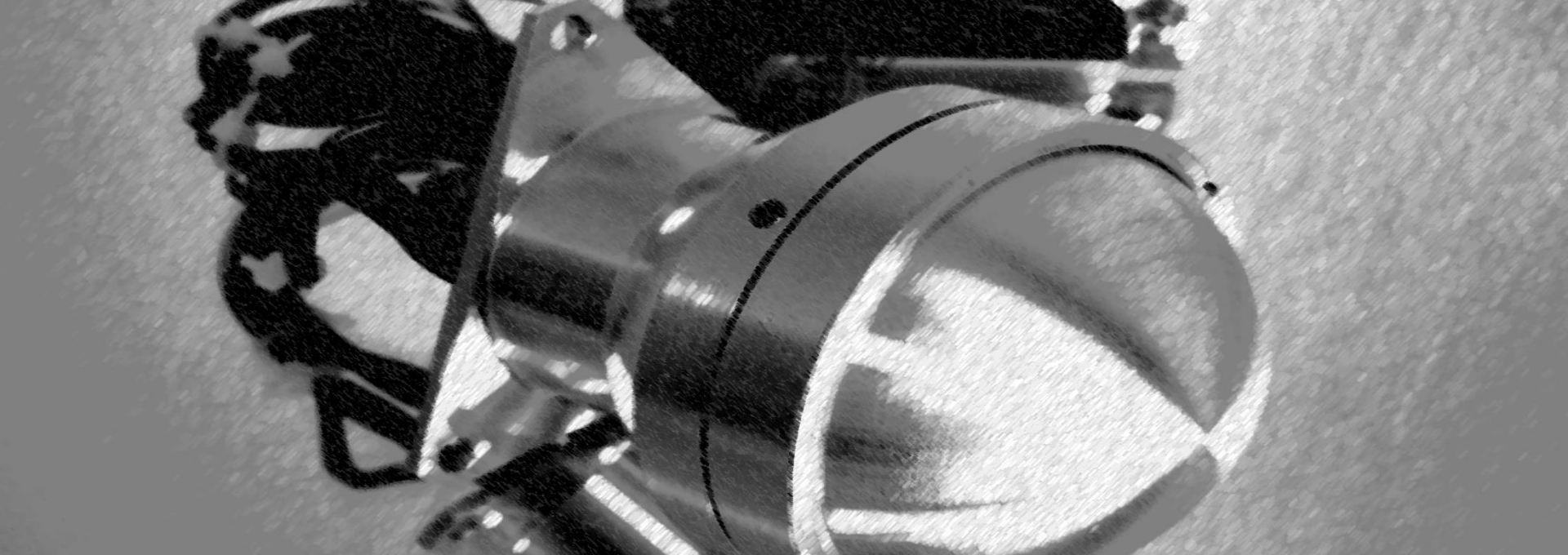


In-Orbit Demonstration of a MEMS-based Micropropulsion System for Cubesats



Kristoffer Palmer, Johan Sundqvist, Ana Zaldivar Salaverri, Tor-Arne Grönland,
NanoSpace AB, Uppsala Science Park, SE-75183 Uppsala, Sweden

Zhao Li, Shufan Wu

Shanghai Engineering Centre for Microsatellite(SECM), Chinese Academy of Science
Haik Road 99, Pudong District, 201203, Shanghai, P.R.China

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NANOSPACE

Outline

- Introduction
- Propulsion for micro/nanosatellites
 - Propulsion module designs
 - Closed loop thrust control
- Flight data from TW-1 mission
- Next steps
- Concluding remark
- *Swedish lesson?*



MEMS – MicroElectroMechanical Systems

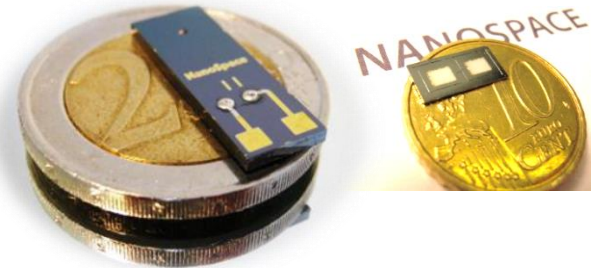
- **MEMS enables small sizes**
 - μm feature sizes
 - **MEMS enables batch fabrication**
 - **MEMS enables on-chip integration**
 - *Nozzles, sensors, actuators...*
- ➔ **“Small & smart components in large numbers”**



Blue Bottle Fly
(*Calliphora vomitoria*)

NanoSpace Idea:

To provide products for the space market based on novel MEMS technology



NanoSpace Products

MEMS based Micropropulsion System

- Miniaturized propulsion system for precision control of satellites

Xenon Flow Control

- Miniaturized components for flow control in electric propulsion systems

Propellant Gauging System

- A propellant gauging system for telecommunication satellites

Individual sensors and actuators

- Flow control valves
- Isolation and safety valves
- Filters
- Sensors
- *Terrestrial applications*



ISO 9001:2008 certified
Airbus approved supplier

Propulsion for micro-/nanosatellites



Propulsion Modules for Cubesats

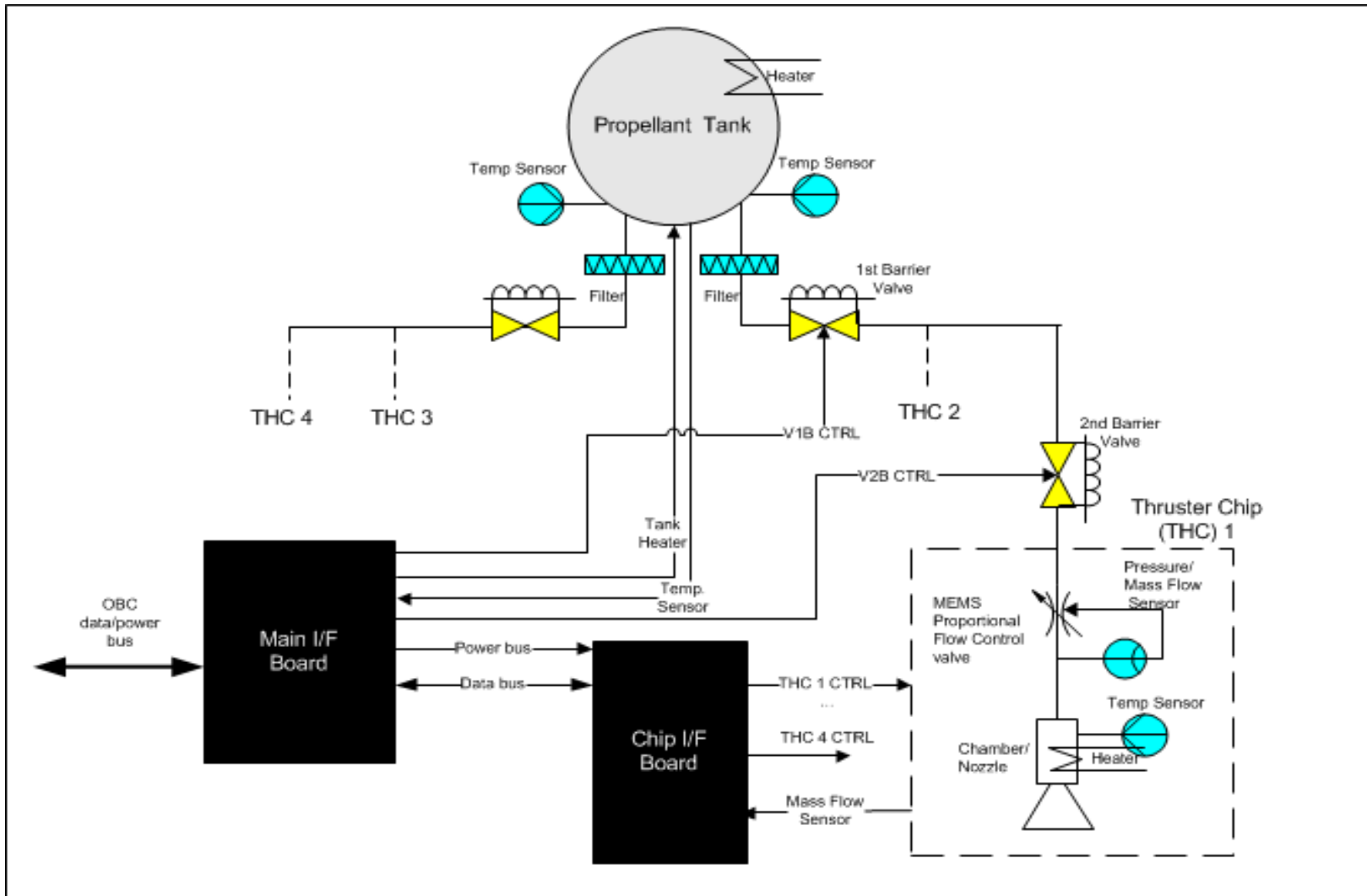
- 3U cubesat propulsion module: in orbit since Sept 2015
- 6U cubesat propulsion module: first flight 2017
- Custom designs: *Tank size, number and orientation of thrusters, etc*

Complete system:

- Propellant tank and feed system including filters, isolation valves, sensors, heaters
- Thrusters with proportional control
- Control and interface electronics to the satellite platform



3U Design – System Schematic

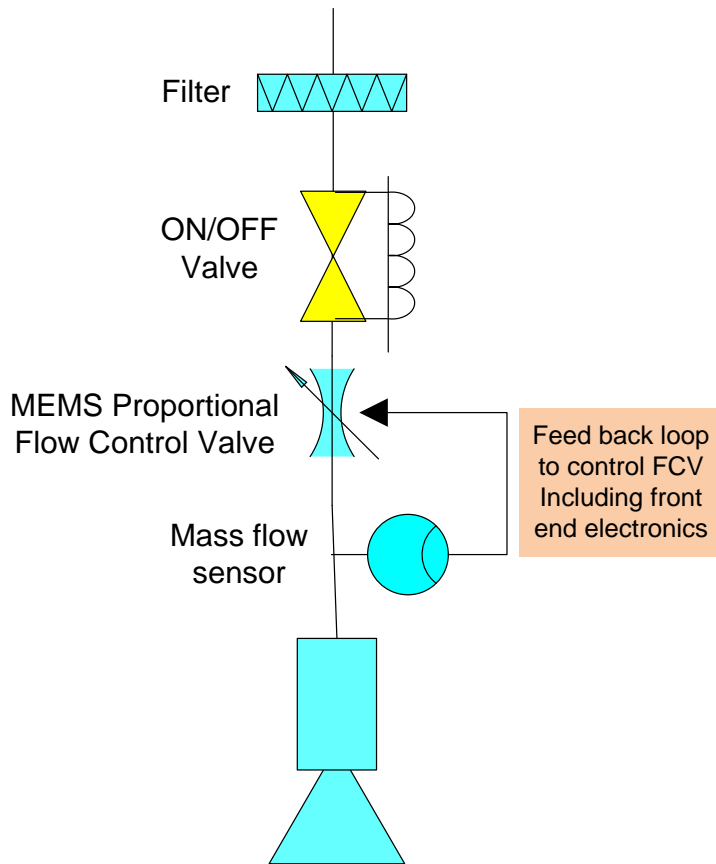


The 3U CubeSat propulsion module

- Four 1mN thrusters with closed loop thrust control
- Thrust resolution: $<10\mu\text{N}$
- Propellant: Butane
- Total impulse: 40Ns
- Size: 10 x 10 x (3-5) cm
- Mass: 300/350 g (Dry/Wet)
- Operating pressure: 2-5 bar
- Power consumption: 2 W (average, operating)
- Electrical interface:
 - Power: 12V, 3.3V
 - Communication: CAN / I2C
- Mechanical interface:
 - Conforms to 4x M3 (position according to PC/104 spec.)



Closed-Loop Thrust Control



Integrated mass flow sensor provides control signal to the proportional flow control valve

⇒ Closed loop thrust control



Thruster chip and front end electronics

Figure: Schematic view of a complete closed loop control thruster. ON/OFF valve in conventional technology, the rest in MEMS.

Closed-Loop Thrust Control

– *Unlike most other*

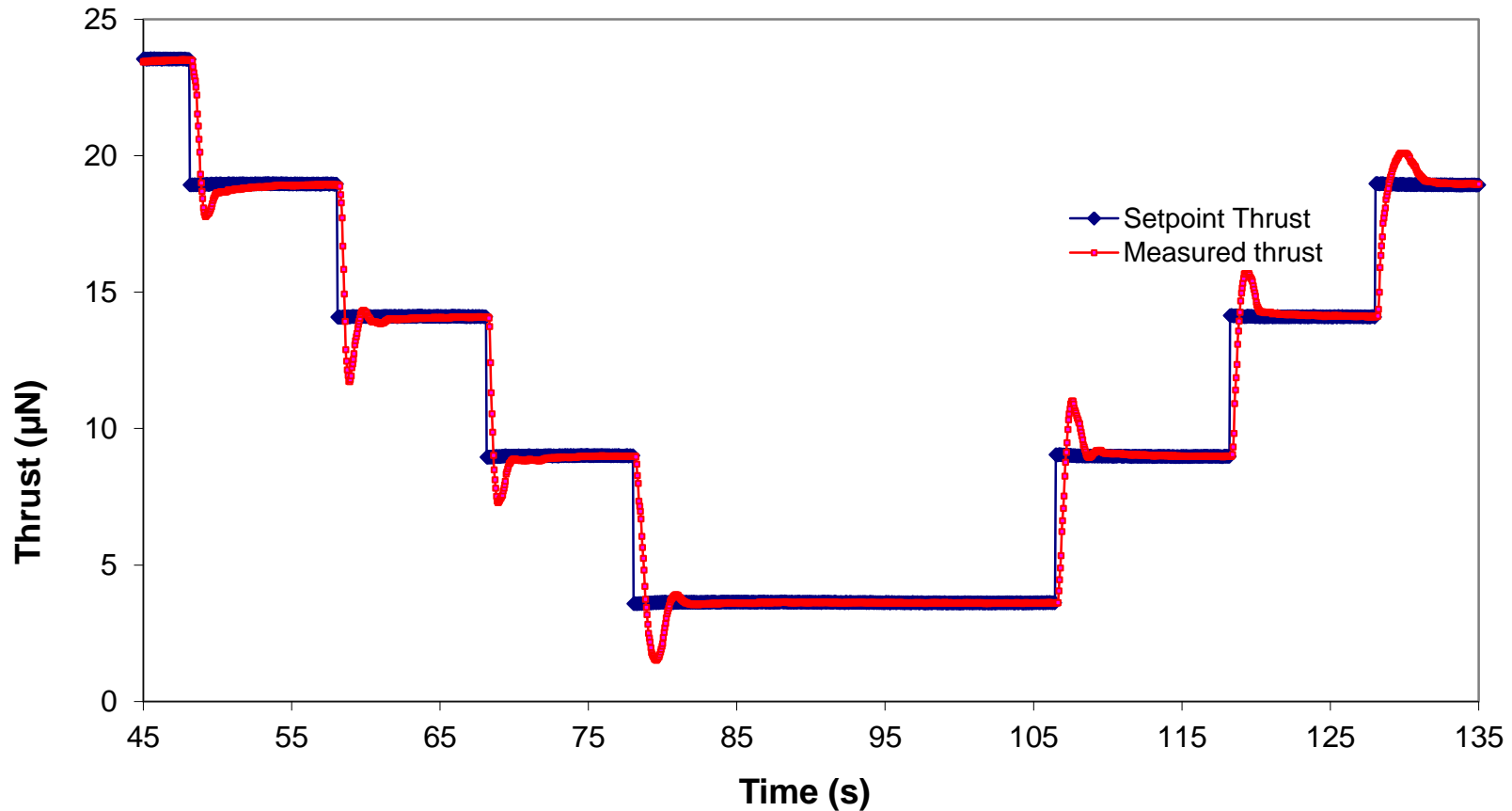
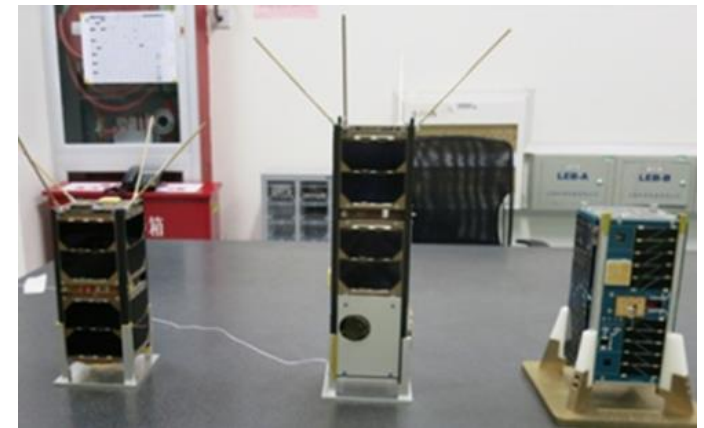


Figure: Test result of a MEMS valve operating in closed loop control mode showing the the thrust response to commanded steps of 5 μN .

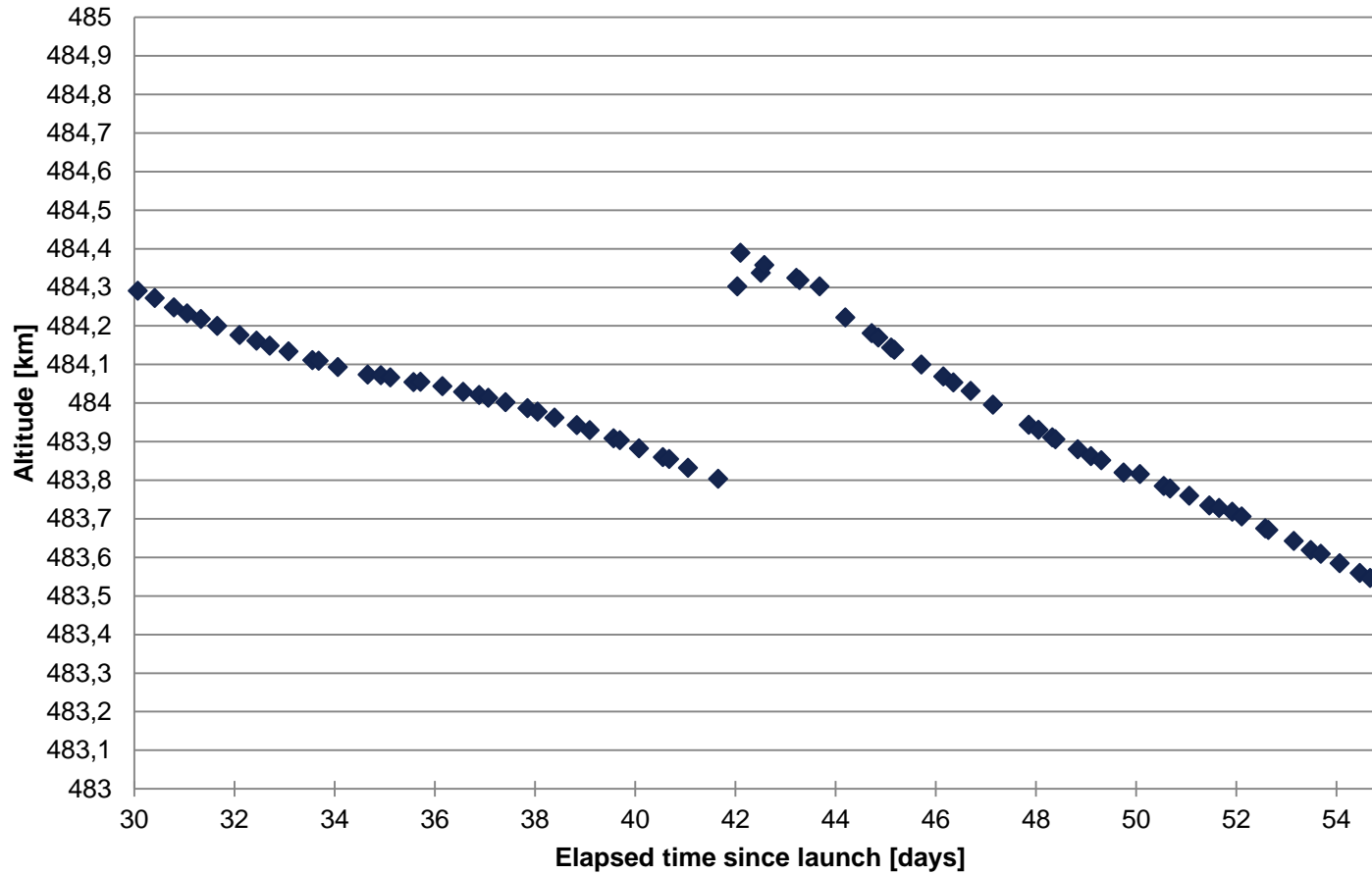
In Orbit Demonstration on TW-1

- TW-1 constellation (also named STU-2)
 - Two 2U + one 3U cubesats
 - Built by Shanghai Engineering Centre for Microsatellites (SECM)
 - Launched on September 25th 2015 with the new LM-11 to 480 km SSO
- Propulsion to be used for along track formation
 - Control relative distance between 1 and 1500 km
- Payloads
 - AIS, ADS-B, GPS/BD-2, ISL (S-band),
 - Camera
- Mission objectives
 - Ad-hoc intersatellite networking
 - Ship and polar ice monitoring
 - Payload and propulsion demonstration

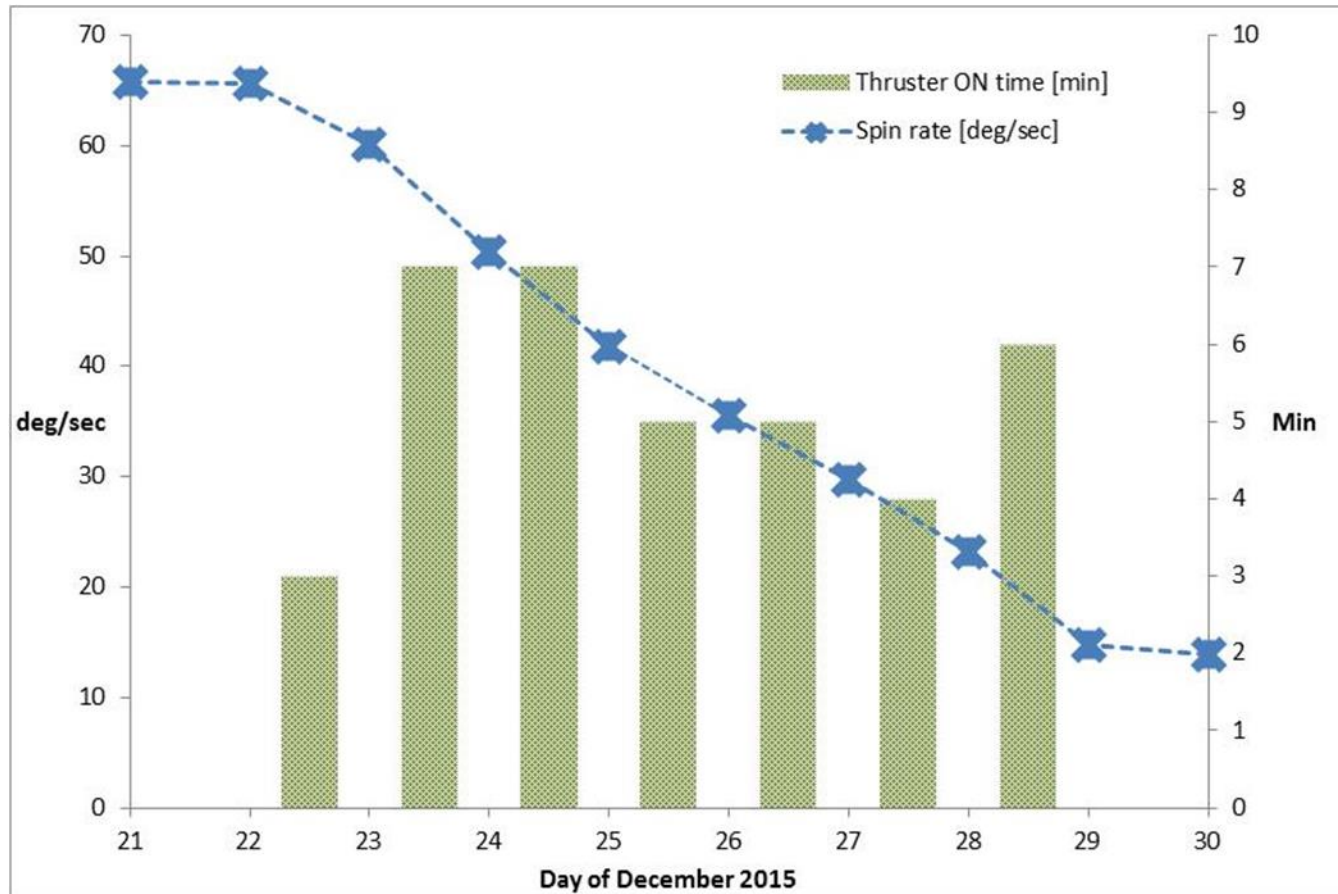


Orbital data of TW-1 mission

Altitude of TW-1A



De-spinning the satellite



.. by "live" operation during passage

Next steps

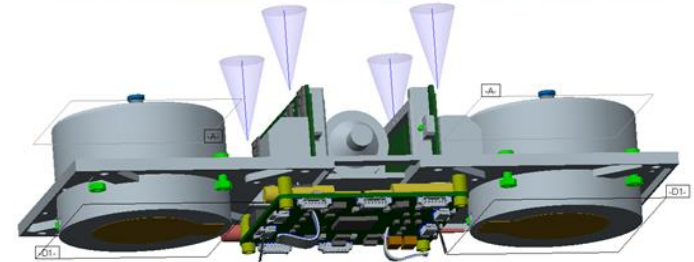
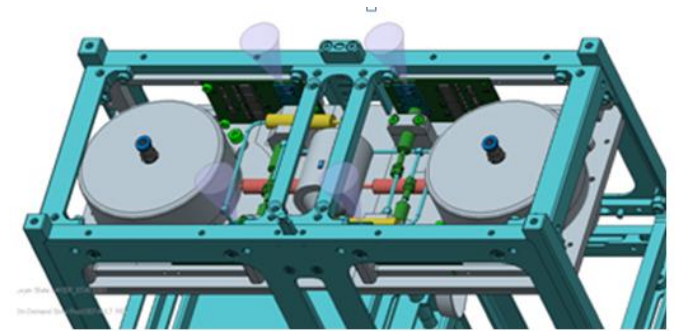
- TW-1 mission continues:
 - *10 months+ in orbit, plenty of propellant left*
- Multiple flights coming up for the 3U propulsion module the coming years:
 - *2017 – 3U cubesat, University demo mission: "MIST"*
 - *2017 – 3U cubesat precursor for "Internet of Things" constellation*
 - *2018 – ESTCube-2: 3U cubesat, precursor for interplanetary electric solar sail missions ESTCube-3 and thereafter ESTCube-n*
- 2017 - First flight of the 6U propulsion



ESTCube-2

Upcoming 6U flight: GOMX-4B

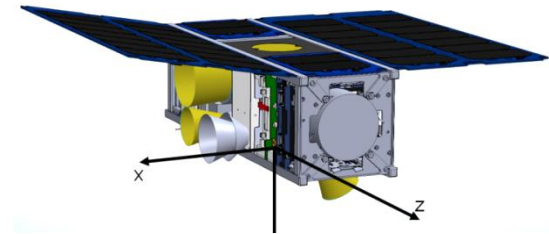
- Our propulsion system is onboard on of the 6U cubesats in the tandem mission GOMX-4
- Propulsion needed to demonstrate formation deployment and control
- 6U design with heritage from flight demonstrated 3U design + “*ESA style*” verification process
- Project schedule:
 - *PDR passed in May 2016*
 - *CDR in October 2016*
 - *Launch in Q3 2017*



Next steps - 2

- 2020 – AIM/PALS: Two 3U cubesats on Asteriod Impact Mission, 6DOF is key
- 2018 - ESA qualification of a generic propulsion module for advanced cubesat missions
(12 thrusters x 10mN, 500g, 375Ns, 6W)
- Thruster upscaling – for larger cubesats and microsats
 - 10-50 mN butane thrusters
 - Distributed thruster architecture

-> All together we foresee ~100 cubesats with propulsion the coming 4-5 years

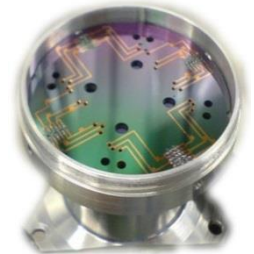


Concluding remark

Propulsion is here
- also for the micro/nano satellites



Come see our **SMÖRGÅSBORD** ['smøergos_bu:d] of miniaturized components in **SSCs boot 26-27**



Isolation valves, flow control devices, filters, thrusters



Xenon flow control module



CubeSat propulsion module



Thank you for your attention!

