Efficient Deorbiting with the IFM Nano thruster

26th May 2016

Clean Space Industry Days

FOTEC Forschungs- und Technologietransfer GmbH

Research Subsidiary of the University of Applied Sciences Wiener Neustadt

- Founded: 1998
- Employees: 35
- R&D Turnover : 2 Mio. EUR

More than 25 national and international R&D Projects ongoing

ISO 9001:2008 certified since October 2011


ZERTIFIKAT

TÜV AUSTRIA

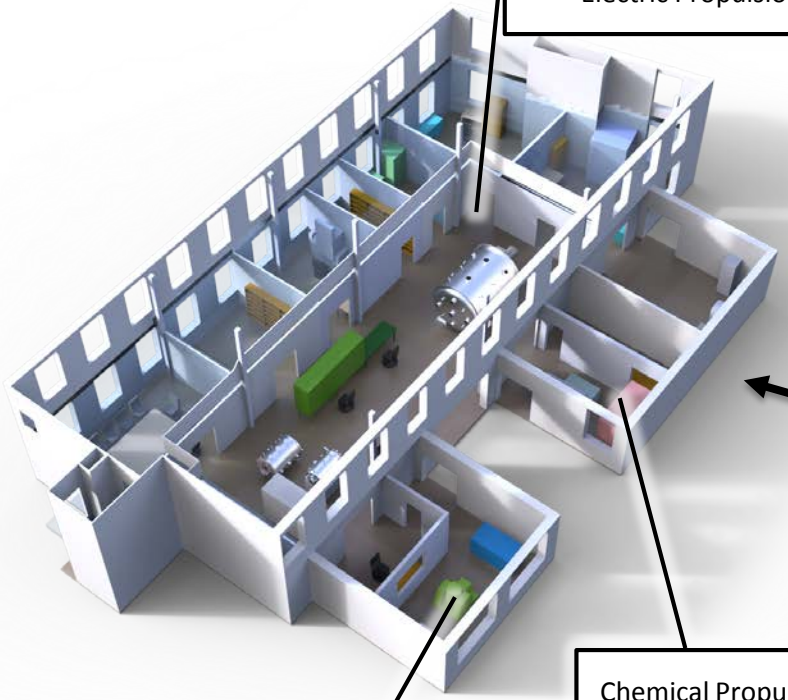
für das Managementsystem nach
EN ISO 9001:2008

FOTEC Forschungs- und Technologietransfer GmbH
Viktor Kaplan-Straße 2
A-2700 Wiener Neustadt

Forschung und Entwicklung

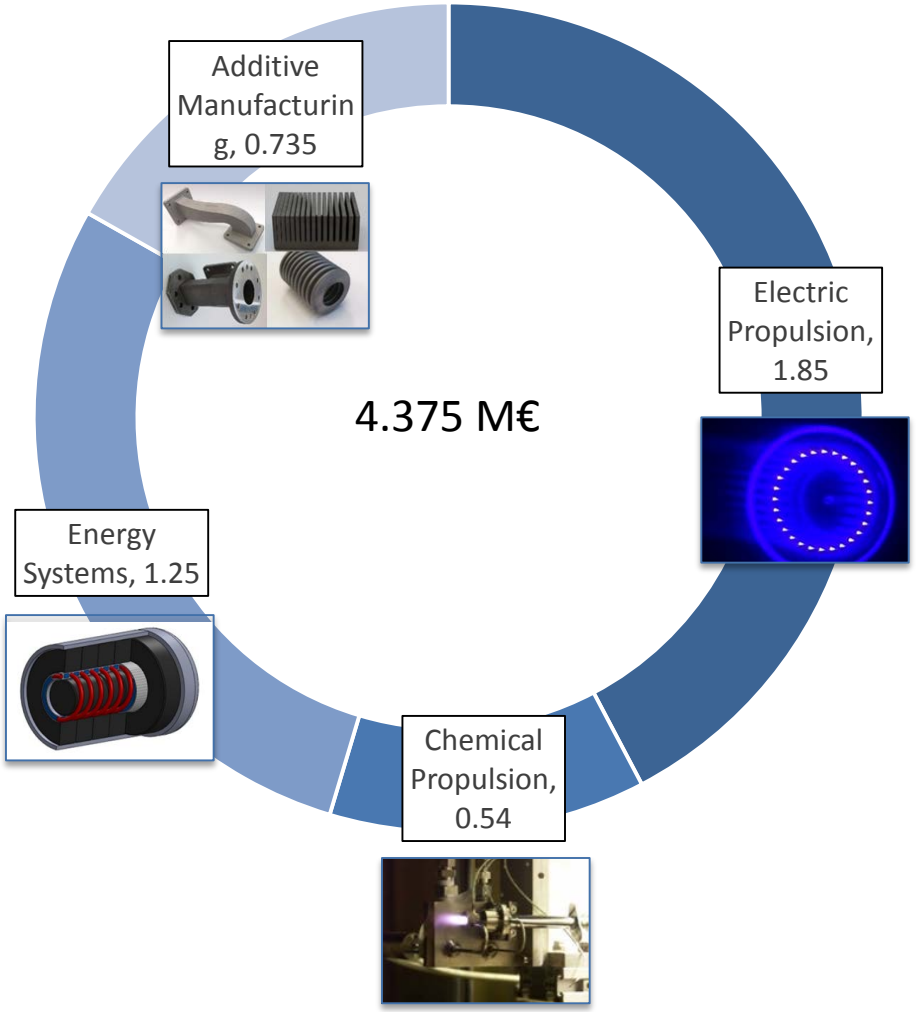
FOTEC Propulsion Laboratories 2016

- FOTEC is currently building completely new Laboratory space dedicated to Spacecraft Propulsion Technologies.

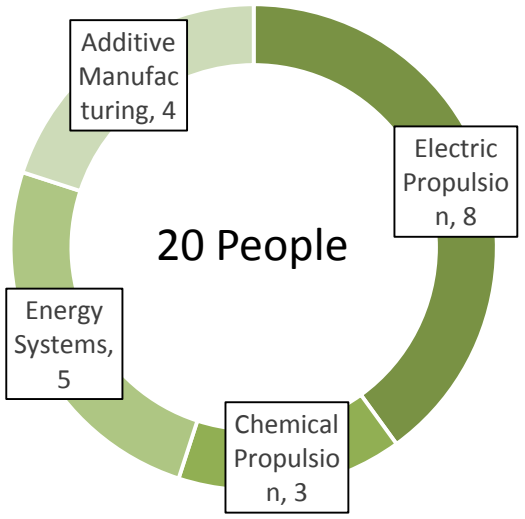


Key Figures for Space Activities (Q1 2016)

Project Volume [M€]

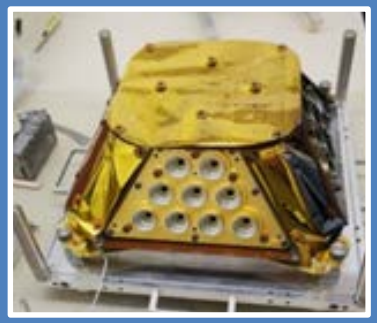


Team Size



FOTEC Electric Propulsion Capabilities

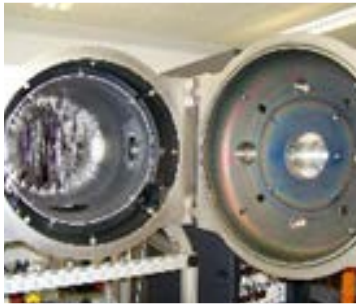
Thruster (FEEP)



- Capillary Emitter
- Porous Multiemitter

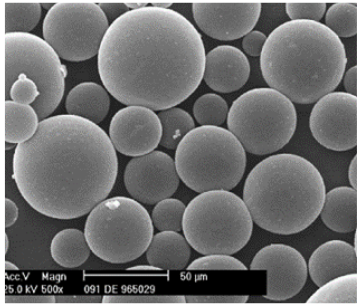
- 1µN to 2mN continuous operation
- ISP 5000+
- Mass efficiency 40-60%

Testing/ Qualification



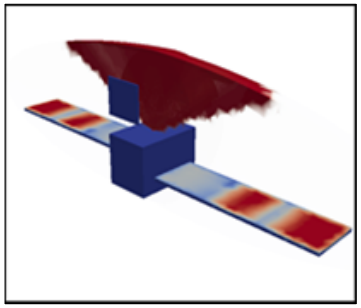
- Vacuum Facilities
- Plume Diagnostics
- Direct Thrust Measurements
- Environmental Testing
  - TVT, Thermal, Vibration

Innovative Gas Storage



- High density – Low Pressure Gas storage
- H2, He
- Xe

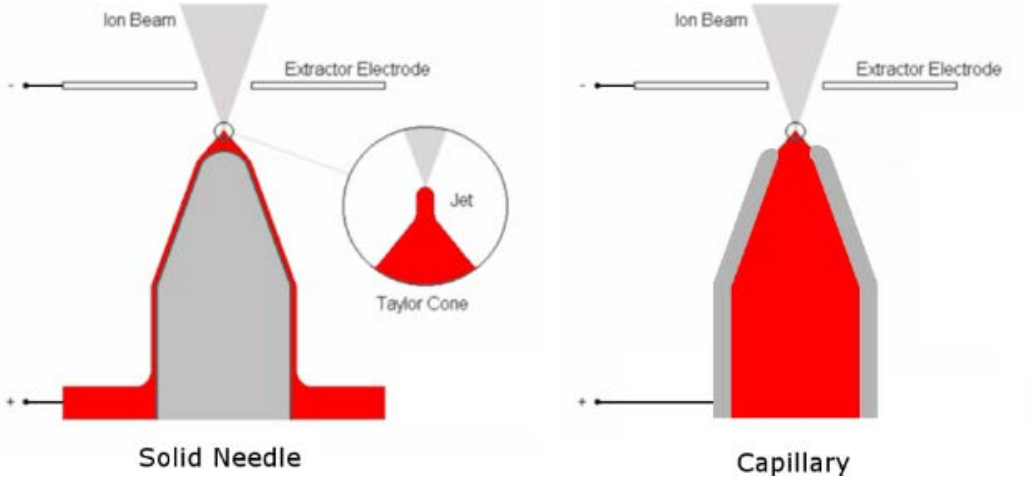
Simulations



- S/C Plasma interactions
- CEX simulations

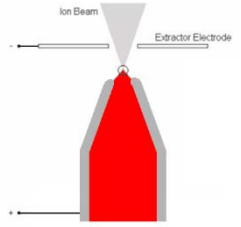
Liquid Metal Ion Sources and Field Emission

- Over 30 years of flight experience with Liquid Metal Ion Sources (LMIS).
- Up to now, FOTEC is the only company worldwide that has flight heritage with liquid metal ion sources.



Experiment	Function	Spacecraft	Nr. of LMiS	Operation Time
LOGION	Test of LMIS in µ-Gravity	MIR	1	24 h (1991)
MIGMAS/A	Mass Spectrometer	MIR	1	120 h (1991-94)
EFE-IE	S/C Potential Control	GEOTAIL	8	600 h (1992 -)
PCD	S/C Potential Control	EQUATOR-S	8	250 h (1998)
ASPOC	S/C Potential Control	CLUSTER	32	Ariane 5 Launch Failure 1996 Still operational after Crash
ASPOC-II	S/C Potential Control	CLUSTER-II	32	6516 (2000 -)
COSIMA	Mass Spectrometer	ROSETTA	2	Fully Operational, Experiment Ongoing
ASPOC/DSP	S/C Potential Control	DoubleStar	4	8979 h (2004 – 2007)
MMS ASPOC	S/C Potential Control	MMS	32	Commissioned successfully in 2015

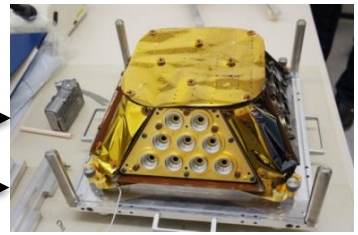
History of In-FEEP Developments

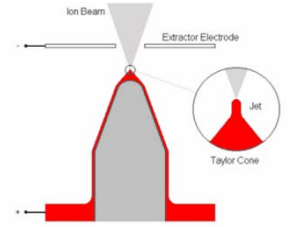


Capillary

Ion Source for Spacecraft Charge Control
Cluster, MMS, …

TRL 6 (Emitter TRL 9)
Thrust 1-100µN
Demonstrated lifetime
1000 h (Emitter >9000h)

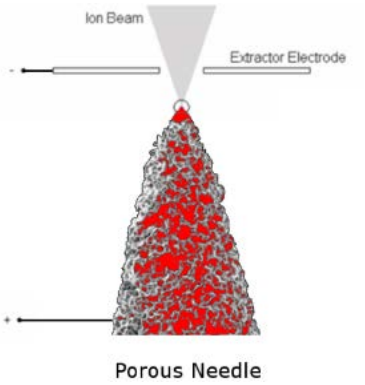




Solid Needle

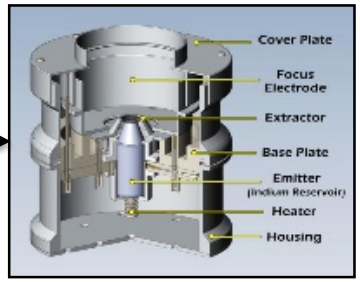
GOCE
Performance Issues

LISA PF
Good Performance
Manufacturing Issues



Porous Needle

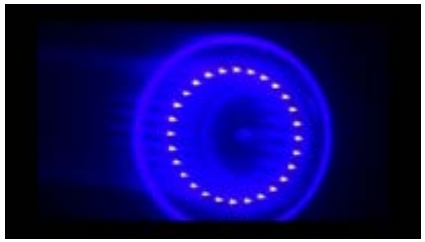
Good Performance
Repeatable Batch Production
>9500h stable Performance

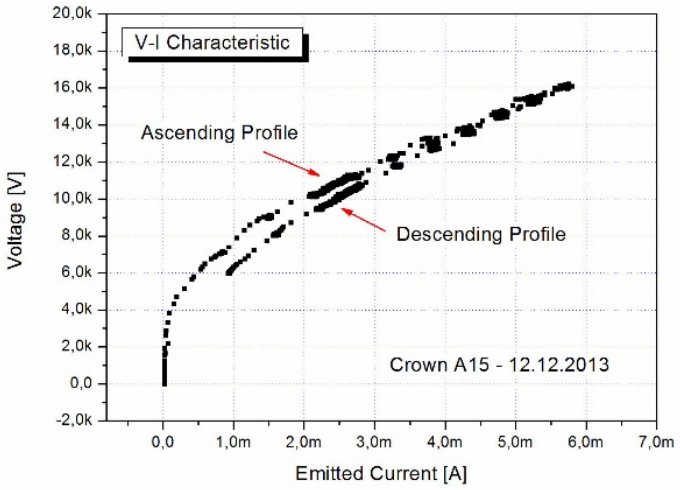


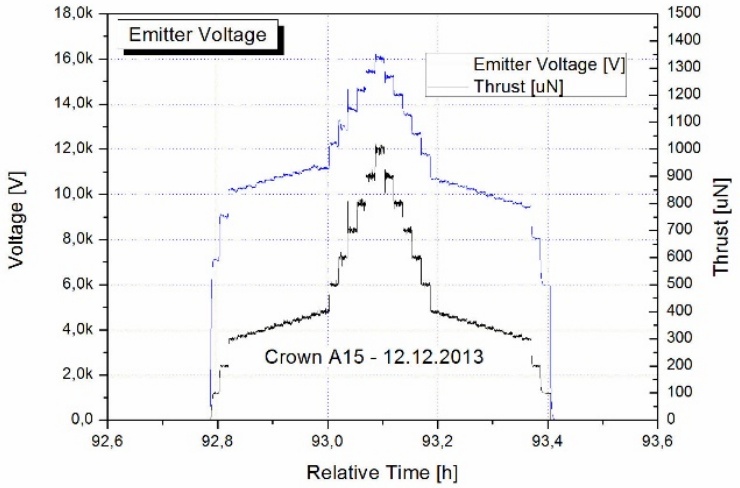
TRL 4
Thrust 0.3µN-2mN
Demonstrated lifetime
9000+ h

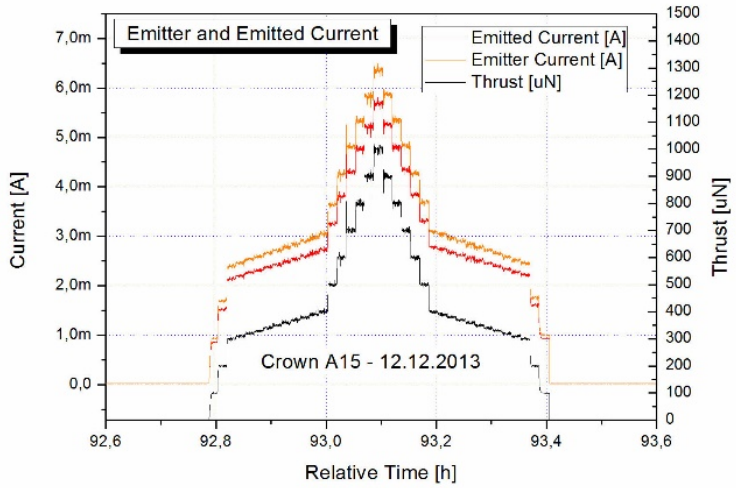
IFM-350: the mN-FEEP thruster

- liftime testing ongoing, 8700h completed
  - No degradation in performance
  - Stable mass efficiency >40%
- Performance characterization on large number of emitter ongoing









Reissner et al., "Detailed Performance Characterization of the mN-FEEP Thruster.", SPC 2014

IFM Nano Thruster Spin-Off

mN-FEEP thruster
developed for ESA missions

Formation Flight Control
1mN

N-S Station Keeping / Orbit Raising
1N

No miniaturization necessary!
Building on 10 years of ESA technology development

Constellation of
1-15 kg satellites

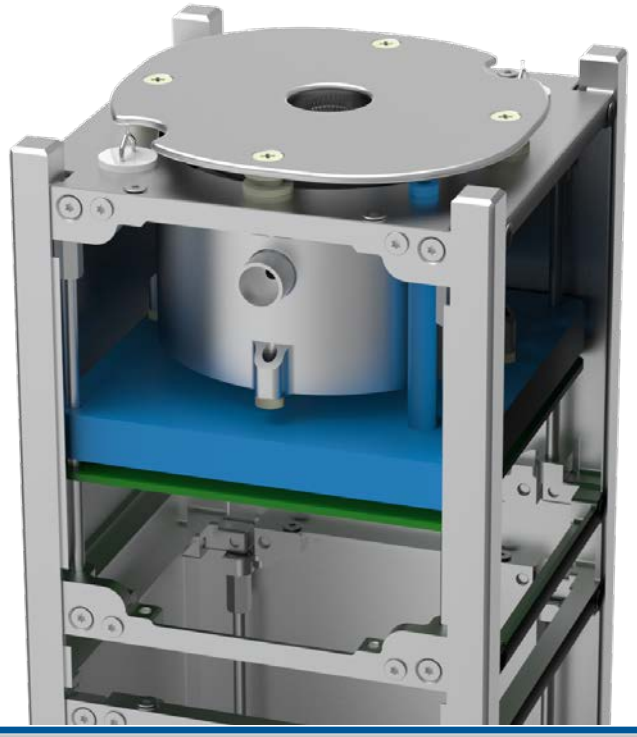
Formation Flight Control
1µN

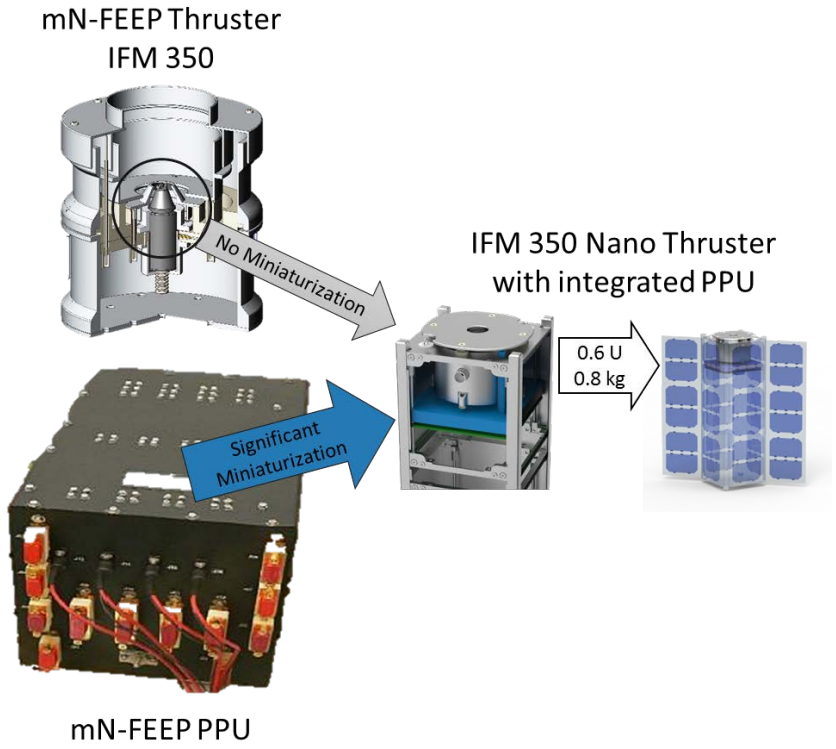
Drag Compensation / Orbit Raising
1mN

mN-FEEP thruster
Re-Designed for Nano and Micro-Satellites

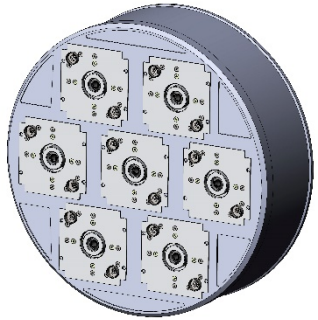
Thruster Design Concept

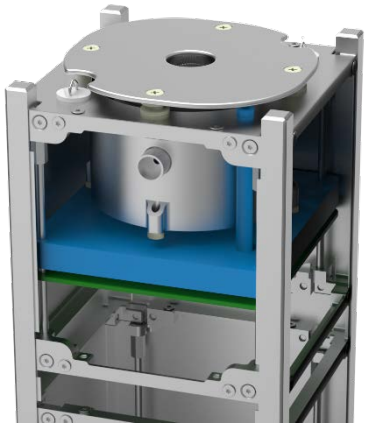
- Each module includes in a 10x10x6 cm Volume and <800g
  - Ion Emitter
  - Propellant
  - Propellant Heater
  - High Voltage Electronics
  - Power Processing Unit
  - 2 Neutralizer

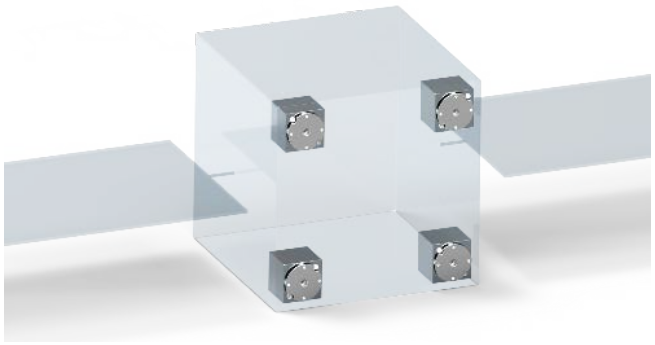


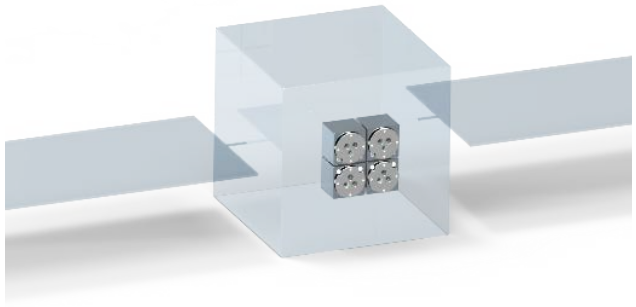


IFM Nano Thruster Module

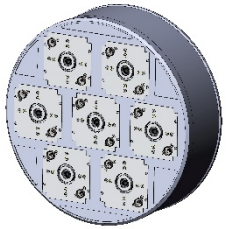


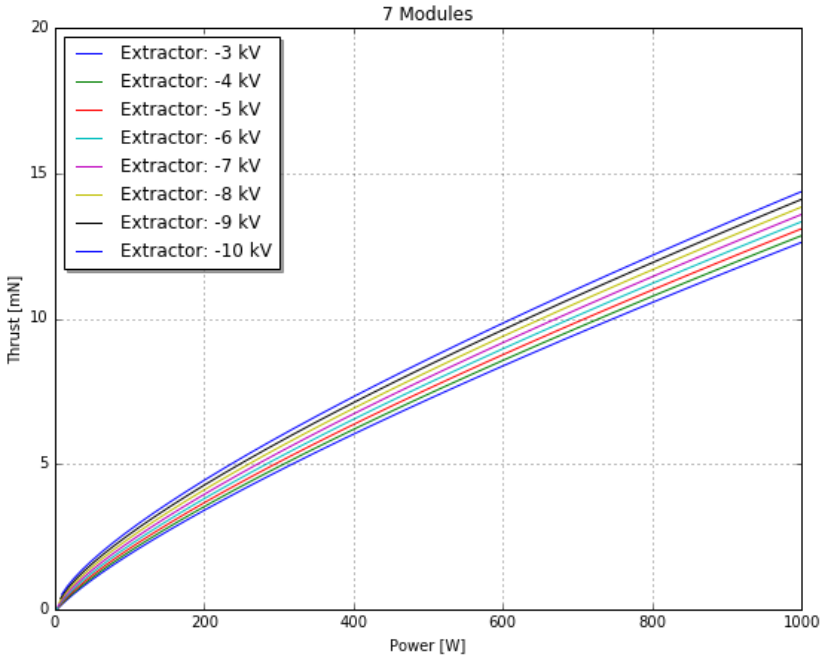


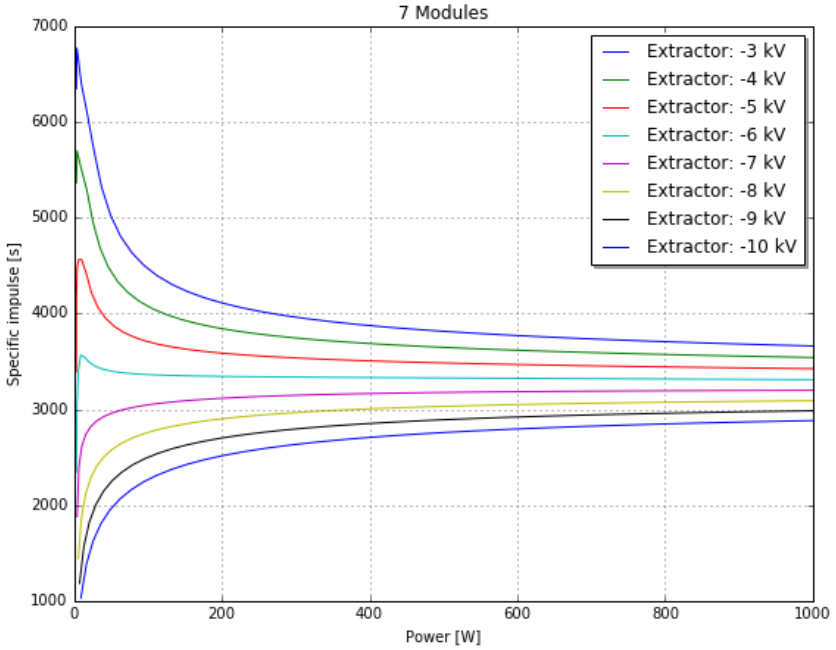




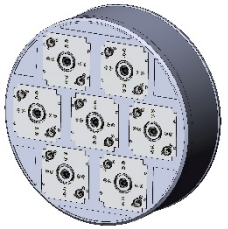
Thruster Performance (7 Module Configuration)

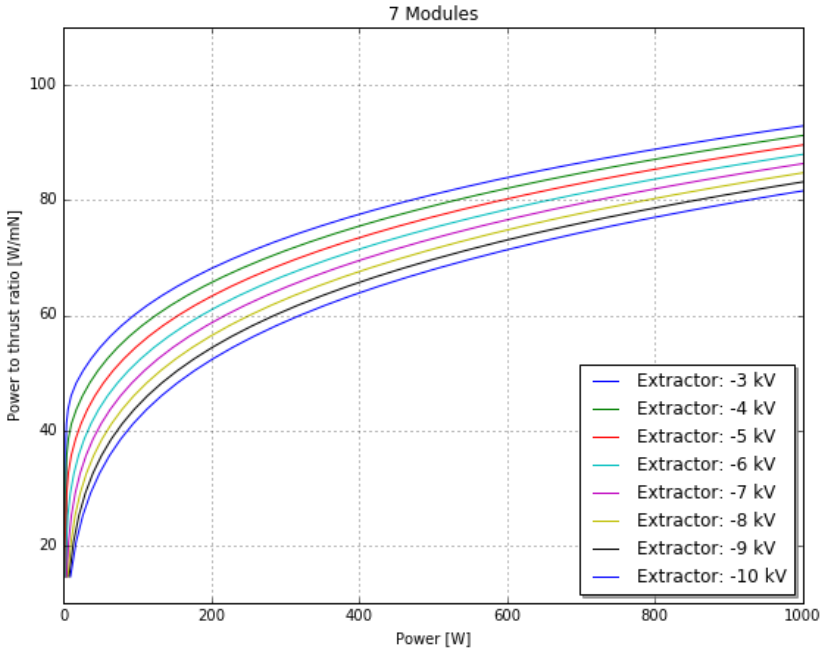


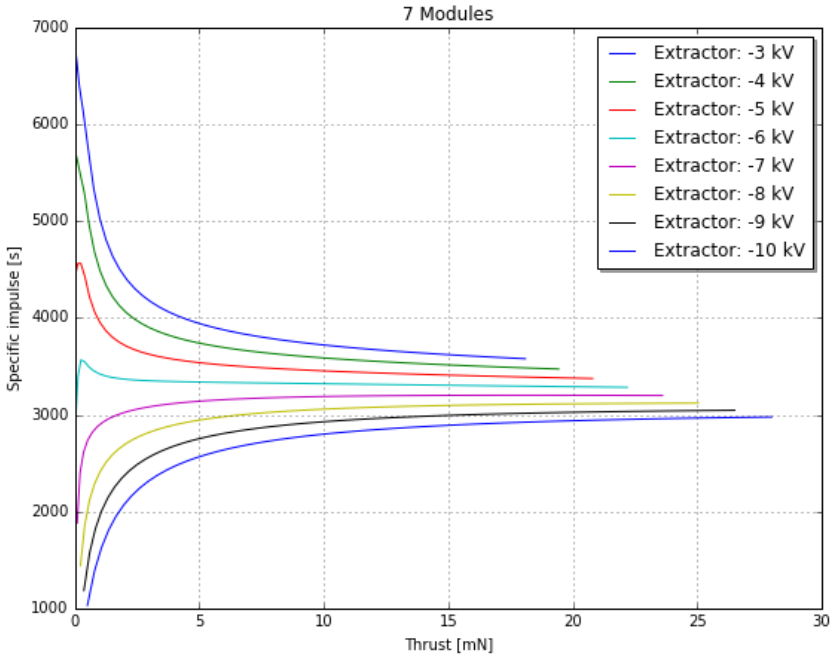




Thruster Performance (7 Module Configuration)





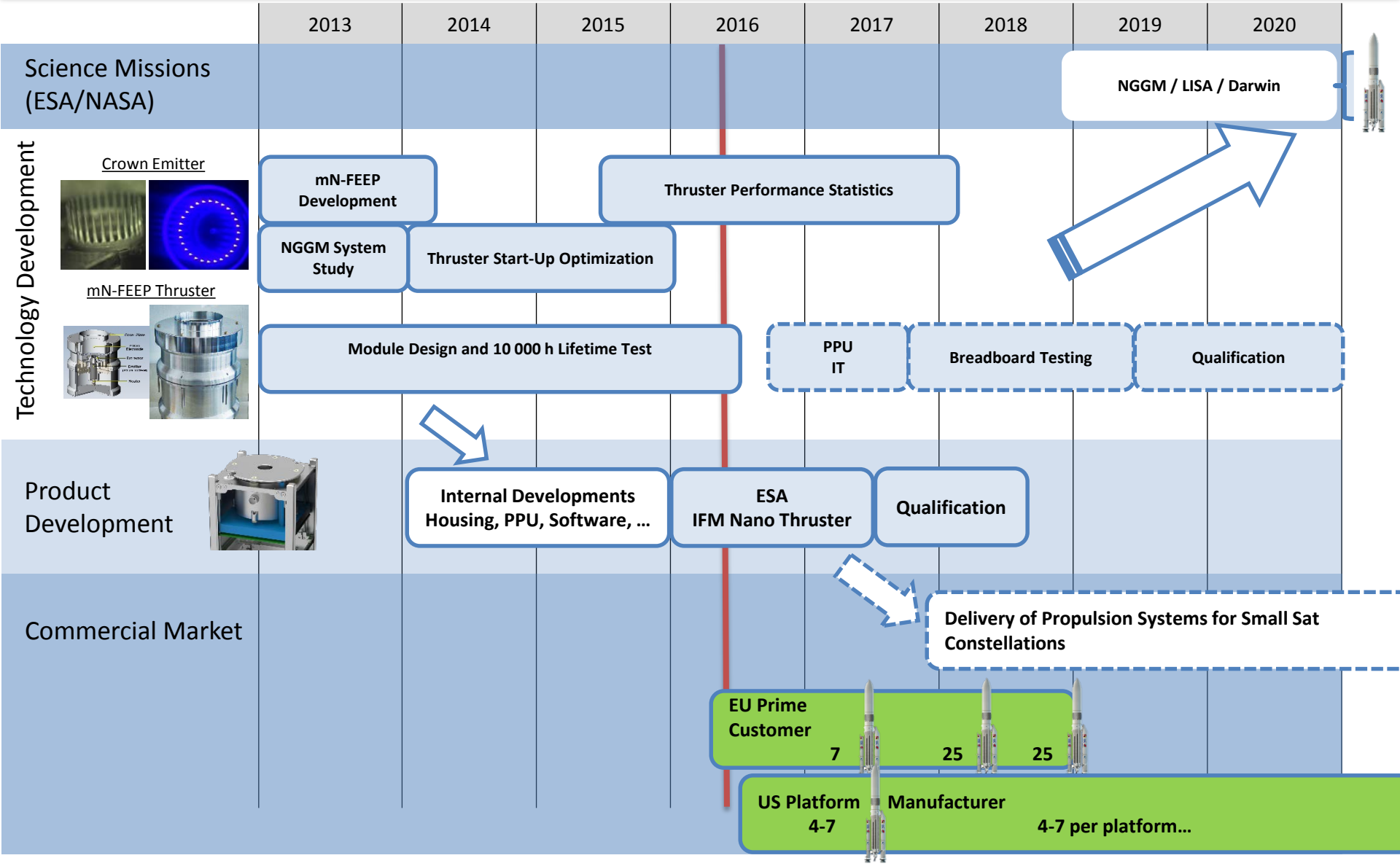


Nominal Performance

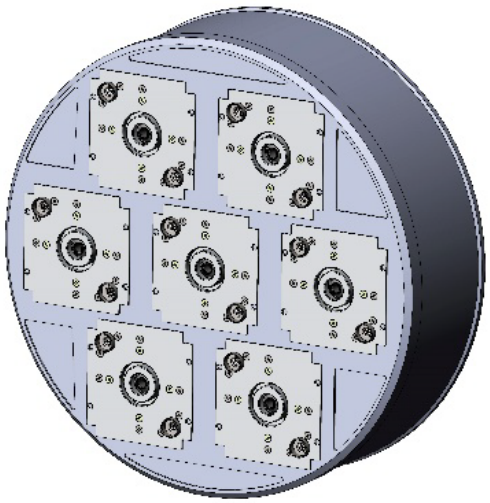
	Full Range	Individual Module		7 Modules	
		High Thrust Operation	High Isp Operation	High Thrust Operation	High Isp Operation
Thrust	1 µN – 1 mN	340 µN	220 µN	2.4 mN	1.5 mN
ISP	2000 - 4500 s	3000 s	4500 s	3000 s	4500 s
Tank Sizes	10 - 250 g	250 g		1750 g	
Total Impulse**	up to 10,000 Ns	3680 Ns	5520 Ns	25 760 Ns	38 640 Ns
Power Demand	2.5 - 80 W	32 W (28 W**)		224 W (196 W**)	
Outside Dimension	0.6 - 1 dm³	10 x 10 x 10 cm		∅30 x 10 cm	
Dry mass		700g			
System Efficiency		85%			
Demonstrated lifetime of the emitter		9600 h			

*** For pulsed mode with extended duty cycle

Development Status



IOD on the ICEYE Constellation



- 50kg / 200W spacecrafts
- Initial Orbit Maneuver from 600km to ~400km **high Thrust operation**
- 2 years of drag compensation **high Isp Operation**
- First FM delivered Q1 2017
- IOD planned in Q4 2017

Advantages	Disadvantages
• High Impulse Density (x10) • High Thrust / High Isp • No Pressurized Components or Chemicals – Inert Launch Conditions • Low Cost (COTS Components) • High Modularity - No SPF	• High P/T Ratio (x2) • COTS Components (PPU)