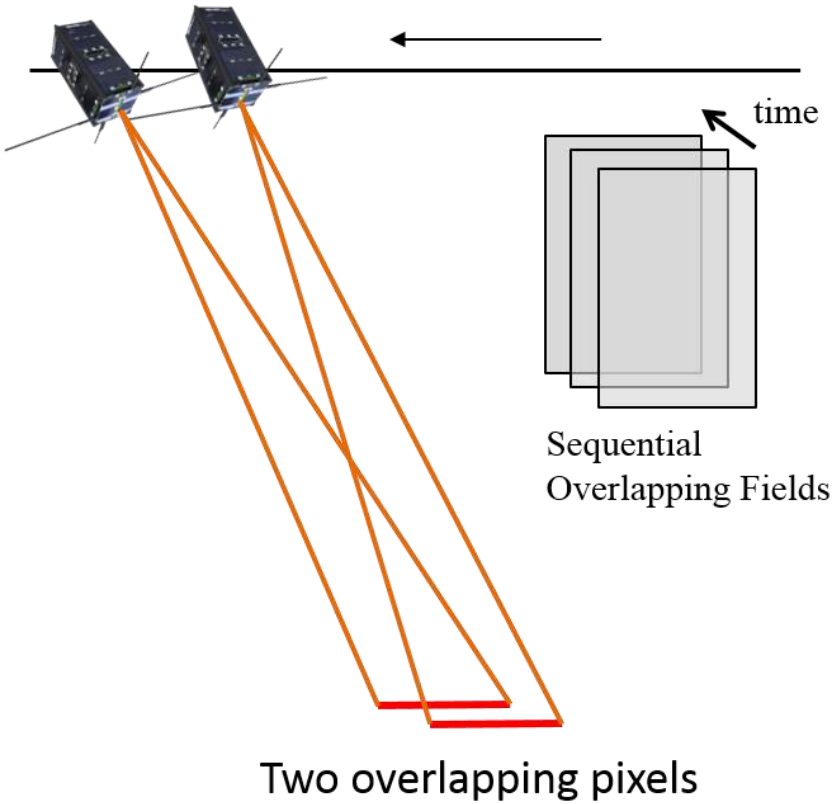
Observer: NTNU_Trondheim

Start Time (UTC)	Stop Time (UTC)	Duration (s)
01 Jul 2018 08:15:41.561	01 Jul 2018 08:22:10.578	389.01718687
01 Jul 2018 09:49:46.056	01 Jul 2018 09:58:08.545	502.48963548
01 Jul 2018 11:26:36.876	01 Jul 2018 11:33:17.025	400.14833029
01 Jul 2018 22:55:51.403	01 Jul 2018 23:03:37.550	466.14723962
02 Jul 2018 00:31:18.491	02 Jul 2018 00:39:36.433	497.94238752
02 Jul 2018 02:07:27.362	02 Jul 2018 02:13:00.503	333.14039593

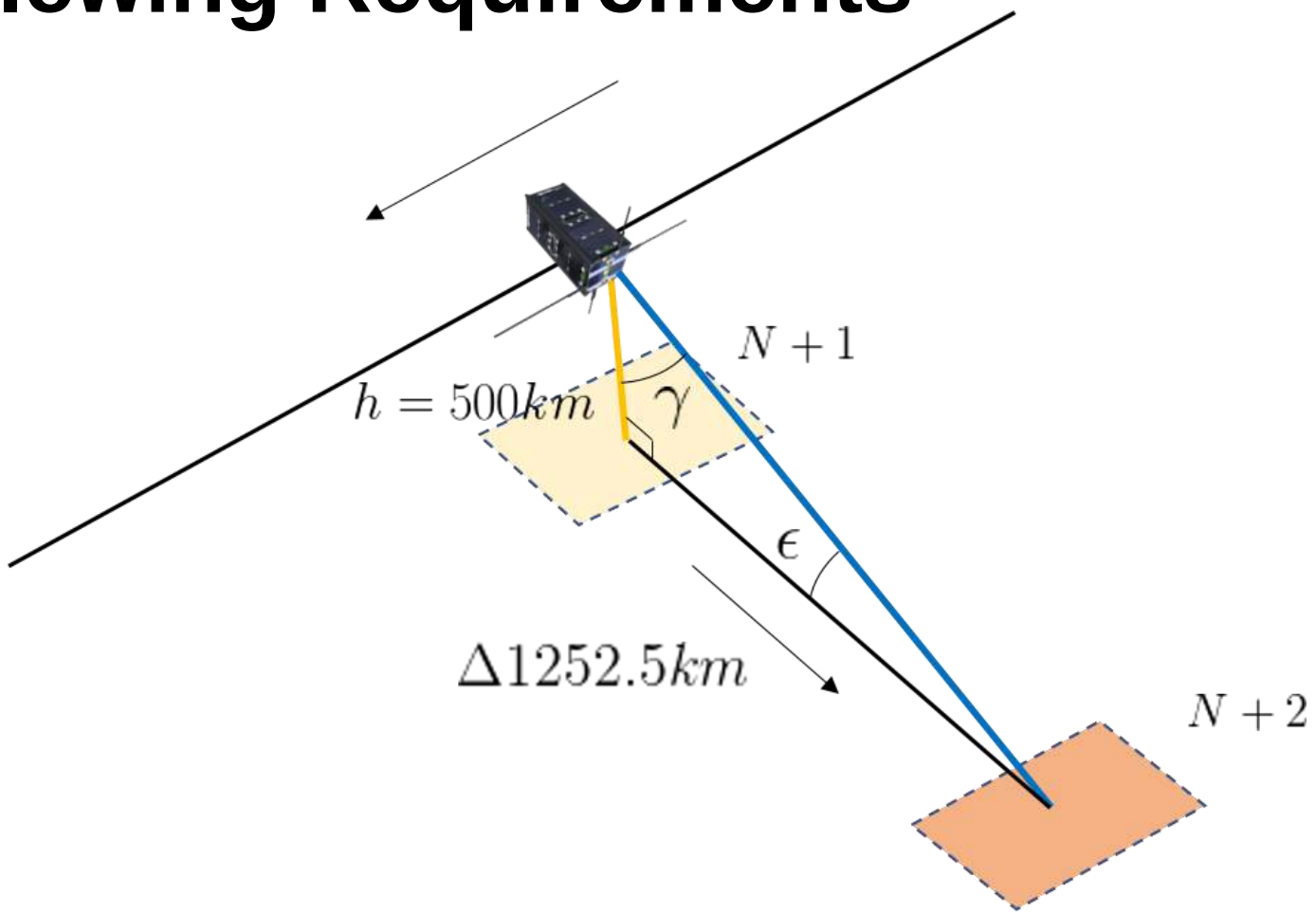
Number of events : 6

Slew maneuver



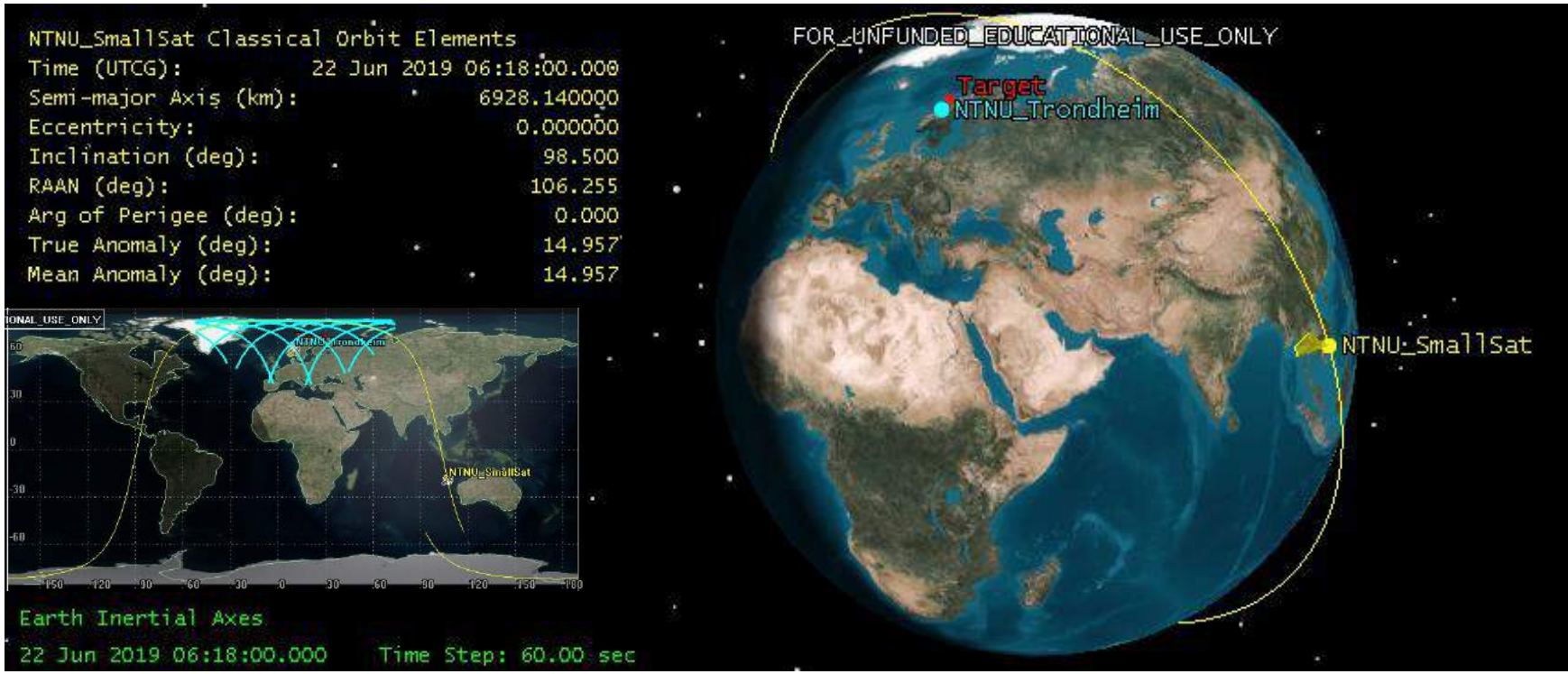


Slewing Requirements

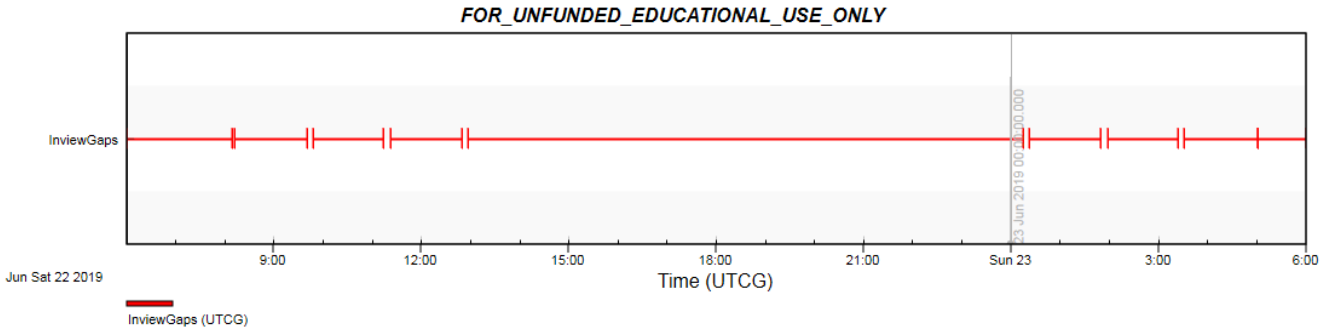


θ=30 deg from Nadir is required along-track
γ=64 deg from Nadir is required cross-track
Slew rate = <1 deg/s
Pointing accuracy = 0.1 deg (relative to target area)

STK Mission Analysis



Number of passes (HSI)



Satellite-NTNU_SmallSat-To-AreaTarget-Target: Access Summary Report

NTNU_SmallSat-To-Target

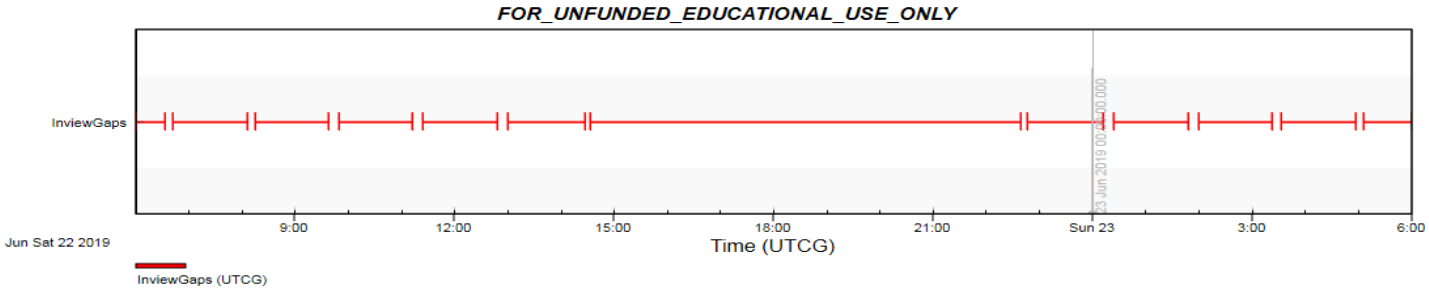
Access	Start Time (UTCG)	Stop Time (UTCG)	Duration (sec)
1	22 Jun 2019 06:33:12.372	22 Jun 2019 06:41:57.550	525.178
2	22 Jun 2019 08:05:55.694	22 Jun 2019 08:15:47.845	592.152
3	22 Jun 2019 09:38:49.748	22 Jun 2019 09:50:20.626	690.877
4	22 Jun 2019 11:12:58.869	22 Jun 2019 11:25:09.847	730.978
5	22 Jun 2019 12:49:06.168	22 Jun 2019 12:59:55.123	648.955
6	22 Jun 2019 14:28:10.698	22 Jun 2019 14:33:51.045	340.347
7	22 Jun 2019 22:37:58.239	22 Jun 2019 22:45:55.163	476.924
8	23 Jun 2019 00:12:17.662	23 Jun 2019 00:23:48.056	690.394
9	23 Jun 2019 01:47:06.077	23 Jun 2019 01:59:07.434	721.357
10	23 Jun 2019 03:21:53.119	23 Jun 2019 03:32:49.067	655.948
11	23 Jun 2019 04:56:17.722	23 Jun 2019 05:05:38.024	560.302

Global Statistics

Min Duration	6	22 Jun 2019 14:28:10.698	22 Jun 2019 14:33:51.045	340.347
Max Duration	4	22 Jun 2019 11:12:58.869	22 Jun 2019 11:25:09.847	730.978
Mean Duration				603.037
Total Duration				6633.411

h=550 km, duration = 12,12 min

Number of passes (Comms.)



Facility-NTNU_Trondheim-Receiver-Antenna-To-Satellite-NTNU_SmallSat: Access Summary Report

Antenna-To-NTNU_SmallSat

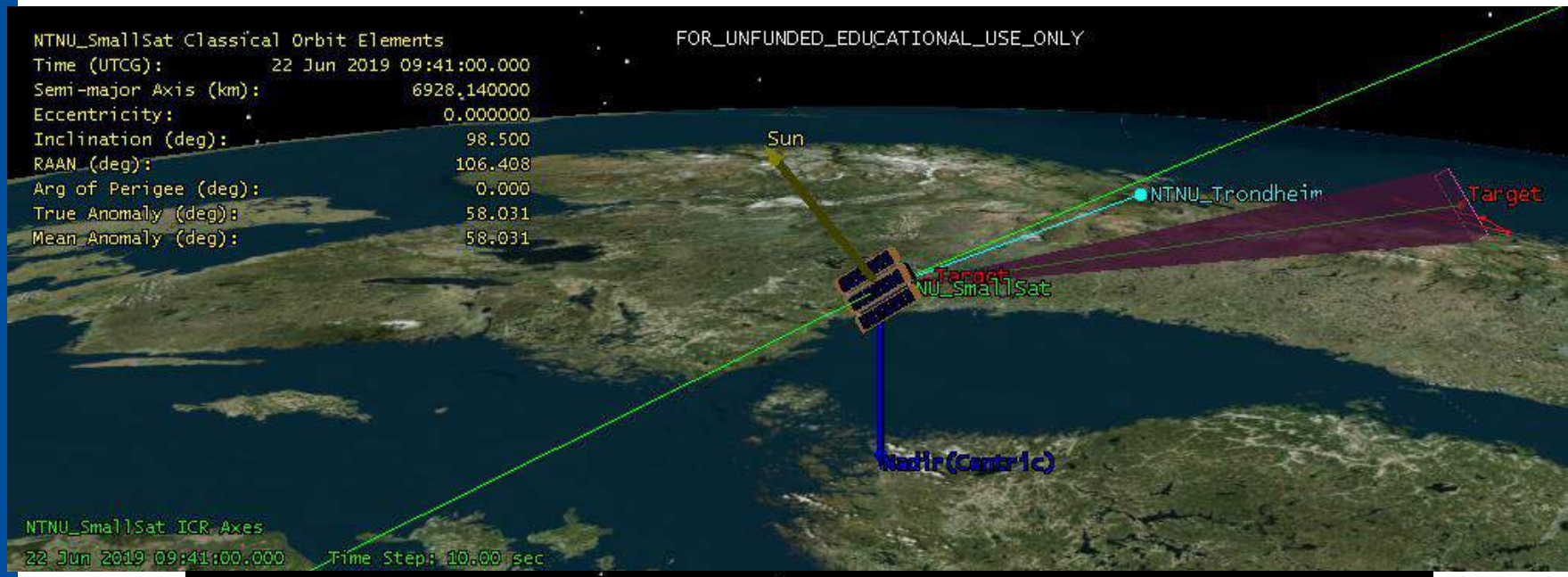
Access	Start Time (UTCG)	Stop Time (UTCG)	Duration (sec)
1	22 Jun 2019 06:33:34.437	22 Jun 2019 06:41:31.627	477.190
2	22 Jun 2019 08:05:53.375	22 Jun 2019 08:15:18.233	564.858
3	22 Jun 2019 09:38:25.027	22 Jun 2019 09:49:54.097	689.070
4	22 Jun 2019 11:12:17.627	22 Jun 2019 11:24:44.593	746.966
5	22 Jun 2019 12:48:12.332	22 Jun 2019 12:59:27.153	674.821
6	22 Jun 2019 14:27:23.646	22 Jun 2019 14:33:05.490	341.844
7	22 Jun 2019 22:38:35.017	22 Jun 2019 22:46:29.674	474.658
8	23 Jun 2019 00:12:44.391	23 Jun 2019 00:24:33.934	709.543
9	23 Jun 2019 01:47:31.376	23 Jun 2019 01:59:53.494	742.118
10	23 Jun 2019 03:22:20.406	23 Jun 2019 03:33:20.981	660.575
11	23 Jun 2019 04:56:47.745	23 Jun 2019 05:05:41.238	533.493

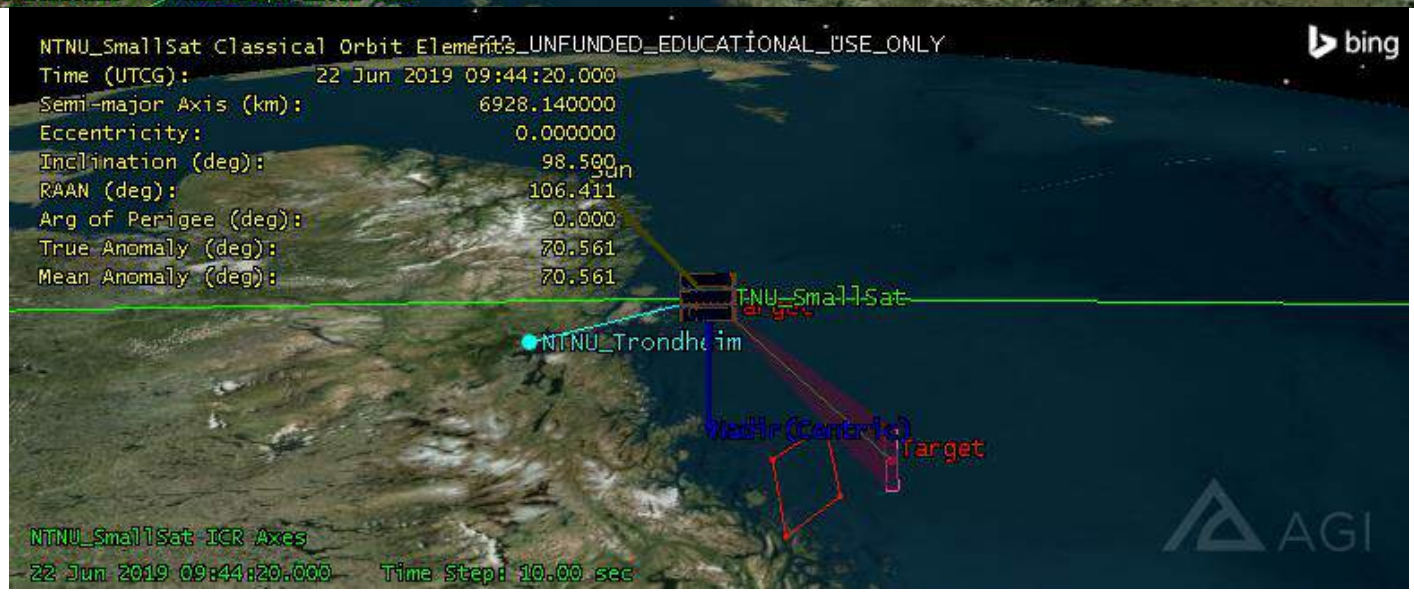
Global Statistics

Min Duration	6	22 Jun 2019 14:27:23.646	22 Jun 2019 14:33:05.490	341.844
Max Duration	4	22 Jun 2019 11:12:17.627	22 Jun 2019 11:24:44.593	746.966
Mean Duration				601.376
Total Duration				6615.135

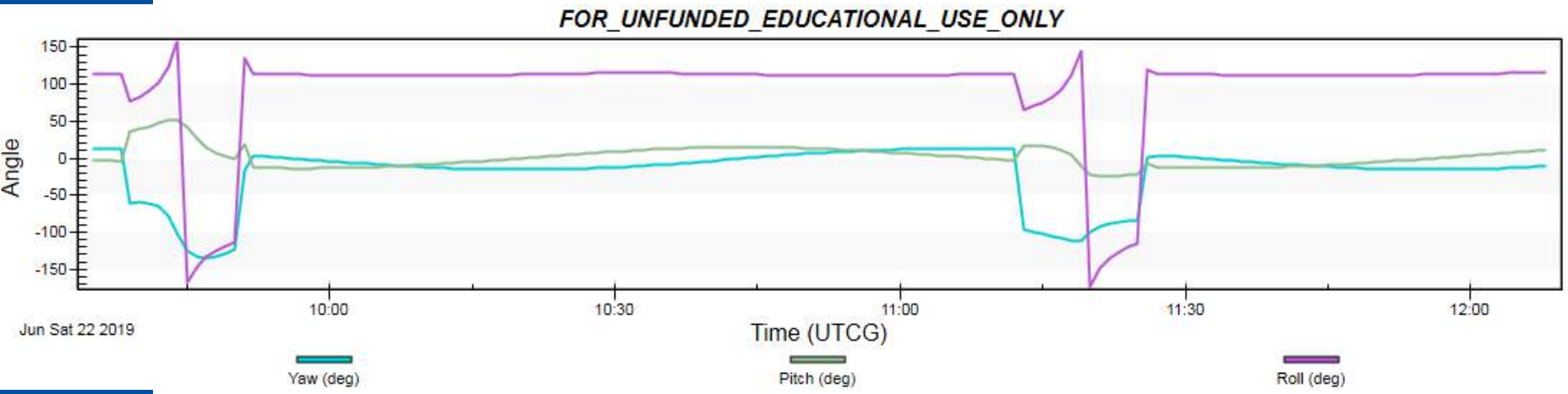
h=550 km, duration = 12,45 min

Simulations

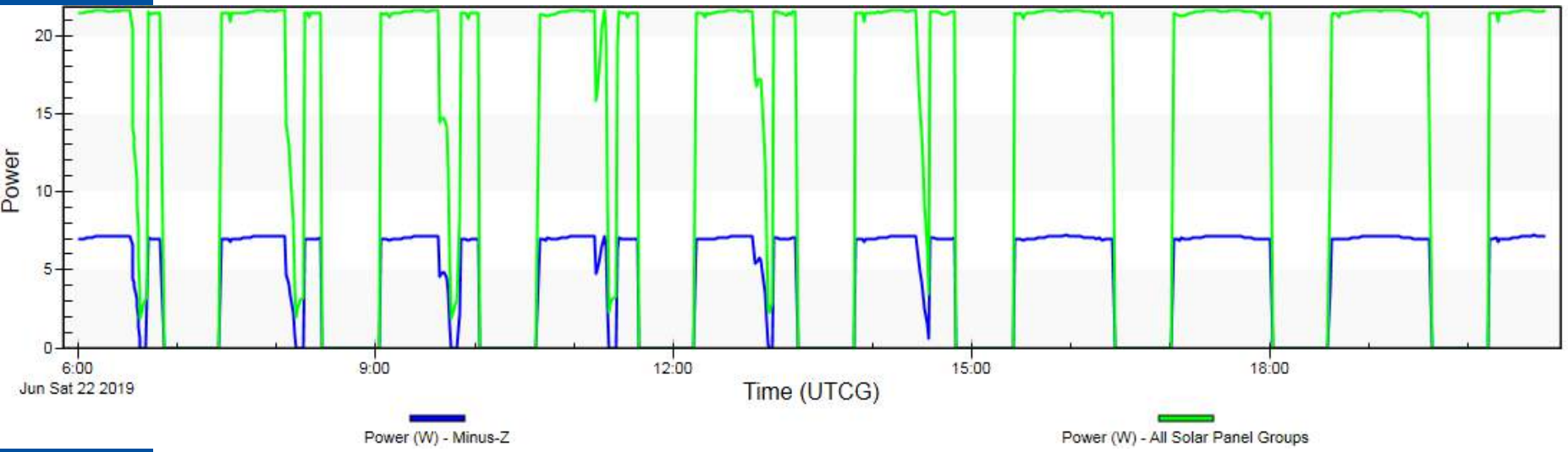




Yaw-Pitch-Roll at Slew



Solar Panels

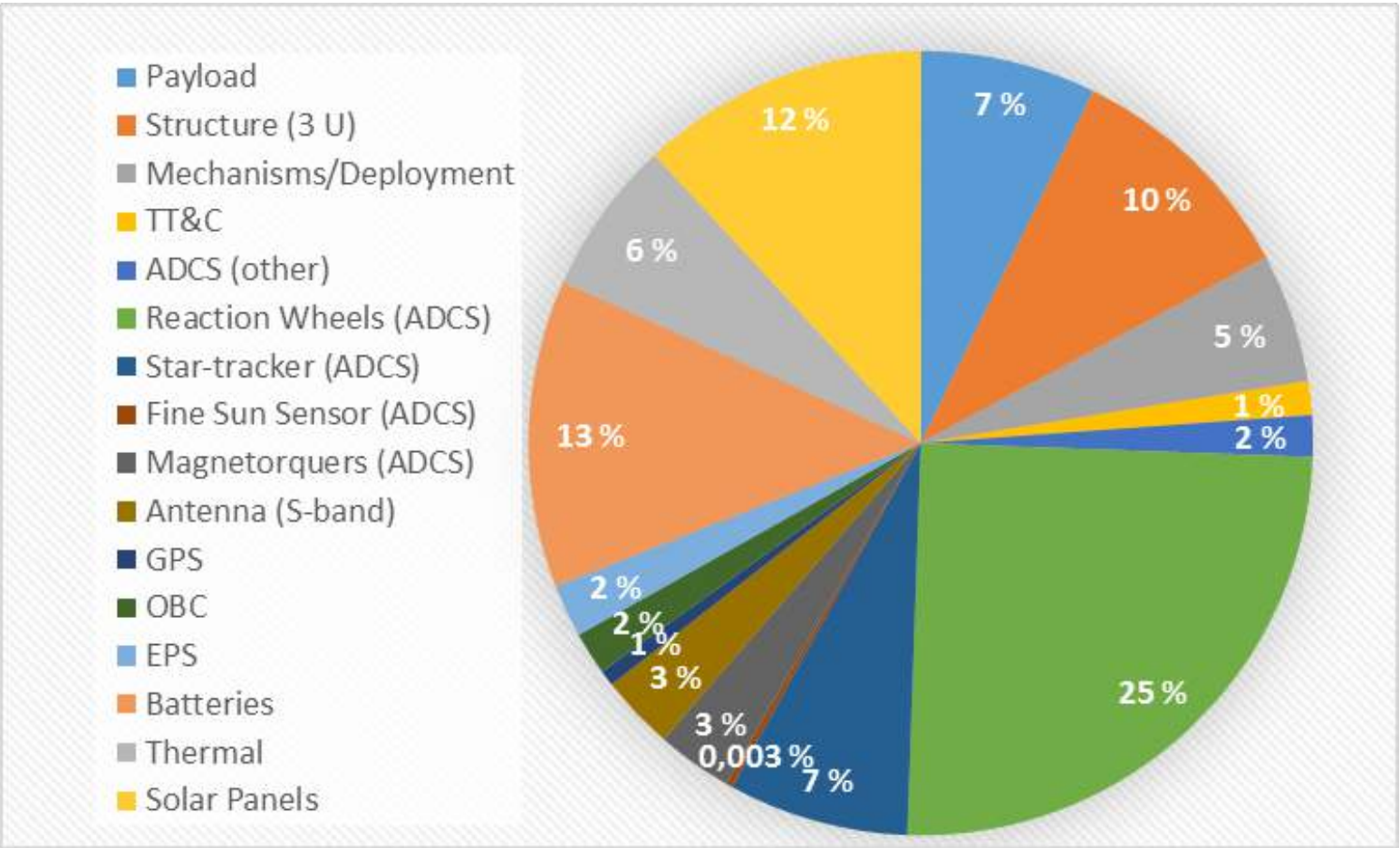


Mass Budget

Subsystem	Nominal Mass (g)	Margin (%	Mass w. Margin (g)
Payload	250	20	300
Structure (3 U)	390	5	409,5
Mechanisms/Deployment	200	10	220
TT&C	55	5	57,75
ADCS (other)	64	10	70,4
Reaction Wheels (ADCS)	940	10	1034
Star-tracker (ADCS)	280	10	308
Fine Sun Sensor (ADCS)	9	20	10,8
Magnetorquers (ADCS)	108	20	129,6
Antenna (S-band)	110	15	126,5
GPS	24	15	27,6
OBC	69,5	5	72,975
EPS	86	5	90,3
Batteries	500	5	525
Thermal	240	10	264
Solar Panels	468	5	491,4
Total	3793,5		4137,825
Total with extra Margin (10%)	4172,85		4551,6075

Ref: Survey of COTS from Gomspace, Hyperion Technologies, Clydespace
https://gomspace.com/
https://www.clyde.space/
http://hyperiontechnologies.nl

Mass Budget


Payload
Structure (3 U)
Mechanisms/Deployment
TT&C
ADCS (other)
Reaction Wheels (ADCS)
Star-tracker (ADCS)
Fine Sun Sensor (ADCS)
Magnetorquers (ADCS)
Antenna (S-band)
GPS
OBC
EPS
Batteries
Thermal
Solar Panels
7 %
10 %
5 %
1 %
2 %
25 %
7 %
0,003 %
3 %
3 %
1 %
2 %
2 %
13 %
6 %
12 %

Power Budget (Average)

Subsystem	Power (W)	Margin (%)	Power w. Margin (W)
Payload	3	5	3,15
Mechanisms/Deployment	0,01	5	0,0105
TT&C	1	5	1,05
ADCS (other)	1	5	1,05
Reaction Wheels (ADCS)	0,9	5	0,945
Star-tracker (ADCS) 5 Hz	0,7	5	0,735
Fine Sun Sensor (ADCS)	0,00001005	5	1,05525E-05
Magnetorquers (ADCS)	3,9	5	4,095
Antenna (S-band) Idle	0,2	5	0,21
GPS	1,155	5	1,21275
OBC	2,3	5	2,415
EPS	1	5	1,05
Batteries	0,064	5	0,0672
Thermal	2	5	2,1
Solar Panels	0	5	0
Total	17,22901005		18,09046055
Total with extra Margin (10%)	18,95191106		19,89950661

Ref: Survey of COTS from Gomspace, Hyperion Technologies, Clydespace
https://gomspace.com/
https://www.clyde.space/
http://hyperiontechnologies.nl

Power Budget (TX Transmitting)

TX ON (Comms. Only)			
Subsystem	**Peak Power (W)**	**Margin (%)**	**Peak Power w. Margin (W)**
Payload	0	5	0
Mechanisms/Deployment	0	5	0
TT&C	1	5	1,05
ADCS (other)	1	5	1,05
Reaction Wheels (ADCS)	1,8	10	1,98
Star-tracker (ADCS) 20 Hz	0,7	10	0,77
Fine Sun Sensor (ADCS)	0,00001005	10	0,000011055
Magnetorquers (ADCS)	3	10	3,3
Antenna (S-band) TX	10,7	10	11,77
GPS	1,155	5	1,21275
OBC	2,3	5	2,415
EPS	1	5	1,05
Batteries	0,064	5	0,0672
Thermal	0	5	0
Solar Panels	0	5	0
Total	22,71901005		24,66496106
Total with extra Margin (10%)	24,99091106		27,13145716

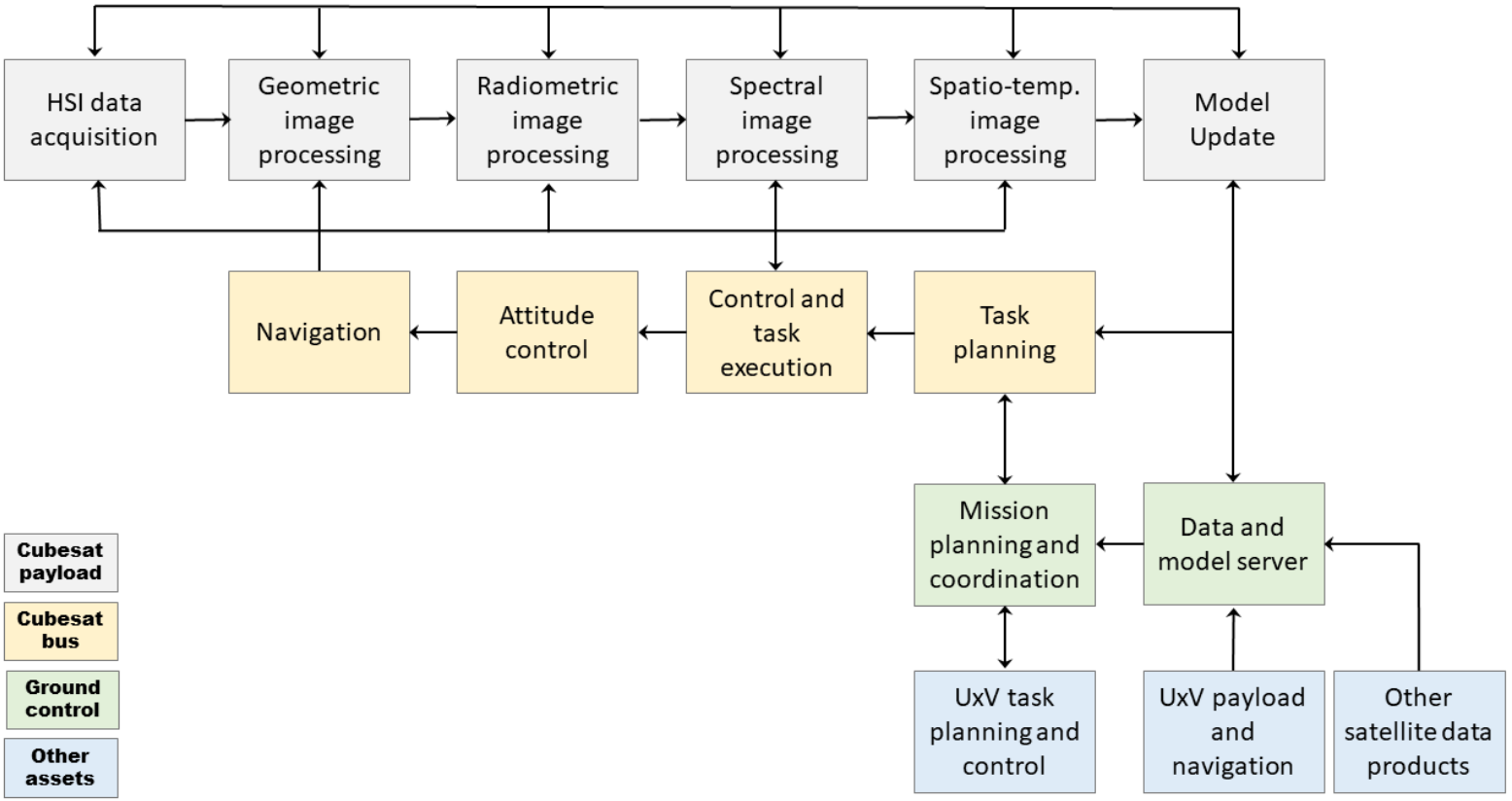
Ref: Survey of COTS from Gomspace, Hyperion Technologies, Clydespace
https://gomspace.com/
https://www.clyde.space/
http://hyperiontechnologies.nl

Power Budget (HSI Operations)

HSI + Slewing			
Subsystem	**Peak Power (W)**	**Margin (%)**	**Peak Power w. Margin (W)**
Payload	8	5	8,4
Mechanisms/Deployment	0	5	0
TT&C	2	5	2,1
ADCS (other)	3	5	3,15
Reaction Wheels (ADCS)	4,65	10	5,115
Star-tracker (ADCS) 20 Hz	2,8	10	3,08
Fine Sun Sensor (ADCS)	0,0402	10	0,04422
Magnetorquers (ADCS)	3	10	3,3
Antenna (S-band) TX	0,2	5	0,21
GPS	1,155	5	1,21275
OBC	2,3	5	2,415
EPS	1	5	1,05
Batteries	0,064	5	0,0672
Thermal	0	5	0
Solar Panels	0	5	0
Total	28,2092		30,14417
Total with extra Margin (10%)	31,03012		33,158587

Ref: Survey of COTS from Gomspace, Hyperion Technologies, Clydespace
https://gomspace.com/
https://www.clyde.space/
http://hyperiontechnologies.nl

Processing and Control



Preliminary Data Budget

Estimation of size of one target measurement packet, one pr. pass:

- **Compressed (spectral domain)**
  500 pixels x 500 pixels x 2 bytes/pixel x 10 channels = 5 Mbytes = 50 Mbits
  S-band:
  50 Mbits / 0.1 Mbits/s = 500 s
  50 Mbits / 1 Mbits/s = 50 s
  X-band:
  50 Mbits / 10 Mbits/s = 5 s
  50 Mbits / 20 Mbits/s = 2.5 s

- **Uncompressed:**
  500 pixels x 500 pixels x 2 bytes/pixel x 100 channels = 50 Mbytes = 500 Mbits
  S-band:
  500 Mbits / 0.1 Mbits/s = 5000 s
  500 Mbits / 1 Mbits/s = 500 s
  X-band:
  500 Mbits / 10 Mbits/s = 50 s
  500 Mbits / 20 Mbits/s = 25 s

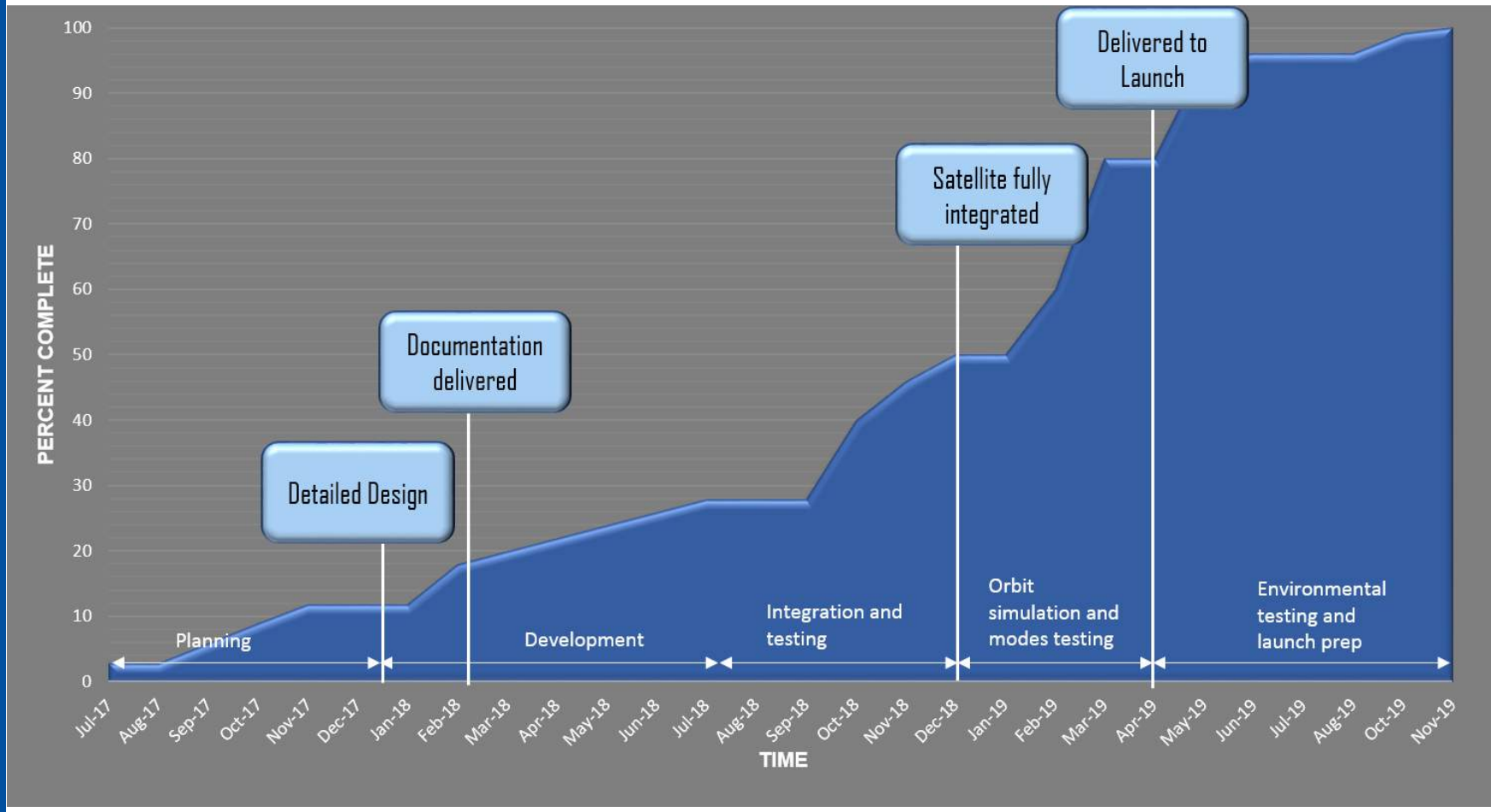
- Attitude log information:
  100 Hz gives additional 1-2 MB

- Duty Cycle for downlink: about 10 min available in one day

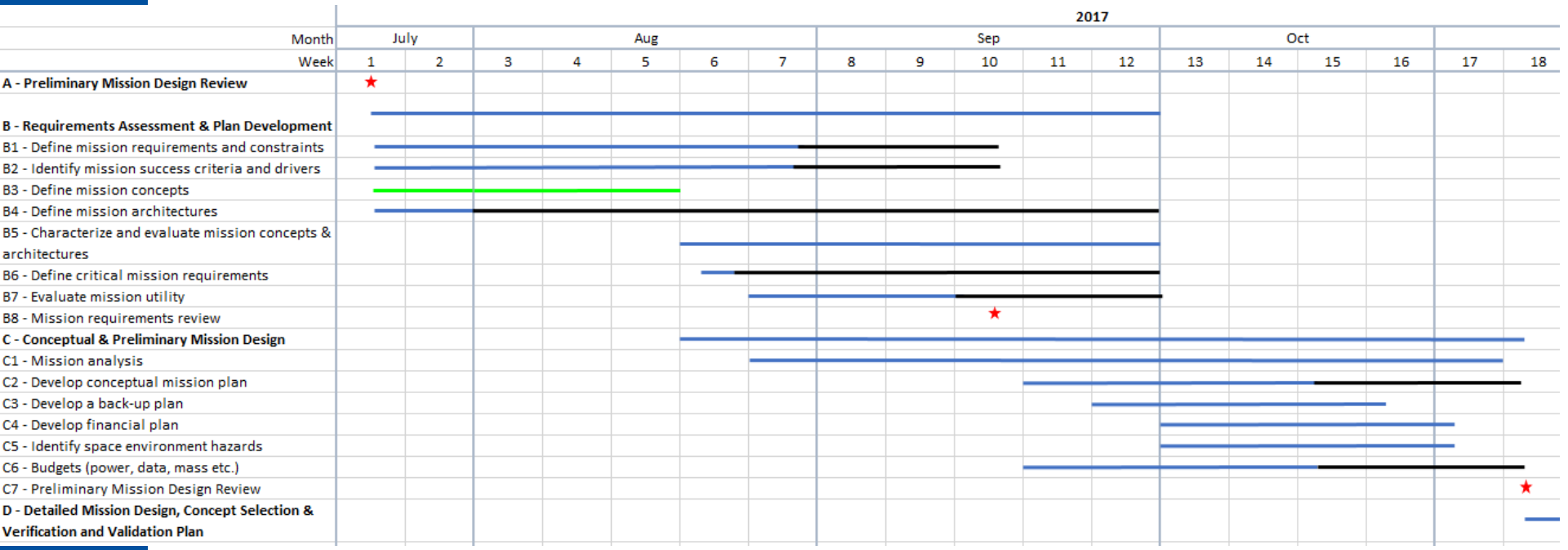
→ Approx. 60 Mbit total

Wish for 1-2 Mbit/s downlink, although 200kbit/s in several consecutive passes is ok.
S-Band or X-band

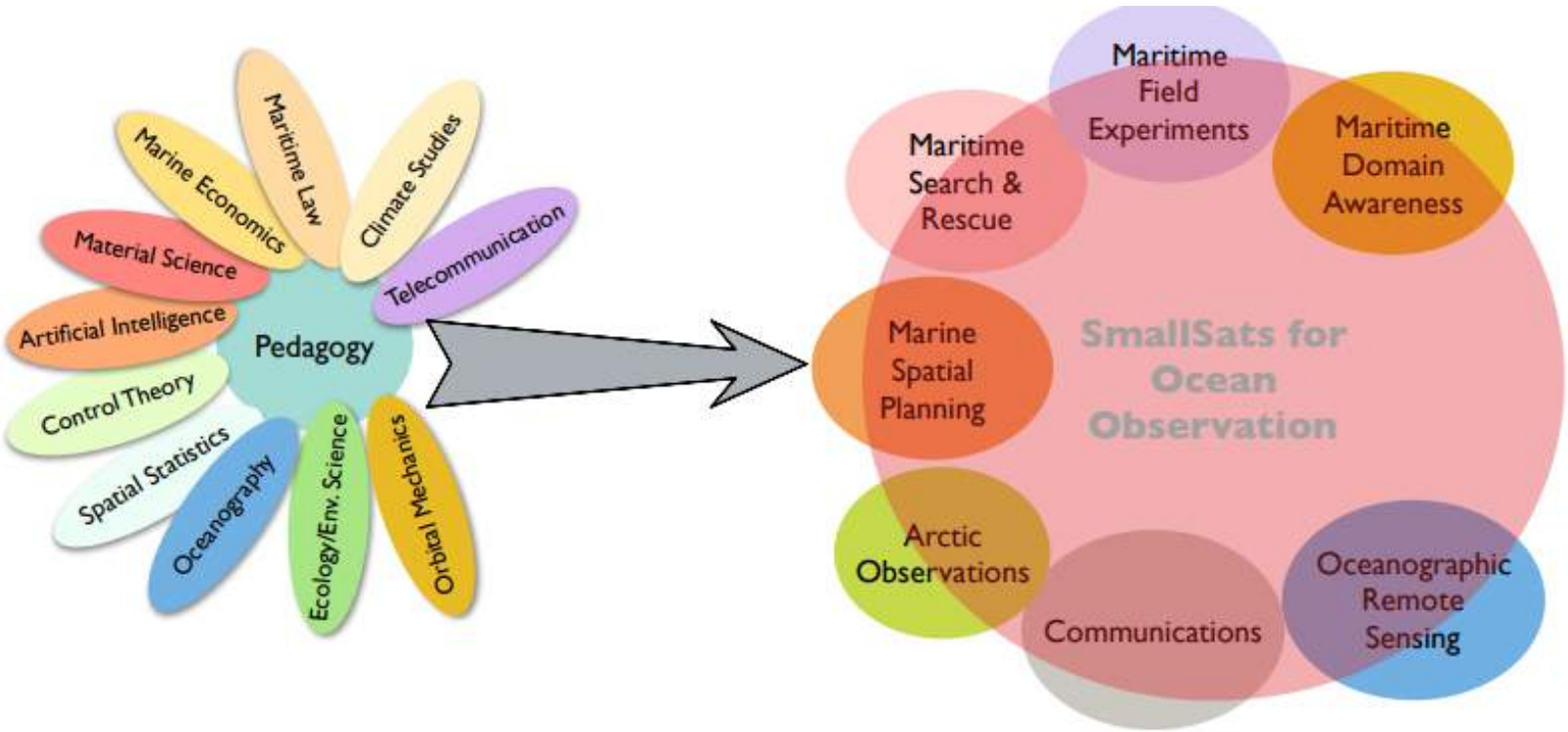
Verification and Validation Plan



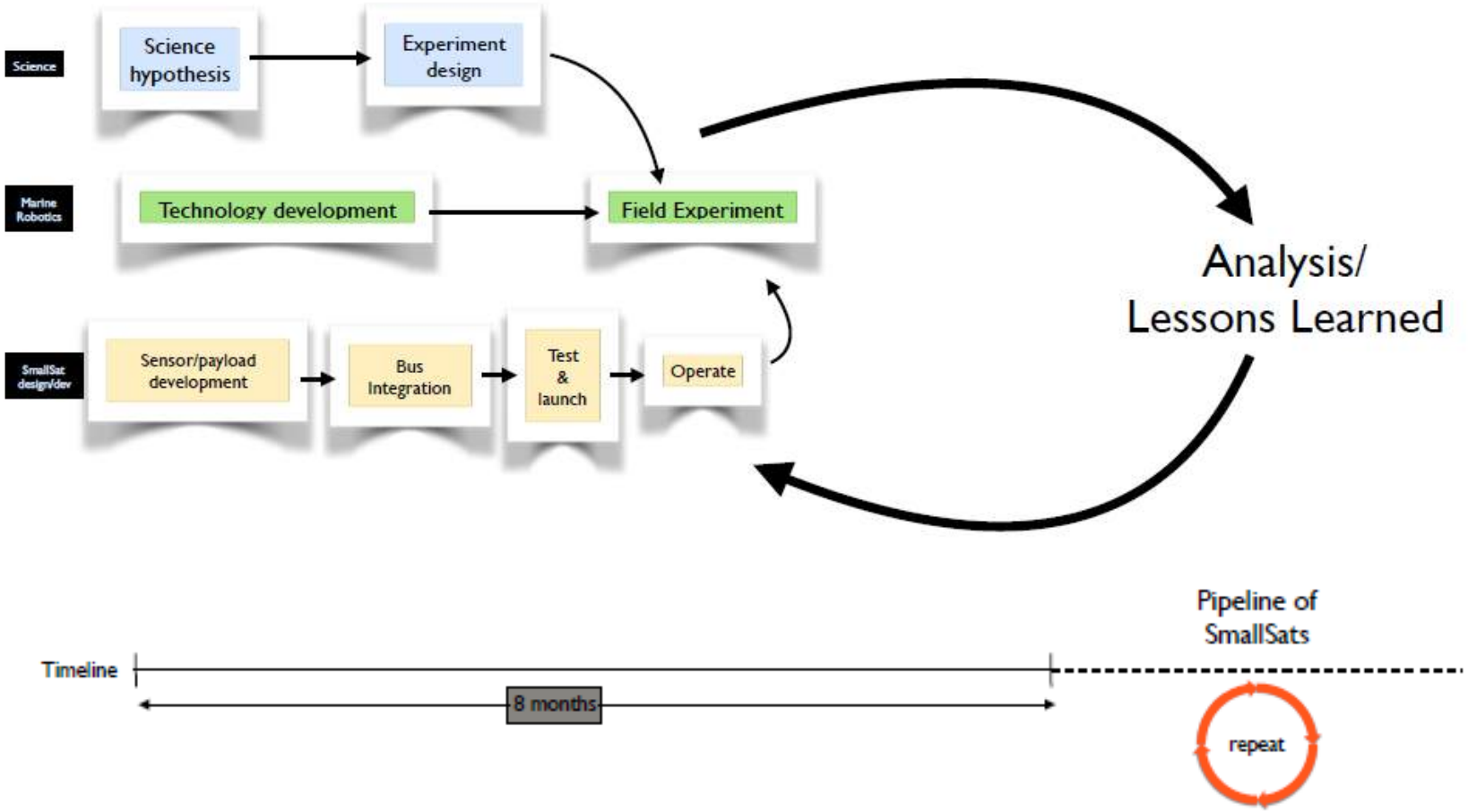
Project Timeline



Roadmap


Pedagogy
Maritime Law
Climate Studies
Marine Economics
Telecommunication
Material Science
Artificial Intelligence
Control Theory
Spatial Statistics
Oceanography
Ecology/Env. Science
Orbital Mechanics
Maritime Field Experiments
Maritime Search & Rescue
Maritime Domain Awareness
Marine Spatial Planning
SmallSats for Ocean Observation
Arctic Observations
Communications
Oceanographic Remote Sensing

Roadmap: how


Science
Science hypothesis
Experiment design
Marine Robotics
Technology development
Field Experiment
SmallSat design/dev
Sensor/payload development
Bus Integration
Test & launch
Operate
Analysis/ Lessons Learned
Timeline
8 months
Pipeline of SmallSats
repeat

Available platforms

Producer	UTIAS SFL	Tyvak	ISIS	GOMSPACE
Make/model	CanX-3	Intrepid		GOMX
Form factor	3 U	3 U	3 U	3 U
Build/make	Costum	Costum	Pumpkin/PC404	Pumpkin/PC404
Architecture	Seperate subsystems	Integrated	Seperate subsystems	Seperate subsystems
Platform mass	2,5 kg	1,3 kg		1,5 kg
Average power to payload	1-2 W @ 100%	3,5 W		3,68 W
Peak power	2-7 W	15 W		9,4 W
Weight to payload excluding ADCS	1 kg	2,6 kg		2,5 kg
Volume to payload excluding ADCS	1 U	2,7 U		2,3 U
Downlink capacity	32 k - 1 Mbit			< 2 Mbit
Flight proven	Yes	Yes	Yes	Yes
Maturity	Mature	New	New	Mature

Clyde Space

3U

- **Payload Volume:** Up to 1.6U
- **Power Generation:** Up to 50W peak
- **Payload Power:** >12W orbit average (typical)
- **Energy Storage:** 40Wh (typical) / expandable to >100Wh
- **Pointing:** <3.5 arcmin
- **Orbit Knowledge:** <10m; <1m/s
- **Data Storage:** 4GB Flash NVM, expandable via microSD
- **Data Downlink:** Up to 100Mb/s
- **Frequency:** V/UHF, S-Band, X-Band
- **Orbit attitude/lifetime:** LEO/up to 5 years

Launch options - Tyvak

Future Commercial Launches Opportunities				
Date	**Mission**	**Destination**	**Availability**	
Q3 2017	Commercial	600km SSO	Yes	CubeSats, SmallSats
Q3 2017	Commercial	500km SSO	Full	
Q4 2017	Commercial	600km SSO	Yes	CubeSats, SmallSats
Q4 2017	Commercial	500km SSO	Yes	CubeSats, SmallSats
Q1 2018	Commercial	550km SSO	Yes	CubeSats, SmallSats
Q2 2018	Commercial	600km SSO	Yes	CubeSats, SmallSats
Q2 2018	Commercial	GTO	Yes	CubeSats, SmallSats
Q3 2018	Commercial	500km SSO	Yes	CubeSats, SmallSats
Q4 2018	Commercial	600km SSO	Yes	CubeSats, SmallSats
Q1 2019	Commercial	500km 40 deg.	Yes	CubeSats, SmallSats

Launch options - ISIS

LAUNCH VEHICLE	LAUNCH PERIOD	ORBIT PARAMETERS		CONTAINERIZED PAYLOAD CAPACITY				MICROSATELLITE CAPACITY		
		ALTITUDE	INCLINATION	1U/2U/3U	6U/6UXL	12U	16U	< 25 KG	< 100 KG	< 250 KG
Asian	Q4 2017	500-600 km	SSO	Ask	Ask	Ask	Full	Full	–	–
USA	H2 2017	450-500 km	SSO	Ask	Full	Full	Full	Ask	Ask	Ask
Asian	Late 2017	500-550 km	SSO	✔	✔	✔	✔	✔	✔	✔
Asian	Late 2017	~500 km	SSO	Ask	Full	Full	–	–	–	–
USA	Q1 2018	500-600 km	SSO	✔	✔	Ask	Ask	Ask	Ask	–
Asian	Q1 2018	500-550 km	SSO	✔	✔	✔	✔	✔	✔	✔
USA	Q1 2018	450-550 km	SSO	✔	✔	✔	Ask	–	–	–
Asian	H1 2018	550-650 km	SSO	✔	✔	✔	✔	Ask	Ask	–
Asian	H1 2018	~500 km	SSO	✔	✔	✔	✔	✔	✔	Ask
Asian	H1 2018	GTO	–	✔	✔	Ask	Ask	Ask	–	–
USA	Q2 2018	~500 km	55 incl.	✔	✔	✔	Ask	–	–	–
Asian	Q2 2018	600-650 km	SSO	✔	✔	✔	✔	✔	✔	✔
Asian	Q2 2018	450-500 km	SSO	✔	✔	✔	✔	✔	✔	✔
USA	mid 2018	450-550 km	SSO	✔	✔	✔	Ask	–	–	–
Asian	mid 2018	900+ km	66 incl.	✔	✔	✔	Ask	Ask	Ask	–
Asian	mid 2018	450-500 km	45 incl.	✔	✔	✔	✔	✔	✔	✔
Asian	Q3 2018	600-750 km	SSO	✔	✔	✔	✔	✔	✔	✔
Asian	H2 2018	~800 km	SSO	✔	✔	✔	Ask	Ask	–	–
European	H2 2018	LTO	–	✔	Ask	–	–	Ask	–	–
Asian	H2 2018	450-500 km	SSO	✔	✔	✔	✔	✔	✔	✔
European	Q4 2018	450-600 km	SSO	✔	✔	✔	✔	Ask	Ask	Ask
Asian	Q4 2018	500-550 km	SSO	✔	✔	✔	✔	✔	✔	✔
Asian	Q4 2018	~650 km	SSO	✔	✔	✔	✔	✔	Ask	–
Russian	H2 2019	450-600 km	SSO	✔	✔	✔	✔	✔	✔	✔
European	Q4 2019	500-700 km	SSO	✔	✔	✔	✔	Ask	Ask	Ask
European	Q4 2019	450-600 km	SSO	✔	✔	✔	✔	Ask	Ask	Ask
European	Q1 2020	500-700 km	SSO	✔	✔	✔	✔	✔	Ask	Ask
European	mid 2020	LTO	–	✔	✔	Ask	Ask	Ask	–	–
Russian	H2 2020	500-700 km	SSO	✔	✔	✔	✔	✔	✔	✔
European	Q2 2020	GTO	–	✔	✔	✔	✔	✔	Ask	Ask

Conclusions & Future Work

- Currently on mission-design and concept evaluation
  - Architectures to be determined soon
  - Orbit to be determined
  - Iteration on mission requirements
  - Feasibility and achievability for HSI payload and related-orbit studies
- Developed HSI payload for UAVs, to be integrated in SmallSat. Built at NTNU.
- If first two missions are successful -> a pipeline of SmallSats will support coordinated oceanographic observations. Space segment shall provide higher temporal and spatial resolution.

Contact

- Mariusz Grøtte (Mission Design; Spacecraft Dynamics and Control)
- Email: mariusz.eivind.grotte@ntnu.no