

CUBESAT PROPULSION MODULE WITH CLOSED-LOOP THRUST CONTROL



T-A. Grönland, K. Palmér, J. Bejhed, A. Zaldivar-Salaverri, and P. Rangsten

NanoSpace
Uppsala Science Park
SE-751 83 Uppsala
SWEDEN

e-mail: tor-arne.gronland@sscspace.com
http: www.sscspace.com/nanospace

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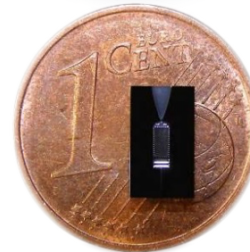
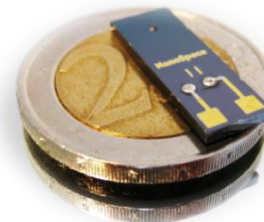
Outline

- Background & Introduction
 - *MEMS & first generation micropropulsion*
 - *Advanced propulsion requirements*
- Second generation MEMS micropropulsion
 - *Closed loop thrust control*
- Some other propulsion developments
- Swedish lessons

MEMS – MicroElectroMechanical Systems

- MEMS enables small sizes
 - μm feature sizes
- MEMS enables batch fabrication
- MEMS enables on-chip integration
 - *Nozzles, sensors, actuators...*

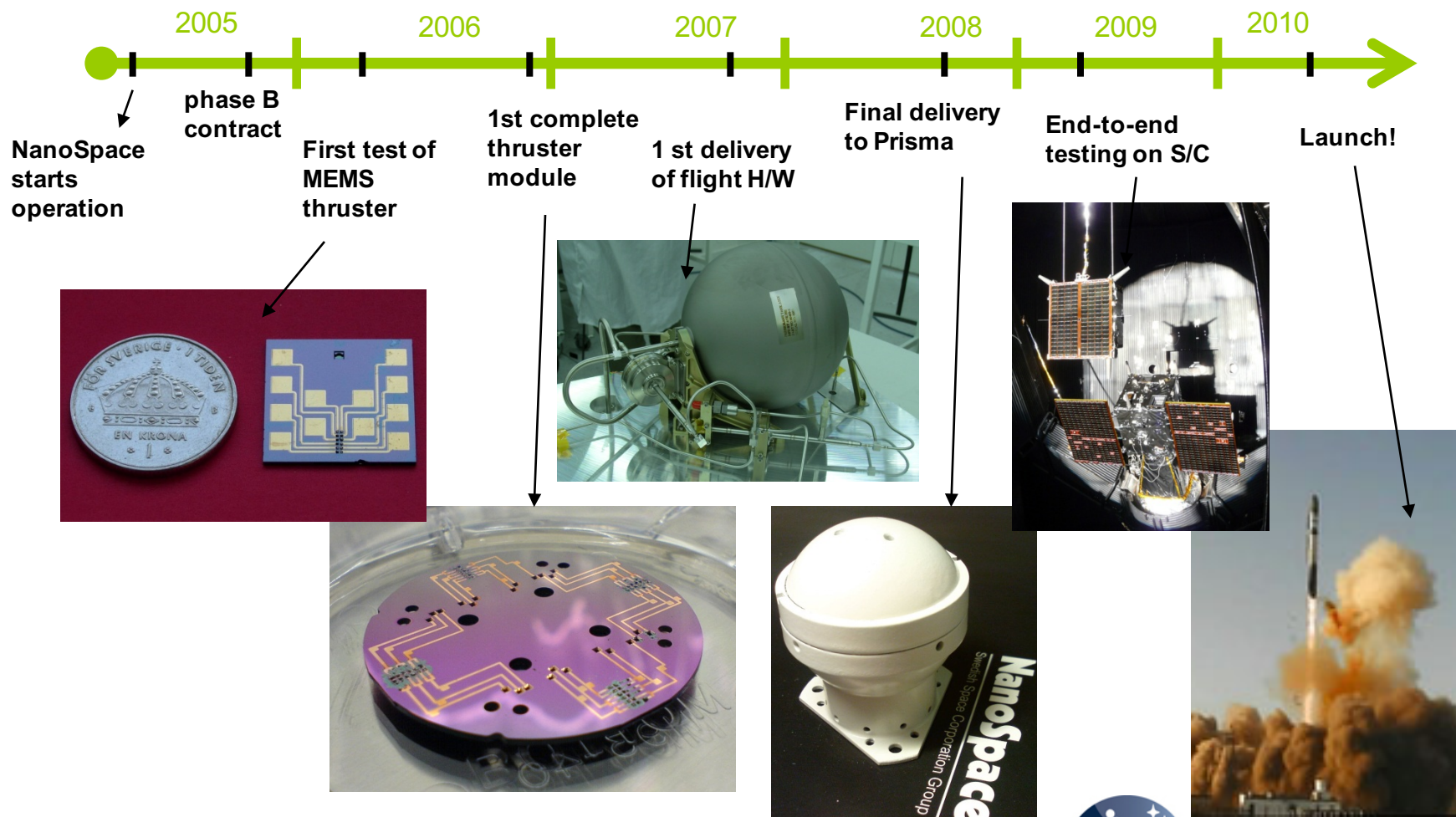
***Integration and small size
=> small internal volumes
=> short response time and
small impulse bits***



Our "MEMS kitchen"

First generation MEMS micropropulsion

- *developed for the Prisma satellites*

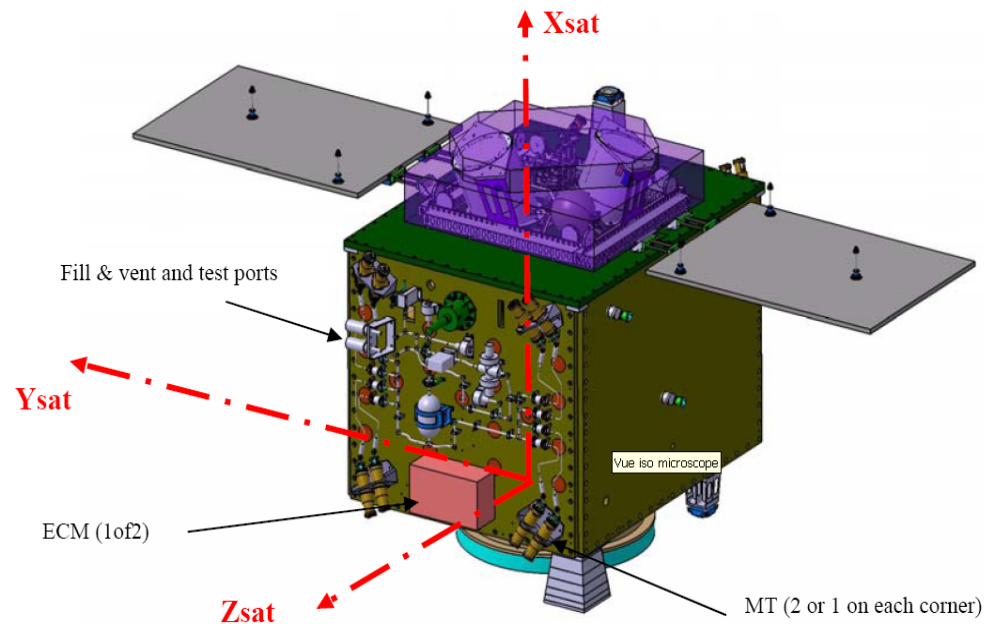


Advanced missions – Demanding requirements

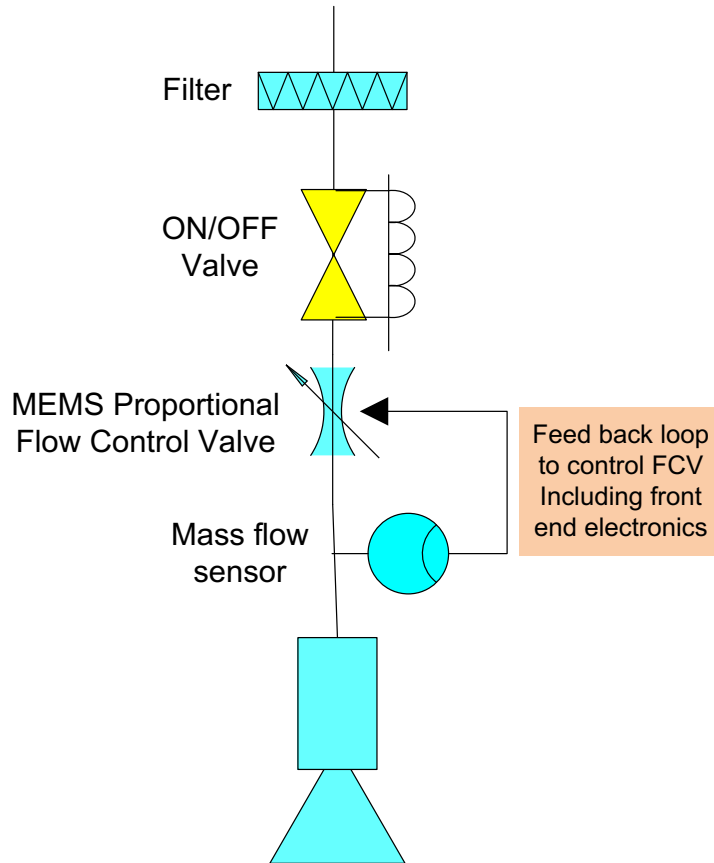
Example: MICROSCOPE – drag free flight

16 thrusters with closed loop thrust control

- 16 thrusters with closed
- 1 – 300 μN thrust range
- 0,2 μN resolution
- 250 ms response time
- 260 million cycles

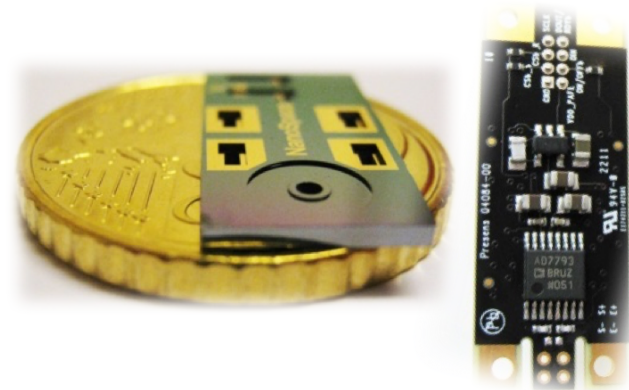


Second generation – Closed-Loop Thrust Control



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.

Key capabilities – Like any other

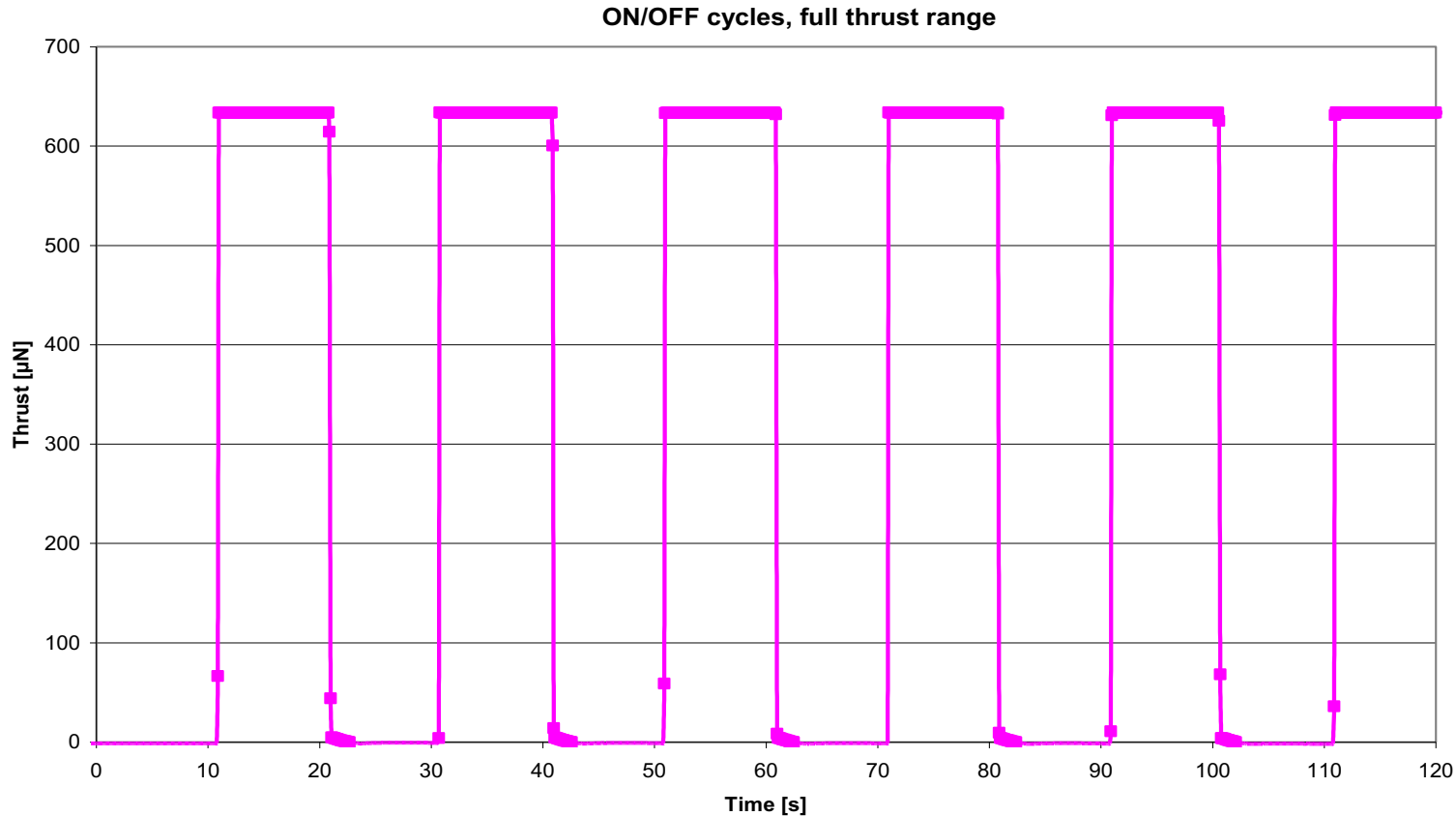


Figure: Test result of MEMS thruster operating in ON/OFF mode (open loop, using solenoid valve only) to show thrust range.

Full thrust can be set in the range **50 micro-Newton** to **10 milli-Newton**

Key capabilities – Unlike any other

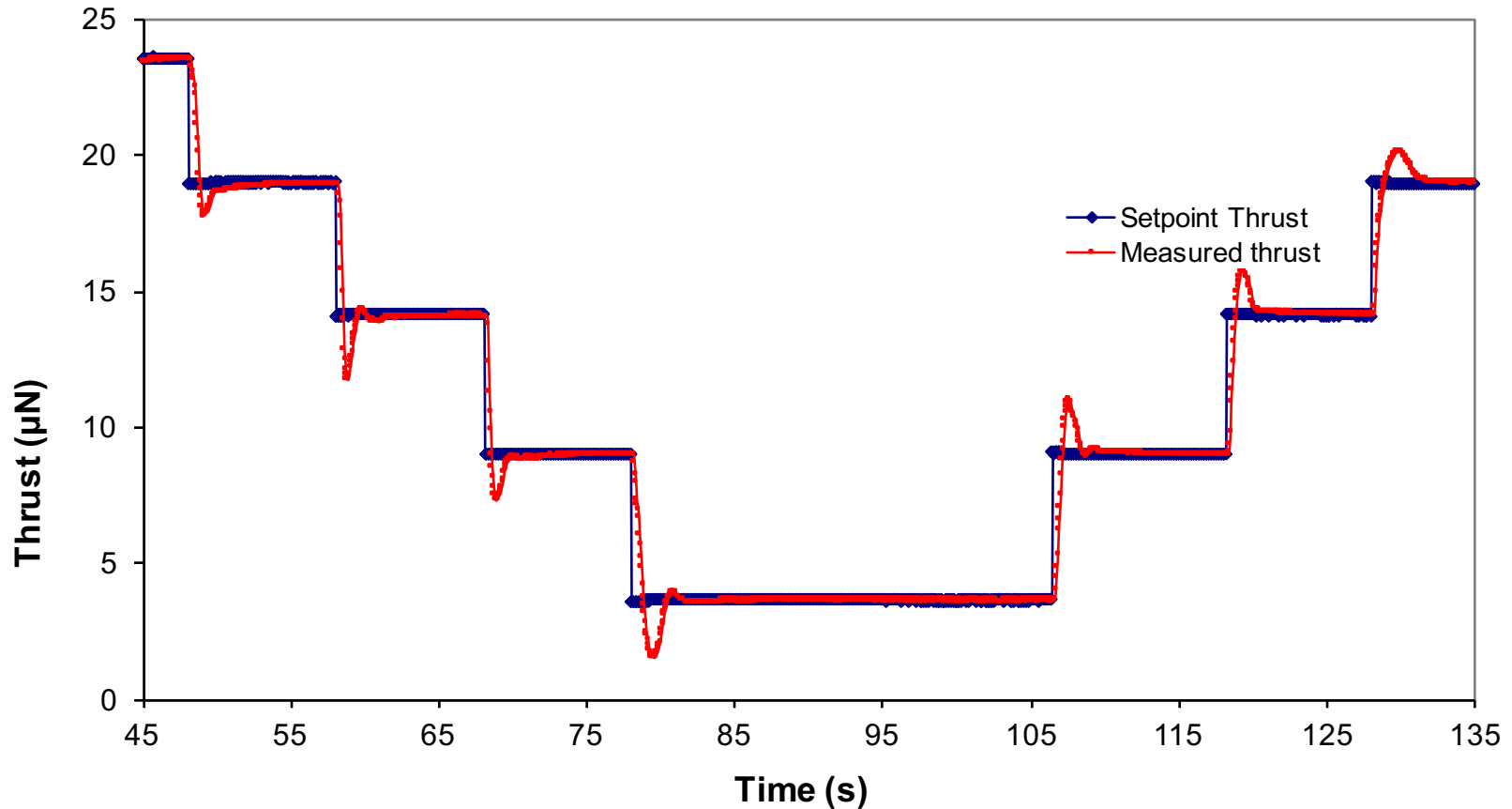


Figure: Test result of a MEMS valve operating in closed loop control mode showing the the thrust response to commanded steps of 5 μN .

Unique performance

Low thrust regime response: 0.1 μ N steps

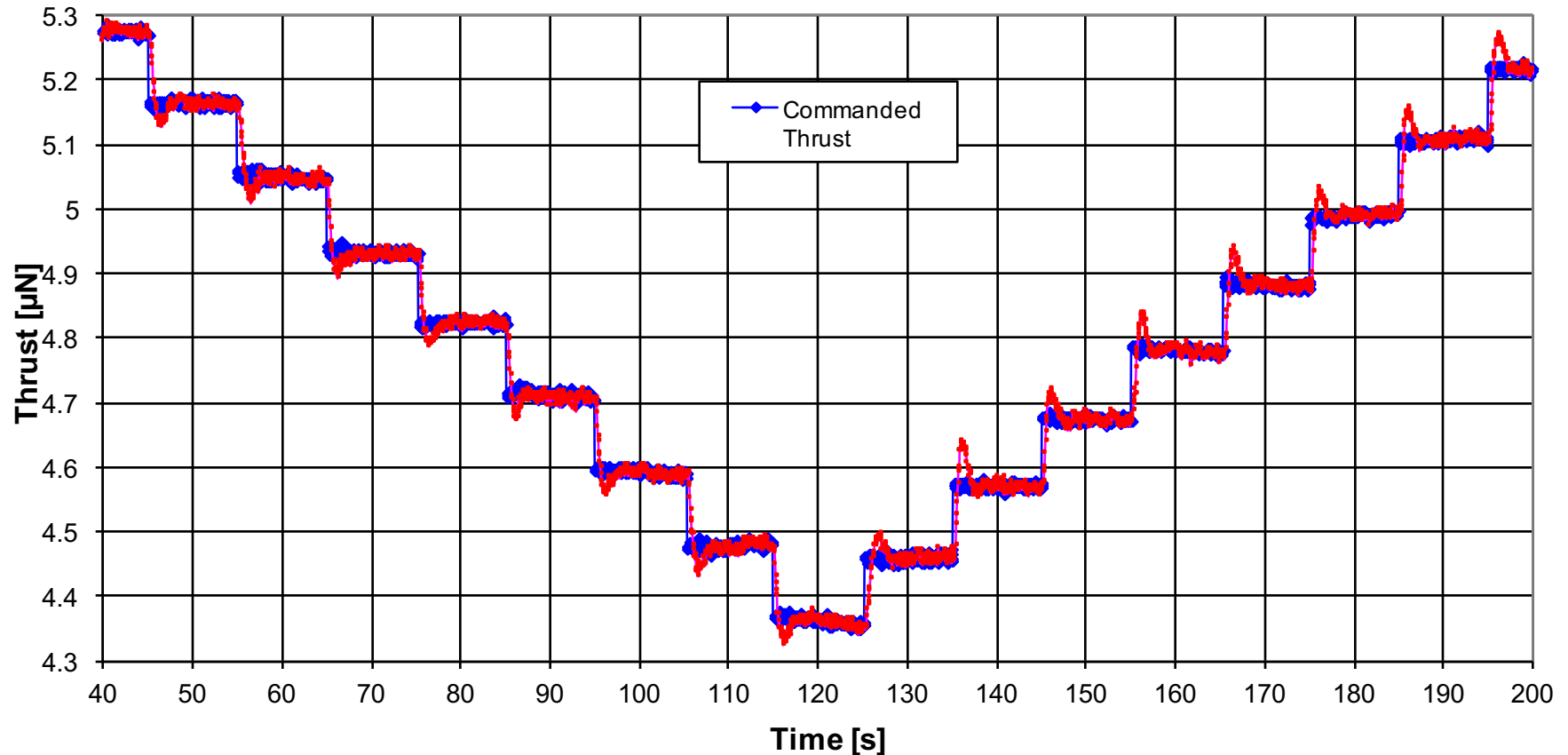
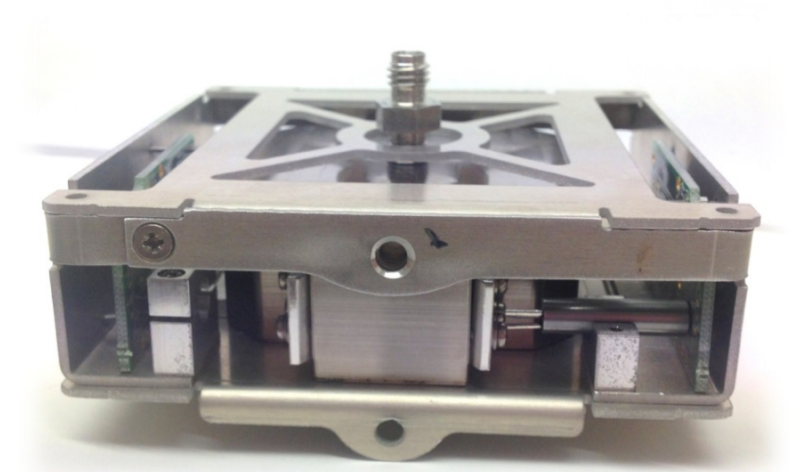


Figure: Test result of a MEMS valve operating in closed loop control mode responding to the commanded steps of 0,1 μ N.

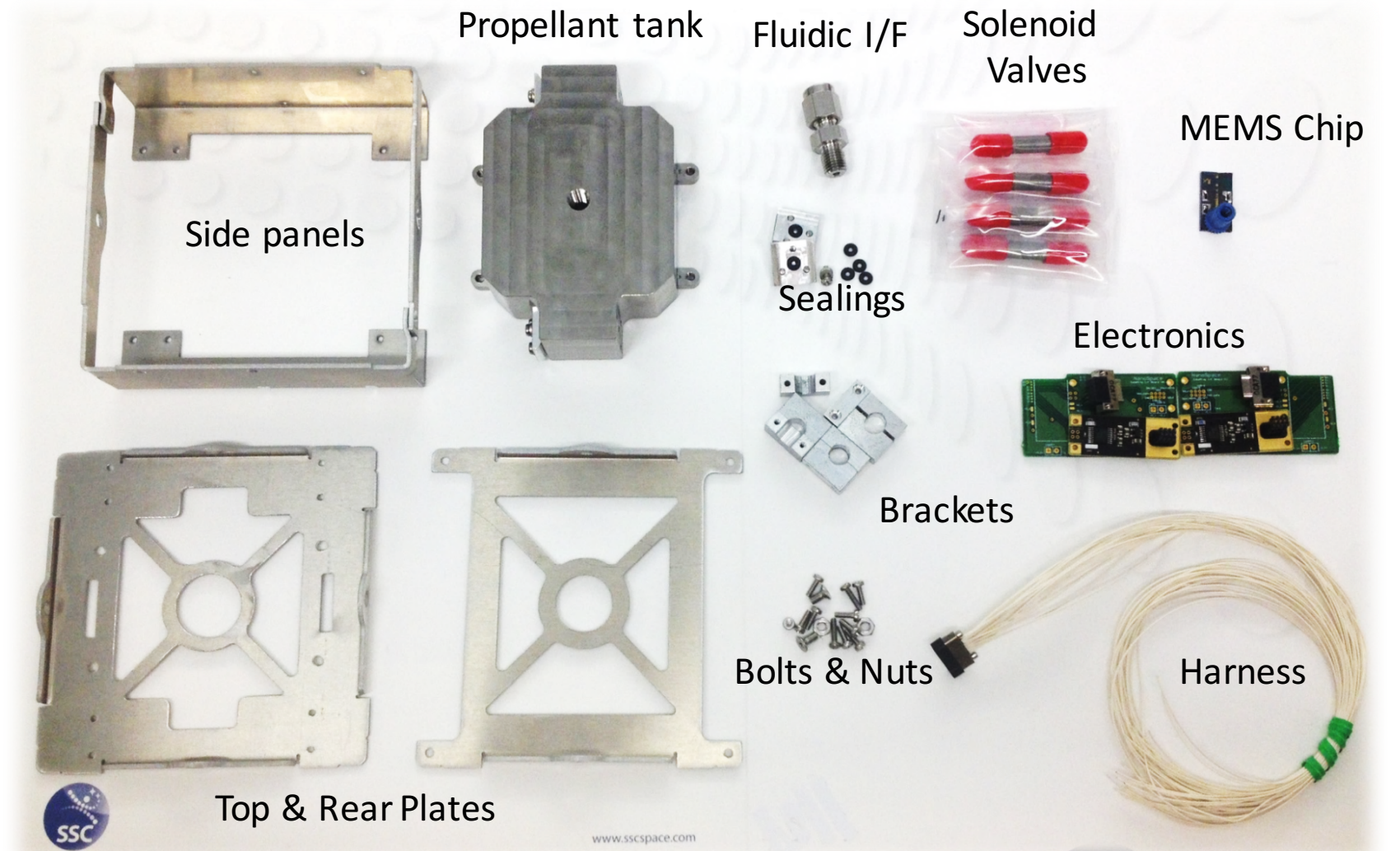
The CubeSat propulsion module

General specification:

- Four 1mN thrusters with closed loop thrust control
- Thrust resolution: $<10\mu\text{N}$
- Propellant: Butane
- Total impulse: 40Ns
- Size: 10*10*3cm
- Mass: 250g
- Operating pressure: 2-5 bar
- Power consumption: 2 W (average, operating)
- Mechanical interface: CubeSat payload I/F (Pumpkin)
- Electrical interface: 52 pins analog (0-12V) and digital (SPI)

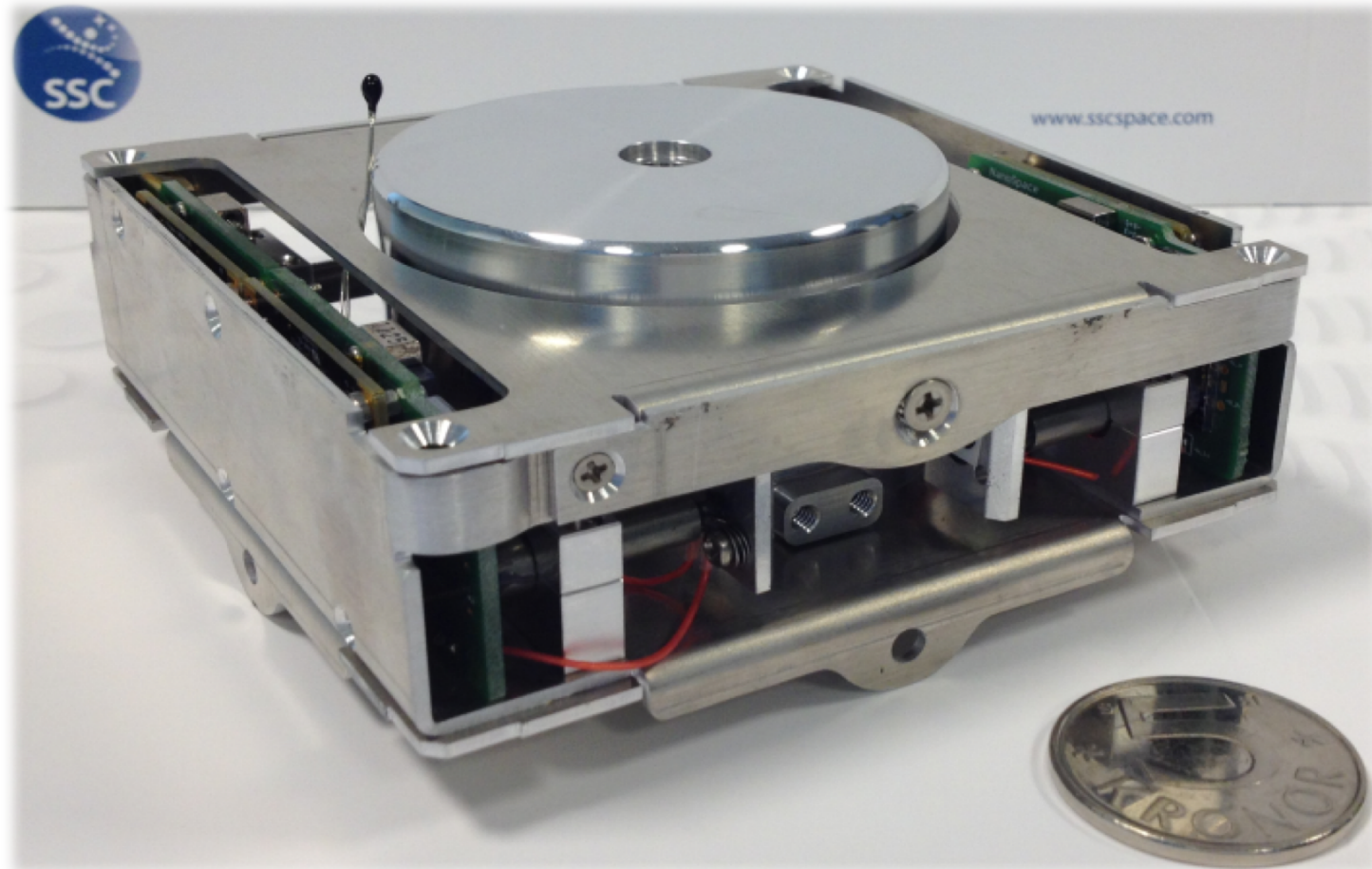


The propulsion module –in bits and pieces



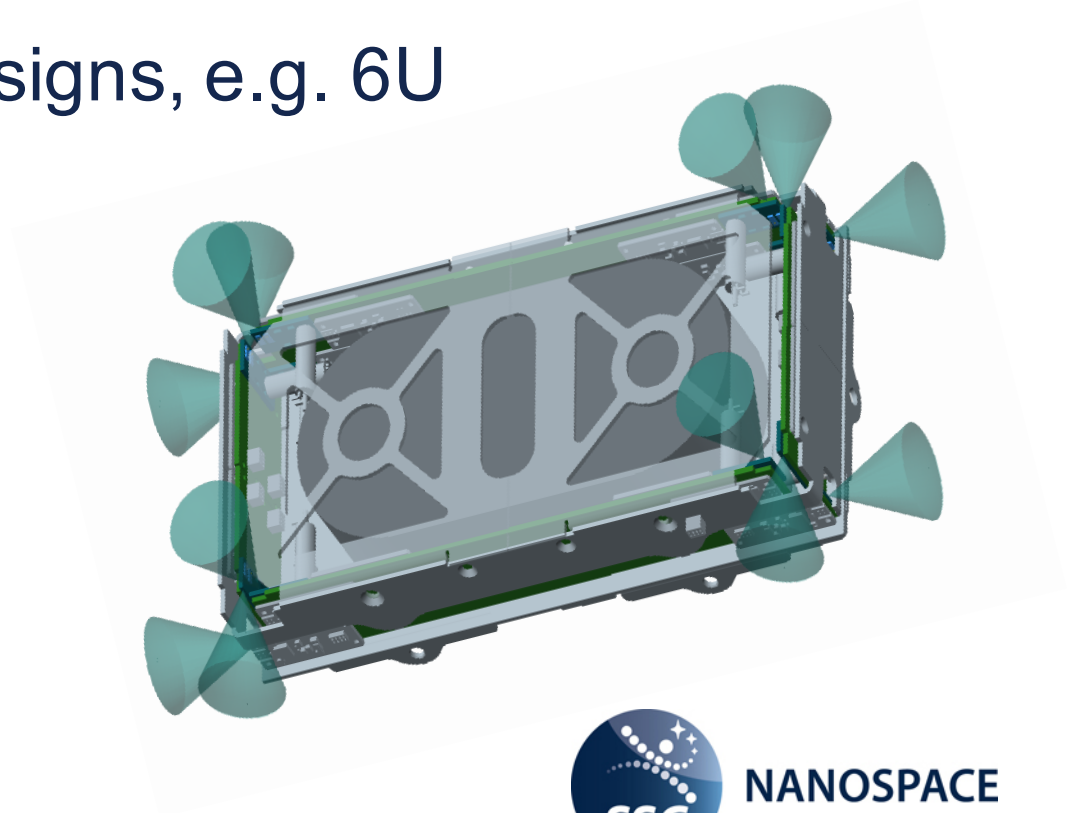
The “tuna can” design

-following the new CubeSat standard



Design, specification and performance changes possible

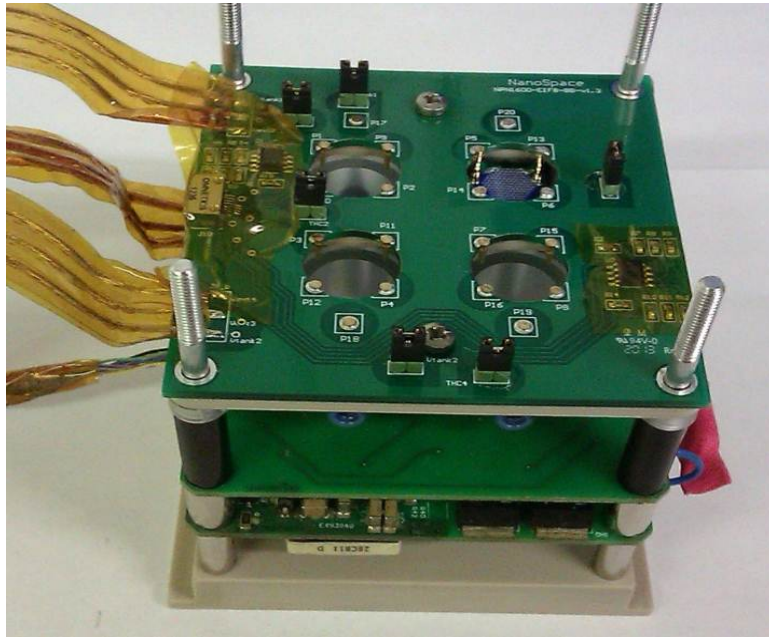
- Thrust levels
- Number of thrusters and thrust directions
- Other CubeSat designs, e.g. 6U
- Tank size
- ...



Outline

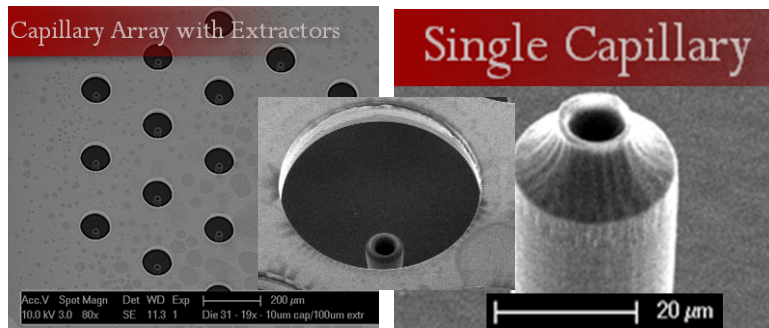
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MicroThrust: MEMS-based colloid thrusters for CubeSats



Specification

Operating media	EMI-BF ₄
Thrust/Power	50 μ N/W
Isp	3000 sec
Δv (1U)	5 km/s
Lifetime	13 000 hours

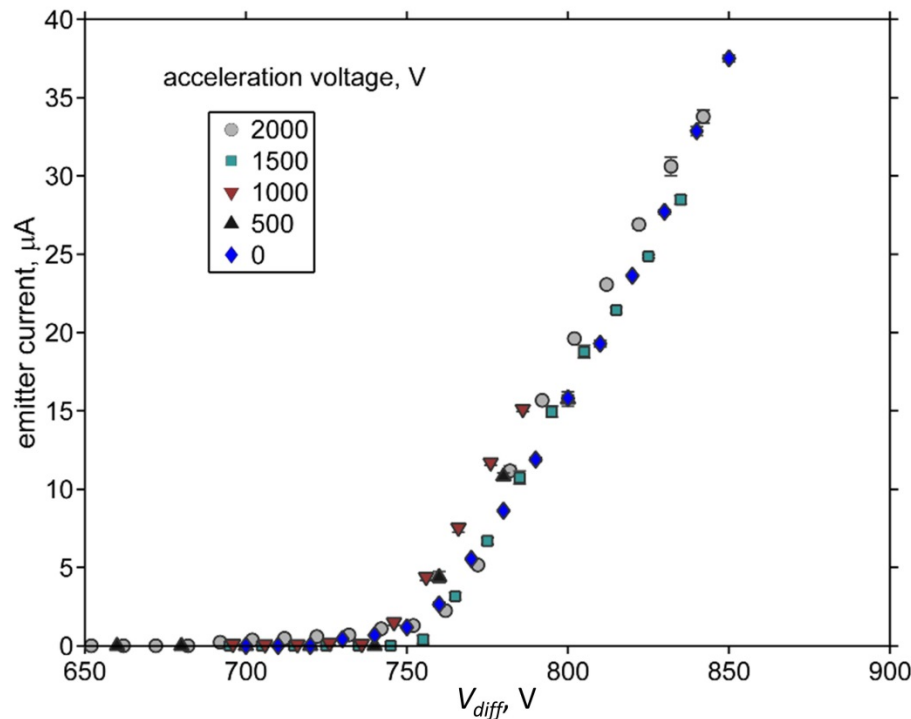


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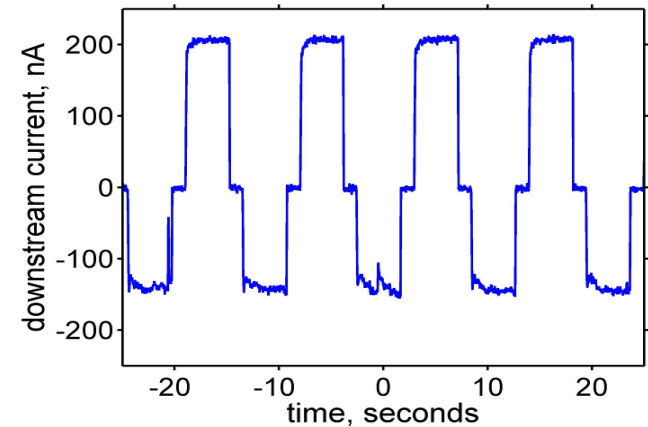
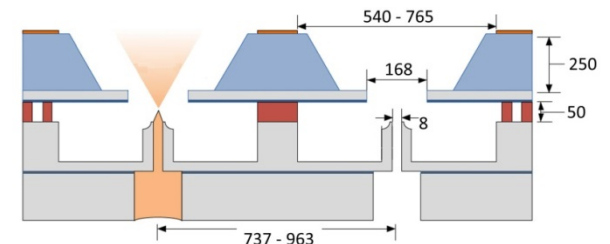
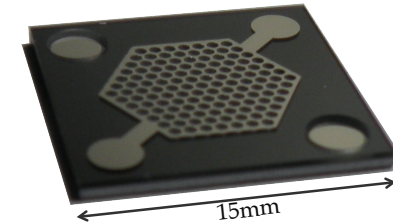


MicroThrust – Recent Results

- Current-voltage measurements
- Time of flight
- Plume angle measurements



Variation of emitter current with voltage difference between emitter and extractor, at different acceleration voltages



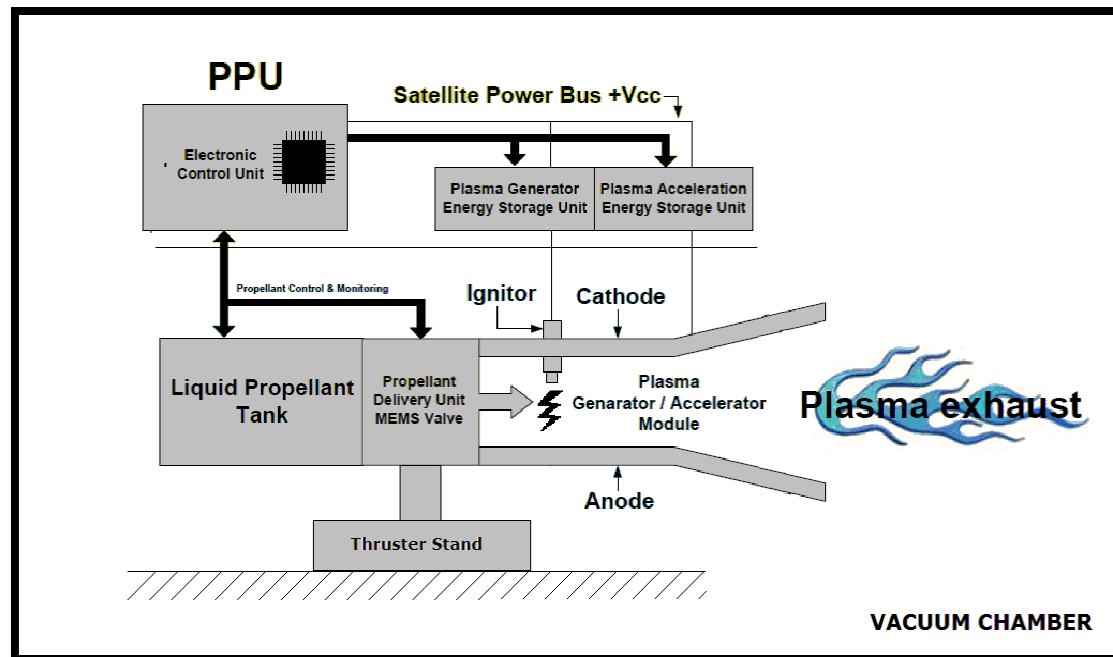
Bipolar mode operation with 127 emitter array



FP7-SPACE-2011-283279: Liquid Micro Pulsed Plasma Thruster



JMP INGENIEROS SL JMP Spain
NAJERA AEROSPACE SL NASP Spain
Mecartex SA MECARTEX Switzerland
IPPLM Poland
NANOSPACE AB NANOSPACE Sweden
KOPOOS, France



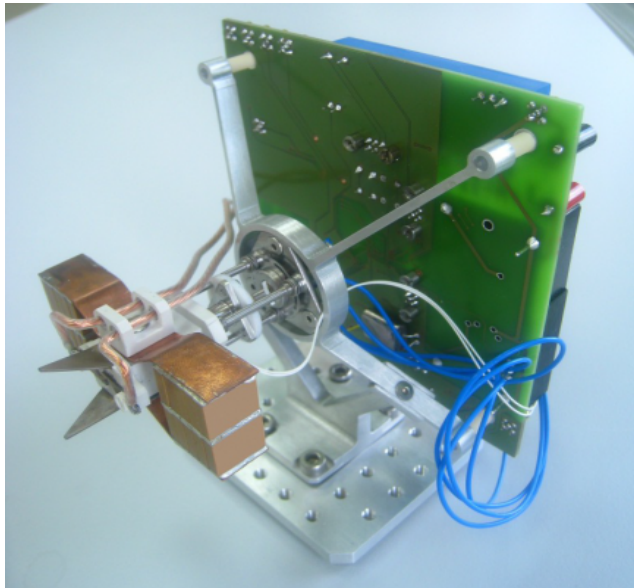
L-μPPT system diagram. Propulsion system and its components.



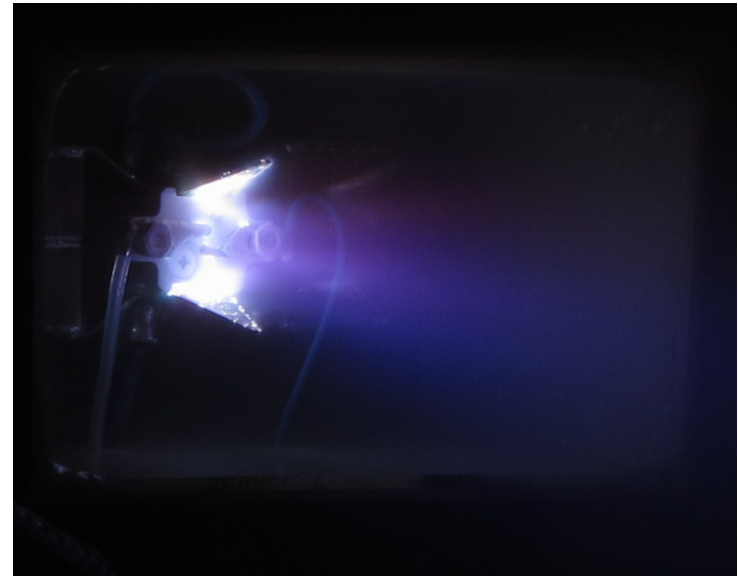
Liquid micro-Pulsed Plasma Thruster

Funding from European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n°283279, the L- μ PPT project.

- Propellant not limited by geometry: **total impulse much less constrained than Teflon PPTs**
- Steady propellant feed geometry: **no long term drift in terms of impulse bit**
- Propellant balancing capability in multi-thruster configuration: **better utilization of propellant mass**

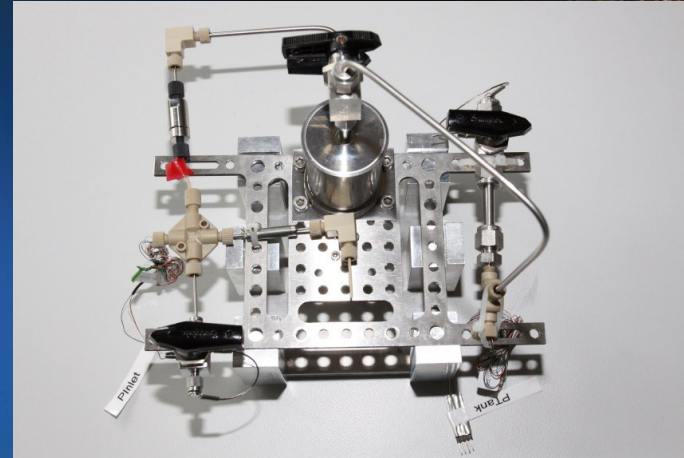
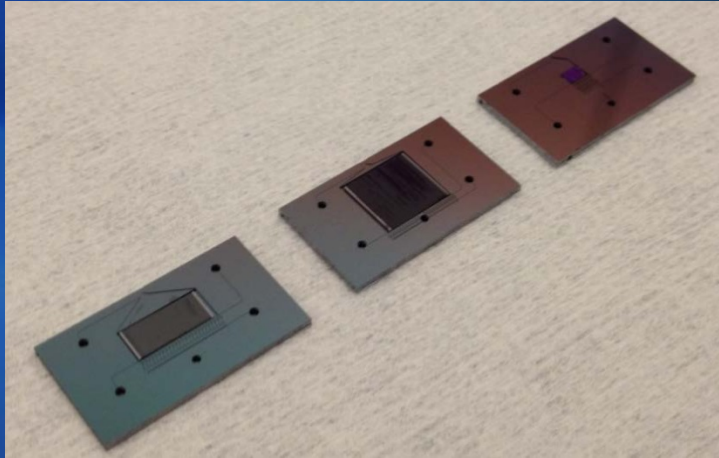
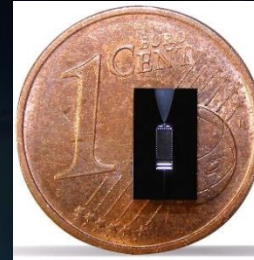


*1st european $L\mu$ PPT prototype
(CubeSat-sized)*



Thruster operating 900 V.
Long exposure photographs over a single discharge.

PRECISE



PRECISE focuses on the research and development of a MEMS-based monopropellant micro Chemical Propulsion System (μ CPS) for highly accurate attitude control of satellites.



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UNIVERSITY OF
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University of Twente
The Netherlands

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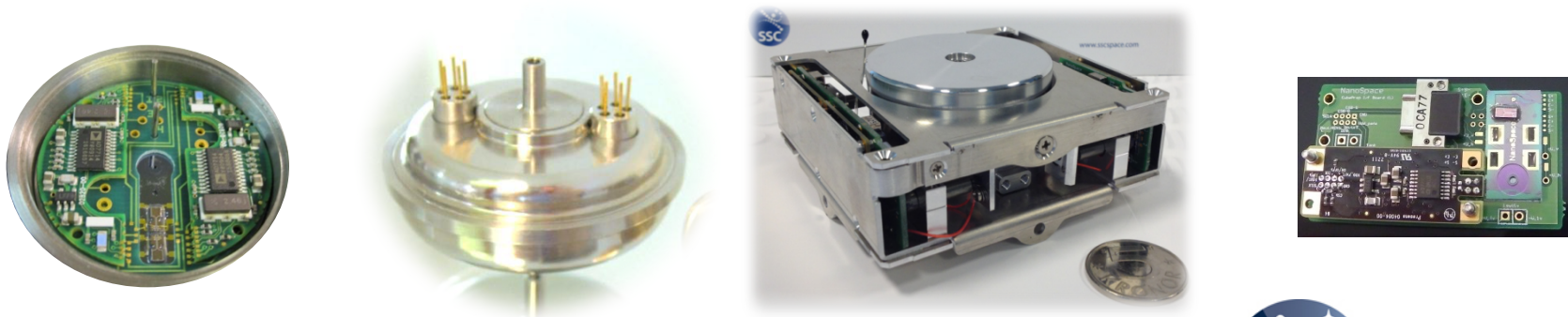
SMÖRGÅSBORD ['smørgøs_bu:d]

MEMS Micropropulsion Components

- First generation MEMS micropropulsion:
 - *Miniaturised, accurate and open-loop*



- Next generation MEMS micropropulsion:
 - ***Closed-loop control***



Xenon flow control module

CubeSat propulsion module

Swedish lesson #2:



Manager (informal: boss)



Chef [sje:f]

Welcome!



SSC booth with USN, ECAPS & NanoSpace

Thank you!

