Delfi-C$^3$

Student Nanosatellite as a Test Bed for New Space Technology

Wouter Jan Ubbels MSc.
PE4WJ
Delft University of Technology, The Netherlands
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:

- Delfi-1 Heritage (1998-2005)
- Thin Film Solar Cells (Dutch Space)
- CubeSat + P-POD Standard (Stanford and CalPoly)
- 3-unit CubeSat Kit (Pumpkin Inc.)
- TU Delft Satellite Opportunity
- MiSat Program
  - Wireless Sun Sensor (TNO)
  - Advanced Transceiver (EEMCS)
- TU Delft Facilities
  - Clean Room
  - Delfi Ground Station
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
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 °
  - 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**
  - \( \text I^2\text C \text{ bus} \)
  - 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

**AWSS flight housing**

**AWSS EM PCB**
Let’s make it happen

Project Partners: Dutch Space, Systematic Design, TU Delft

Project Sponsors: NLR, Microchip, AMSAT-UK, HARWIN
Questions?

www.delfic3.nl
w.j.ubbels@delfic3.nl
info@delfic3.nl