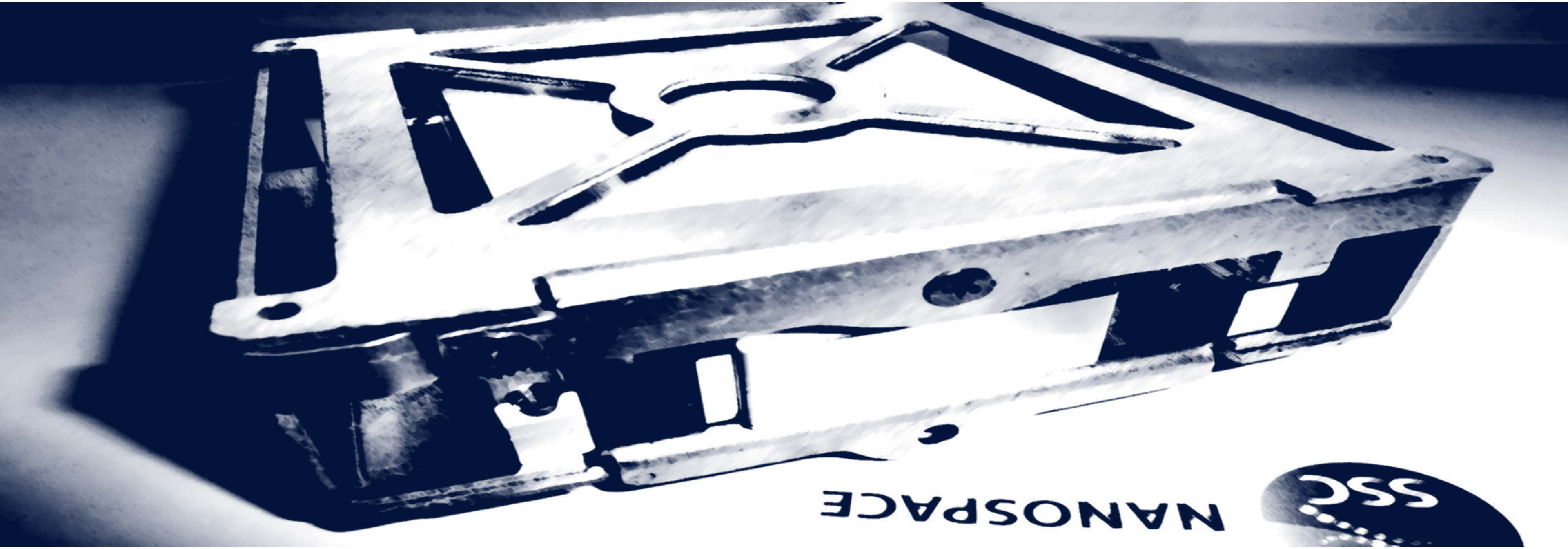
CUBESAT PROPULSION MODULE WITH CLOSED-LOOP THRUST CONTROL



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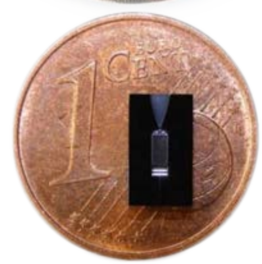
Outline

- 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”

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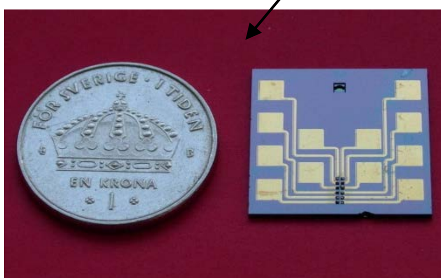
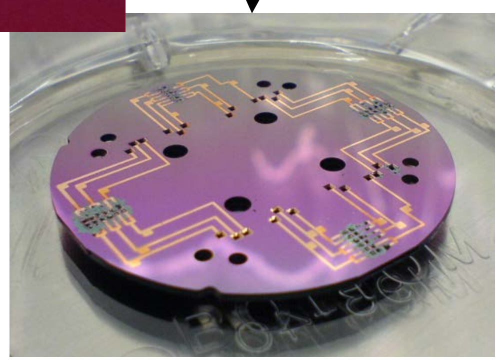
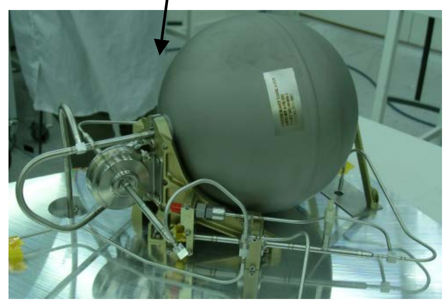
First generation MEMS micropropulsion
- developed for the Prisma satellites

2005 2006 2007 2008 2009 2010

- NanoSpace starts operation
- phase B contract
- First test of MEMS thruster
- 1st complete thruster module
- 1 st delivery of flight H/W
- Final delivery to Prisma
- End-to-end testing on S/C
- Launch!







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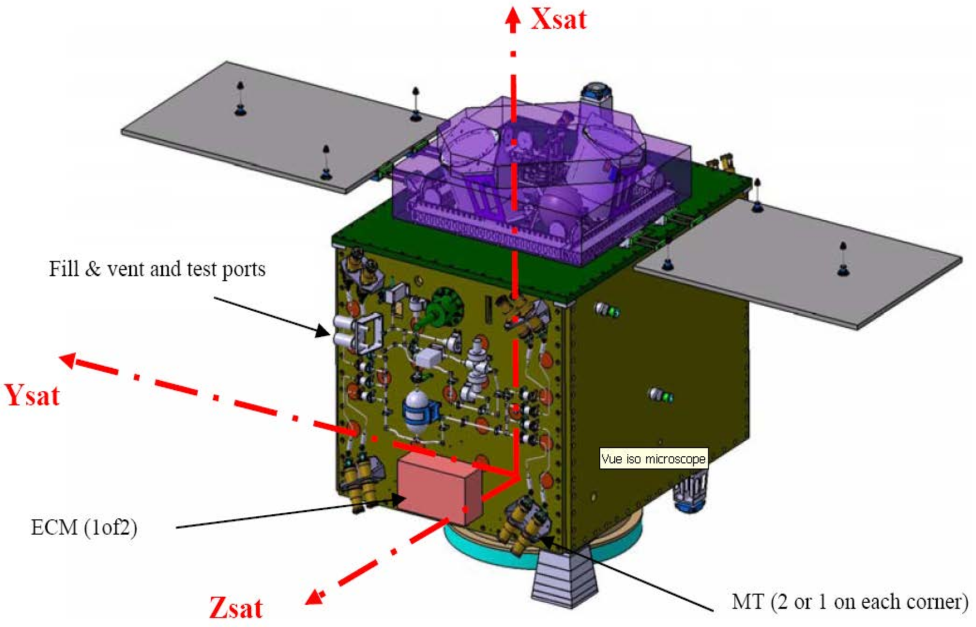
Advanced missions – Demanding requirements

Example: MICROSCOPE – drag free fligth

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



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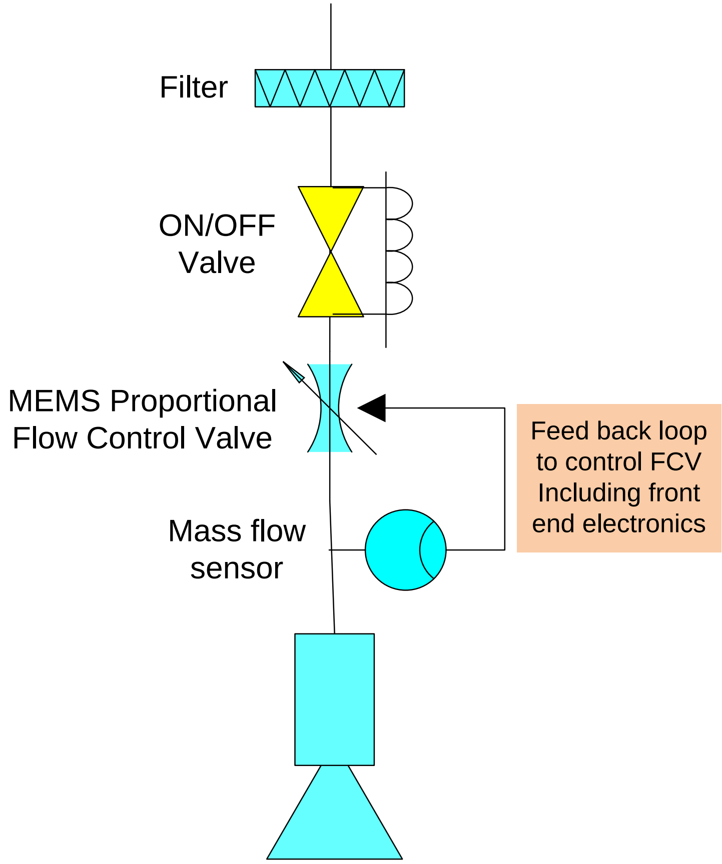
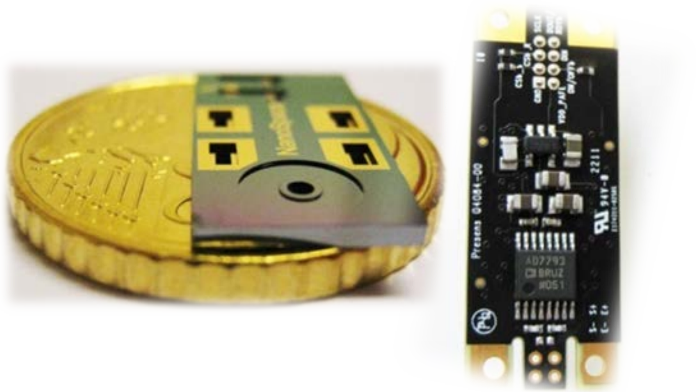
Second generation – Closed-Loop Thrust Control



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

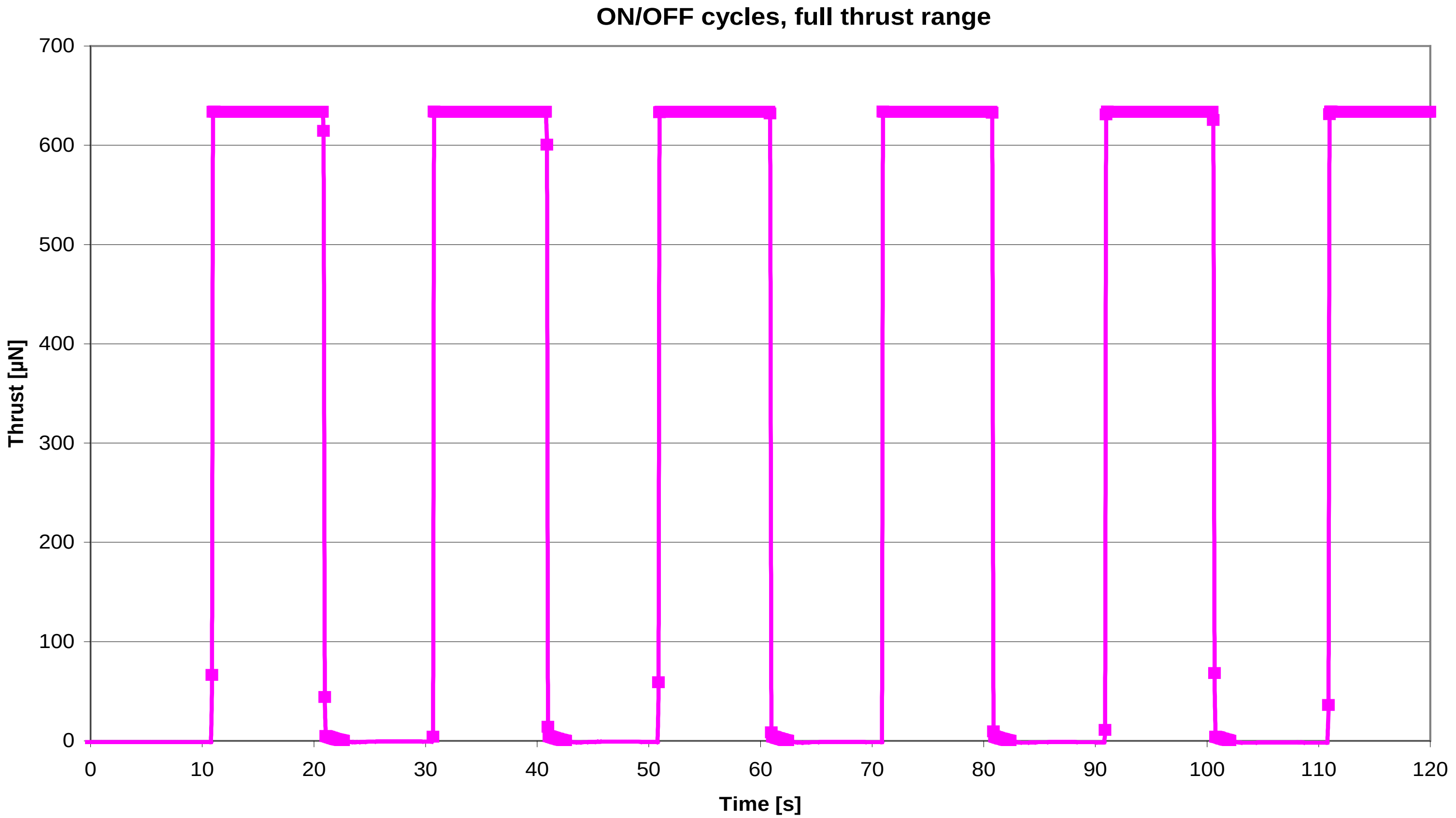


Figure: Test result of MEMS thruster operating in ON/OFF mode (open loop, using solenoid valve only) to show thrust range.
Full thrust can be set in the range **50 micro-Newton** to **10 milli-Newton**

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Key capabilities – Unlike any other

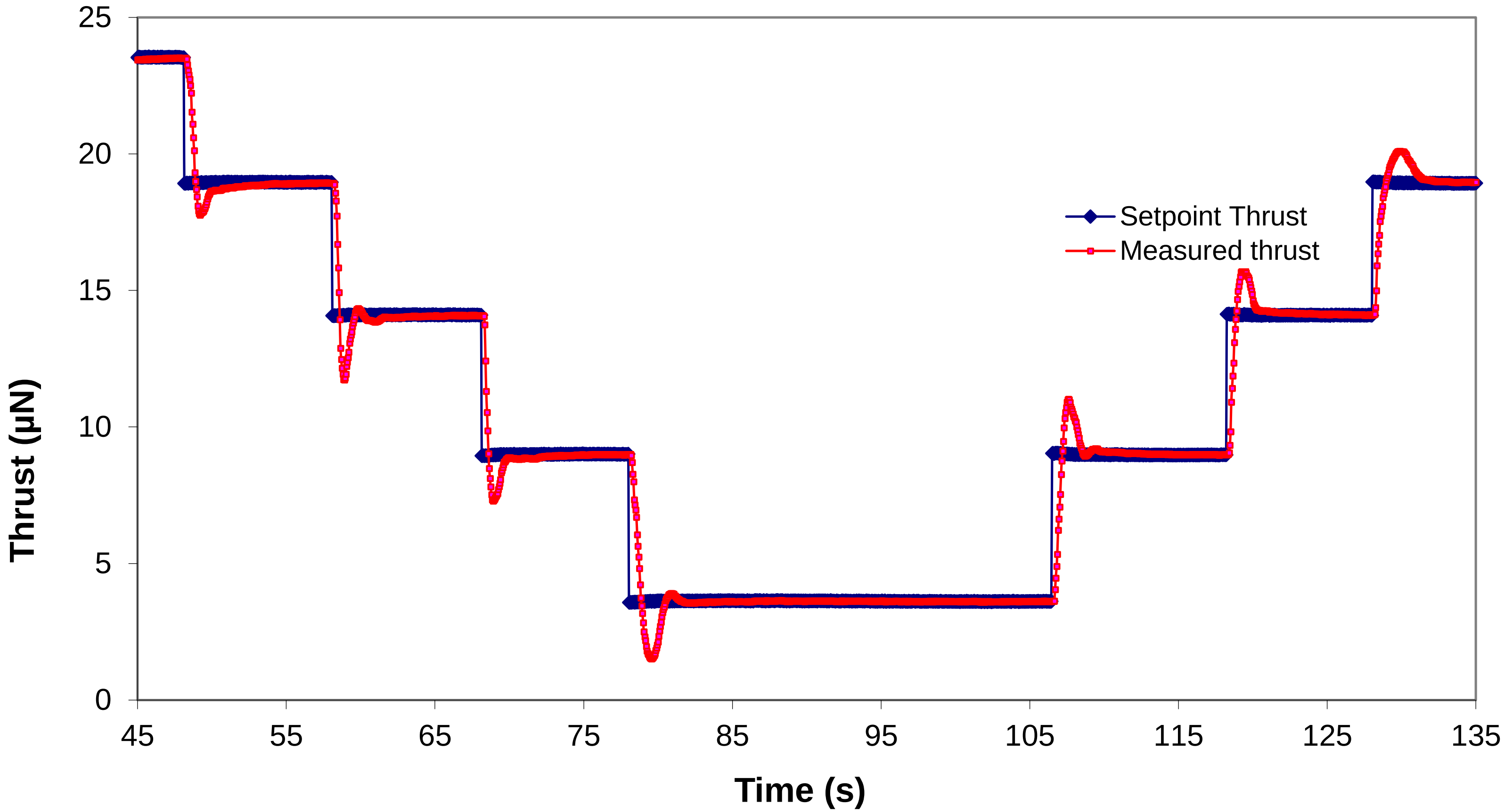

Figure: Test result of a MEMS valve operating in closed loop control mode showing the the thrust response to commanded steps of 5 µN.

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Unique performance

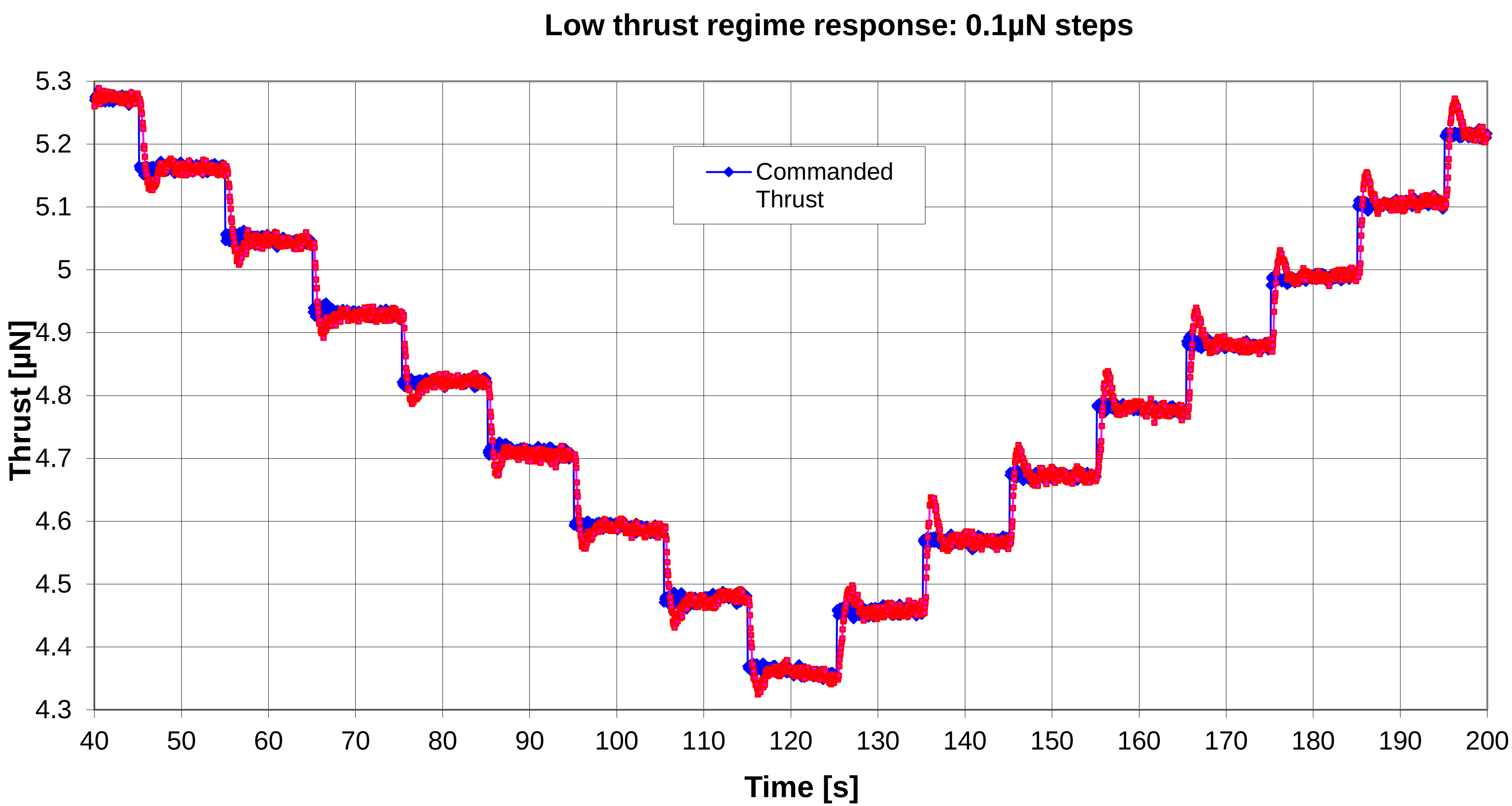


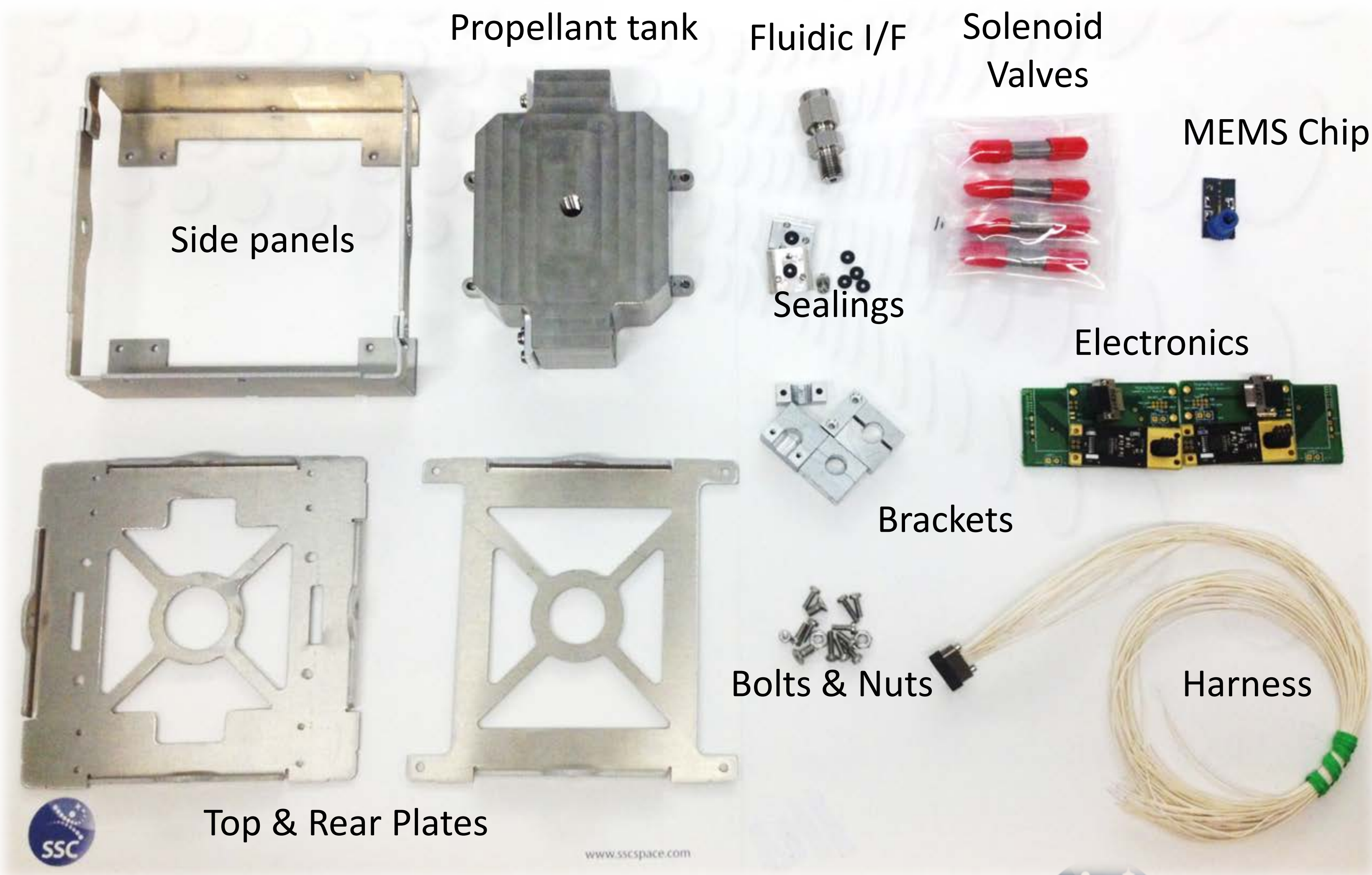
Figure: Test result of a MEMS valve operating in closed loop control mode responding to the commanded steps of 0,1 µN.

The CubeSat propulsion module

General specification:

- Four 1mN thrusters with closed loop thrust control
- Thrust resolution: <10μN
- 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



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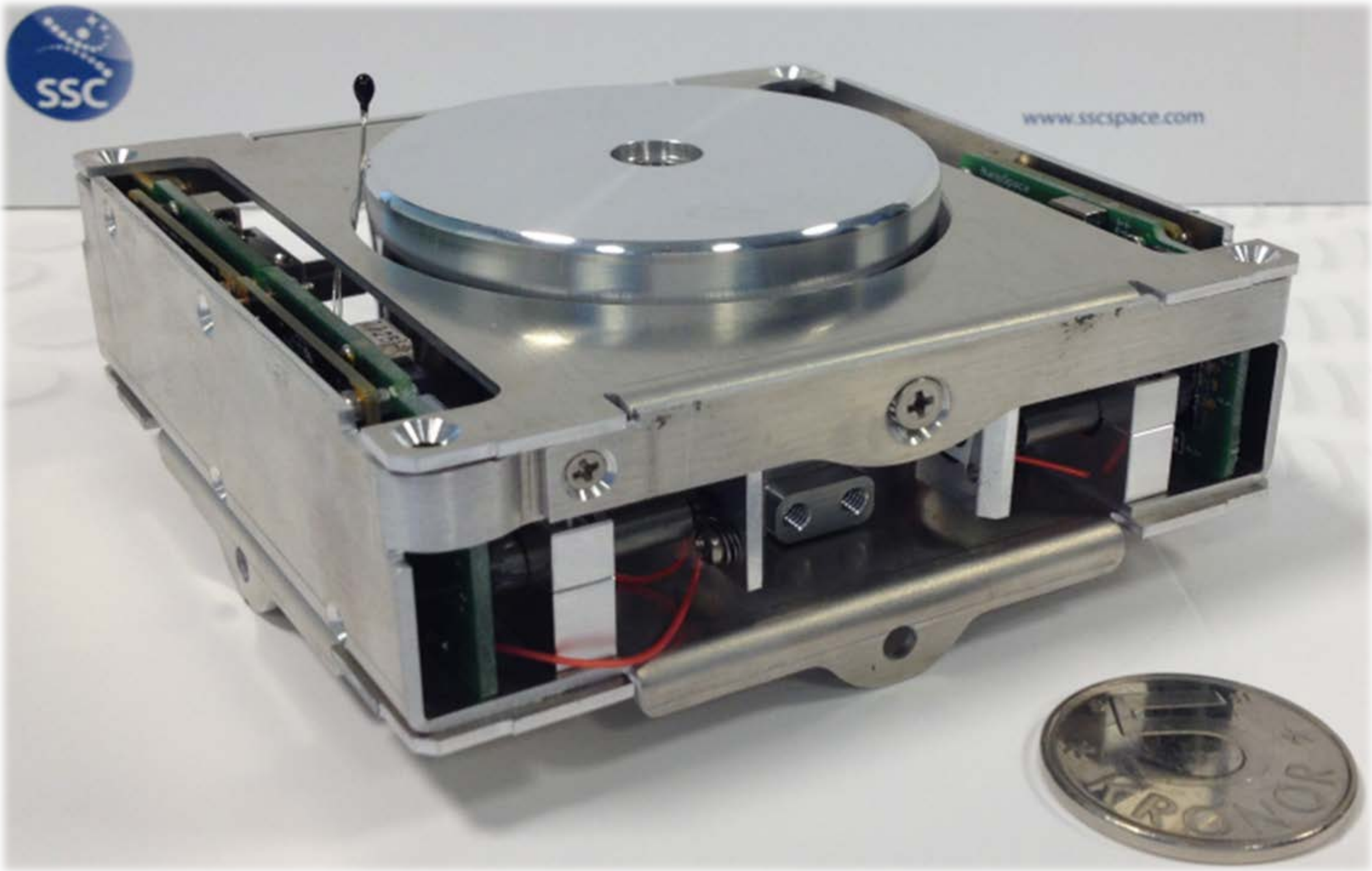
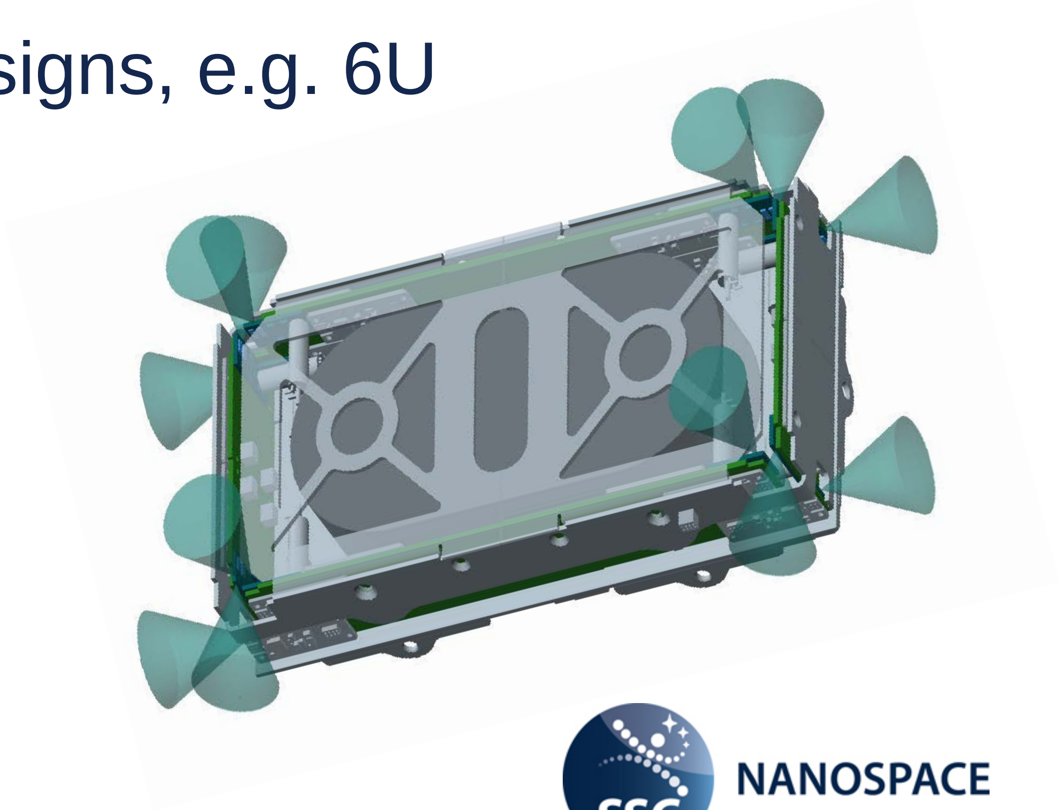
The “tuna can” design

-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
- …



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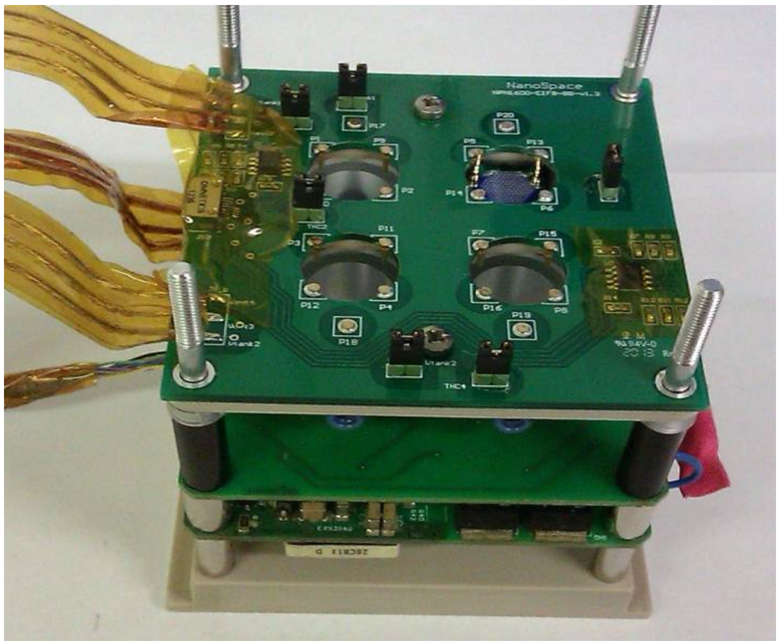
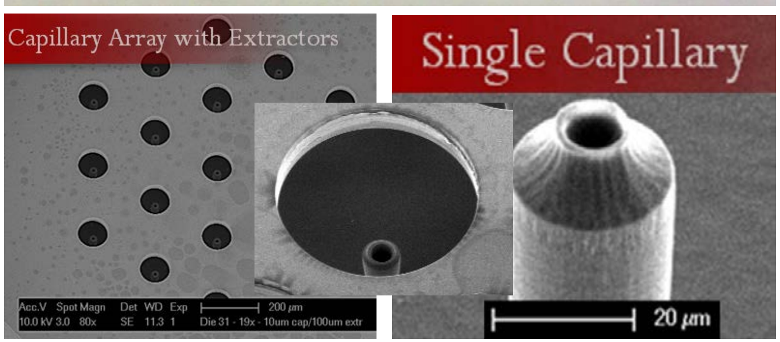
MicroThrust: MEMS-based colloid thrusters for CubeSats





Specification	
Operating media	EMI-BF_4
Thrust/Power	50 μN/W
Isp	3000 sec
Δv (1U)	5 km/s
Lifetime	13 000 hours

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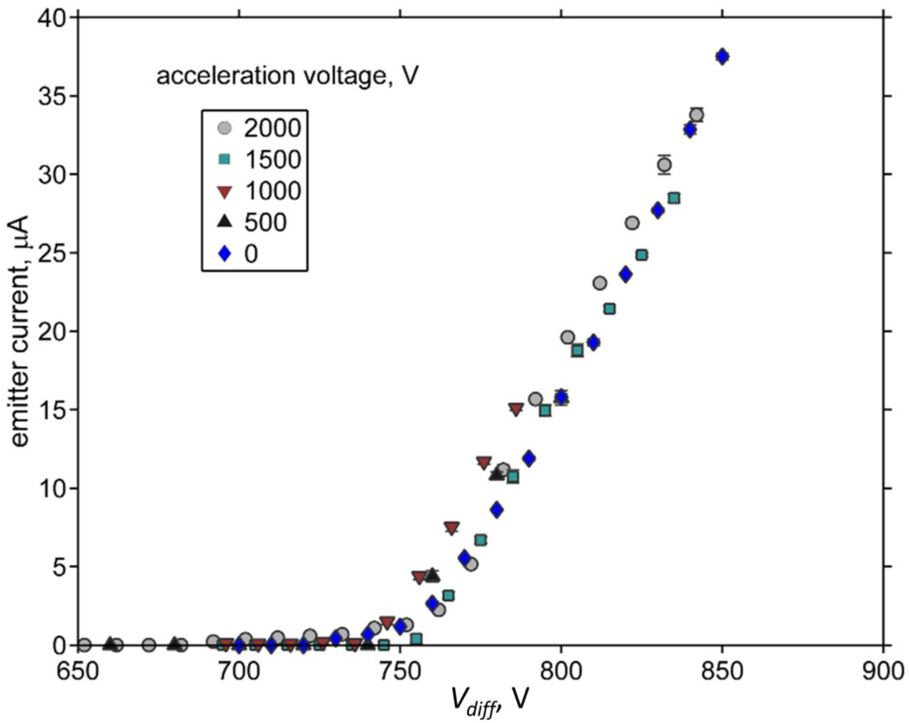
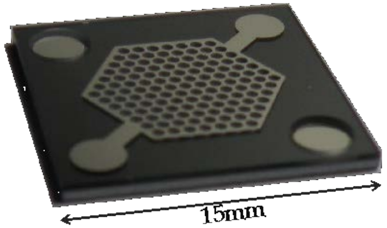
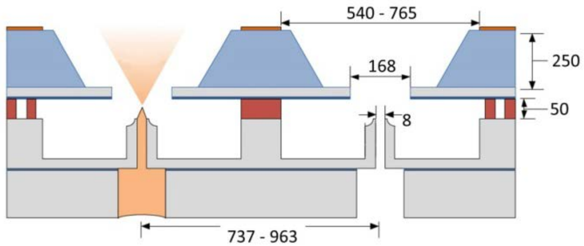
MicroThrust – Recent Results

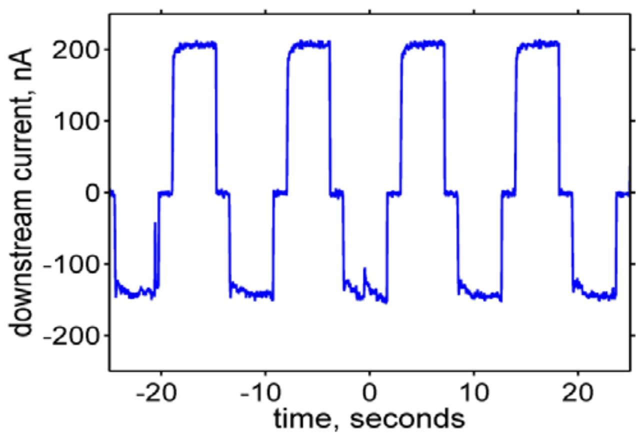
- Current-voltage measurements
- Time of flight
- Plume angle measurements



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







Bipolar mode operation with 127 emitter array

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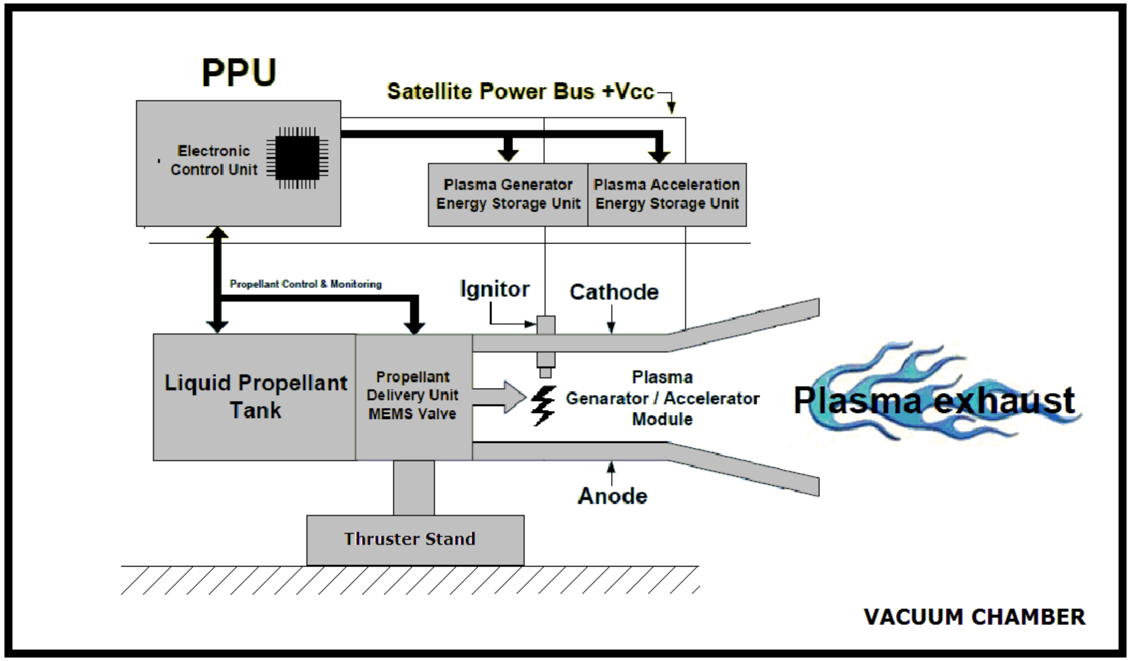
FP7-SPACE-2011-283279: Liquid Micro Pulsed Plasma Thruster

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.

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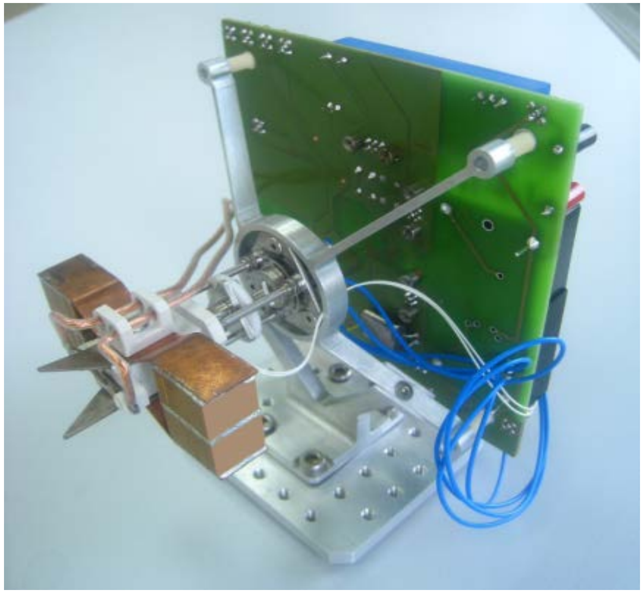
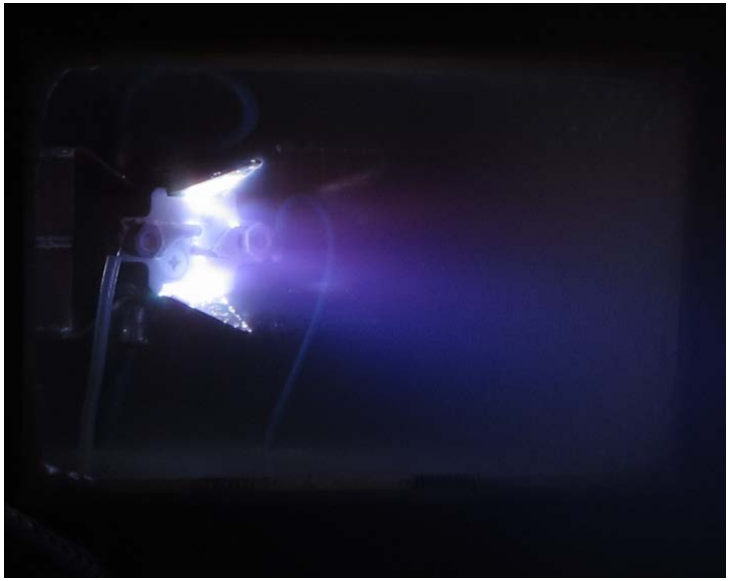
Liquid micro-Pulsed Plasma Thruster

Funding from European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n°283279, the L-μPPT 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 LμPPT prototype (CubeSat-sized)



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

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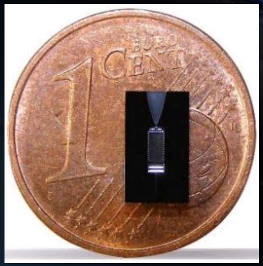
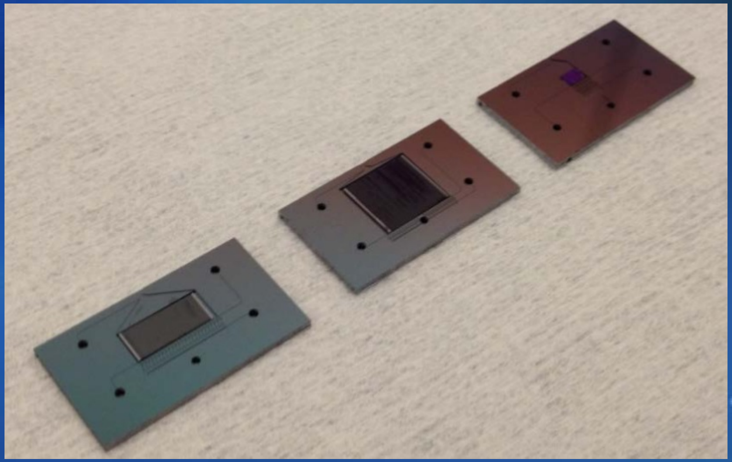
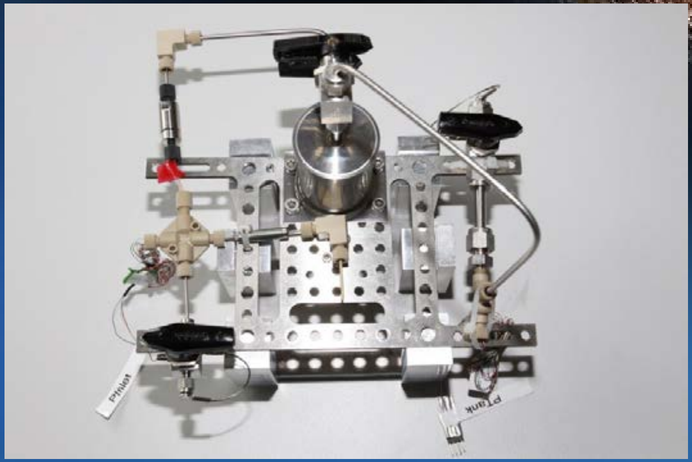
PRECISE







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

SEVENTH FRAMEWORK PROGRAMME · ASTRIUM AN EADS COMPANY · CNRS · DLR · SSC · NANOSPACE · UNIVERSITY OF SURREY · University of Twente The Netherlands

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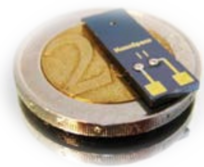
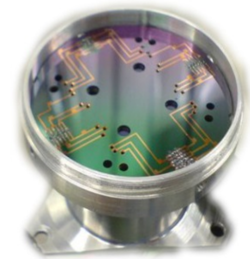
MEMS Micropropulsion Components

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







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


Xenon flow control module

CubeSat propulsion module

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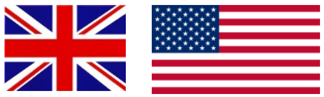
Swedish lesson #2:



Manager (informal: boss)

Chef *[sje:f]*

Welcome!

SSC booth with USN, ECAPS & NanoSpace

Thank you!

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