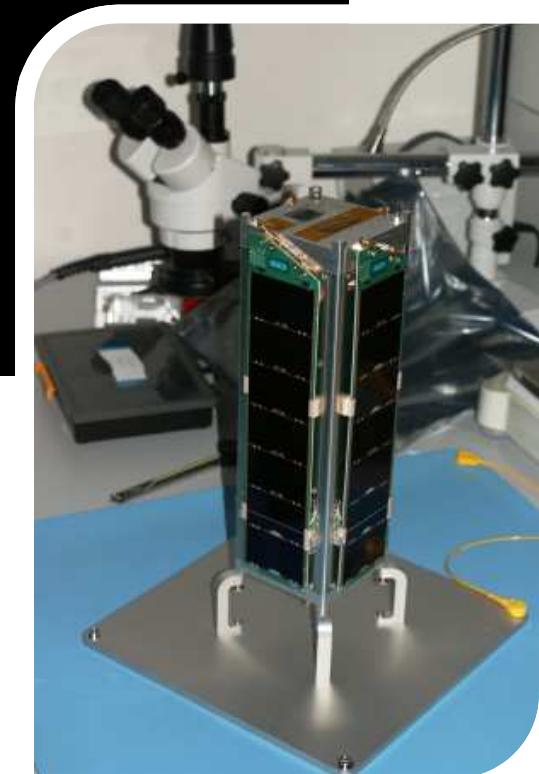


Delfi-n3Xt

Amateur Satellieten Interessedag, Paasloo
Jasper Bouwmeester



Content

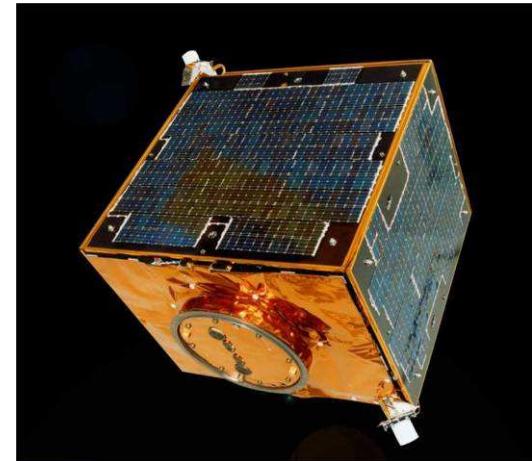
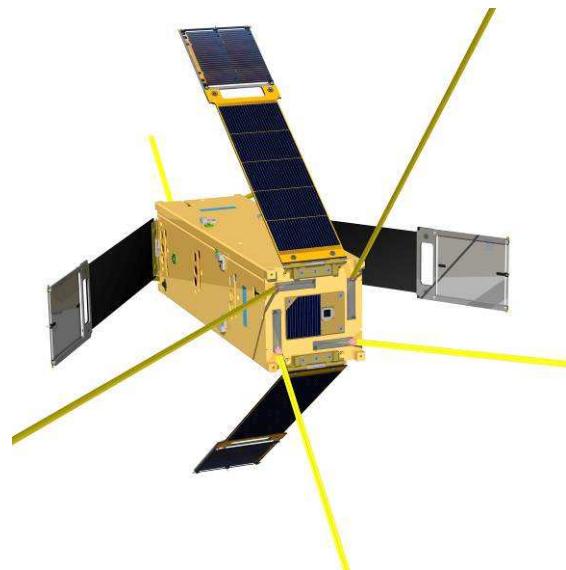
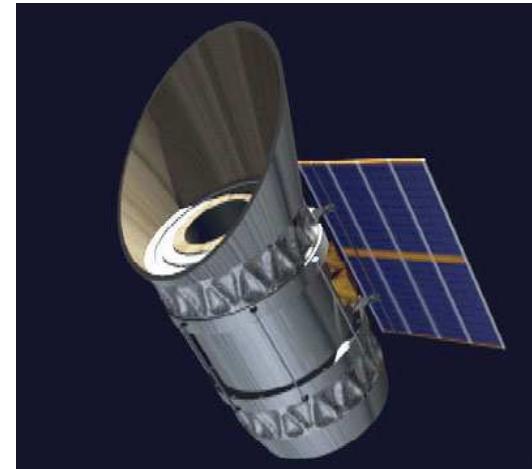
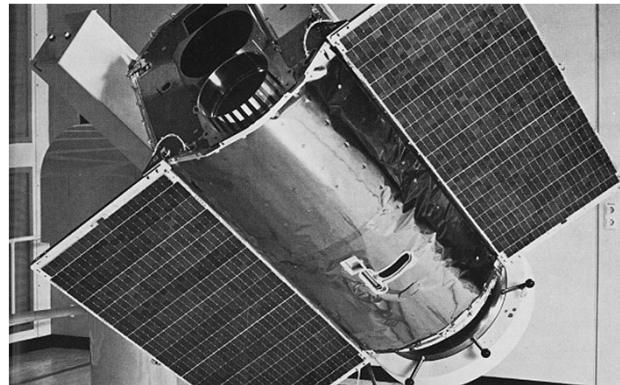
- Introduction to Delfi Space Program
- Where it all began: Delfi-C³
- Delfi-n3Xt Technology
- Delfi-n3Xt Operations
- Delfi-n3Xt for Radio Amateurs
- Future Outlook

Delfi Program Objectives

- Education
- Technology Demonstration
- Advancement of CubeSat Platform
- Scientific Research

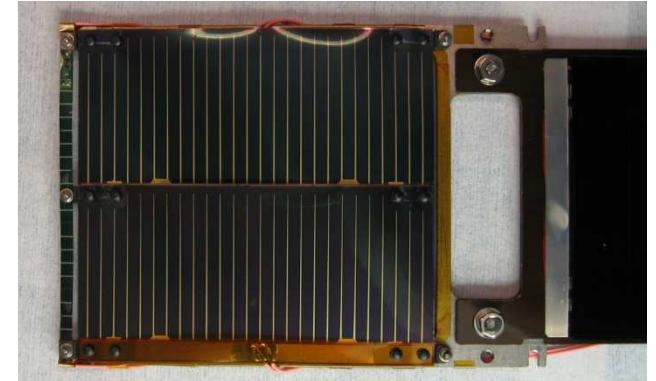
Dutch Satellites

- ANS ('74)
- IRAS ('83)
- SloshSat ('05)
- Delfi-C³ ('08)
- Delfi-n3Xt ('13)
- Triton-1 ('13)
- FunCube ('13)
- Triton-2 ('14)
- 2x DelFFi ('15)

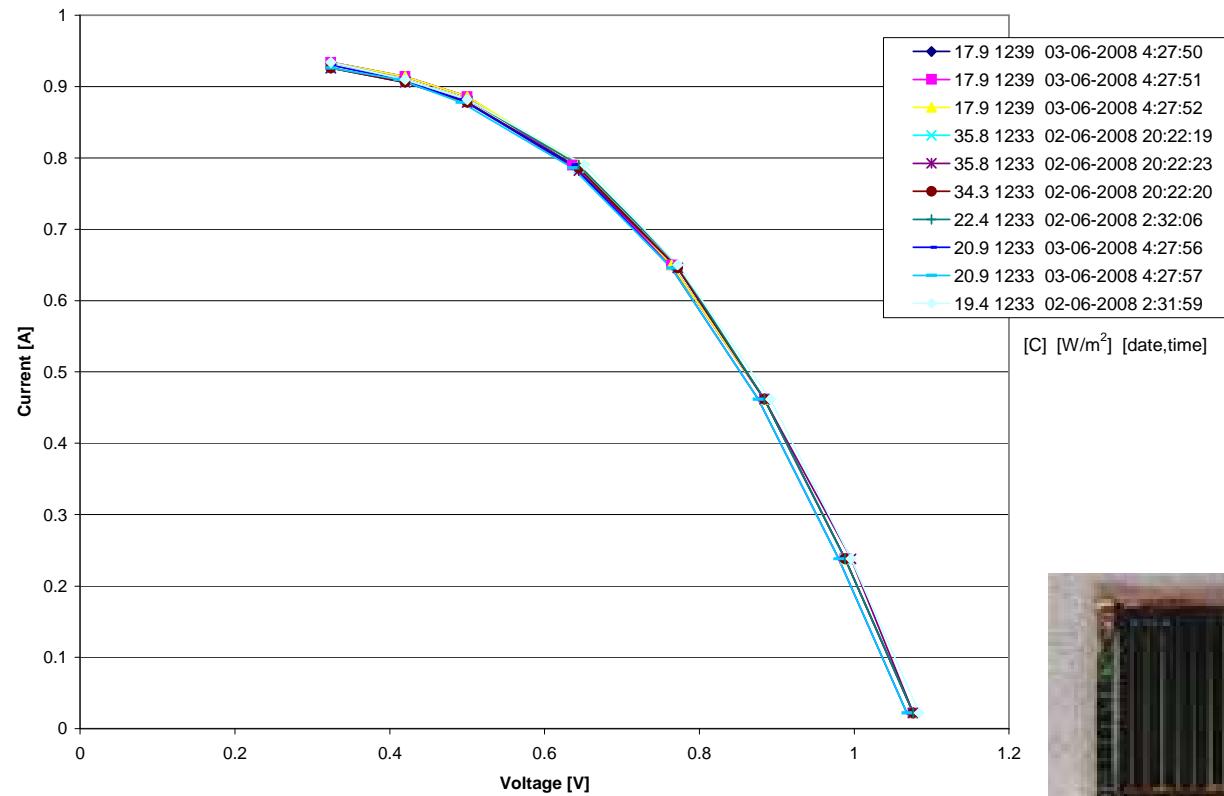


Thin Film Solar Cells

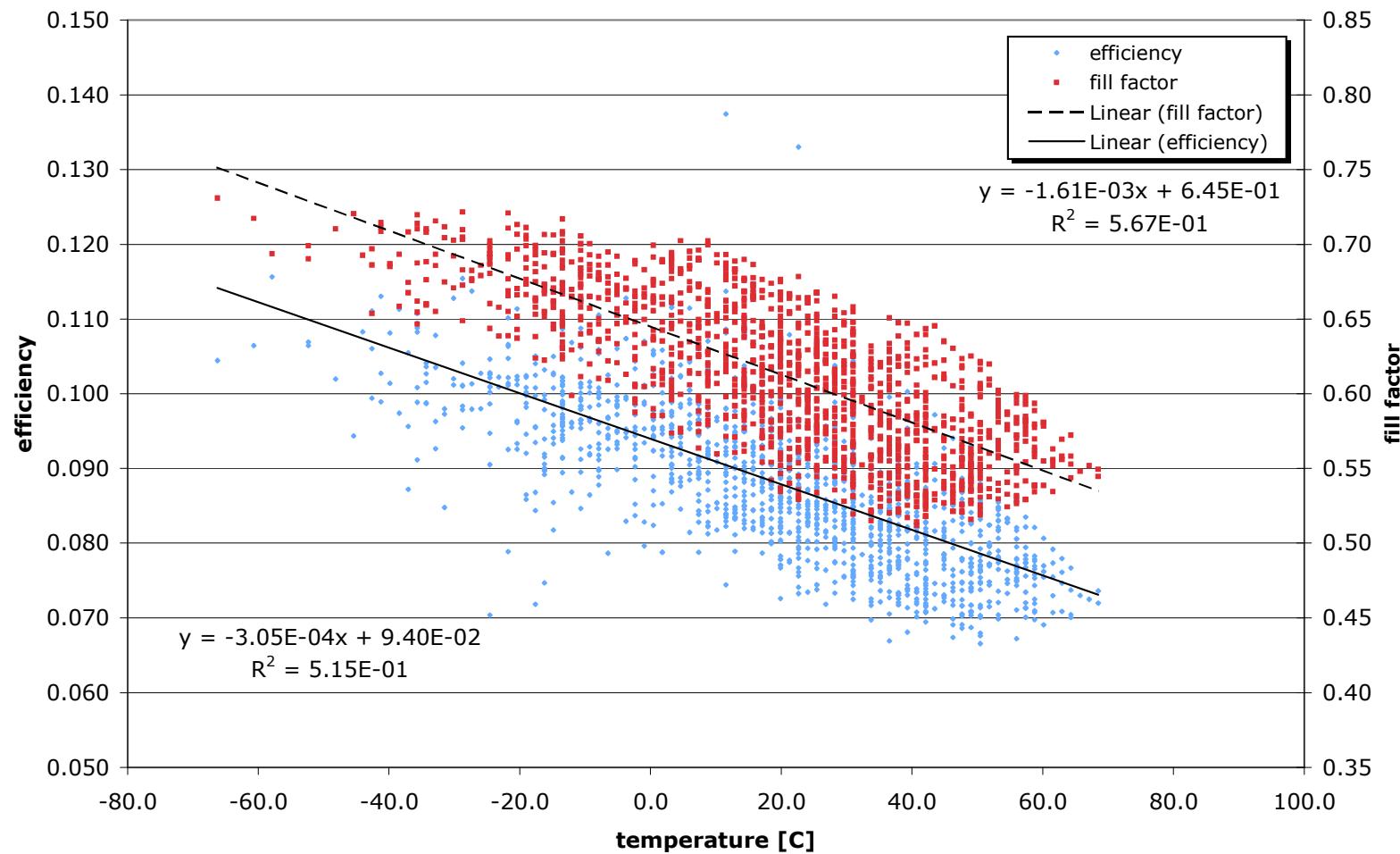
- Cells development by Dutch Space
- 50% cost reduction
- 50% increased power to mass performance



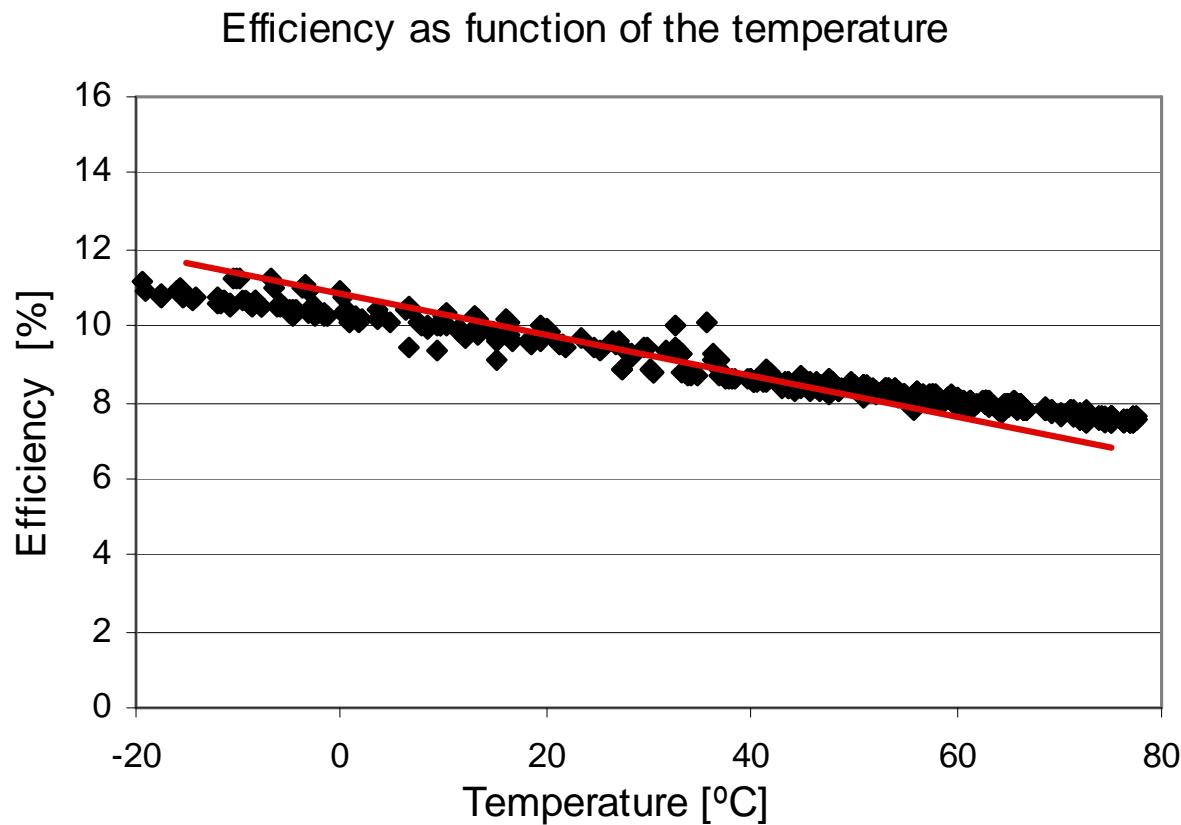
Thin Film Solar Cells (1)



Thin Film Solar Cells (2)

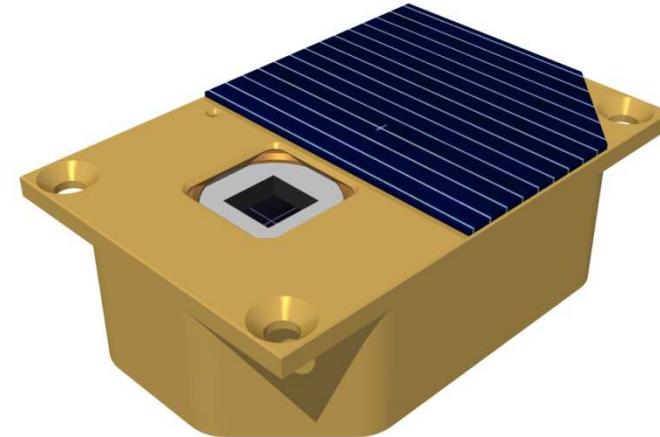


Thin Film Solar Cells (3)



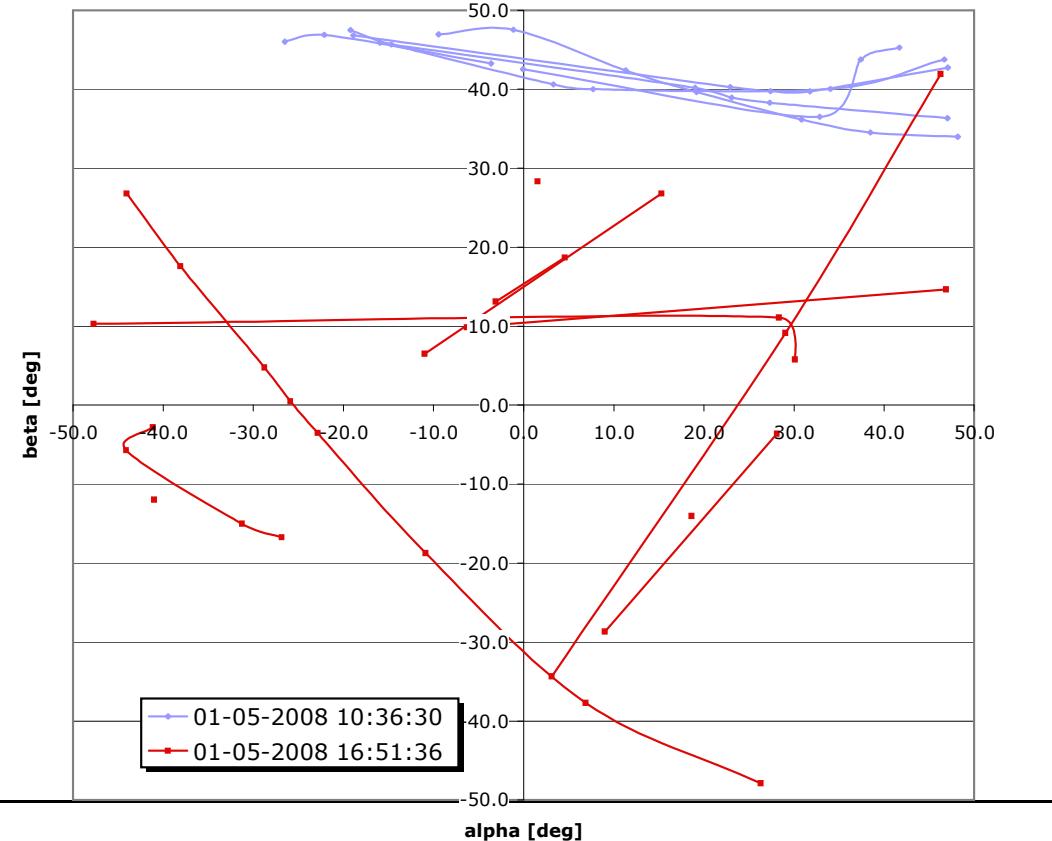
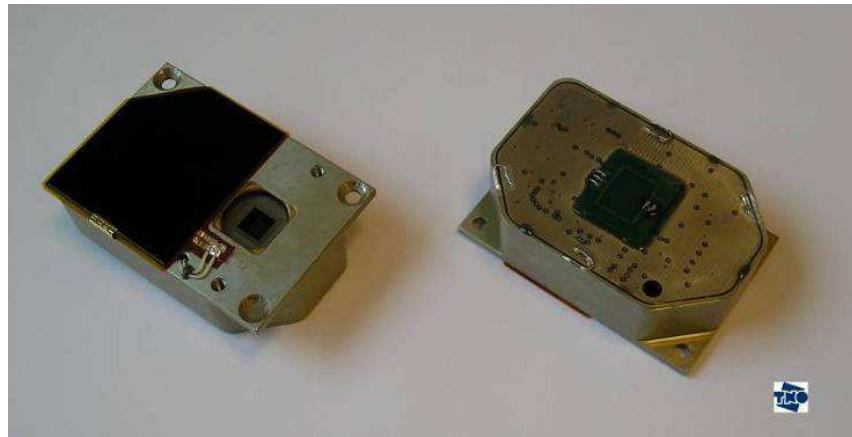
Autonomous Wireless Sun Sensor (1)

- Development by TNO
- Features:
 - Independent power supply (GaAs cells)
 - Wireless radio frequency link
 - 60x40x20mm
- Creating flexible “plug and play” system



Autonomous Wireless Sun Sensor (2)

- AWSS Z+ functions properly
- No data received from AWSS Z-



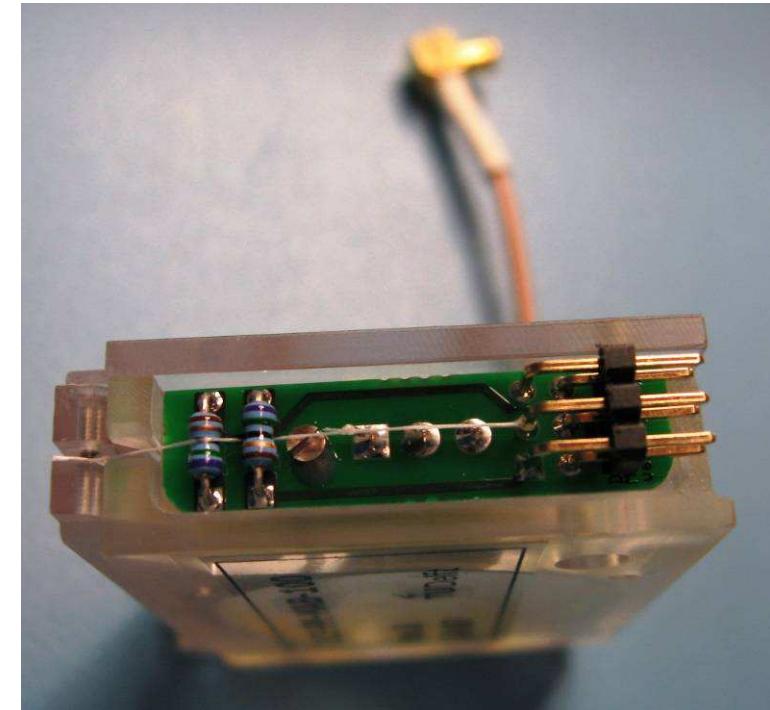
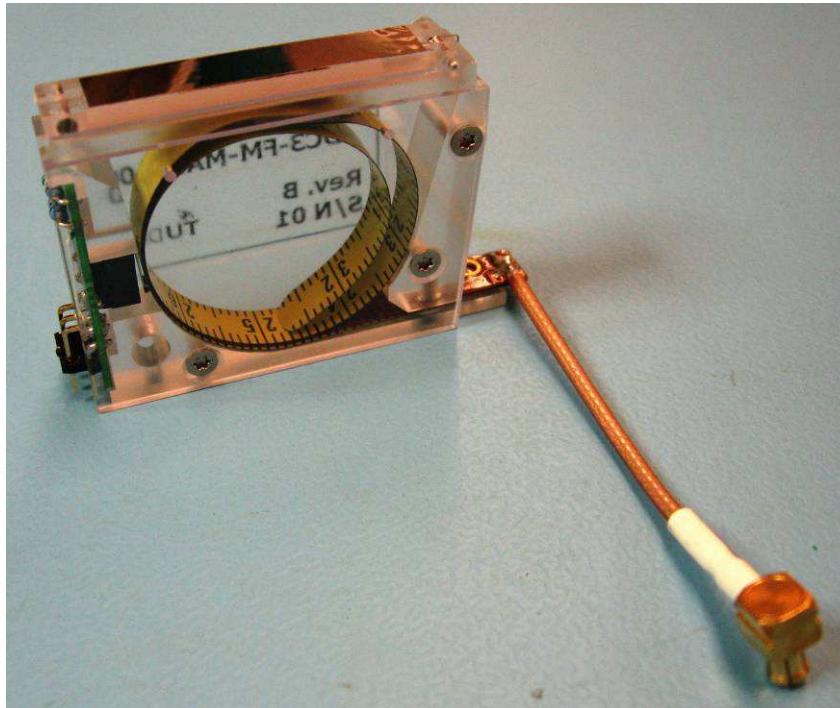
AWSS (3)

Attempts to receive the AWSS's at Westerbork

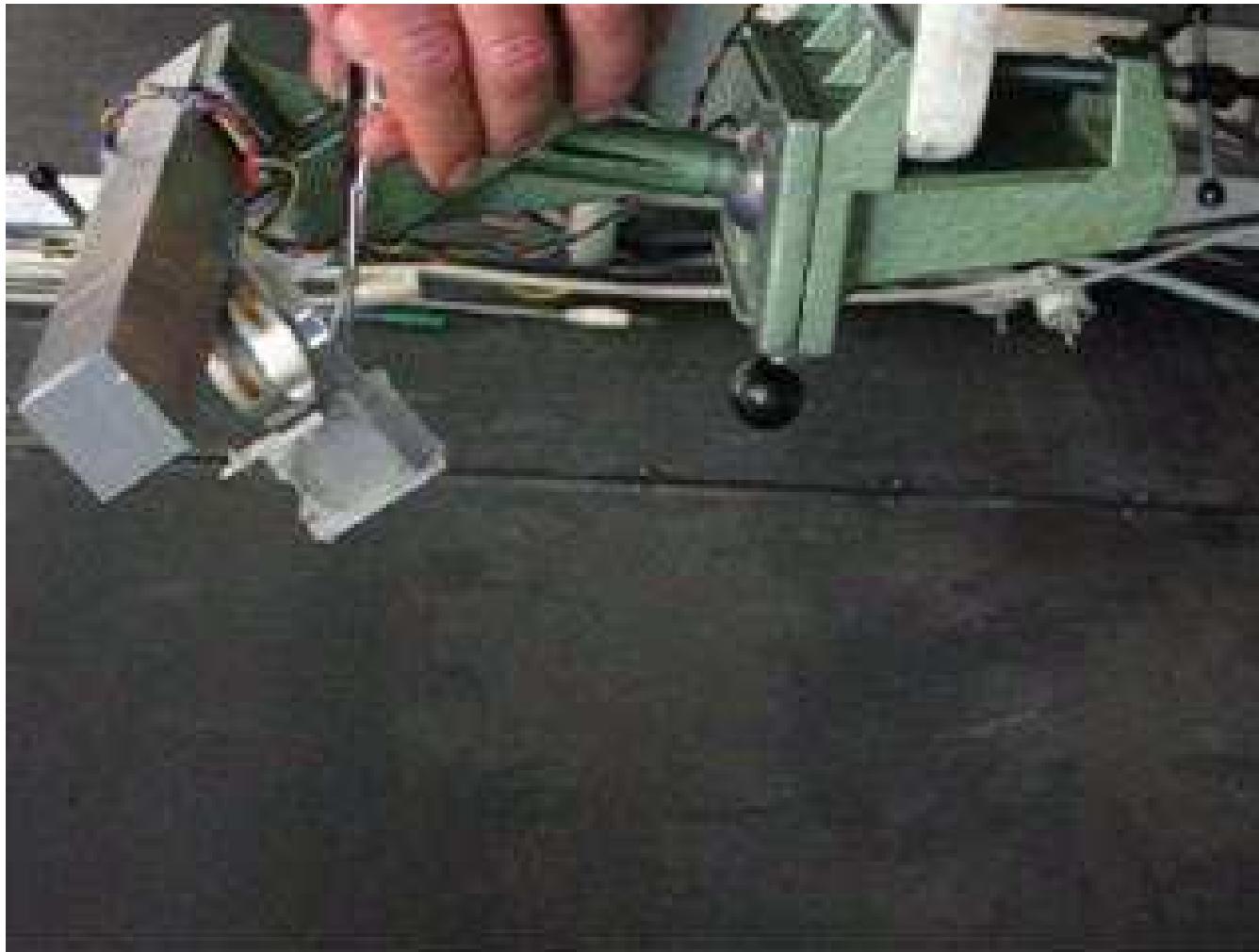
In cooperation with ASTRON



Design Example: Modular Antenna Boxes (1)



Design Example: Modular Antenna Boxes (2)



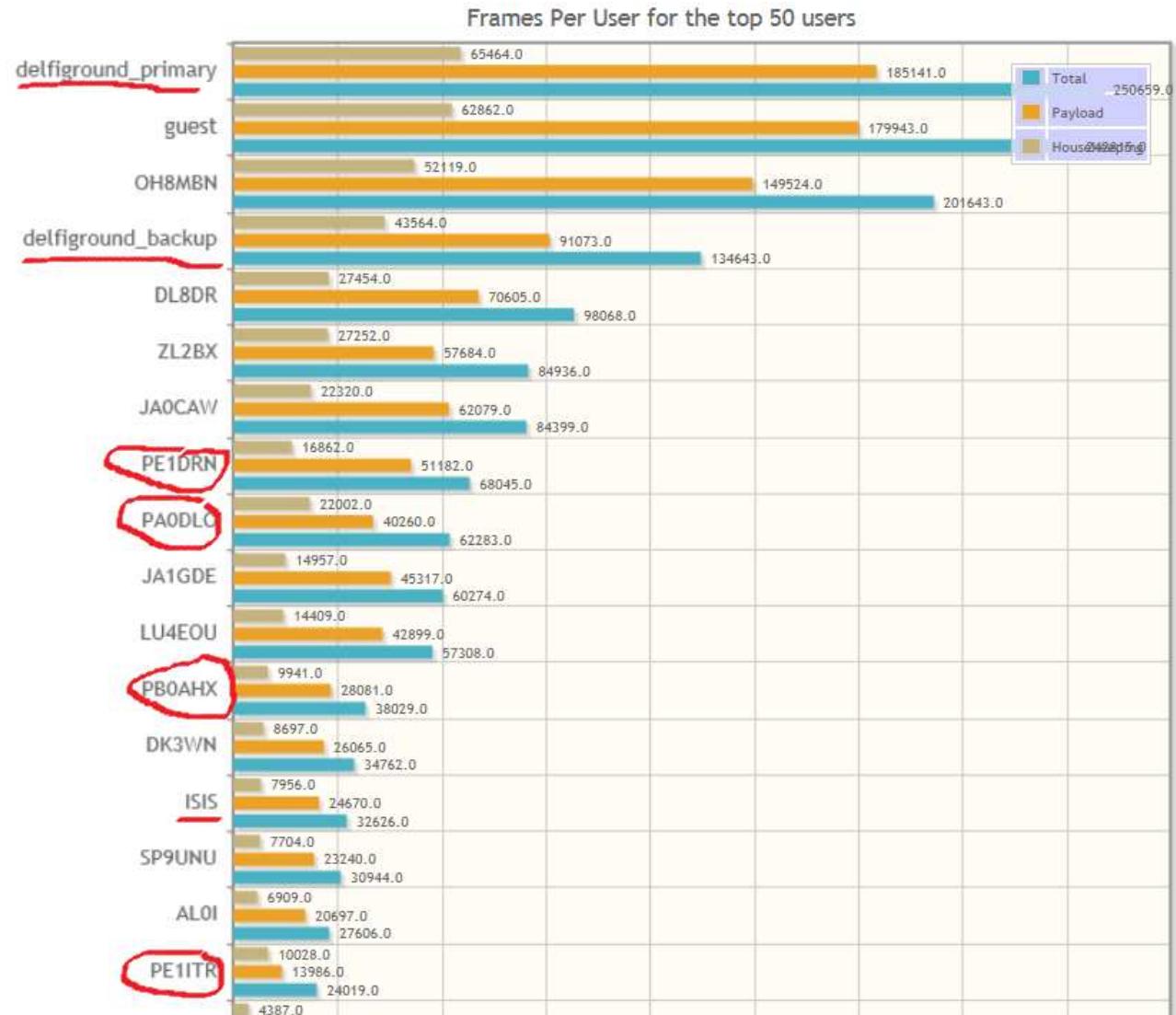
First Ground Reception



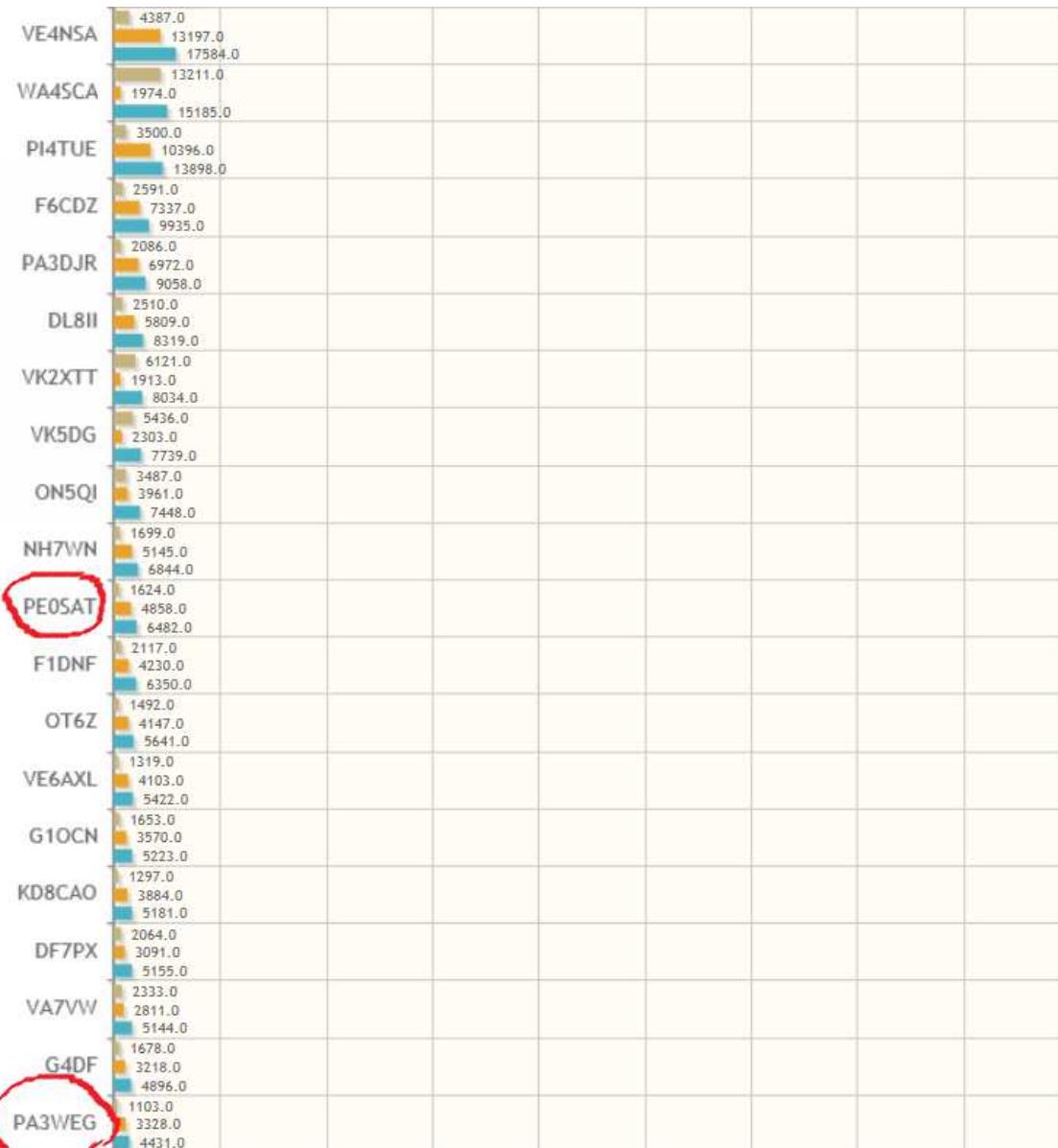
Delfi-C³ Results

- Full mission success
- 5.5 years operational
- ~70 students involved
- >300 radio amateurs worldwide involved
- Many papers published on design and mission results
- Cornerstone for Delfi Space program

Top 50 Radio Amateurs (1 / 2)



Top 50 Radio Amateurs (2/2)





Delfi-n3Xt Mission

Education

> 60 students on mission

Technology demonstration

Project partners from Dutch space sector

Innovation

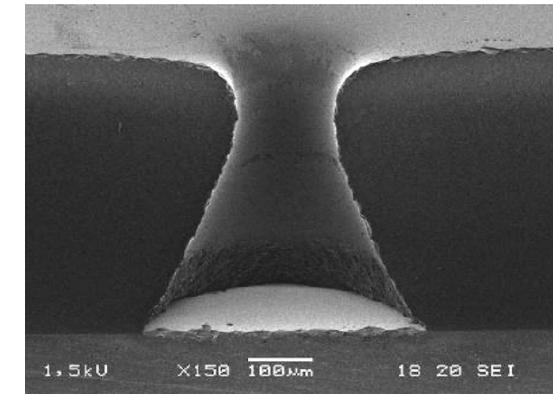
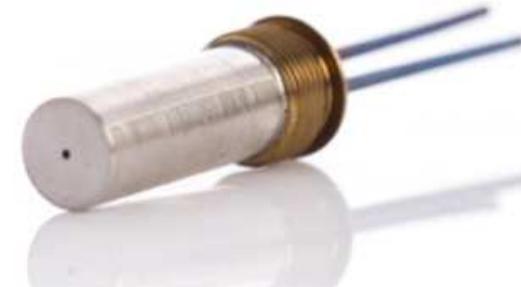
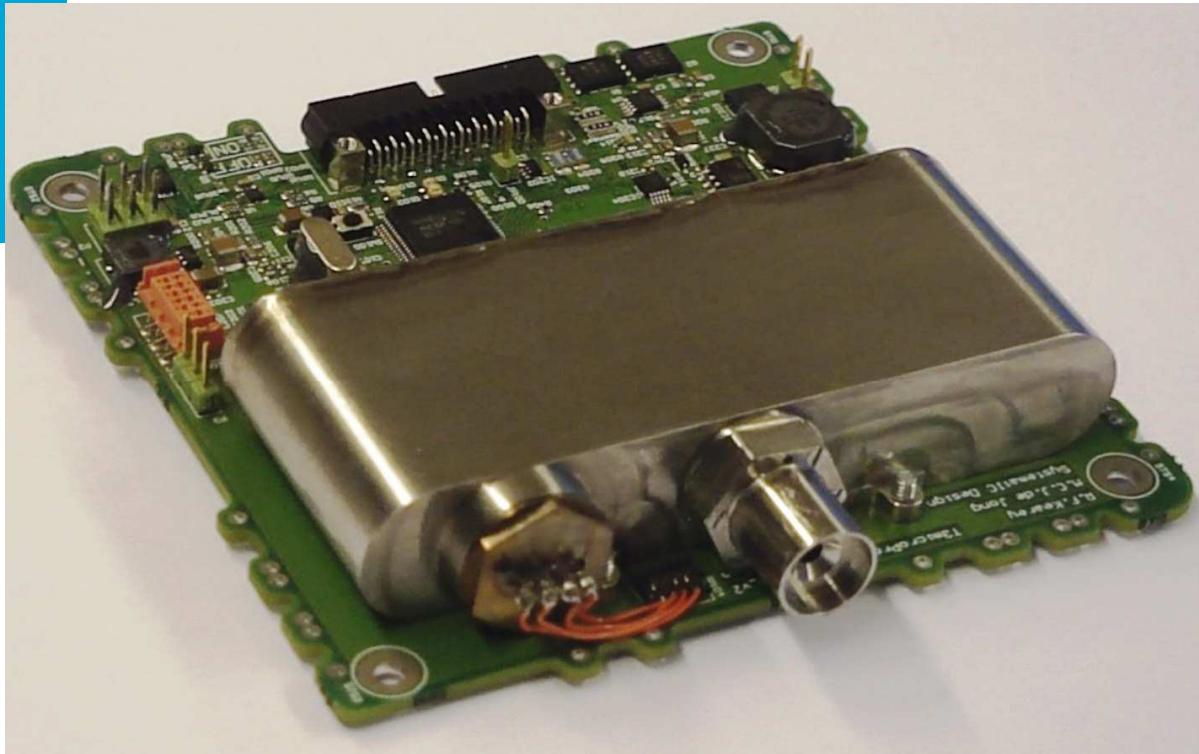
Improvement of CubeSat bus platform

Research

>20 scientific papers

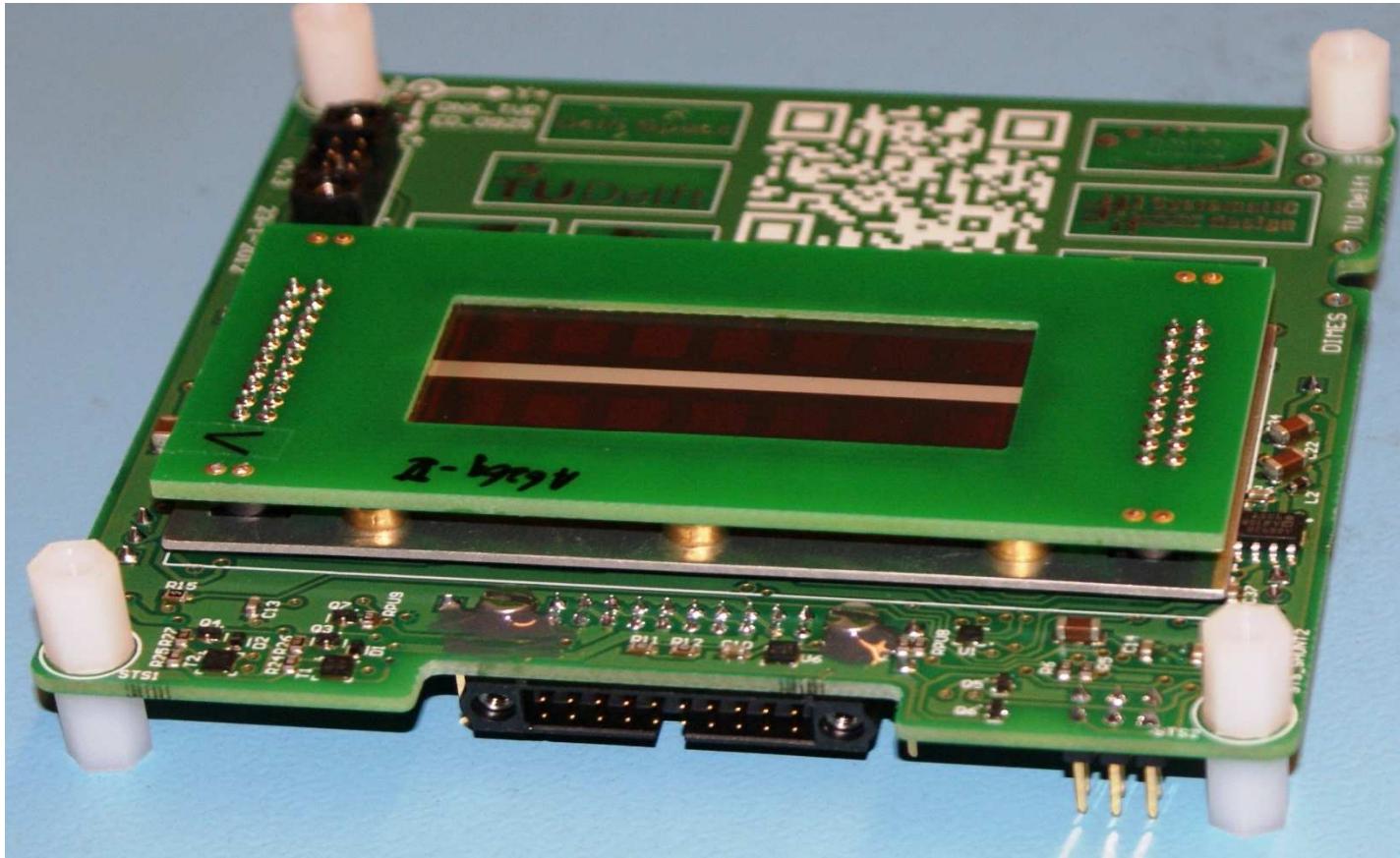


T³ μ PS Micropropulsion Payload



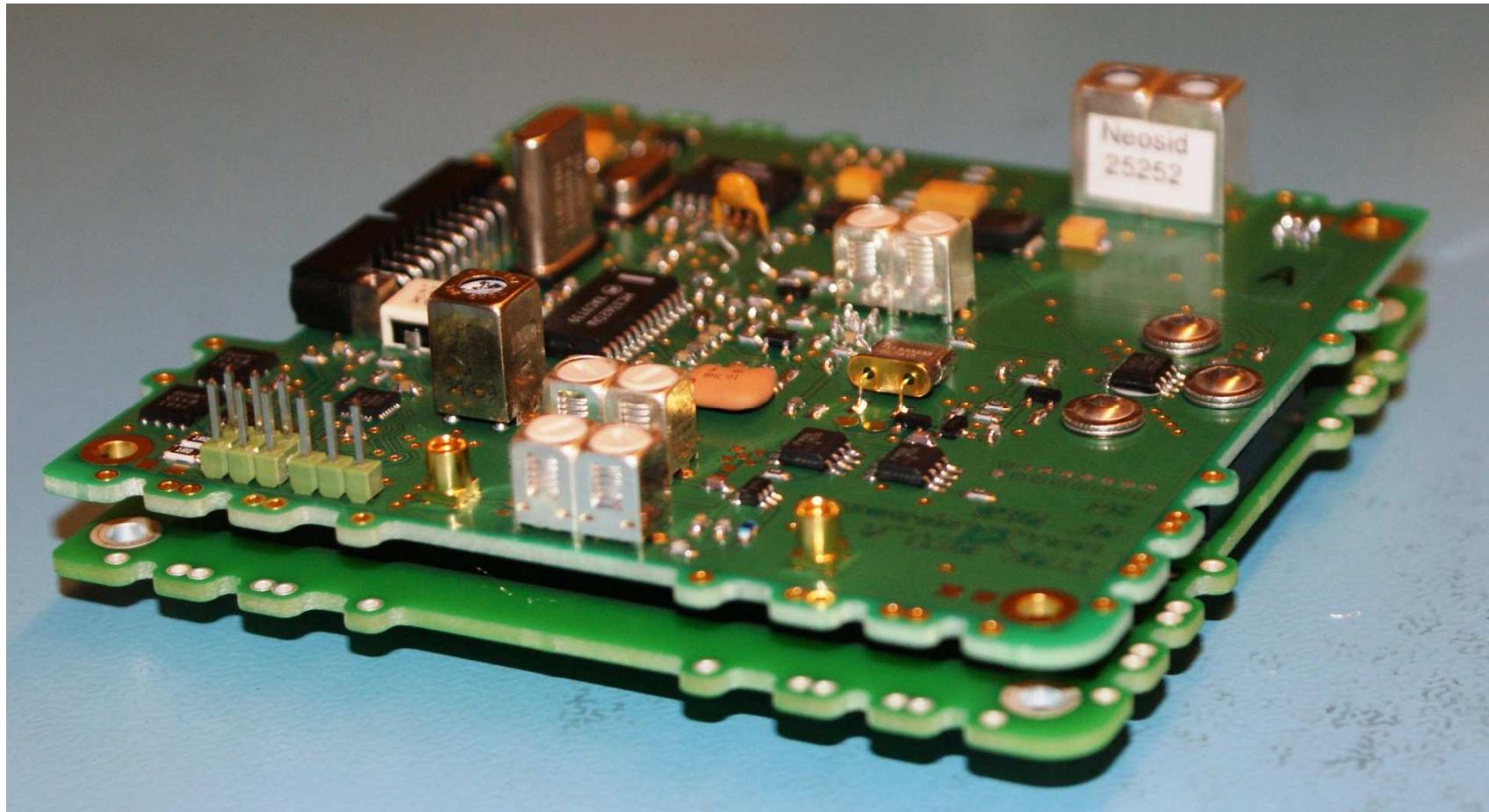
Cold Gas Generator technology: safe upon launch
Variable thrust (0 – 6 mN)
Possible application: formation flying with CubeSats

Silicon Solar Cell Experiment



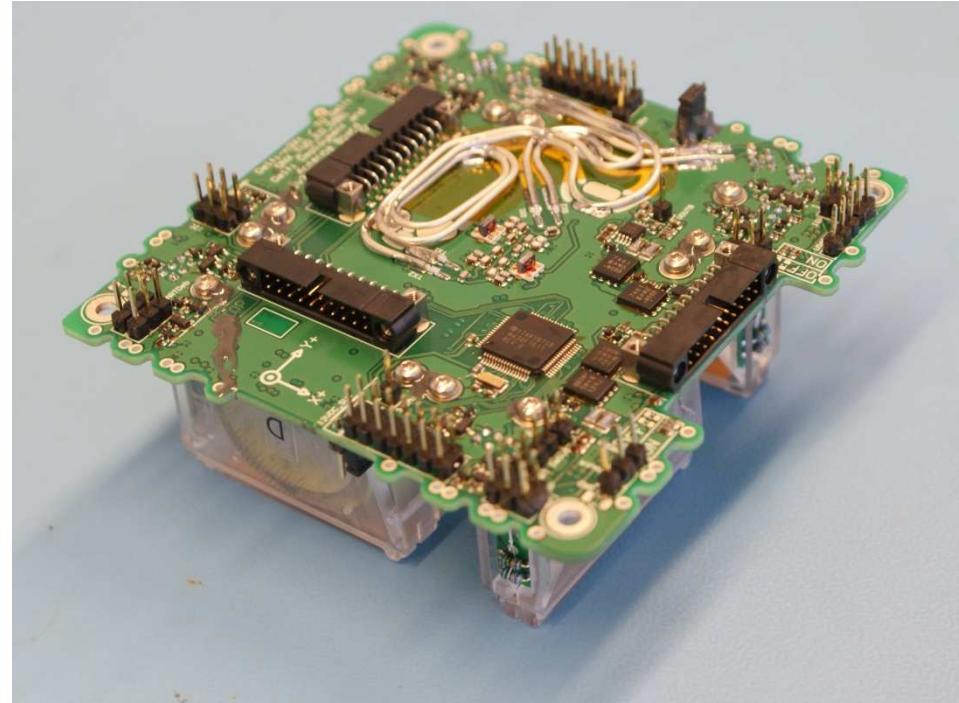
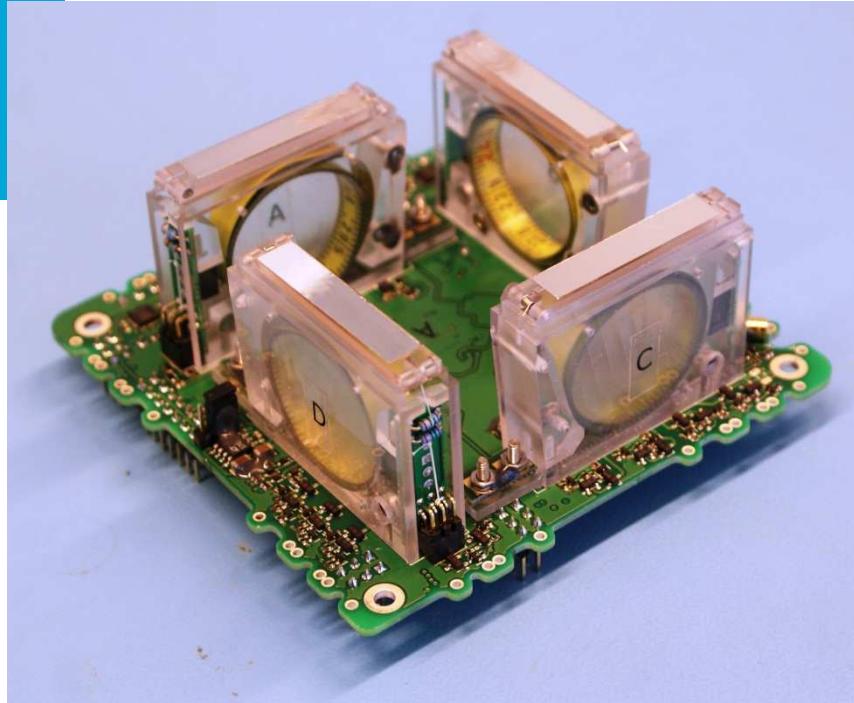
14 amorphous silicon solar cells (a-Si:H)
low cost, low expected degradation
Temperature & current-voltage characteristics measured

ITRX Transceiver Payload



1200 – 9600 bit/s downlink on VHF, 1200 bit/s uplink on UHF
Plug-in linear transponder module
Commercially available radio solution for CubeSats

Deployment & Antenna Board

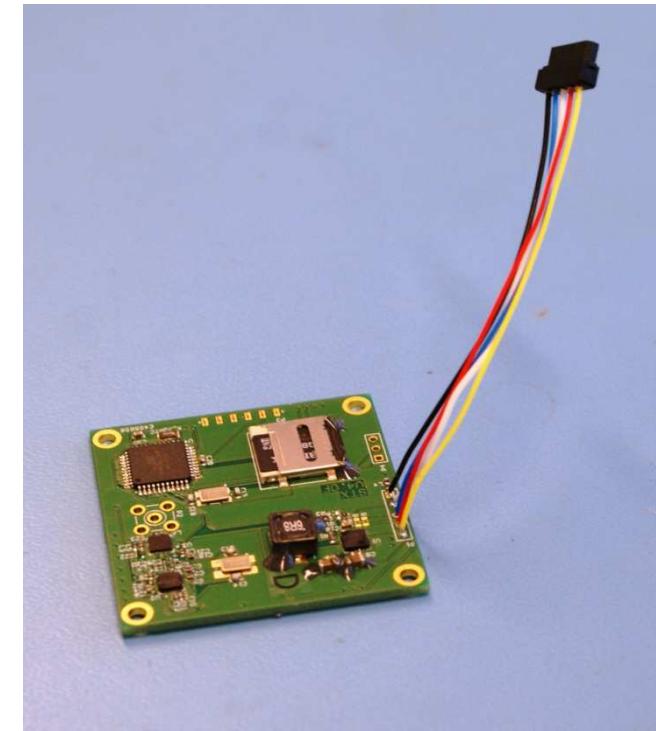
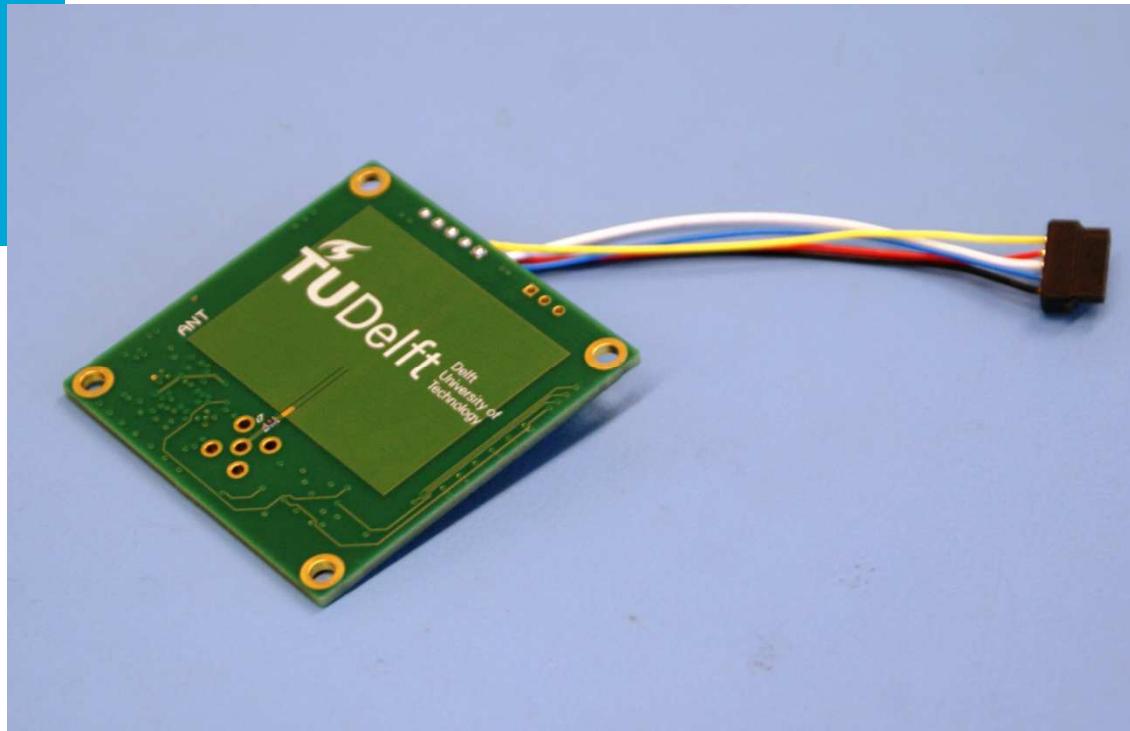


4 deployable antennae
UHF/VHF phasing & isolation circuit
Deployment electronics for antennae and solar panels

Deployment

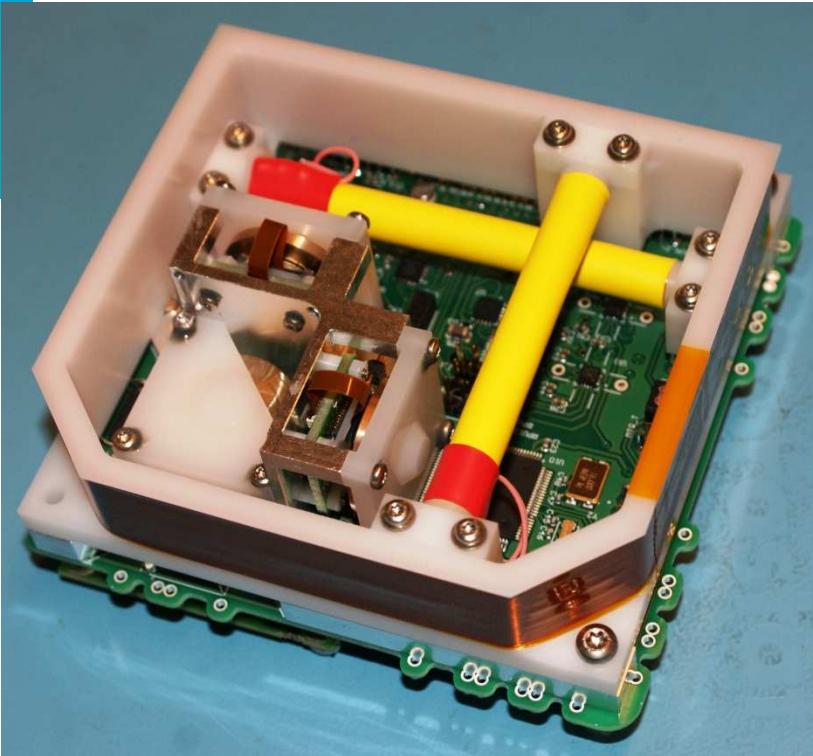


Experimental S-band Transmitter



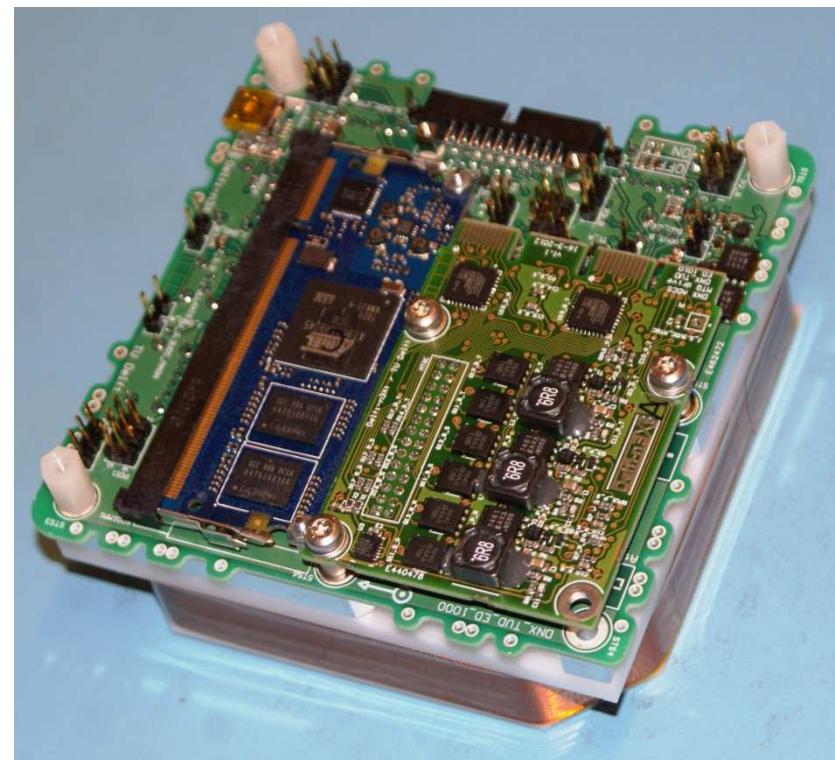
Patch antenna & electronics integrated
2.4 to 500 kbit/s
16 GB of local data storage

Attitude Determination & Control Subsystem

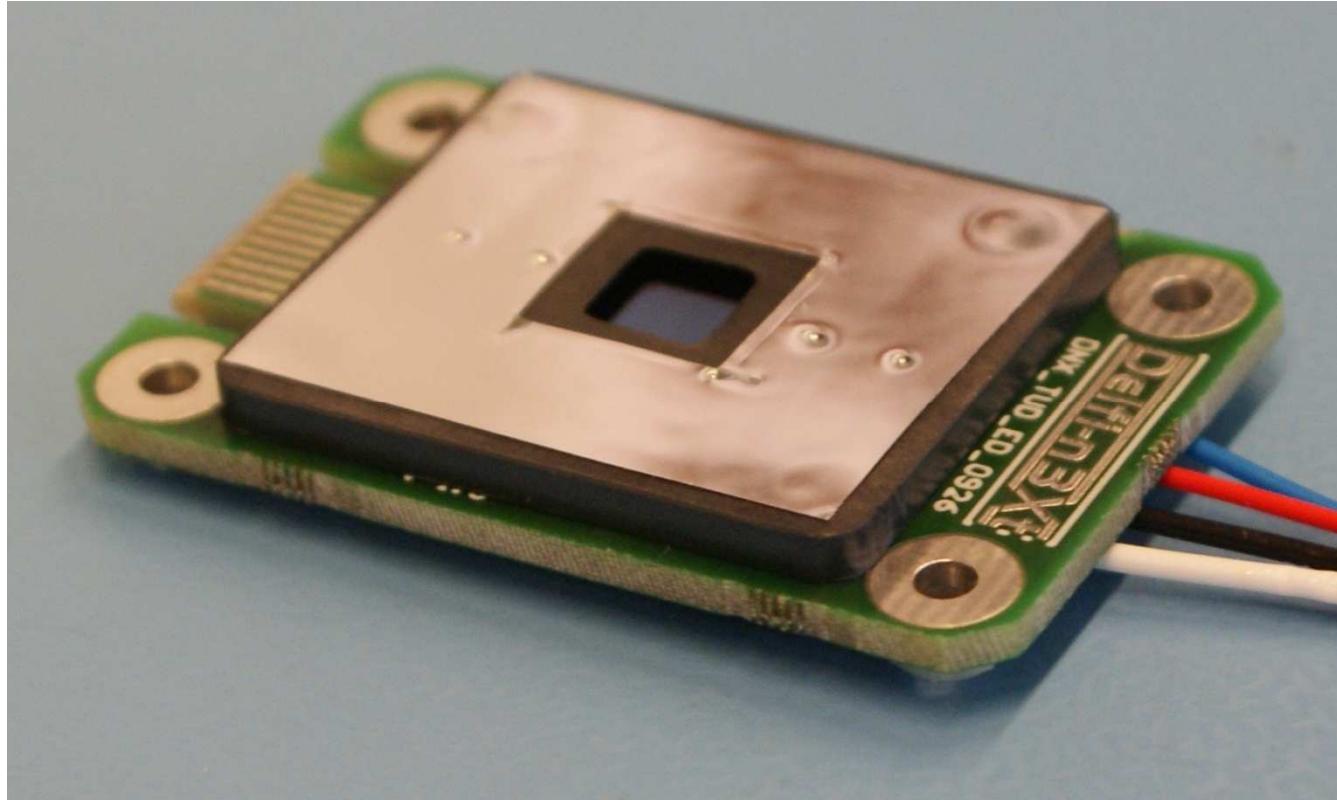


400 MHz ARM9 processor
simple magnetic detumbling
advanced triple-axis control

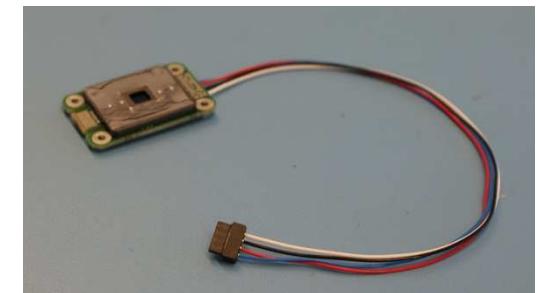
3 reaction wheels
3 magnetorquers
3 magnetometers
6 sun sensors



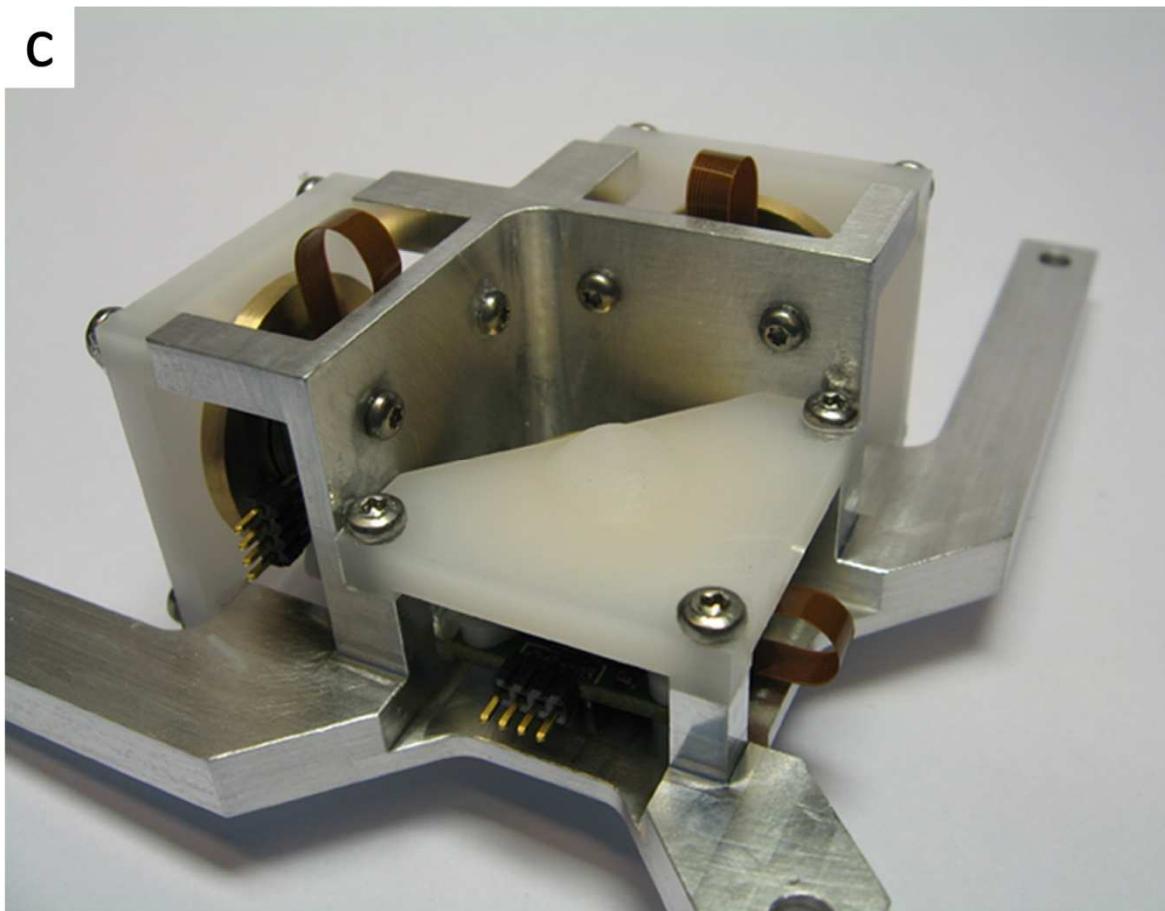
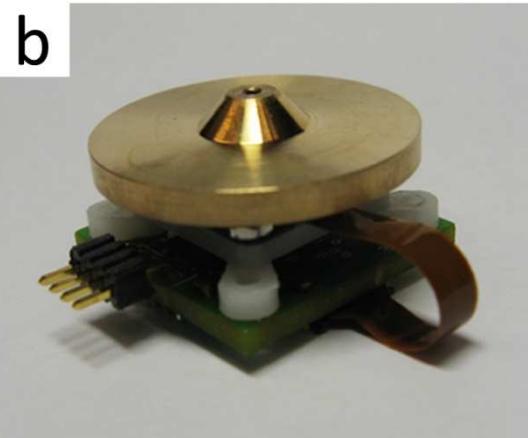
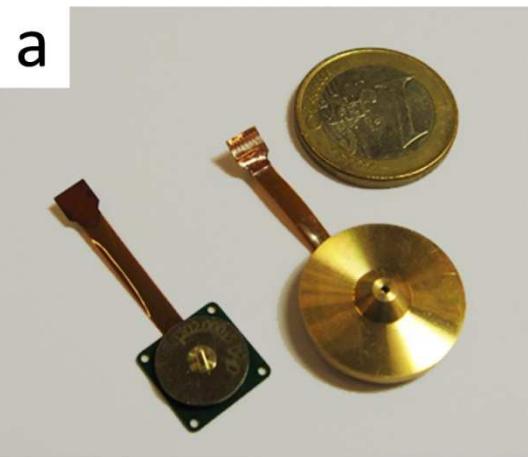
ADCS Sun Sensors



Quadrant photodiode architecture
0.4° noise (1σ), < 3° bias
10 g, 0.03 W, I²C & 3.3V interface



ADCS Reaction Wheels



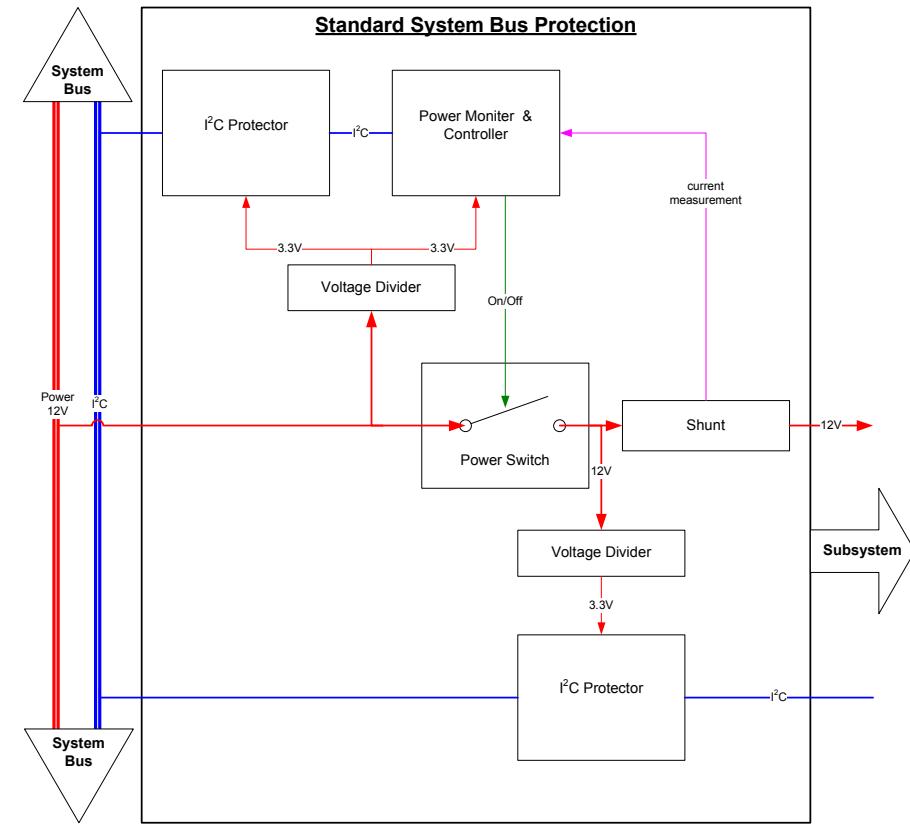
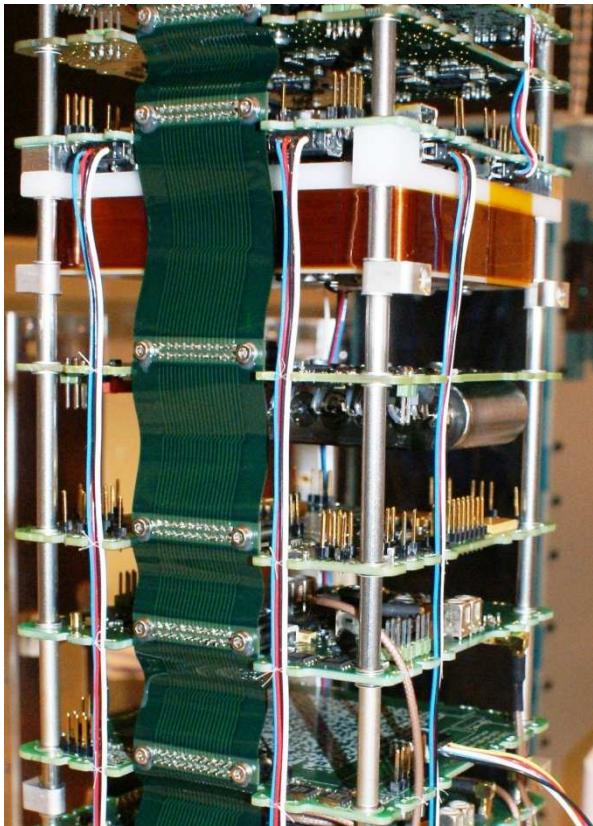
Optimized for volume

Torque $5.6 \mu\text{N}\cdot\text{m}$, dynamic range $1.5 \text{ mN}\cdot\text{m}\cdot\text{s}$

Reaction Wheel Spinning

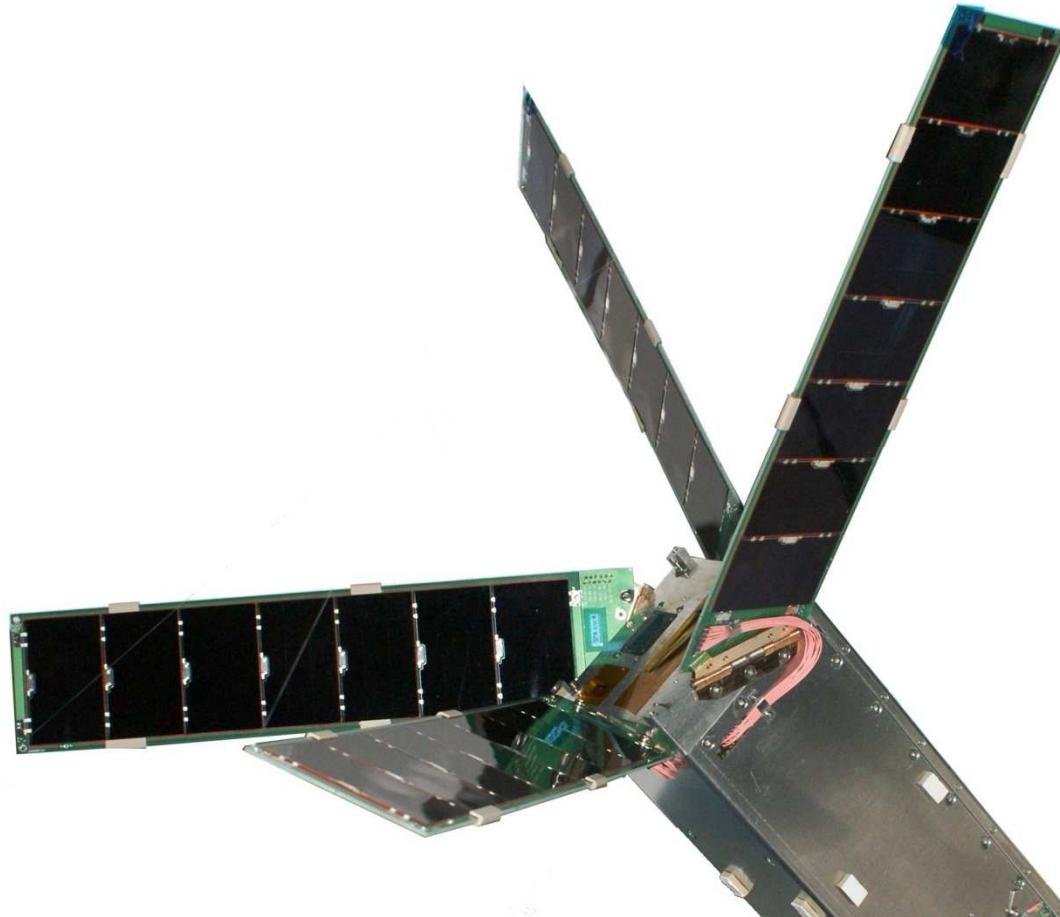


Delfi Standard System Bus



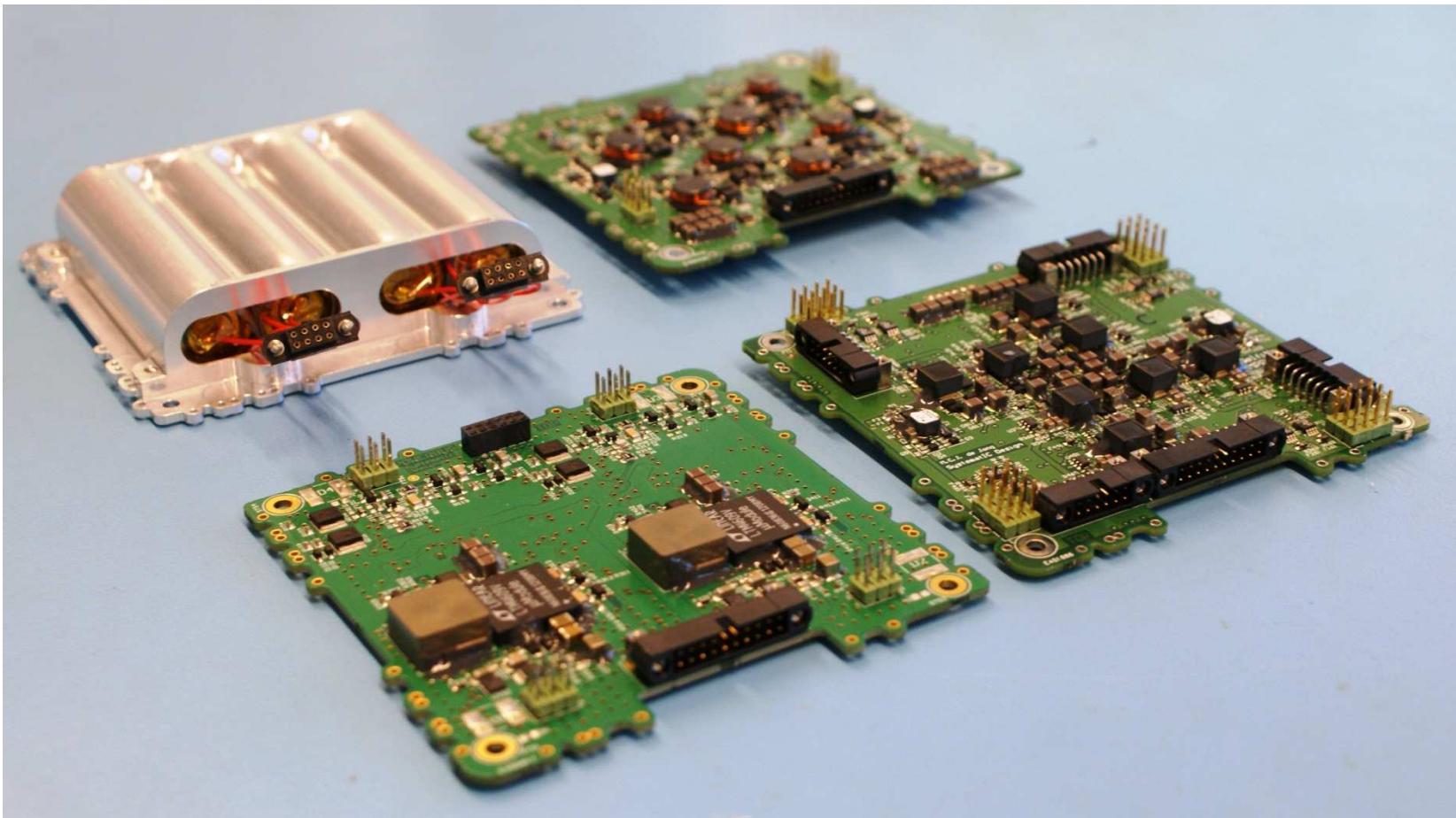
Flex rigid wiring harness
Failure protection for main data and power interface

Solar Panels



Double sided GaAs solar panels
Omnidirectional configuration

Electrical Power Subsystem



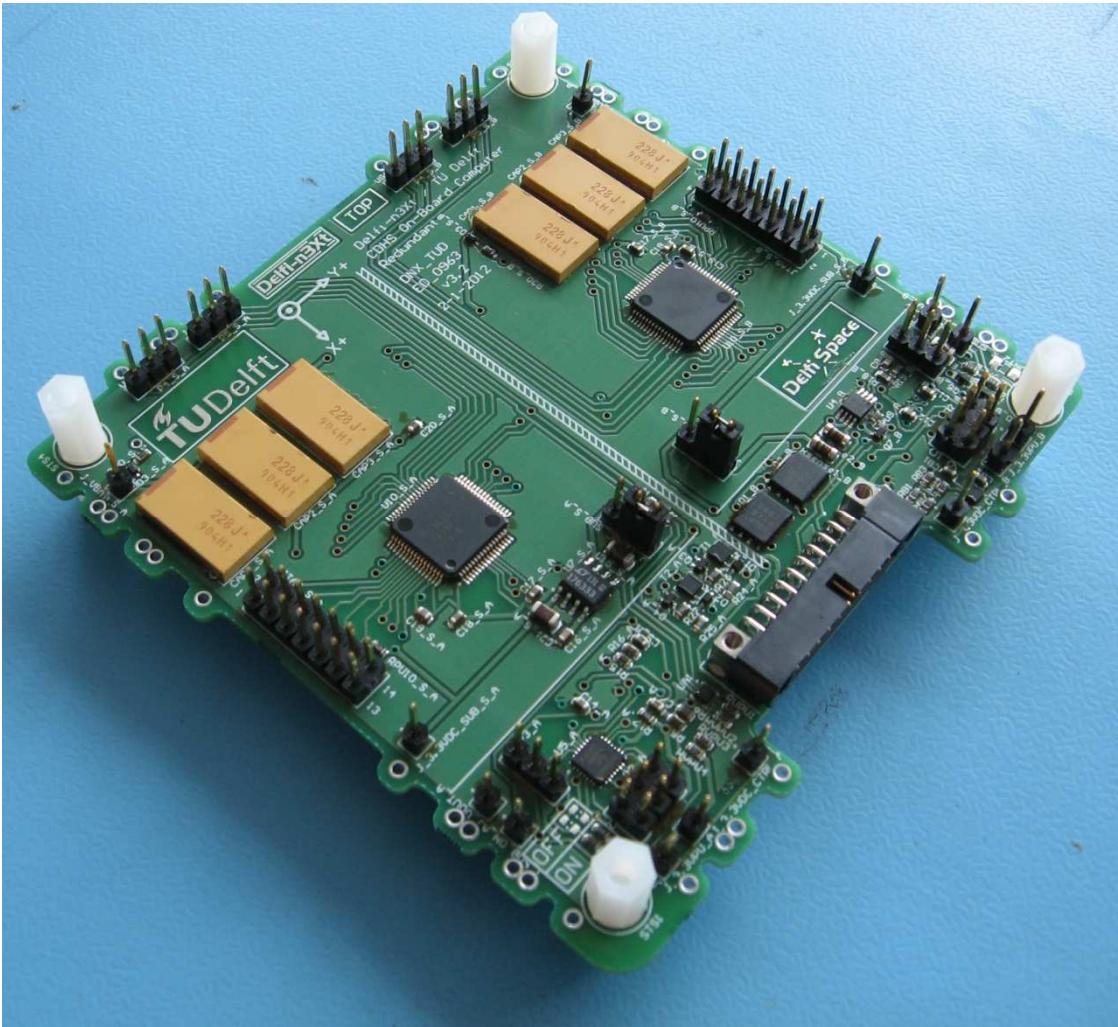
Maximum power point trackers
4 Li-ion batteries with 24 Wh energy storage
Agile global power management

Electrical Power Budget

Available power allocation	Min.	Geom. Average	Z-axis to Sun	Max.
Total Solar Array Power (Sun)	7.5 W	11.1 W	12.7 W	14.0 W
Total Output on Dist. Bus (Sun)	6.3 W	8.6 W	9.9 W	10.7 W
All. Regulated Power in Sunlight	3.6 W	5.1 W	5.9 W	6.3 W
All. Regulated Power in Eclipse	1.0 W	2.0 W	2.4 W	2.9 W

Electrical Subsystem	Sun Mode	Sun Power	Eclipse Mode	Eclipse Power
Micropulsion Payload	measure	45 mW	measure	45 mW
Solar Cell Experiment	on	84 mW	on	84 mW
Attitude Determination & Control	3-axis	1665 mW	idle	130 mW
Primary Radio Transceiver	receive	249 mW	receive	249 mW
ISIS Radio Transceiver	transceive	1554 mW	receive	256 mW
S-band Transmitter	store data	122 mW	store data	122 mW
OnBoard Computer	on	234 mW	on	234 mW
Electrical Power (excl. conv. loss)	MPPT	1048 mW	eclipse	812 mW
Deployment & Temperature Sensors	on	83 mW	on	83 mW
Total power consumption on 12 V bus	sun	5084 mW	eclipse	2016 mW

Command & Data Handling

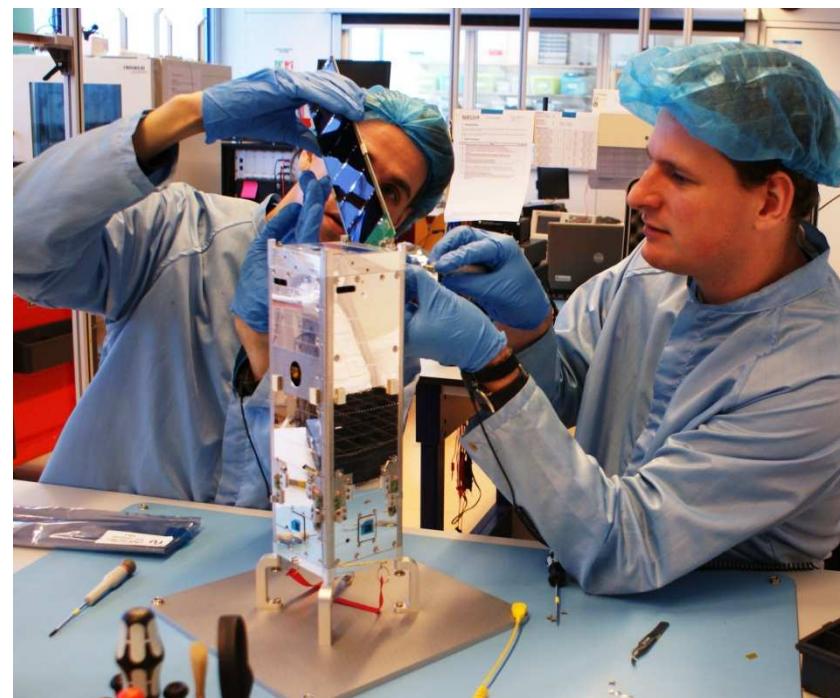


Redundant onboard
computer (MSP430)

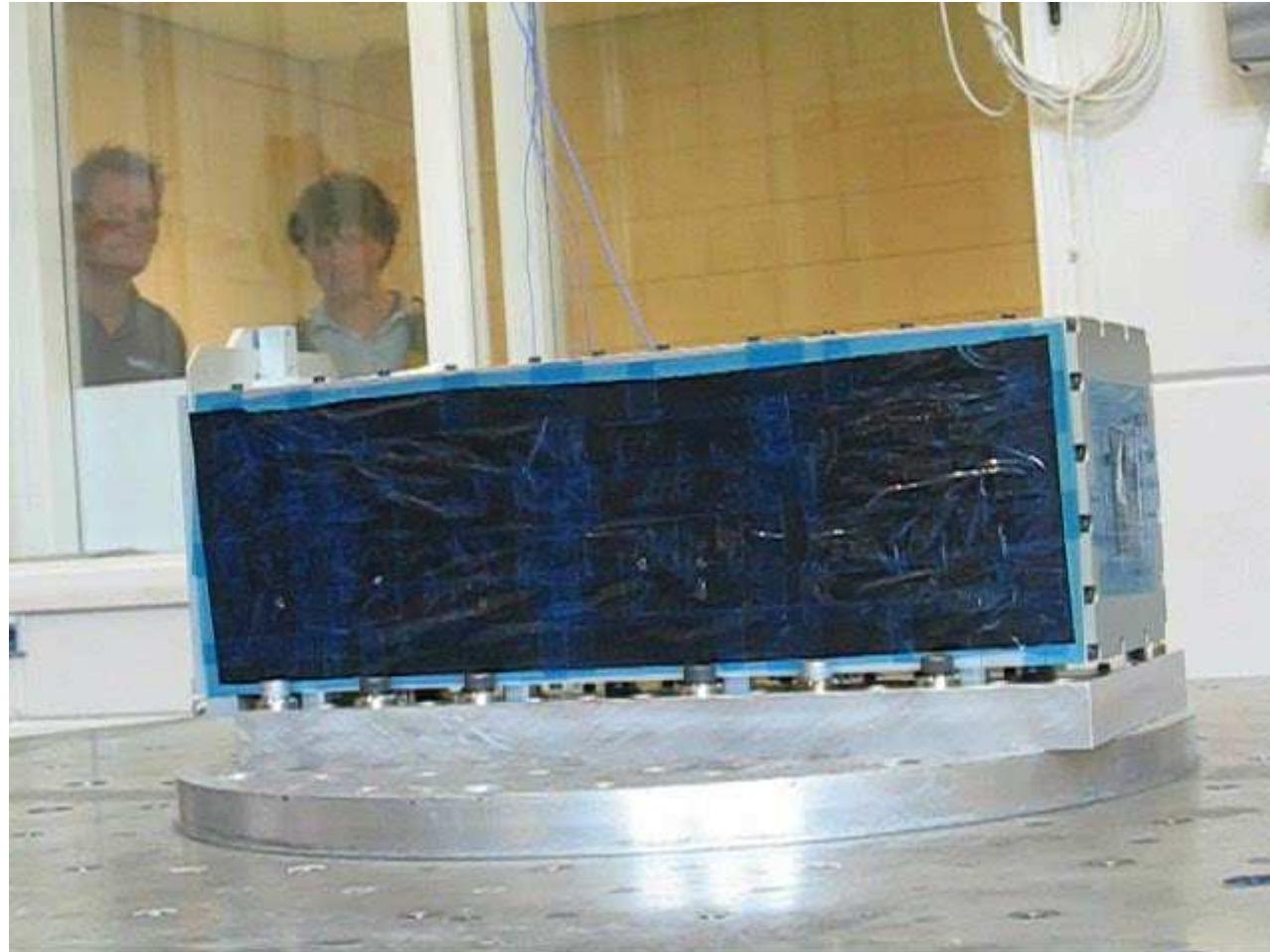
Fully autonomous
operation

Failure detection &
correction

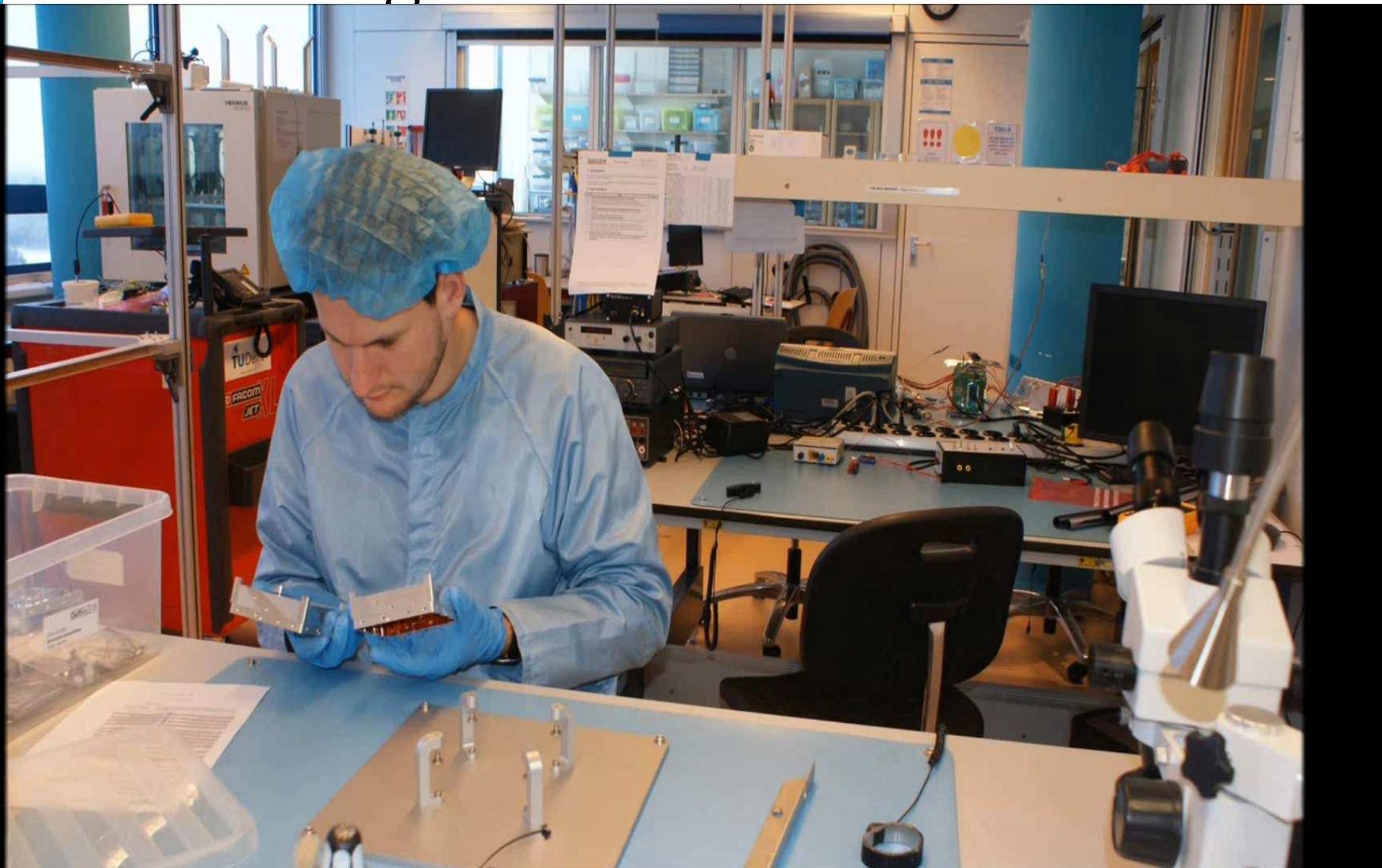
Structure & Thermal Control



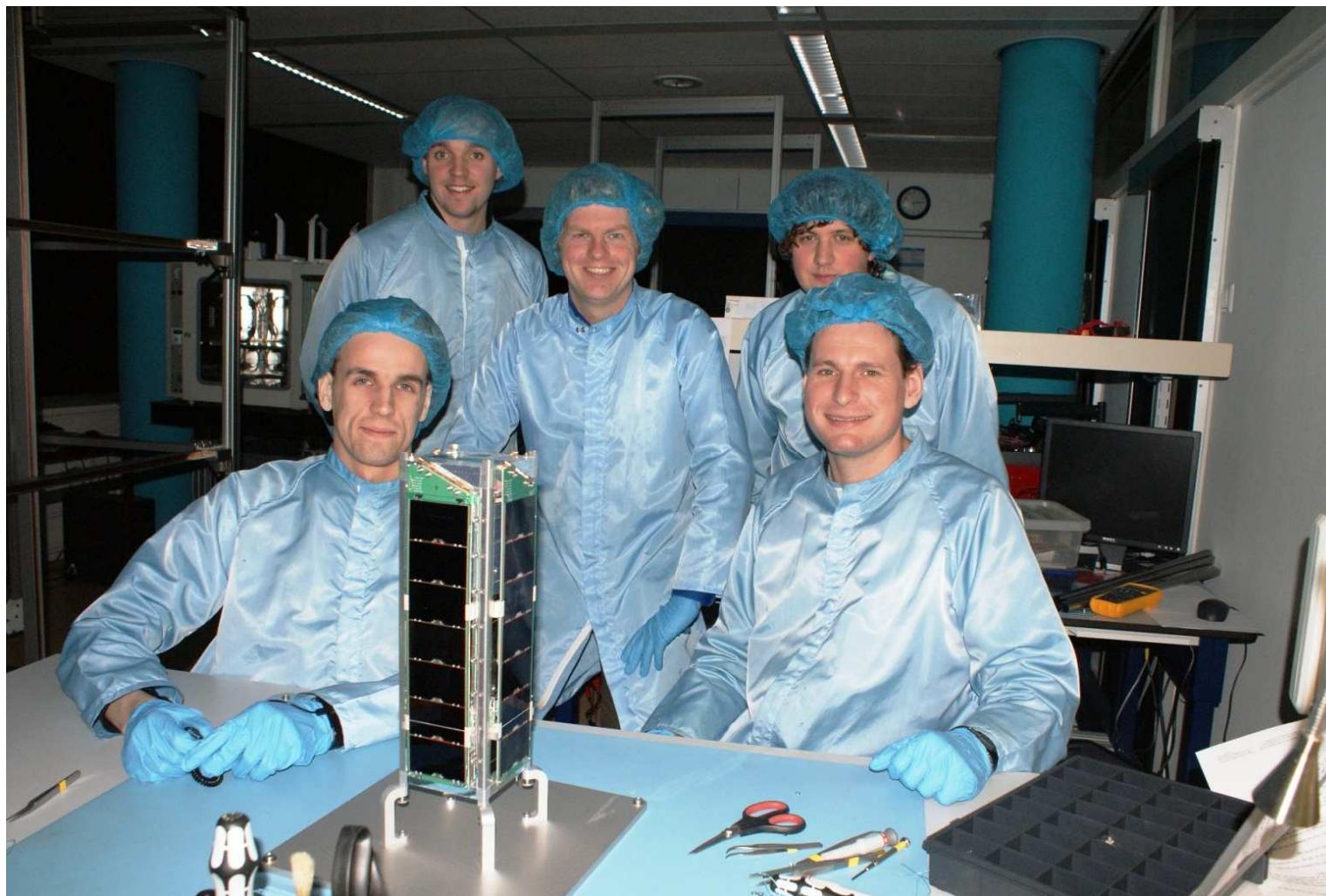
Vibration Testing



Final Integration



Delfi-n3Xt Ready for Launch!



S-Band Dish

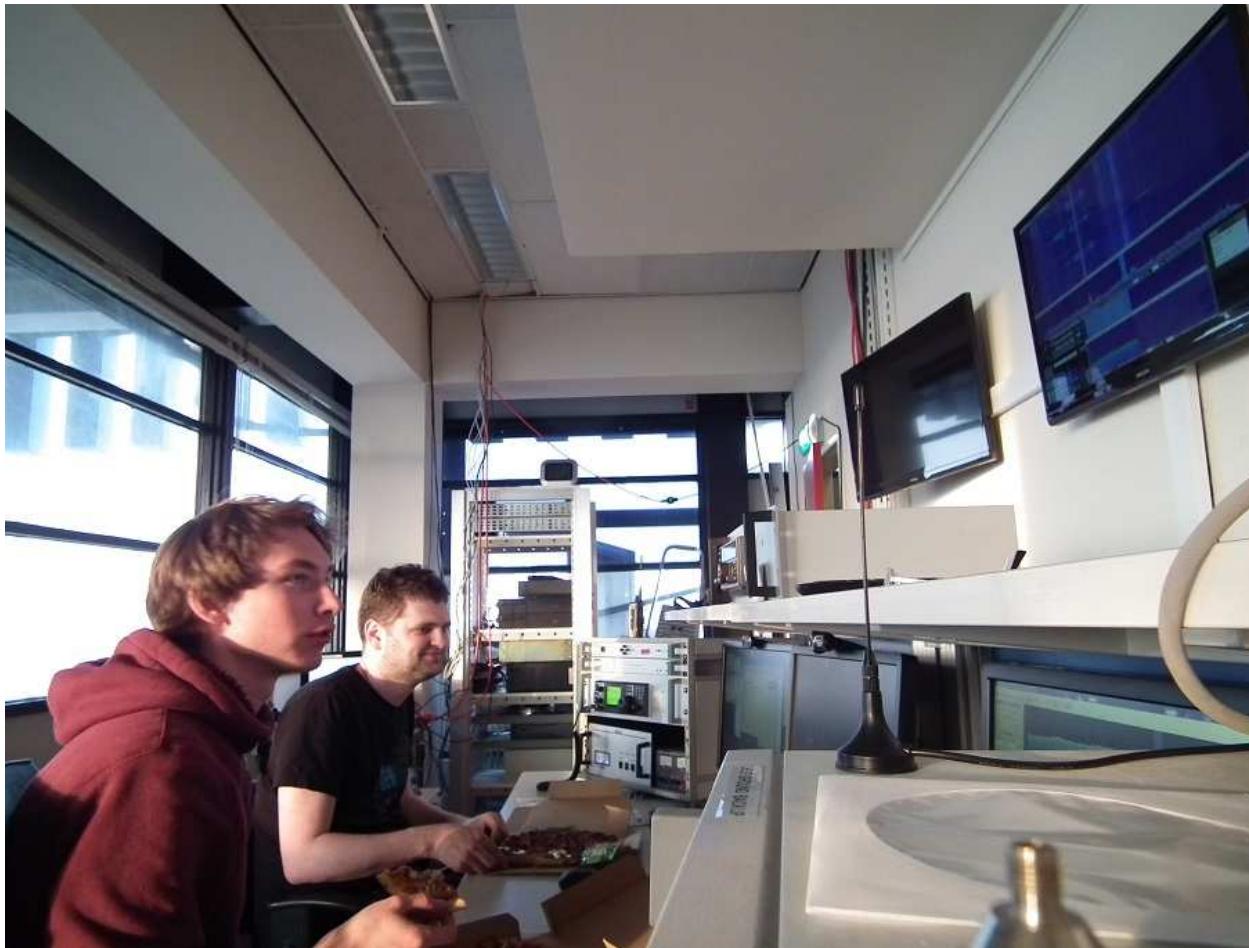


Refurbishment in progress



Tracking operations re-established:

- Successful Delfi-C³ signal reception on 145.870 MHz!



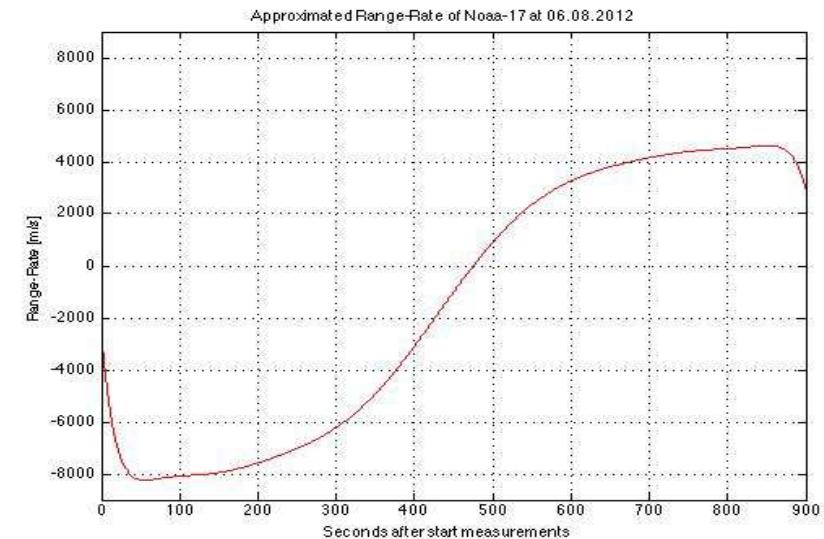
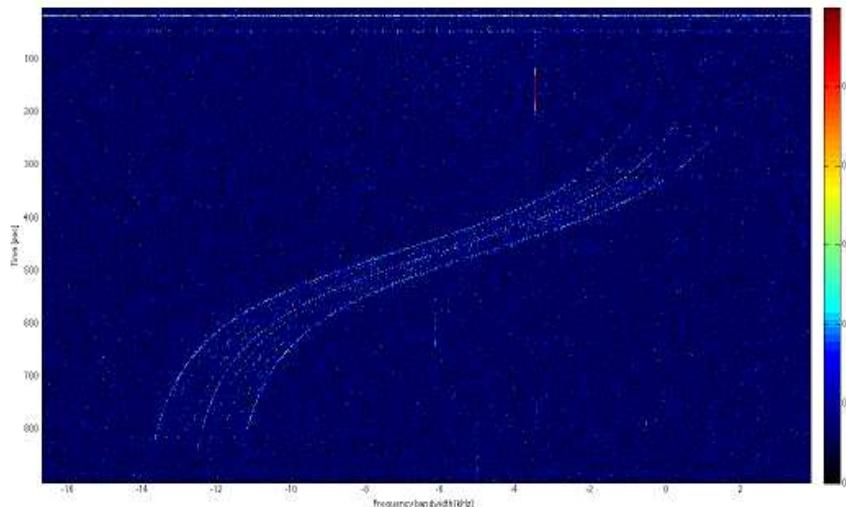
Delfi Ground Station

Ready for Delfi-n3Xt operations!



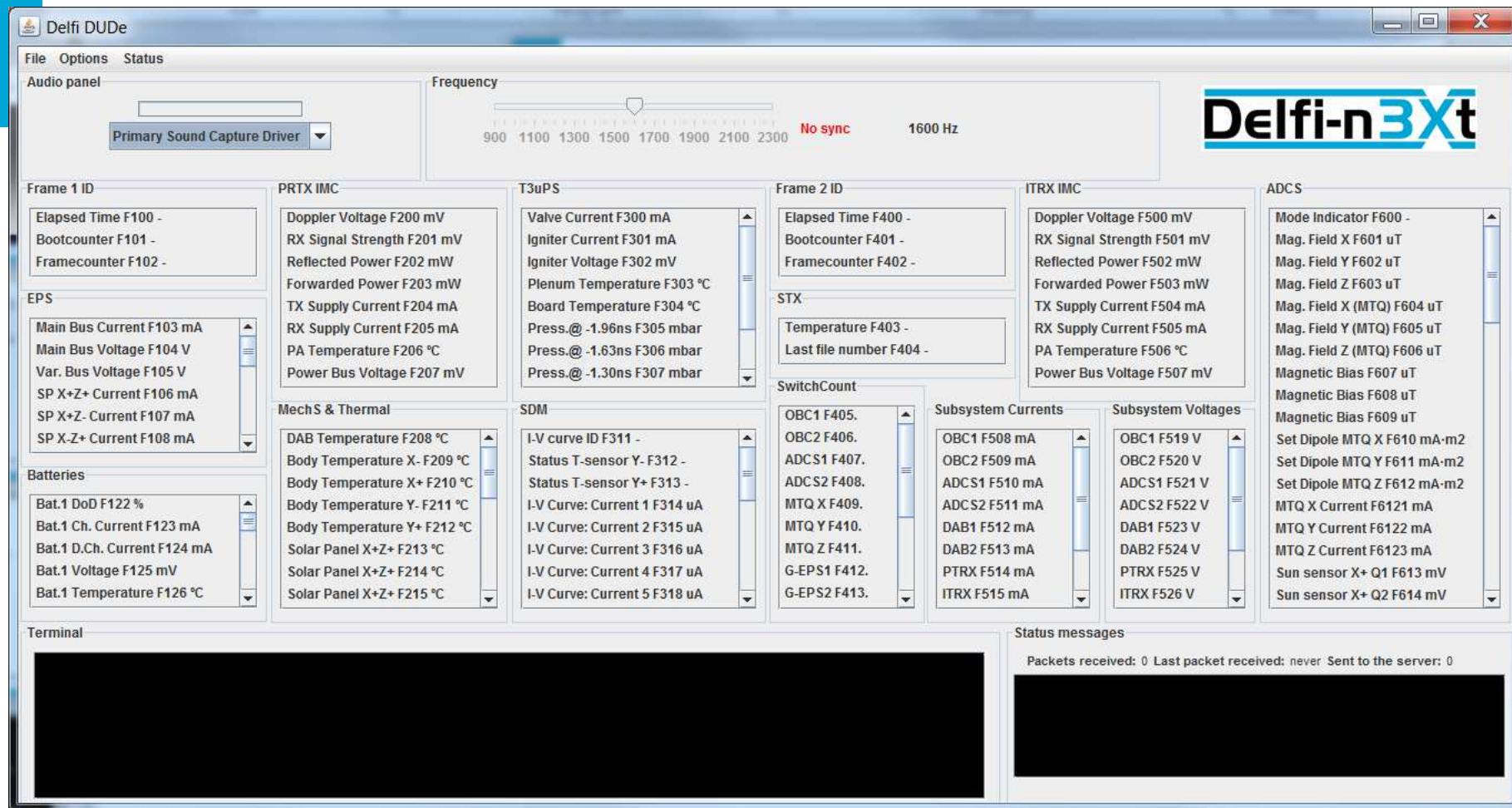
Doppler measurements

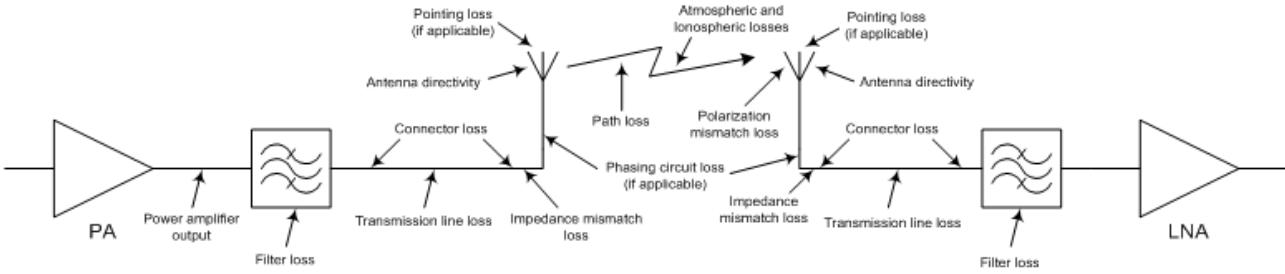
Delfi-C3 raw data used now by students in 2nd year project
“Test Analysis and Simulation” (AE-2222-I)



Delfi-n3Xt for Radio Amateurs (1)

Receive and show telemetry with RASCAL successor: DUDe





	Description	Value	Unit
Transmitter	Power amplifier output	-5.06	dBW
	Transmission line loss + connector loss	-0.10	dB
	Phasing circuit loss	-1.70	dB
	Antenna directivity (minimum)	-5.00	dBi
<i>Transmitted EIRP</i>		-11.86	dBW
Channel	Path loss	-142.18	dB
	Atmosphere loss	-1.84	dB
	Pointing loss	-0.50	dB
	Polarization mismatch loss	0.00	dBi
<i>Total channel loss</i>		-144.52	dB
Receiver	Antenna directivity (maximum)	12.35	dB
	Connector loss	-0.10	dB
	Transmission line loss	-0.40	dB
	*Surge protector loss	-0.20	dB
	*Pre-amplifier loss	-0.20	dB
	<i>Received power</i>	11.46	dB
<i>Total Eb</i> (Total signal power divided by data rate)		= -178.73	dBW
Receiver noise temperature		261	K
<i>Total N0</i> (Noise temperature times Boltzmann's Constant)		-204.43	dBW
<i>Received Eb/N0</i>		+ 25.71	dB
<i>Required Eb/N0 for BER = 10⁻⁵</i>		- 10.30	dB
Minimum link margin		- 3.00	dB

fi-n3Xt

Delfi-n3Xt for Radio Amateurs (3)

- Receive S-band signal (beacon or full speed)
 - Software still under development
 - Need >2 m dish to go above the noise level
 - Beacon mode contains same data as primary downlink
 - High speed mode contains requested packed data from gaps in primary downlink
- Use linear transponder: UHF up, VHF down!
 - Passband downlink: 145.880 - 145.920 MHz (inverting) 200mW PEP
 - Linear transponder passband uplink: 435.570 - 435.530 MHz
 - will be switched on after primary objectives are met
 - Uplink requires antenna with sufficient gain and high power amplifier

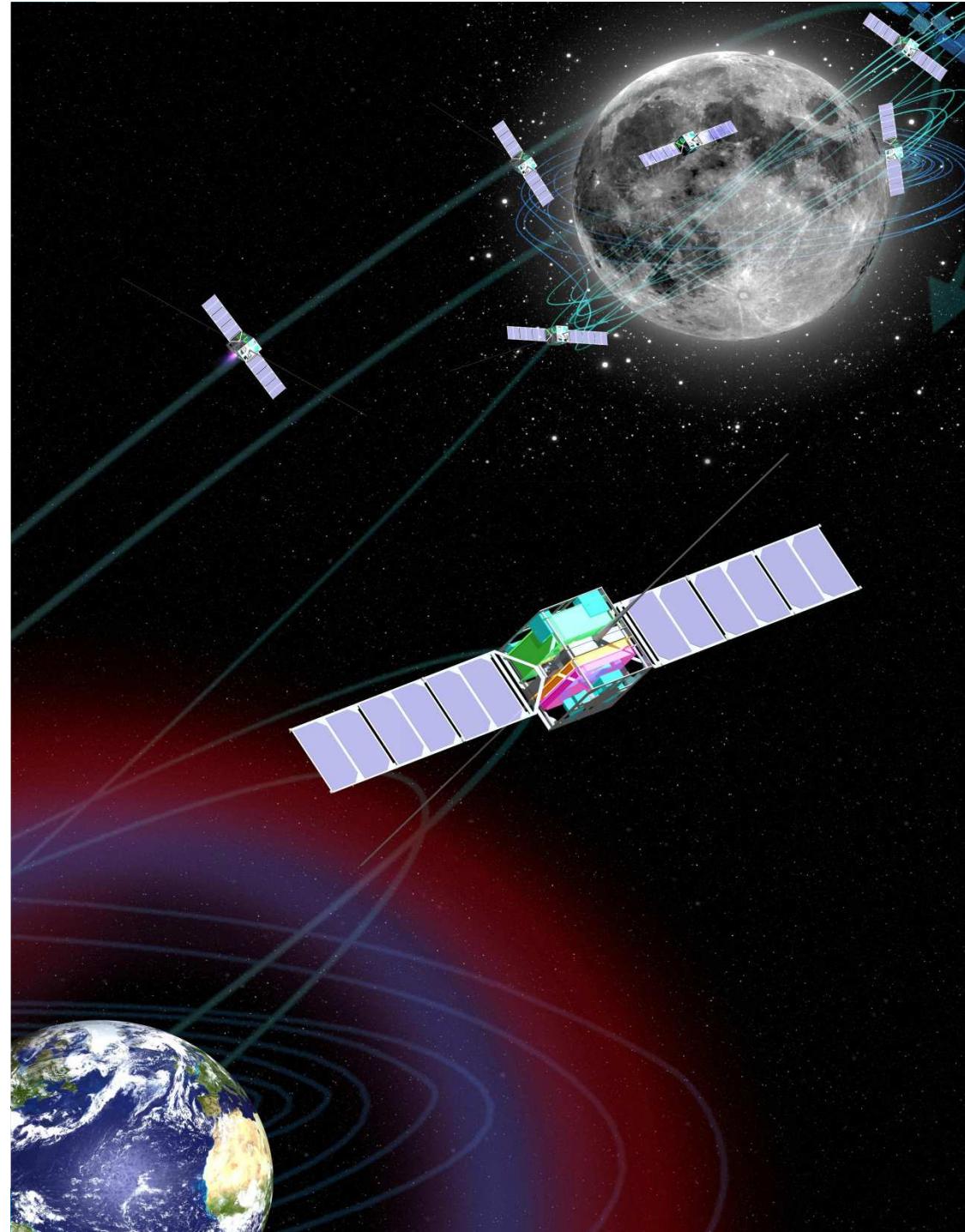
Future Outlook

New space applications will be enabled by deploying networks of small satellites.

DelFFi: Delta & Phi

Demonstrates formation flying
Delfi-n3Xt as baseline EM
Part of QB-50 mission





OLFAR

Orbiting Low Frequency Array

“Extending LOFAR to the Moon”

Autonomous nanosatellite swarm

Self-propelled to the moon

e-moth

First nanosatellite to the moon
Travelling autonomously
Demonstrating OLFAR concept

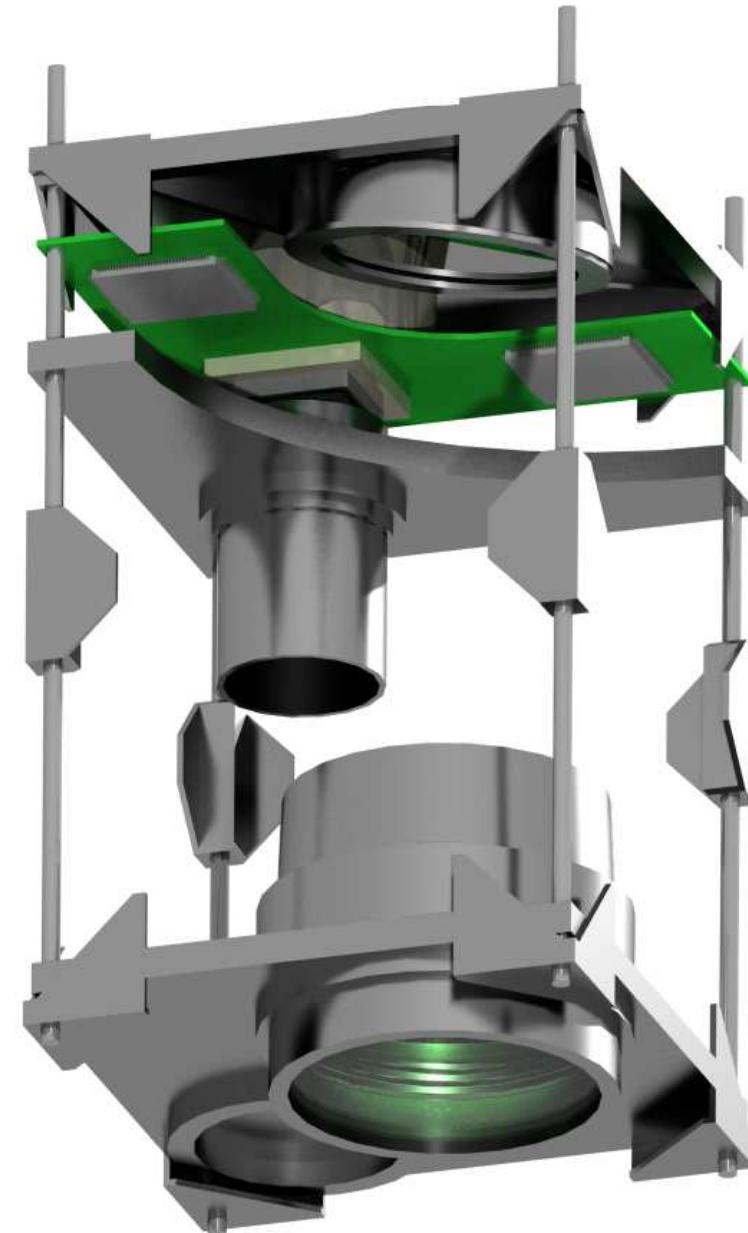


ANT

Advanced Nano Telescope

7.5 m GSD @ 540 km

Compatible with Delfi satellites

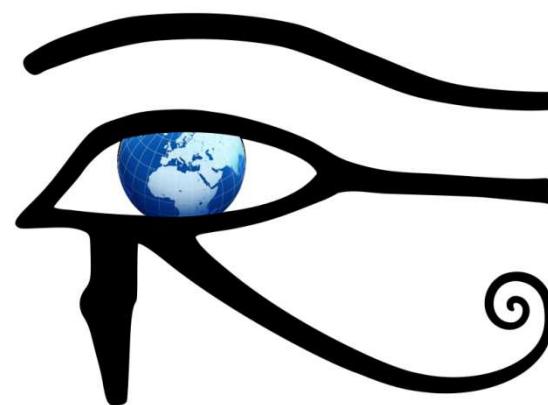
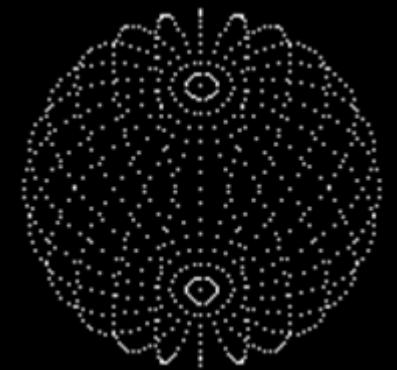


EIECON

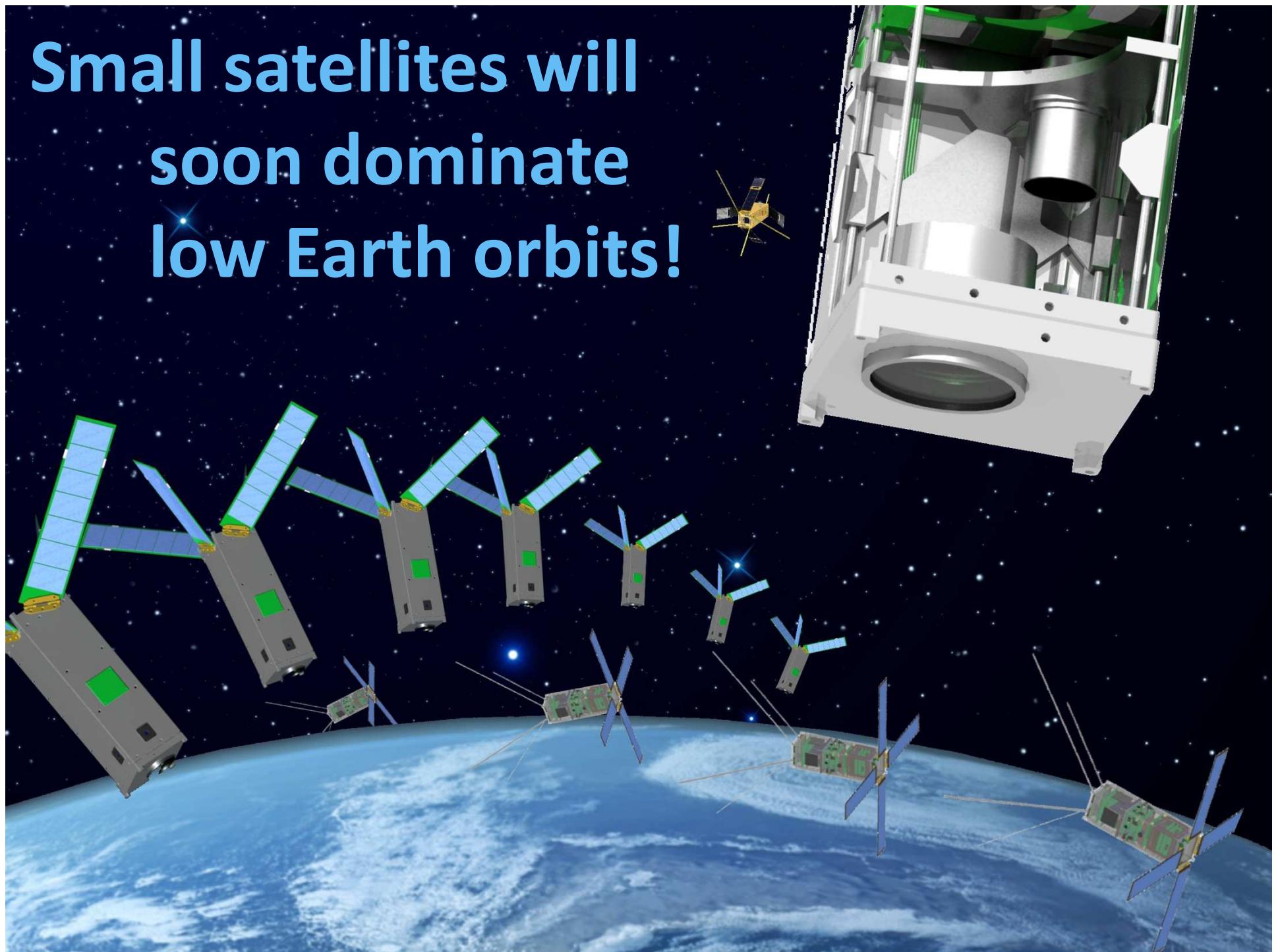
Earth Imaging Extensive Constellation of Nanosatellites

High temporal resolution: 15 minutes for 5% of Earth

About 4000 nanosatellites at 300 km altitude



**Small satellites will
soon dominate
low Earth orbits!**





www.delfispace.nl

