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 Haike Road 99, Pudong District, 201203, Shanghai, P.R.China

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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”

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

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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

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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: <10µN
- 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

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 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

Altitude [km] vs. Elapsed time since launch [days]
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**
Upcoming 6U flight: GOMX-4B

• Our propulsion system is onboard one 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 Asteroid 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 forsee ~100 cubesats with propulsion the coming 4-5 years
Concluding remark

Propulsion is here
- also for the micro/nano satellites
Come see our **SMÖRGÅSBORD** [ˈsmɔːrɡəsˌbuːrd] 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!