CleanSat session

Deorbitation strategy of nano sats in Norway

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Norway as an emerging Space nation

AISSat-1 is a satellite used to receive Automatic Identification System (AIS) signals. Launched on 12 June 2010 from Satish Dhawan Space Center as a secondary payload

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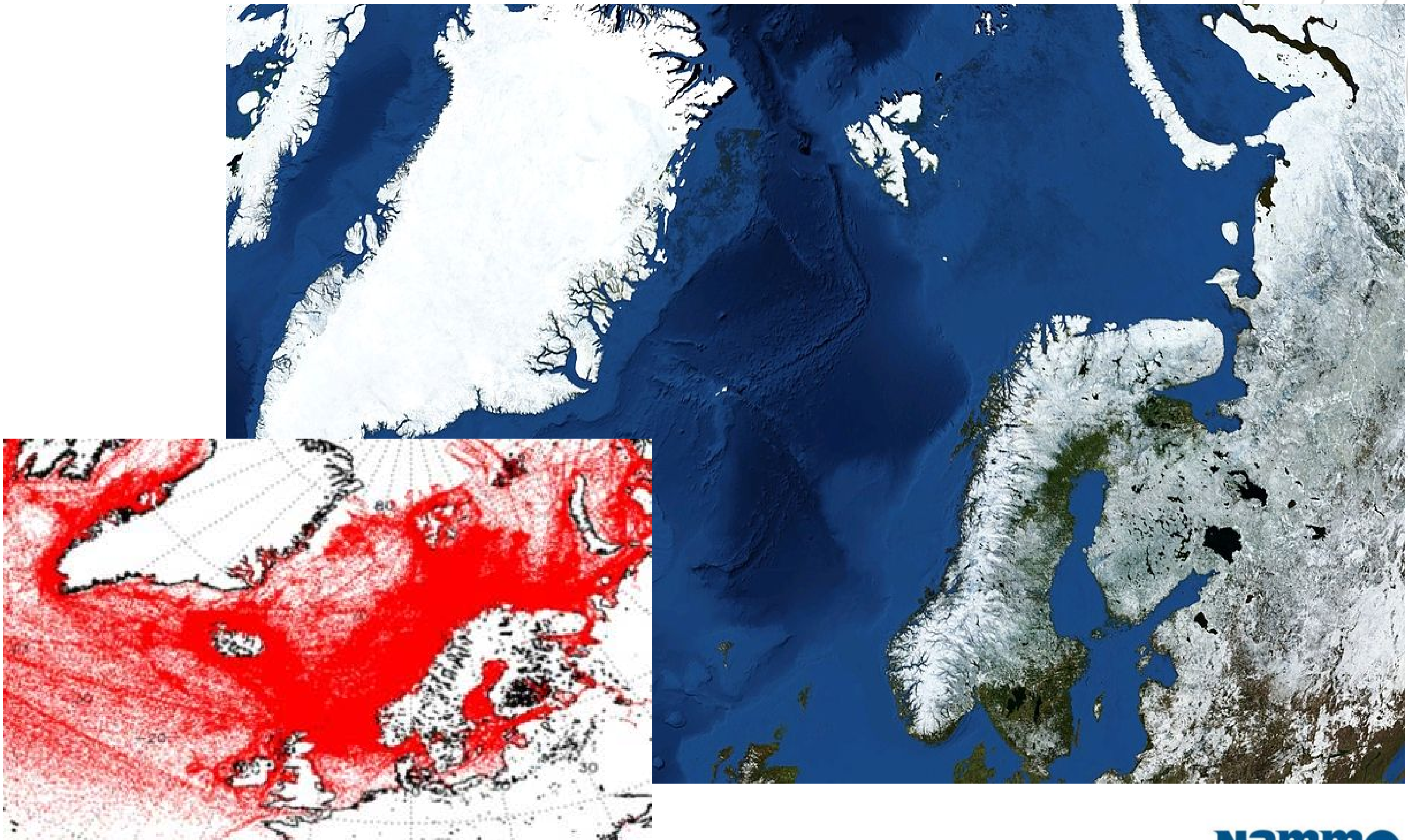
Why is space so interesting for Norway?

- Utilization of the polar regions
- GEO satellites do not cover the higher North very effectively
- Existing non-GEO services are not covering those areas very effective either
- There is a wish to have its own operational space-based ship-monitoring system
- There already exists significant infrastructure on the ground

How to monitor large sea areas?



More satellites are following

- A second, identical satellite called **AISSat-2** was ordered in January 2011 to be ready for launch by early 2012. It was finally launched on the 8th of July 2014 from Baikonur in Kazakhstan.
- A third copy, **AISSat-3** will be launched in 2016
- The **NORSAT-1** satellite will investigate solar radiation, space weather and monitor ship traffic and was to fly in April 2016 as a piggy-back payload on the Sentinel 1B mission on a Soyuz-STA Fregat-M rocket*
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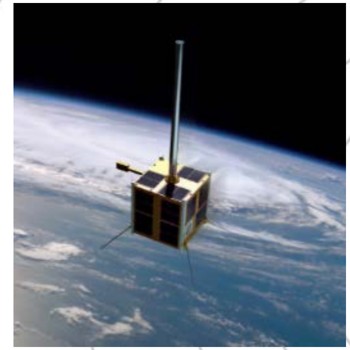

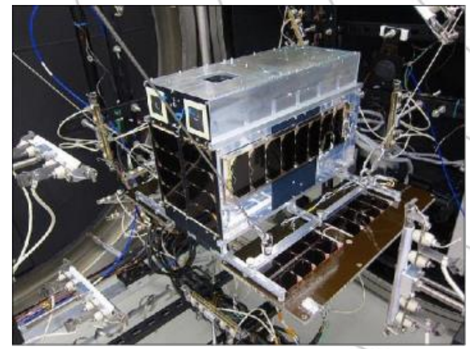

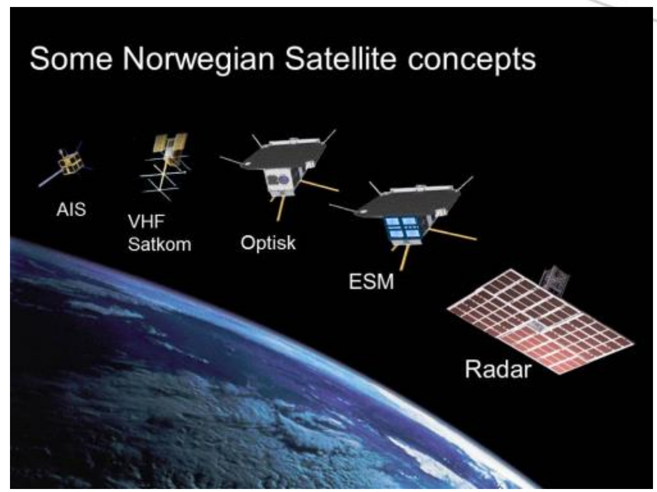

* NORSAT-1 was removed from the launch due to a faulty mounting bracket. A replacement launch later in 2016 is evaluated

Compliance with Space Debris Mitigation

- With ownership follows responsibility
- As new small satellites are being planned, the Norwegian Space Center has made the decision that they want to satisfy the Space Debris Mitigation rules as soon as possible
- The planned new satellites have a mass in the order of 25-50kg
- Without a dedicated Launcher, they will end up in typical intermediate orbits between 600-900km as secondary payloads.
- These altitudes will not automatically satisfy the 25 year requirement
- Conclusion:
  - A Space Debris Mitigation strategy is needed

Norwegian Space Debris Mitigation strategy

- Introduce as soon as possible a form of Space Debris Mitigation method for the upcoming Norwegian Satellites
- The deorbiting maneuver has to be such that a re-entry of the satellite in atmosphere, and thus its disintegration, is guaranteed in 25 years [Requirement]
- Assume initial orbit of 850 km and a satellite mass between 25 and 50kg (based on piggy-back launch options
- Instead of an "End-Of-Life" maneuver, apply a "Beginning-Of-Life" maneuver, i.e. perform a reorbit maneuver

Motivation: For a low cost satellite, the Space Debris Mitigation method needs to be based on a low cost approach. Therefore, perform all the "tricky stuff" while you are still sure you have control over your S/C and the aging and radiation effects have not yet reduced your reliability

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Study contract with Nammo Raufoss

- Provide a preliminary sizing of a propulsion unit for Space Debris Mitigation for a satellite of the NORSAT-class
- Base the scaling of the propulsion system on three basic technologies and compare:
  - Solid Rocket Motor
  - Hybrid Rocket Motor
  - Mono-Propellant Motor
- All three designs have to satisfy the same delta-V requirement(s)
- Determine a tentative system mass and cost for each solution

The study is still on-going

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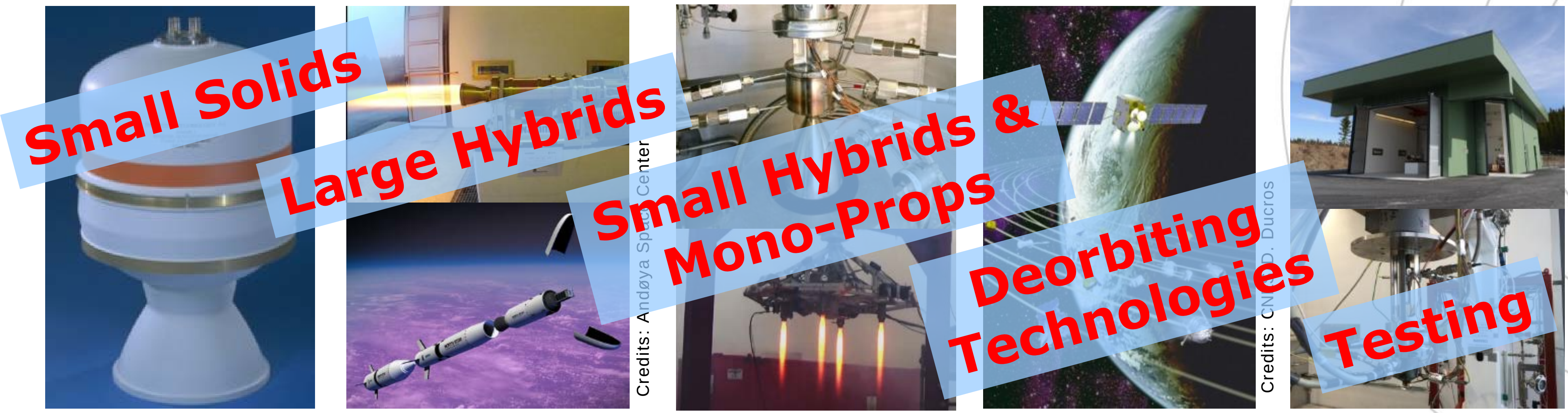
Nammo Space Propulsion



Solid Rocket Motors & Igniters

- Ariane 5 acceleration and separation boosters
- Well established capabilities for rocket motors and igniters with propellant masses from 5 - 150kg

Hybrid Rockets based on Clean Propellants

- Sounding Rockets
- North Star Launch Vehicle
- H2020 SMILE, small innovative launcher
- H2020 ALTAIR, air launched small launcher

Green In-Space Propulsion

- Mono-propellant ACS/RCS for Ariane 5ME, 6 and Vega
- FP7 SPARTAN - Hybrid Rocket with throttle capabilities
- H2020 HYPROGEO, Long duration nozzle

De-orbiting and related technologies

- Development contract on particle-free Propellant Formulation for CleanSpace
- GSP with ESA on debris remediation based on hybrid technolog
- Nano-deorbit study for Norwegian Space Agency

Test facilities for hybrid and green propulsion

- New test facilities and equipment dedicated to Green Propulsion

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Description of the study

- The study focusses on the propulsion system needed to reorbit only
- The propulsion system is embedded in the satellite architecture from the beginning of the mission
- The reorbiting maneuver will take place "at once“, when "tumbling" phase after release is over and the satellite is placed into orbit.
- Assume release height of 850km and satellite mass between 25-50kg
- Lower the orbit to the 450-600km region
- Assume a single pulse into an elliptical orbit and a dual pulse into a new circular orbit at lower altitude
- No additional delta-v for attitude control is taken into account in sizing the system during this study

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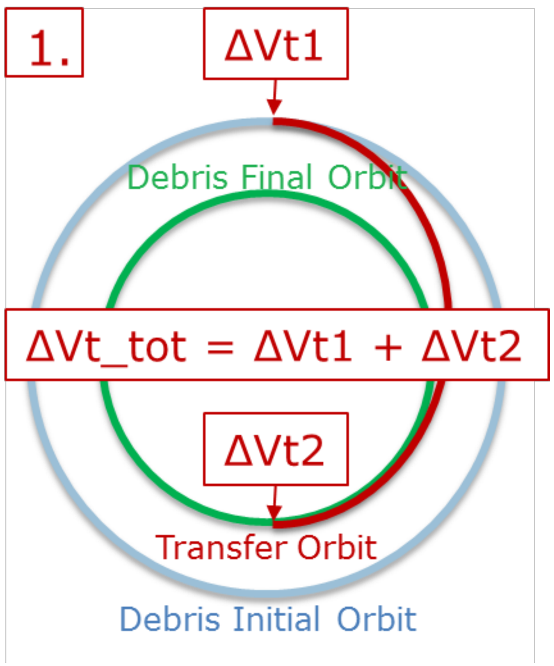
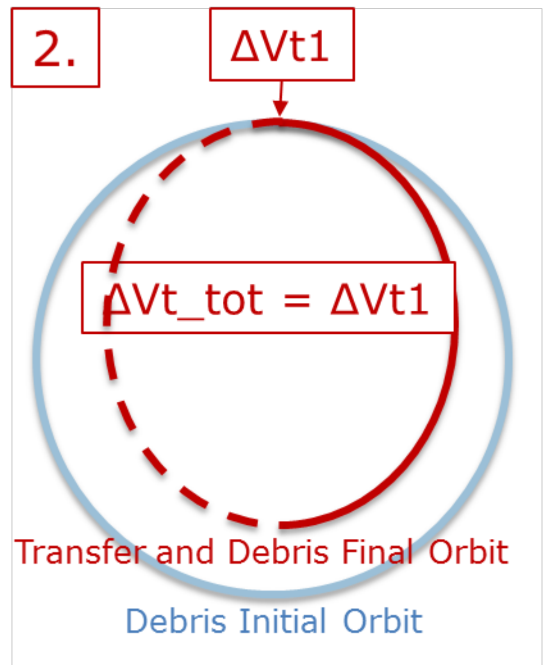
Two reorbiting options

1. The maneuver is a Hohmann transfer with 2 burns: a first pulse is needed to convert the 850 km circular orbit into an elliptical orbit with the perigee at 500-600 km, and a second pulse circularizes the new orbit
2. The maneuver is a Hohmann transfer with 1 burn: a single pulse is performed to convert the 850 km circular orbit into an elliptical orbit with the perigee at 470-670 km





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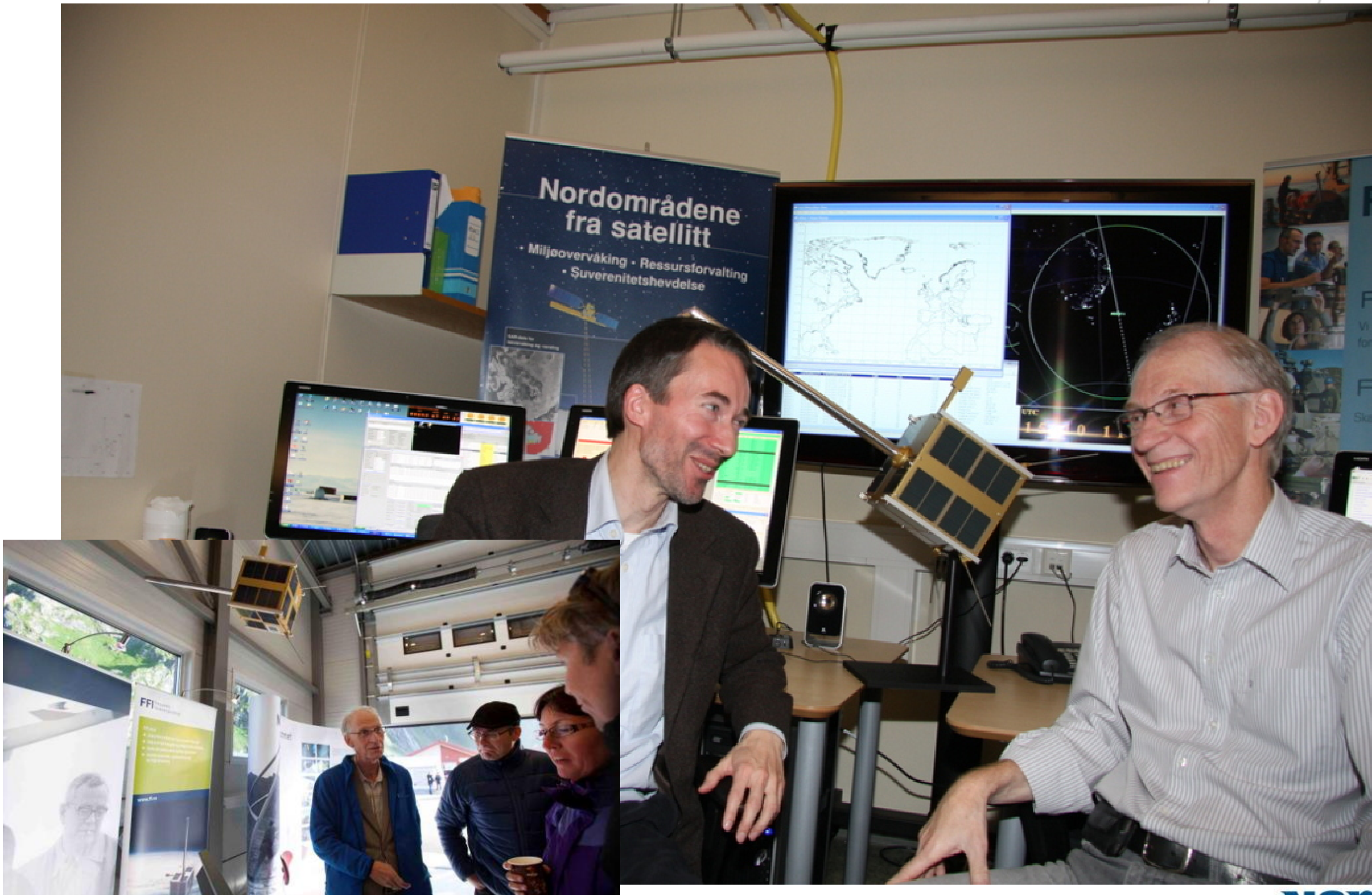
Maximum acceleration requirement



Maximum acceleration requirement

Maximum allowable acceleration for the study: 1g

"Ongoing long duration 1g acceleration test"

Maximum acceleration requirement

Maximum allowable acceleration for the study: 1g

Why?

- Low cost satellites need requirements adapted to low cost concepts
- Small Sats need requirements adapted to Small Sat concepts
- Imposing a requirement, means that it needs to be verified sooner or later during the design and testing phase
- Low cost projects need low cost verification methods and/or built in compliance by design
- Any acceleration requirement <1g will impose costly verification methods, if possible at all
- Mass penalty for satifying a 1g requirement will be neglectible for most Small Sats, merely because of standard handling requirements

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Other requirements to the study

- Two categories of satellite mass and sizes are considered in the study:
  - 25 kg - 20x20x40 cm
  - 50 kg - 40x40x40 cm
- 2 mission profiles are studied for the elliptical and circular final orbit

Mission #	Working orbit [km]	Orbit shape	Required Δv [m/s]
1A	470 (perigee)	Elliptical	101
1B	670 (perigee)	Elliptical	47
2A	500	Circular	93 + 94 = 187
2B	600	Circular	66 + 66 = 132

- Applied margins are in line with those commonly used in ESA studies:
  - 5% margin applied on the total require ΔV for deorbiting maneuver
  - 20% margin applied to propulsion system dry mass
  - 5% margin on consumed propellant for the monopropellant and hybrid propulsion option (residual)

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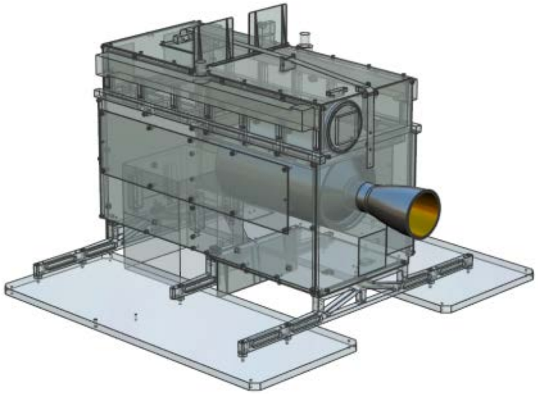
Preliminary sizing of the Solid Propellant option - System Mass

Orbit	Mission	ΔV [m/s]	25 kg system	50 kg system
Elliptical	1A	101	3.14 kg	5.22 kg
	1B	47	2.04 kg	3.03 kg
Circular (two rocket motors)	2A	187 (93+94)	5.85 kg	9.60 kg
	2B	132 (66+66)	4.79kg	7.49 kg



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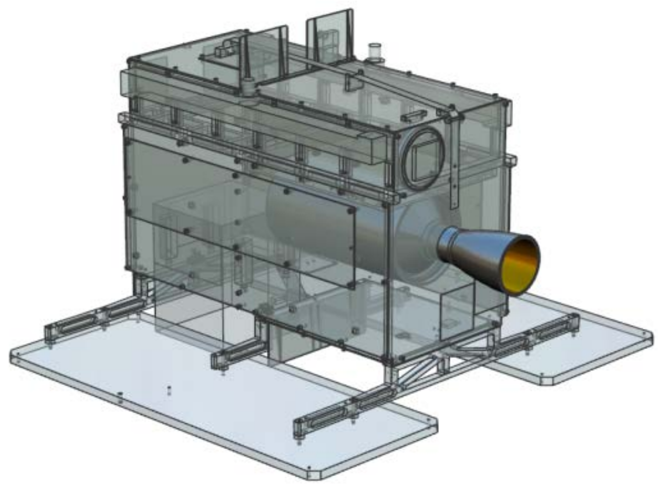
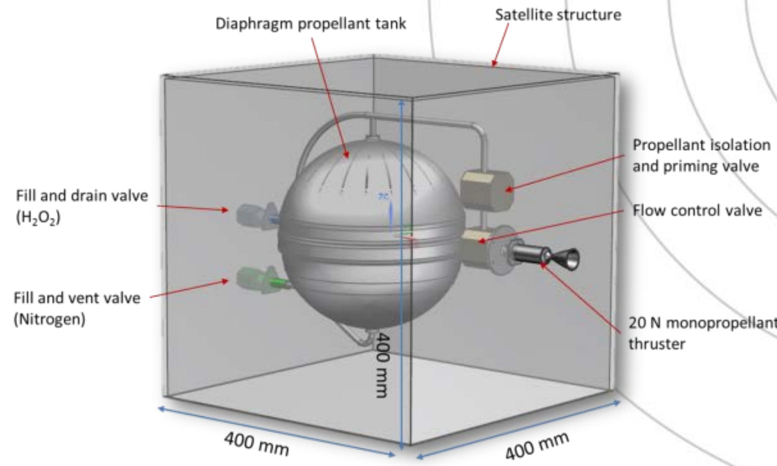
Effect on system architecture

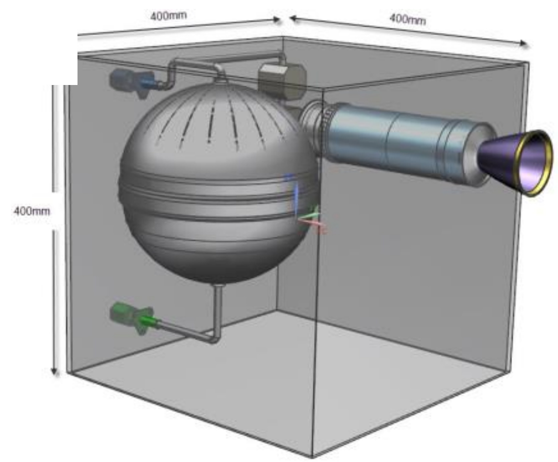
- Relative sizing of the three options to the plattform



Solid propulsion
mission 1A, single pulse



Mono-propellant
mission 2A, two
pulses



Hybrid propulsion
mission 2A, two
pulses

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Wrap-up

- The Norwegian Space Debris Mitigation strategy is based on a "Beginning-of Life" concept after a piggy-back launch
- Introduction into the uture Norwegian Small Sats rather sooner than later in order to become compliant
- A low cost approach requires low cost solutions
- A maximum 1g acceleration is accepted
- Three existing chemical propulsion based solution are compared
  - Solid propulsion
  - Hybrid propulsion
  - Mono-propellant
- Preliminary conclusion
  - Soild propulsion is the simplest
  - Mono-propellant is the most versatile with less impact on the system archictecture than the hybrid
- System masses between 2-10kg can be obtained depending on the mission

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