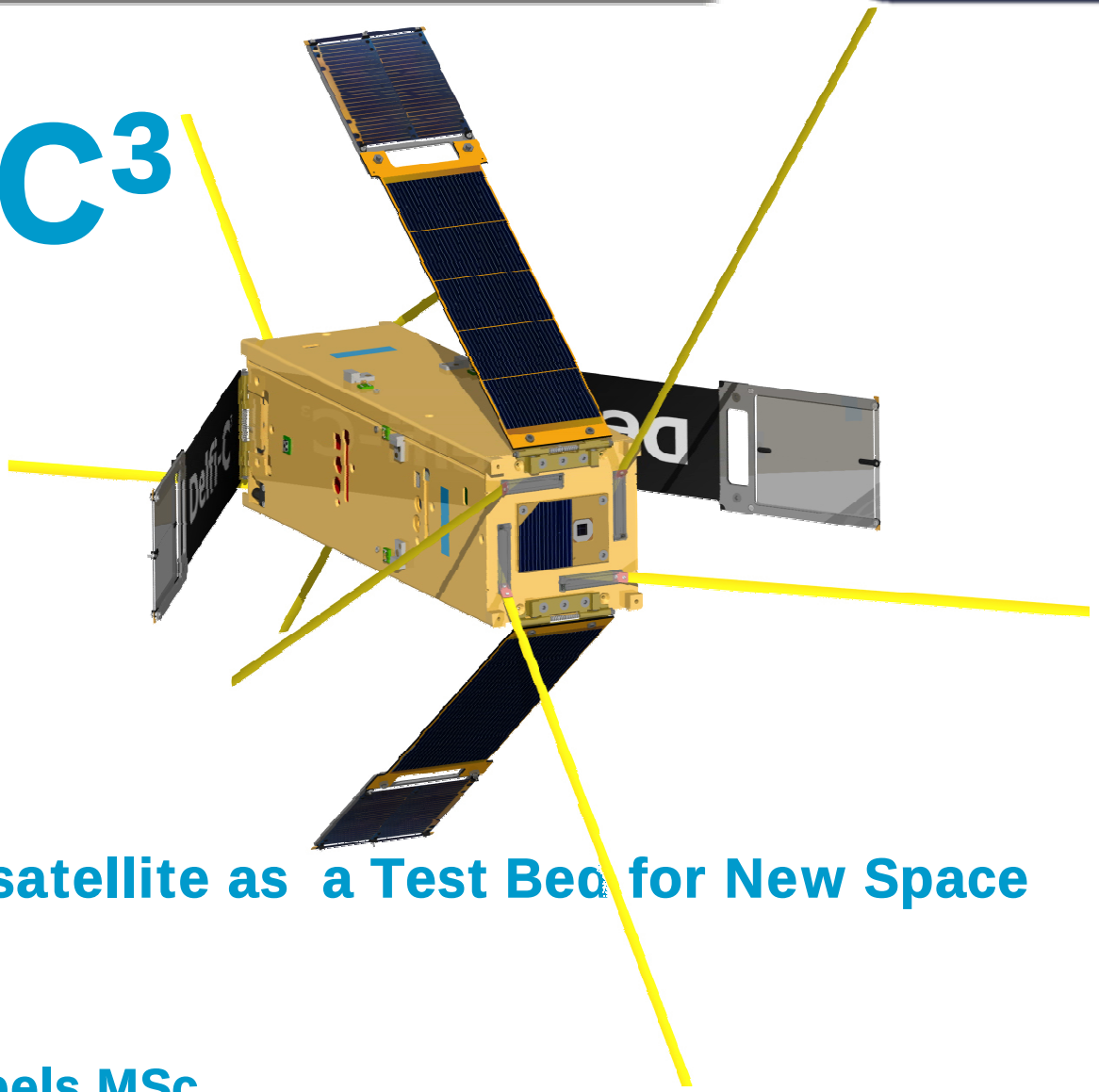
Delfi-C³



Student Nanosatellite as a Test Bed for New Space Technology

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PE4WJ
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Contents

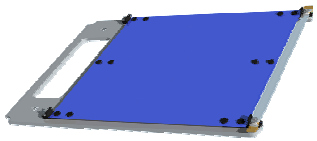
- Project History and Point of Departure
- Mission Objectives
- Payload Overview
- Mission Characteristics and Launch
- Satellite overview
- Ground Segment and Data Collection

Project Background

- Started in November 2004
- Current team consists of 12 MSc and 5 BEng students
  - 6 at Aerospace Engineering
  - 11 at Electrical Engineering, Mathematics and Computer Science
- In-house Clean Room & EMC test facilities
- Three involved companies / customers:
  - Dutch Space – solar arrays, robotics (ERA)
  - TNO – research institute, scientific instruments department
  - Systematic design BV – partner in electronic design
- Predecessor to extensive MISAT project (start 2005)

Project History and Point of Departure

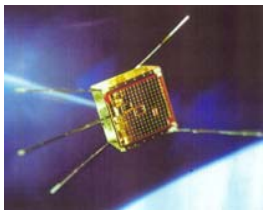
November 2004:



Thin Film Solar Cells
(Dutch Space)

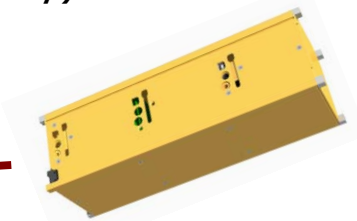
+

CubeSat + P-POD Standard
(Stanford and CalPoly)



Delfi-1 Heritage
(1998-2005)

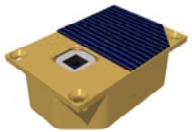
TU Delft Satellite Opportunity



3-unit CubeSat Kit
(Pumpkin Inc.)

MiSat Program
- Wireless Sun Sensor (TNO)
- Advanced Transceiver (EEMCS)

MicroNed



TU Delft Facilities
- Clean Room
- Delfi Ground Station

Delfi-C3 Mission Overview - Objectives

Summarized Technical Objectives:

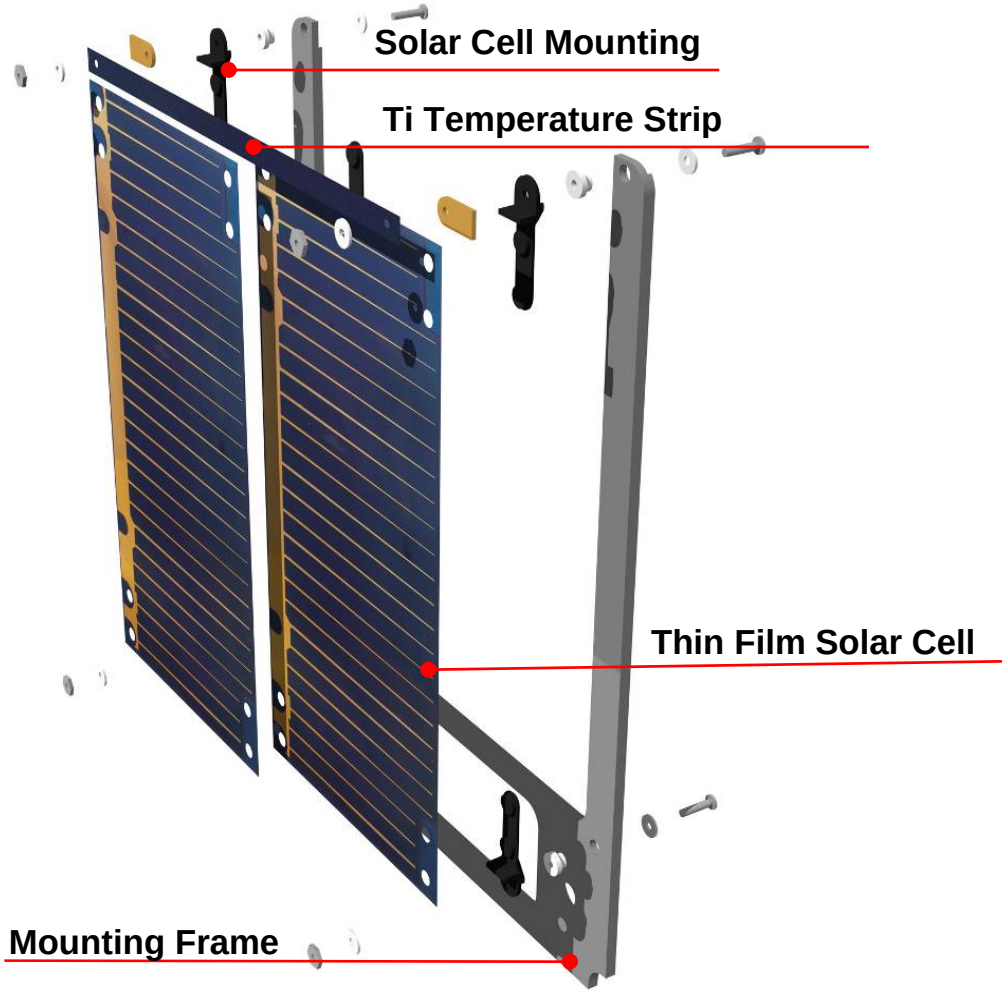
- Perform in-orbit test of a Thin Film Solar Cells
- Perform in-orbit test of an Autonomous Wireless Sun Sensor
- Perform in-orbit test of an Advanced Transceiver (high efficiency PA)
- Create a distributed ground station network for Delfi-C3 and future missions

Summarized Educational Objectives:

- Provide interdisciplinary hands-on engineering experience
- Develop teamwork, leadership, and communication skills
- Interface with the MSc. programs of TU Delft
- Provide an opportunity to a variety of educational organizations to participate

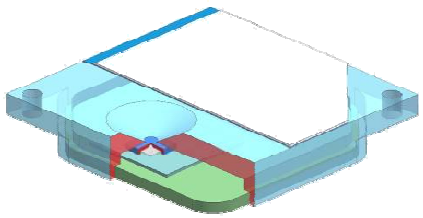
Thin Film Solar Cells (Dutch Space)

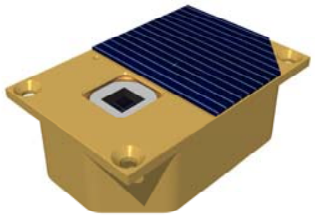
- First flight opportunity
- Innovative technology:
  - Thin film titanium substrate ~ 25 µm
  - High power to mass ratio
  - Very low stack height
- IV-curve measurement
- Temperature measurement
- Modular payload
- *No body mounting*



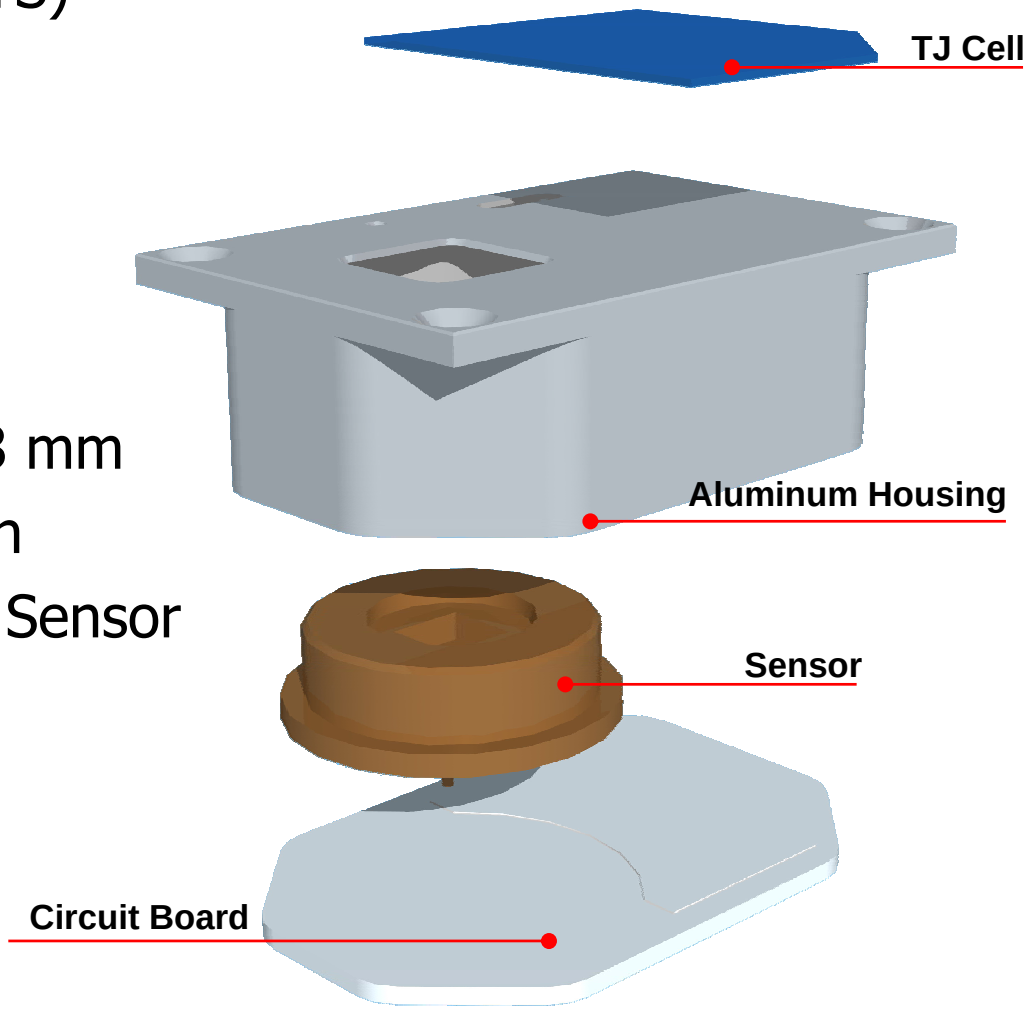
Autonomous Wireless Sun Sensor (TNO)

- Analog Quadrant Sun Sensor (OTS)
- Wireless RF-Interface
  - UHF Link (915 MHz)
  - Patch antenna on sensor
  - 1 RF-receiver connected to OBC
- Integrated GaAs solar cell
- Sensor envelope ~ 60x40.5x17.8 mm
- 2 Sensor units, mass ~ 75 g each
- Predecessor to Micro Digital Sun Sensor



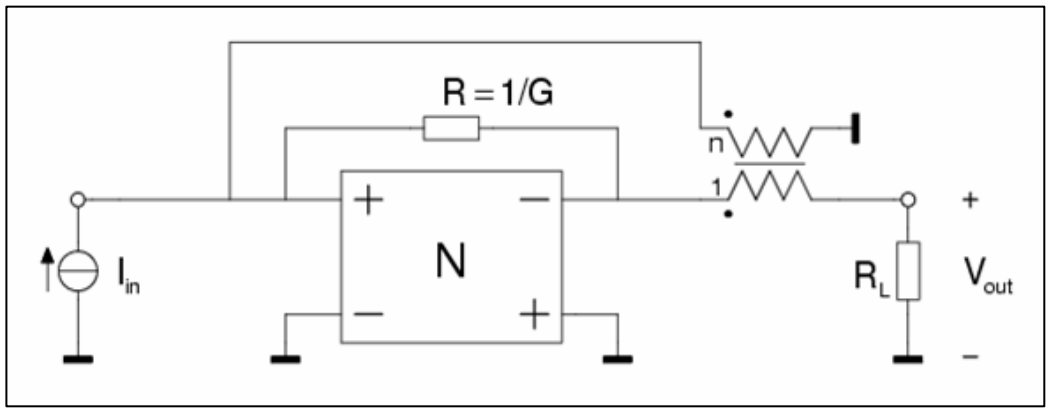


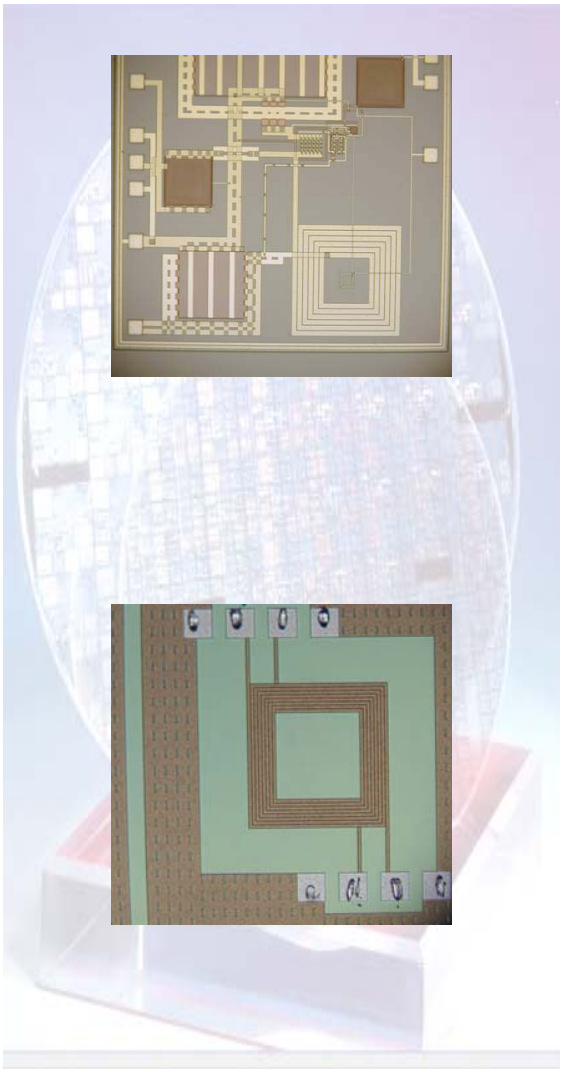
Digital Sun Sensor [TNO]



Advanced Transceiver (TU Delft - Electr. Eng.)

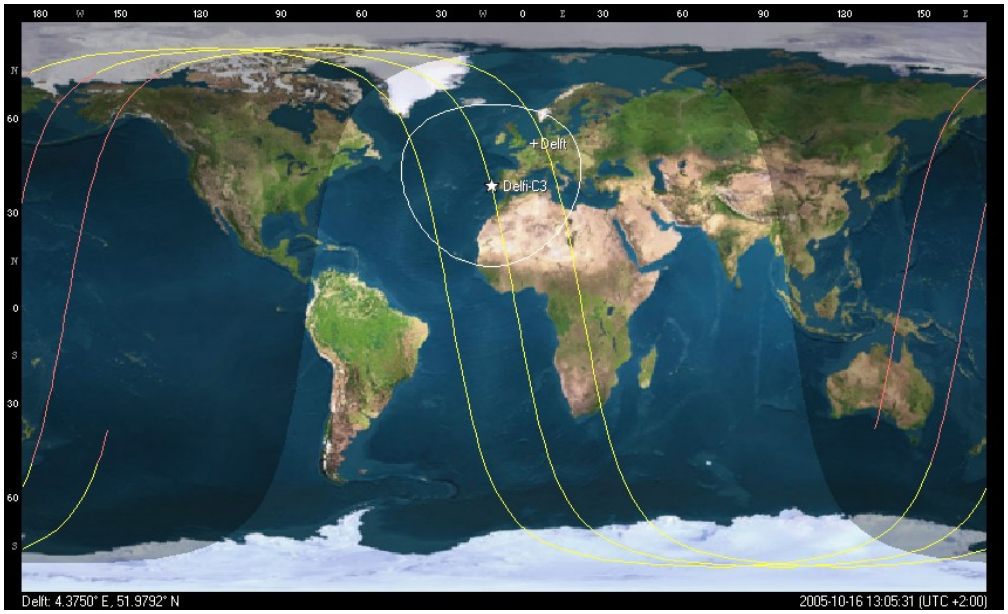
- Focus on high efficiency miniaturized PA
- Precursor to double loop negative feedback technique
- Prequalification for MISAT mission
- One transceiver fitted with novel PA





Mission Characteristics, launch and Realization

- Design and development by a self-organized student team
- Telemetry gathering through Radio Amateurs
- *Mode U/V Linear transponder*
- Designed for 1 year LEO



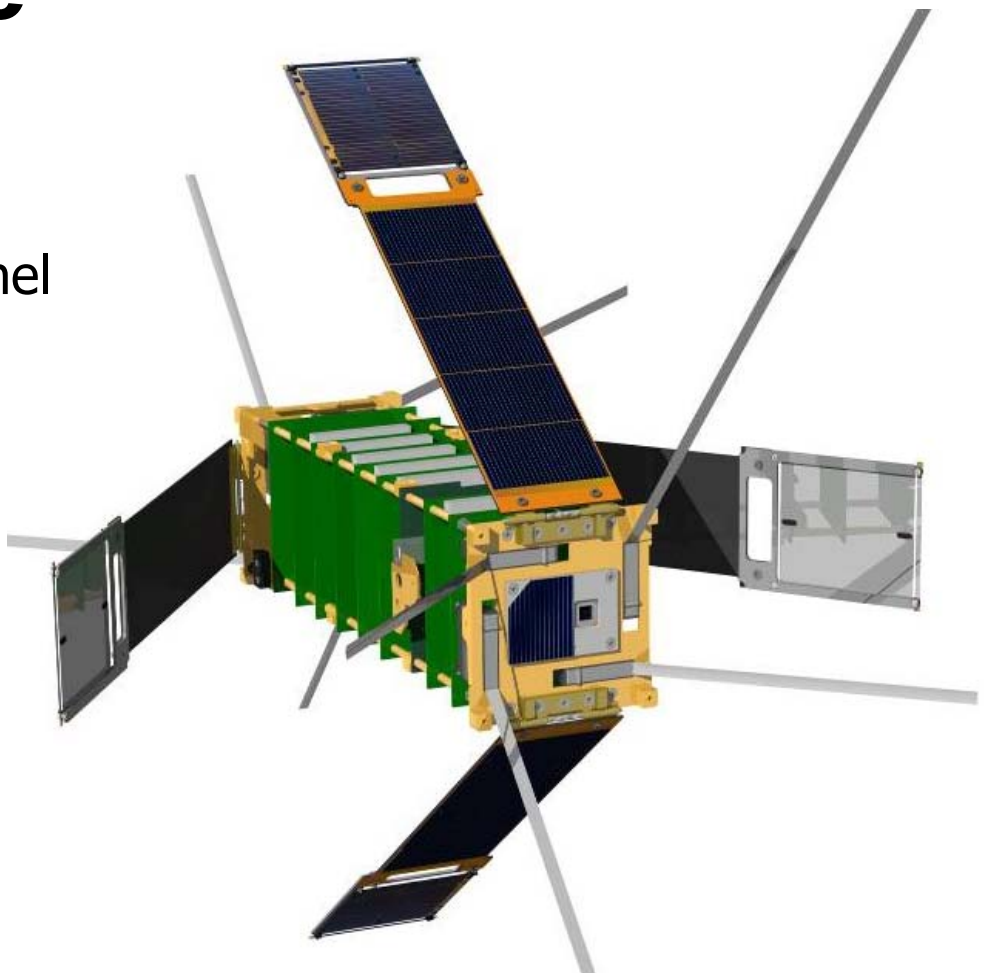
- "Piggyback" Launch in P-POD or T-POD
- Expected Orbit:
  - Inclination ~ 98 º
  - Sun synchronous
  - Altitude ~ 500-1000 km
- 3 months science mission, after which linear transponder mode

The Delfi-C3 satellite

- 3 unit CubeSat structure, 3kg
- 2 AWSS payload units
- 4 deployable panels at 35 degrees (max/min power):
  - –Carbon Fiber Reinforced Plastic
  - –TFSC payload suspension frame
  - –5 TEC1 GaAs TJ solar cells
- 2.5 W min. power available
- 8 antennas:
  - –4 VHF 50 cm downlink
  - –4 UHF 18 cm uplink
- ***No battery***
- ***No active attitude control***

The Delfi-C3 satellite

- EPS
  - 1 DC DC converter per solar panel
  - Current measurement
- CDHS
  - TI MSP430 OBC
  - Microchip PIC18LF4220 microcontrollers per subsystem
- Attitude Control
  - Magnetic hysteresis rods
- COMMS
  - Two Redundant Transceivers
- Standard board interface
  - I^2C bus
  - 12 V DC power bus
- Passive thermal subsystem (thermal tapes)



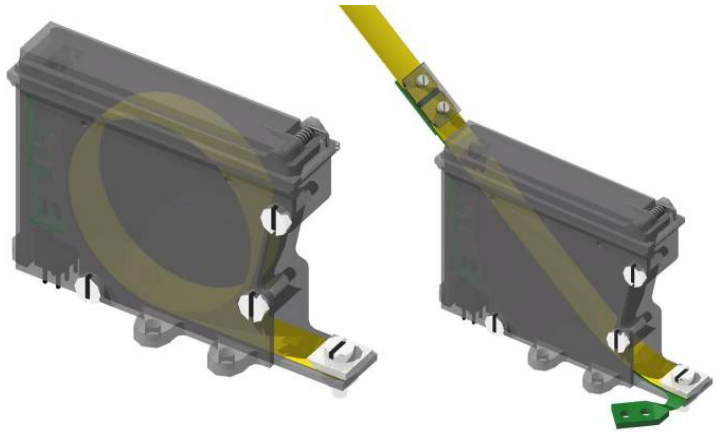
Frequencies

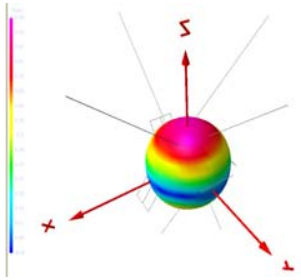
- Primary telemetry downlink: 145.870MHz
  - RC-BPSK, 1200bd AX.25, UI frames, 1 frame/sec
- Back-up: 145.930MHz
- Transponder downlink: 145.880-145.920MHz linear (inverting) + CW telemetry 40mW at 145.930MHz
- Transponder uplink: 435.570-435.530MHz
  - 40kHz passband, 400mW PEP
  - Simple transponder
  - Basic AGC circuit
- Telecommand uplink: unpublished
  - FSK, 1200bd AX.25 + Encryption

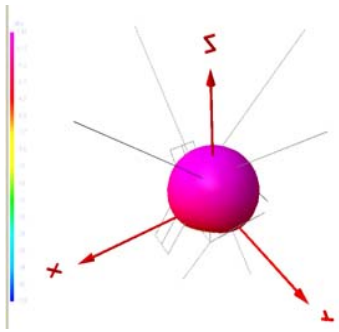
Antenna subsystem

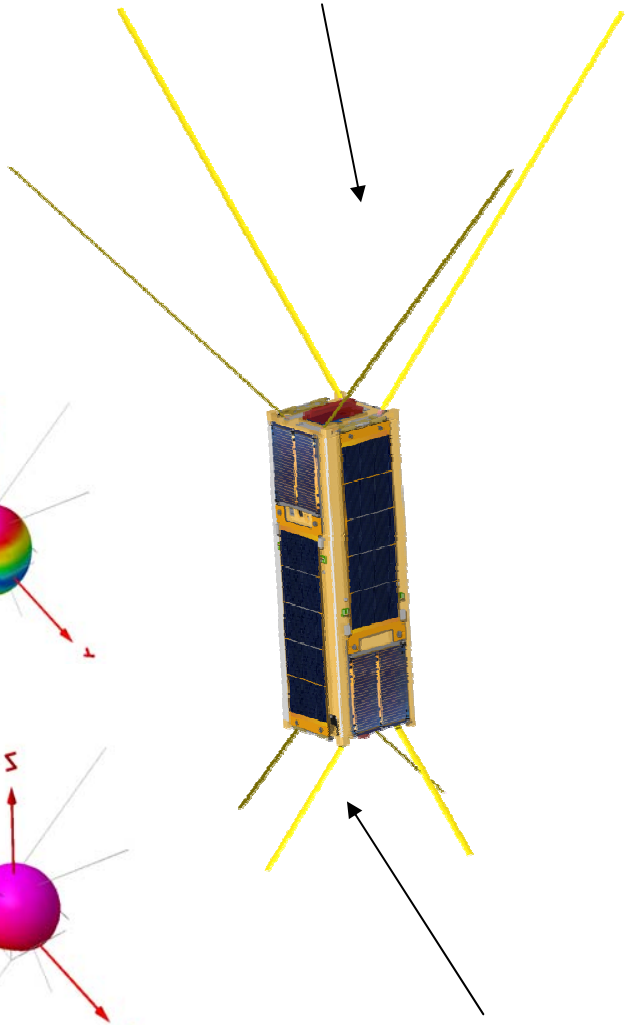
Uplink & downlink: turnstile antenna system

- 4 whips in phase quadrature → pattern and polarization
- VHF: 50cm
- UHF: 18cm
- Phasing harness to achieve phase relationship
- 6mm tape measure antenna whips
- Modular Antenna Boxes



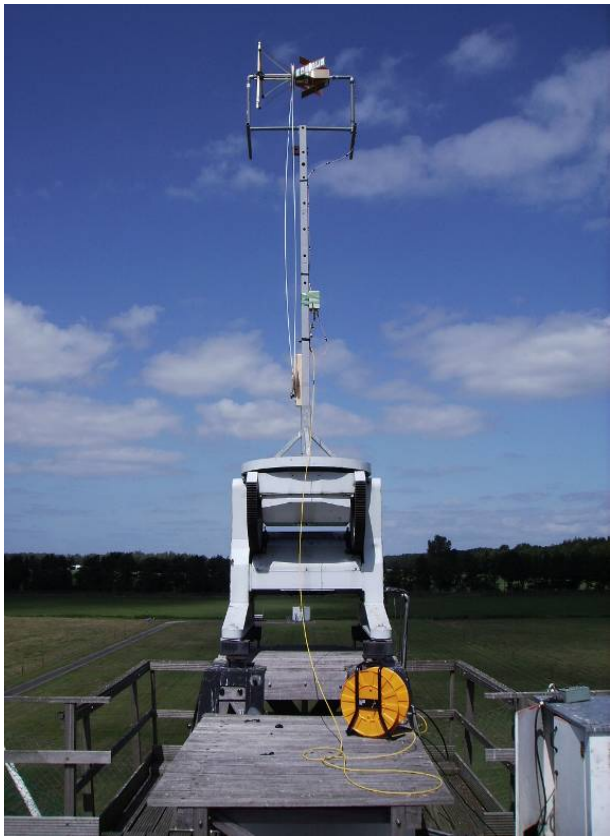






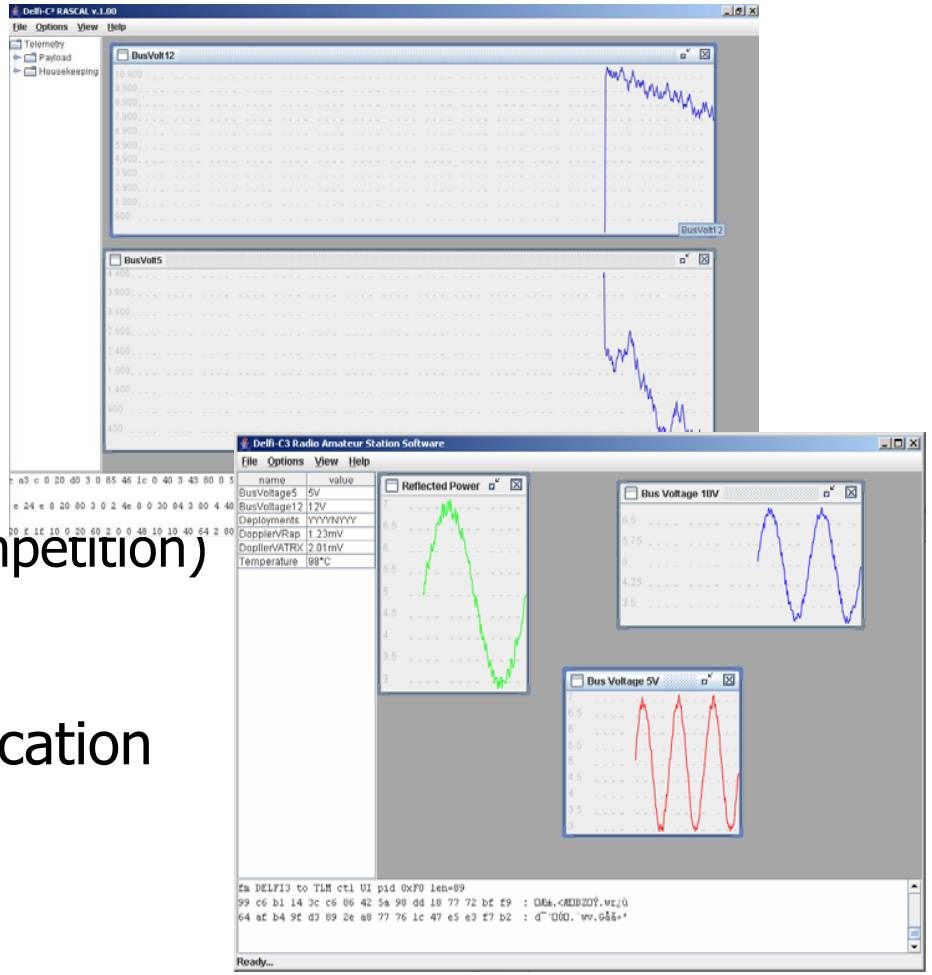
Antenna testing

- NLR Far Field range
- Verification of VHF / UHF radiation pattern
- Radiation pattern in case of deployment failure



Ground Segment & Data Collection

- Command stations in Delft and backup in Eindhoven (TU/e)
- Distributed ground station network
  - Radio amateurs worldwide
  - Universities worldwide
  - Software will be made available
- Soundcard software
  - PE1RXQ Gstreamer module
- RASCAL
  - Displays data realtime
  - Packet storage
  - Website with statistics (amateur competition)
  - Payload data processing
  - Attitude reconstruction
- Satellite status reconstruction / verification
  →Data delivery to customer



Ground Station

- Fully operational, 2 redundant units
- VHF / UHF / S-Band capability
- AFSK / FSK / GMSK / BPSK modems / TNC's
- Backup power
- Tracking and decoding telemetry from LEO satellites
- Remotely controllable
- Also operating as 9k6 APRS satgate

Webcam

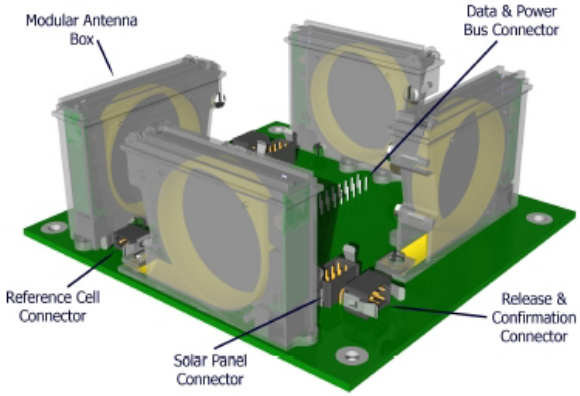
Clean Room

- Satellite Integration
- Small rocket propulsion test stand
- Fully equipped electronics workshop

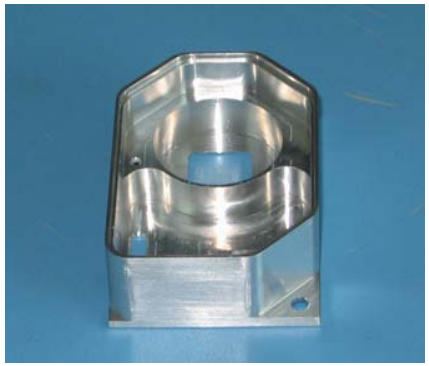
Delfi-C3 status

- Full scale breadboarding "Benchsat"
- Flight hardware is being produced
- Test campaign (TFSC payload thermal test, measurement system verification, antennas)
- Solar panels produced this week
- MAB verification with SPFC
- AWSS payload flight ready within 2 months

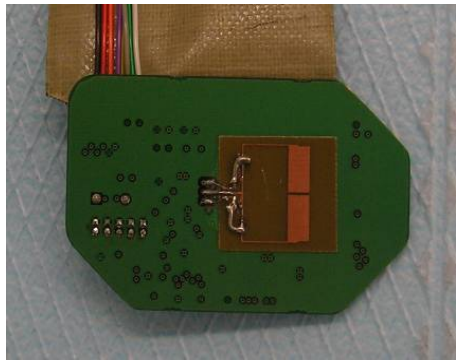
From design



To hardware



AWSS flight housing



AWSS EM PCB

Let's make it happen

Project Partners:

TNO Dutch Space SystematIC design TU Delft Technische Universiteit Delft

Project Sponsors:

NLR MICROCHIP AMSAT-UK

HARWiN INTERCONNECT DESIGN & MANUFACTURE

Questions?

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