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From the Delfi-C^3 nano-satellite towards the Delfi-n3Xt nano-satellite

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ABSTRACT

On April 29, 2008, the first 3-unit CubeSat of the Delft University of Technology, Delfi-C^3, was launched on a PSLV-C9 rocket and is operational. The objectives of the Delfi-C^3 project were successfully fulfilled. Currently students are working on its successor Delfi-n3Xt. Both satellites are developments of the faculties of Aerospace and Electrical Engineering, Mathematics and Computer Science (EEMCS).

The paper starts with an overview of results and lessons learned from the Delfi-C^3 development and the mission with emphasis on sub-system development, satellite design, manufacturing, assembly, integration and test.
Subsequently an assessment is presented about differences and improvements from Delfi-C^3 towards Delfi-n3Xt in view of the satellite development line. In a comparison common aspects and differences are addressed; both in hardware and project approach: mission goals and objectives, custom structure design, Electrical Power Subsystem with local protection circuits and Maximum Power Point Tracking, combination of UHF/VHF antennae, addition of S-band antenna, a new Command and Data Handling Subsystem, an Attitude Determination and Control Subsystem with sensors and actuators for 3-axis attitude control, satellite testing and adapted operations approach. Finally the payloads of Delfi-n3Xt: ITRX, MPS, SDM, SPLASH, T3µPS and some options are addressed.

Keywords:
Delfi-C^3, Delfi-n3Xt, CubeSat, S-band, 3-axis stabilization, nanosatellite, lessons learned.

INTRODUCTION

At the Delft University of Technology Delfi-C^3, a three-unit CubeSat (see Figure1), has been built as the first of a range of satellites, which are intended to give students hands-on experience in designing and operating it and to ‘struggle’ with real hardware in a project environment *[1, Vaartjes, 2008]*.
For the payloads, manufacturing and testing also external companies were involved. Apart from the Master of Science (MSc) students also Bachelor of Engineering (BEng) and staff from various levels of education are working on these projects and as such representing to a certain extent a normal industrial setting, which is of course the future working environment of the majority of engineering students. Next to the educational experience a secondary objective of the project was set to provide a means for in-orbit technology demonstration.
A comprehensive description of satellite and its mission can be found in *[2, Ubbels, 2008]*.
Because the university had no earlier experience in building satellites, a Pumpkin three unit kit and an on-board computer were purchased. The Pico satellite Orbital Deployer (POD) was delivered by University of Toronto Institute for Aerospace Studies Space

Figure 1 Delfi-C^3 in stowed configuration

Flight Laboratory (UTIAS SFL), which also acted as launch broker.

Two payloads were provided by the Dutch space industry: 4 sets of Thin Film Solar Cells (TFSC) developed by Dutch Space and two Autonomous Wireless Sun Sensors (AWSS), developed by the Dutch institute TNO.

As both payloads operate only in sunlight, it was decided not to implement a battery system and thus a failure-prone from the Electrical Power Sub-system (EPS) subsystem had been removed. Both payloads required a varying incident angle of the sunlight and therefore a passive attitude control system was implemented, which damped the tumbling of the satellite with a small magnet and two rods of magnetic hysteresis material.

Communication was done with an UHF uplink and VHF downlink on radio amateur frequencies with an in-house developed modular antenna system, which showed to be very successful in flight. As a return favor for transferring the satellite data by radio amateurs from the satellite to the ground station in Delft, a transponder for radio amateur usage was implemented. Its presence was very much appreciated as the project learned in contacts. Therefore the next satellite also will be equipped with a transponder. Other subsystems supported the collection of data from the payloads and on-board systems.

Delfi-C^3 has been successfully launched on April 28th, 2008 with an Indian PSLV-C9 rocket together with a whole range of CubeSats into a synchronous orbit of 635 km altitude and at the time of preparation of this article it is still in operation in Science Mode. This is far longer than the three month operational period aimed for. In this respect we were grateful, that basically the satellite was designed Single Point of Failure (SPF) free, because not all (sub)-systems do function anymore (within their specified limits) *[3, Hamann 2009]*.

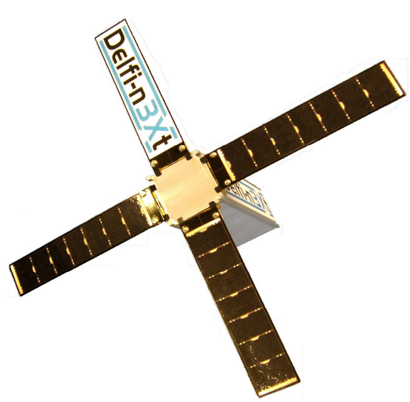

Figure 2 Delfi-n3Xt satellite

Designing and building the satellite involved about 3 years. Over 60 MSc and BEng students worked with enthusiasm on the project, either on their thesis or in an internship. From staff side to about four full-time equivalent staff contributed to the project, making the students/staff man-hour ratio about 6:1.

Changing to the successor of a successful project puts challenges to be fulfilled. Delfi-n3Xt does not lack these new challenges with a custom designed structure sub-system, an Attitude Determination & Control Subsystem (ADCS) 3-axis stabilization (2 axes will be used for sun-pointing and one Z- axis for pointing of experiments), an Electrical Power Subsystem (EPS) with battery system and Maximum Power Point Tracking (MPPT), a newly developed Command & Data Handling Subsystem (CDHS), a combined UHF/VHF antenna system or when this is not fully feasible with the UHF antenna incorporated on the solar panels. The five (or eventually six) payloads are setting their own sometimes very specific requirements to the satellite and to the operations.
All the fields of activities require a well coordinated organizational approach, for which an effective interface control program is being set-up within the system engineering activities for the project. *[4, Lebbink 2009]*

As Delfi-C^3, Delfi-n3Xt will be developed in the context of the MISAT research program *[5, Gill et al. 2007]* at Delft University of Technology by students from the faculty of Aerospace Engineering and the faculty of Electrical Engineering, Mathematics and Computer science. Furthermore, a number of Dutch polytechnic institutes are involved in the project.

LESSONS LEARNED

Looking back to the Delfi-C^3 project one year after the launch time has come to collect experiences and findings in a number lessons learned to be used with the follow-on projects with the emphasis on design, manufacturing, integration, test and operational activities.

Delfi-C^3 structure subsystem and POD

Two Pumpkin structures were purchased in order to have at least a possibility for a spare satellite or replacement of the structure in case of misfortune. Inspection on dimensions learned that the bodies were slightly oversized with respect to specified limits and the shape showed some barrel distortion. The POD was delivered to a custom design specification in order to be able to accommodate the larger envelope of our solar panels. Incoming inspection learned that the POD was slightly undersized on the slide rails, but this was solved in due time and a proper functioning combination throughout the program was obtained.

Delfi-n3Xt structure subsystem

The Pumpkin 3U structure was used as the basis for the Delfi-C^3 satellite. However in the design period of Delfi-C^3 it was found that many modifications to the tube structure had to be made. Also the top- and bottom platforms needed to be replaced by custom design ones in order to achieve our goals *[6, Go 2009]*. For the Delfi-C^3 body tube several compromises were made in order not to disturb the integrity due to the existing holes, but leading to less optimum solutions. Furthermore the tube chassis is limiting the accessibility of the inside of the satellite.
For these reasons for Delfi-n3Xt a custom design structure will be developed. It will provide more flexibility and accessibility. Also it is an excellent educational exercise to build your own structure.

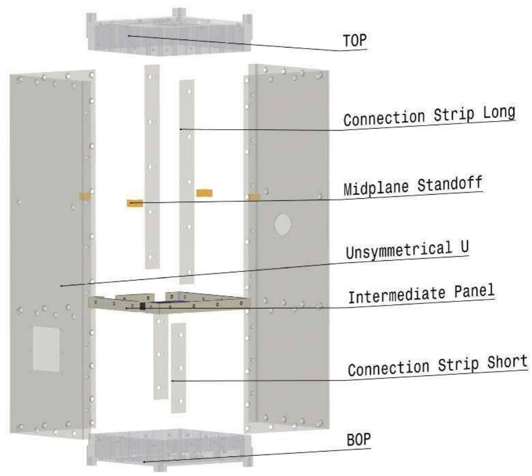

Figure 3 Delfi-n3Xt structure

ESD protection

During the assembly, integration and test period, it was decided, that everyone was required to work with a wrist strap to avoid damage to electronics by electrostatic discharge (probably the reason of the loss of a number of PIC's during development). Every time when entering the clean room the wrist straps has to be tested. In particular it was found, that the straps made with textile were not reliable, anyhow not with everyone; so these were excluded permanently. Another experience is that the metal bracelets wear out on their snap fasteners and leads may fall off without knowing, causing loss of ESD protection. So they need to be checked regularly and replaced in time. What made work also pleasant, was the addition of snap fasteners onto MGSE items (see Figure 4), e.g. to ease internal transportation; at least the hardware and the person connected to it are about on the same potential. An omission on the structure of Delfi-C^3, was to implement a proper electrical grounding point; so alligator clips were used, but they may jump off. Therefore for Delfi-n3Xt it has been decided to have at least two proper grounding points on the structure.

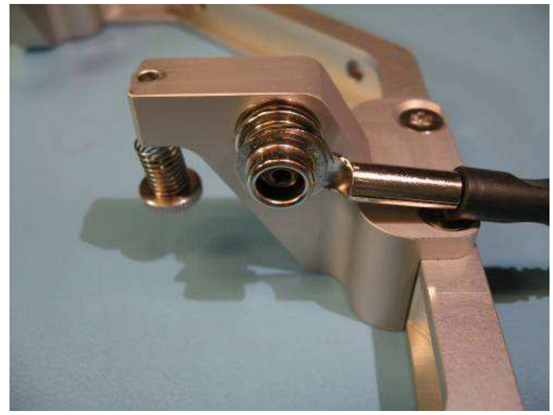

Figure 4 Snap fastener on MGSE

Modular antenna box

Designing the antenna system on Delfi-C^3 was an activity, which brought up a number of improvements throughout the project *[7, Brouwer 2008]*. Lately for testing purposes of Delfi-n3Xt the VHF antennae of the spare Delfi-C^3 were deployed These antennae had been stored rolled-up for 22 month and it was found that the antennae were not straight anymore once deployed. This means that the tape measure material (¼" width) had been deformed permanently. It was about 28 mm hollow (see Figure 5). In all deployment tests during the assembly, integration and test activities, this phenomenon never had been seen before. Further attention will be given to this as it may have an influence on proper deployment. Five spares are still available to monitor this in the course of time. It is noted that the roll-up diameter of our antennae is in range of 25-28 mm, while in the tape measure box of Stanley it is 36-44 mm. An investigation on the shorter UHF antennae showed a similar curvature of a few mm.

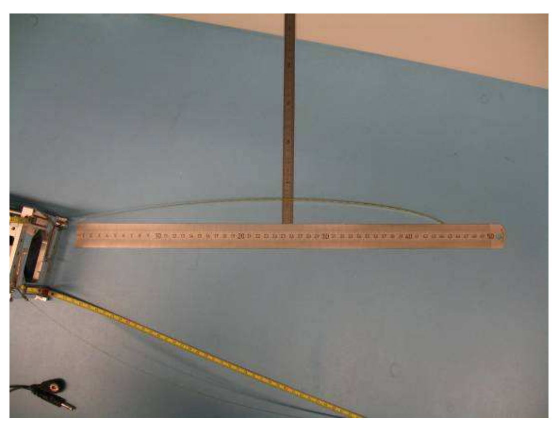

Figure 5 Bent VHF antenna after 22 month roll-up period

Design of printed circuit boards

For the design of the Printed Circuit Boards (PCBs) of Delfi-C3, a proto-flight approach was taken. This means that it was assumed that the PCB designs would be correctly implemented from paper to hardware without any iteration except for some individual components *[8, Bouwmeester 2008]*. This has been proven to be a naive approach as almost all subsystems needed revisions. As there was no time available anymore for making new PCBs, this has lead to out-of-PCB wiring to replace wrong tracks, extra circuitry along the wiring harness to cover for missing components and software solutions to cope with hardware specific problems. A reliability problem on the command and data handling protocol (I^2C) has not been fully solved, although it did not have any impact on the mission success.

For Delfi-n3Xt it is decided to start bread boarding and prototyping early in the detailed design phase, taking several design iterations of electrical circuits and PCB design into account. Special emphasis is placed on the reliability of the interfaces between the subsystems, like the I^2C communication between the onboard computer en the local subsystem controllers and the electrical power supply system. Both interfaces are using node protection circuits at each electrical subsystem to ensure the overall reliability of the system and avoid single points of failure.

The mechanical design of the PCB's for Delfi-n3Xt has been reduced to 90X90 mm with a symmetrical hole pattern and fixed locations for the connectors. With a slightly smaller PCB more room is available between the structure and the PCB's for the magnetorquers and electrical harness.

Experience in testing

The solar panels of Delfi-C^3 were tested on two locations, i.e. during manufacturing and acceptance at Dutch Space with the VLASS facility and during satellite (sub-) system testing at TU Delft using a theatre lamp. The latter was not successful for the performance tests, due to the mismatch spectral distribution of the light in combination with the triple junction solar cells.

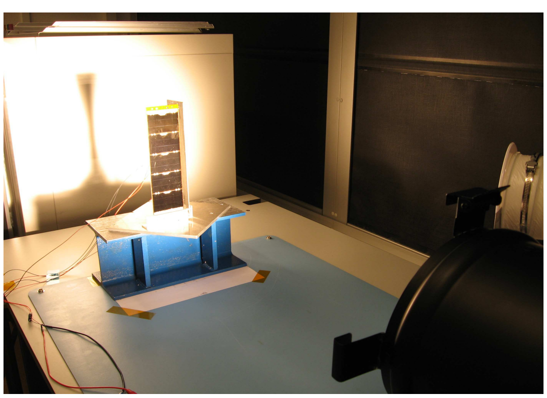

Figure 6 Solar panel measurement set-up with theatre lamp

Also inhomogeneous illumination and warming up of the solar cells and the TFSC influenced the test results. The lower intensity of the lamp was not a real problem in this respect. Nevertheless the set-up could be used to do functional performance to check responses. On Delfi-C^3 the solar panels are mounted two by two on both ends of the satellite under an angle of 35°. This is because the satellite is tumbling in space on purpose and this way optimum power can be obtained. Representative electrical testing in the lab of the transition from one solar panel to the other was not possible. It was partly replaced by the use of simulated power inputs on the solar panel connectors.

For future testing of solar panels a test set-up using e.g. a gas-discharge lamp with a more representative spectral light distribution and a higher intensity is currently under investigation.

Environmental testing

Delfi-C^3 was in the healthy situation, that it could get support for vibration testing and the thermal vacuum test form Dutch industry and institutions. We visited all facilities in time to prepare the test both in flight and support hardware and documents as for example plans and procedures. This approach did pay off well.

The tests were done in good cooperation and were successful and therefore the team would be very happy to continue on this basis in the future. The students learned a lot from these tests and can have benefit of these in their future careers. Especially when things do not go as planned a lot can be learned; as for example the regular interruptions during vibration test by very high responses in the accelerometers. It appeared that the push-out spring of the POD was rattling against the walls of the POD. After the application of some glass cloth tape locally on these locations of the walls, the high responses were reduced and testing was continued flawlessly.

In a late stage of the Delfi-C^3 program it was decided, that a calibration of photo diodes present on the solar panels needed to be done at the launch site. So a portable test set-up was made for this (see Figure 7). Illumination of the photo-diodes was done with a LED flash torch to be independent of electrical power. Though the response of the photo diode on the LED light was excellent, the output of the LEDs was very dependent on warming up of the LEDs and the battery load level. Using a stabilized power supply would have been better. Nevertheless repeated measurements showed that the achieved accuracy achieved was about 0.5°, where 2° were acceptable for the project.

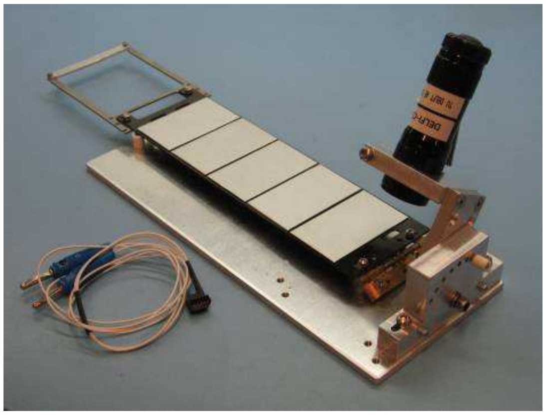

Figure 7 Calibration set-up photo diode (with dummy solar panel in jig)

Mechanical Ground Support Equipment (MGSE)

In the design period of Delfi-C^3 quite some effort was paid to MGSE in parallel. A successful item was the integration jig. It supports horizontal and vertical access to the satellite; with and without the tube. The design was made modular in order to be able to use it on more projects without major modifications.
Other MGSE items made are a development test set-up for solar panel deployment test, vibration adaptor and a handling tool for insertion into the X-POD. Furthermore a number of tools have been made: assembly and installation tools, manufacturing-, drilling- and calibration jigs. For Delfi-n3Xt they might be used again with or without modification.

Figure 8 Integration jig

Electrical Ground Support Equipment (EGSE)

For Delfi-C3 there was some electrical ground support equipment available, like external power supplies, radio receivers, payload simulators and command and data handling interfaces and monitors. Although they were very useful, they were sometimes not representing the real conditions of the satellite, making proper end-to-end testing very difficult. For Delfi-n3Xt, electrical ground support equipment should be part of the whole design phase of the satellite.

The ground station for Delfi-C3 yields professional rotating antennae on top of the tallest building of the TU Delft, receivers for the VHF downlink, and a 400W amplifier for UHF uplink. It has been performing flawlessly and could be used without iteration for Delfi-n3Xt UHF and VHF frequencies. It needs to be complemented with an S-band receiver and antenna for the high speed downlink of Delfi-n3Xt.

Organizational aspects

We have seen that the predicted launch for Delfi-C^3 was delayed a few times for a number of reasons. This has an effect on the progress and the continuity of the project and in particular when students are involved in relevant tasks, because they graduate and are often not available anymore for supporting the launch and operations. Therefore sufficient knowledge and experience should remain available with the permanent staff to be able to finalize the project.
A related aspect is that reporting within a student project shall be done more consequently. For students, being enthusiastic, they want to go on and on with testing etc. and state that reporting will be done afterwards. And then the important points may disappear from memory. For the next project reporting must be improved to retain the results in a better way.

In-flight experiences

Signals from the Delfi-C^3 satellite were successfully acquired shortly after launch by amateur radio operators worldwide, and shortly after also by the Delfi-C^3 ground station. Satellite commissioning was completed in 2 days, in which all important functions were successfully tested. A worldwide distributed network of amateur radio operators has so far gathered over 90MB of payload data, and data is still contributed by them on a daily basis.
At a certain moment in flight the linear amateur radio transponder failed. A redundant transponder could have prevented loss of this service to the radio amateurs. We planned to fly a redundant transponder, but this last function was scrapped prior to launch on the PCB due to an unrecoverable PCB design error. The transponder failure has been pinpointed to the receiver frontend, indicating an open circuit somewhere in the chain from the uplink antennas to the first down conversion stage. At present, the satellite is still operational transmitting science payload data.

Temperature measurements

Already during thermal vacuum test on ground we experienced that it would have been practical for the interpretation of results to have more temperature measurements on the inside of the satellite itself. Applying thermocouples inside the satellite is disadvantageous because of thermal leaks between the satellite and the chamber. Thus more temperature sensors should be incorporated in the electronics for Delfi-n3Xt. This also may support any problem investigation in flight.

Miscellaneous notes

The Delfi-C^3 project had a very good cooperation with the Dutch industry and institutions. Cooperation took place in the field of testing, delivery of small quantities of space grade materials (often from left-over's, which are most times sufficient for nano satellites), advices and in-orbit testing of new hardware solutions. Furthermore sponsoring was obtained in the production of flight hardware and software usage. In turn industry and institutions may have possibilities for early flight opportunities to test new developments at relatively low cost. It is worthwhile to have and maintain these relations, because it works out beneficial for both parties.

We have noticed, that the majority of the students, that have been involved in the project could rather easily get a job in domestic space industry and abroad. Also other industries show much appreciation for students with hands-on experience.

DELFI-N3XT CONFIGURATION

Table 1 gives an overview of the similarities and the differences of the two nano satellites of TU Delft (see Table 1).

Table 1 Comparison between Delfi-C^3 and Delfi-n3Xt

	Delfi-C^3	**Delfi-n3Xt**
General Characteristics	• 1^{st} Dutch University Satellite (4th Dutch satellite) • 3 unit CubeSat • 8 deployable antennae • 4 Deployable solar panels • Single point failure free • Sun powered without battery	• 2^{nd} Dutch University Satellite • 3 unit CubeSat • 4 Deployable UHF/VHF antennae • 1 S-band antenna • 4 Deployable solar panels • Single point failure free • Sun powered with battery
Attitude Determination & Control	• Passive rotational rate damping • 2 magnetic hysteresis rods • 1 permanent magnet • 4 photodiodes on solar panels • 2 wireless sun sensors	• Active 3-axis control • 2-axis sun pointing • 1-axis for payloads & S-band antenna • 6 redundant photodiodes on body • 1 fine sun sensor (30x30x17 mm^3, mass <60 gr.) • 4 micro sun sensors as payload option • 3 MEMS gyros and 3 magnetometers (COTS) • Reaction wheels & 3 magnetorquers (TUD)
Command and Data Handling	• Pumpkin FM430 Onboard Computer, (TI MSP-430 at 8 MHz) • 17 local microcontrollers, (PICs at 31 kHz - 20 MHz) • I^2C bus, max. 15 kbps • Decentralized backup mode • Integrated redundant system bus	• 2 redundant OBCs, TI MSP-430 at 8 MHz • 20 local μCs,MSP-430s at > 1 MHz • I^2C bus, 100 kbps • Fault-tolerant design • Redundant Kapton flex-rigid system bus with Harwin connectors as physical harness
Communication	• 2 UHF-VHF radios • 1 linear transponder for radio amateurs • 4 VHF antennae (omni-directional) • 1200 bps VHF downlink • 4 UHF antennae (omni-directional) • UHF uplink	• UHF-VHF radios, 1 primary, 1 ITRX • linear transponder for radio amateurs • 1200 - 9600 bps VHF downlink • UHF uplink • 9.6 – 250 kbps S-band downlink (TUD) • 4 shared UHF-VHF antennae (omni-directional; Delfi-C^3 design) • 1 S-band patch antenna (uni-directional)
Electrical Power	• 4 panels in omni-directional configuration • 2.4 W of guaranteed power • Direct energy transfer method • No battery • 12 V standard bus • System tolerance for discontinued power	• 4 panels in same plane • 18 W max power, 10 W on average • Maximum power point tracking method • 4 Li-ion batteries; failure of battery causes degradation instead of total failure • Single point failure free electrical power system • 12 V standard bus & variable voltage bus

	Delfi-C^3	Delfi-n3Xt
Ground Station	• Mission ground station and operations centre at Delft University • Back-up ground station at TU Eindhoven • Distributed global radio amateur network, using RASCAL software	• Mission ground station and operations centre at Delft University • Back-up ground station at TU Eindhoven • Distributed global radio amateur network • GENSO (TBC) • Data collected, filtered and processed real time at Delft Central Data Server • 'DUDe' radio amateur client for telemetry reception, decoding and visualization
Mechanisms	• Autonomous reliable deployment system • 4 deployable solar panels • 8 deployable antennas in modular boxes	• Autonomous reliable deployment system • 4 deployable solar panels • 4 deployable antennas in modular boxes
Structure	• 3U CubeSat structure from Pumpkin	• 3U Custom designed CubeSat structure
Thermal Control	• Passive thermal control • Heat sinks and thermal tapes	• Passive thermal control • Heat sinks and thermal tapes
Number of payloads:	• Three (TFSC, AWSS, RAP)	• Five (ITRX, MPS, SDM, SPLASH, $T^3\mu PS$) • Two options (μSS, OLFAR)
Orbit	• Sun-synchronous orbit • Inclination: 97.8 degrees • Altitude: 635 km • Local time 9:30 hrs.	• High Inclination orbit • Altitude: 500-800 km • Local time: TBD hrs
Physical properties	• Mass: 2.2 kg • Stowed: 118 X 118 X 340.5 mm • Antennae deployed: 770 X 770 X 800 mm	• Mass: approx. 3.5 kg • Stowed: 118 X 118 X 340.5 mm • Antennae deployed: 707 X 707 X 340.5 mm
Launch	• Launch broker: UTIAS • Launch vehicle: PSLV-C9 • Launch base: Sriharikota, India • Actual launch date: 28 April 2008	• Launch broker: unknown • Launch vehicle: unknown • Launch base: unknown • Launch date: 2010/2111

PAYLOADS ON DELFI-N3XT

At the start of the project a call for payloads was issued to the Dutch industry and scientific institutions to propose candidate payloads. From the proposals the following payloads were selected:

- A High Efficiency Transceiver (ITRX) to test the UHF-VHF transceiver with switching power amplifier in orbit. This transceiver is under development at Innovative Solutions In Space B.V. (ISIS) and is specifically intended for use on CubeSats.
  The key characteristics are: VHF downlink in 145 MHz radio amateur band, UHF uplink in 435 MHz radio amateur band, 1200–9600 bps downlink data rate, 1.5 W total power consumption and 400 mW RF power.
- A in-flight demonstration of the Multifunctional Particle Spectrometer (MPS), which will be able to detect and differentiate the energy level, type and incidence angle of the individual incoming radiation particles. The MPS is under development at cosine B.V.
  The key characteristics are: detection of γ, e-, p+, 3He, 4He, C, N, O and Ne particles, 10° incidence angle accuracy, 3 W total power consumption and 80 mm x 80 mm x 65 mm in size, mass about 0.5 kg. The experiment will be mounted directly on the intermediate platform.
- In-orbit proof of concept of radiation tolerant implementation of commercial flash memory cards, with latch-up protection and error detection and correction (EDAC).
  The key characteristics of the SPLASH experiment prepared by the NLR are: 2 x 4 GB of data storage (expandable), 1 W of maximum power consumption, approx. 50 x 50 x 10 mm
- Space-qualification of cold-gas micro propulsion system ($T^3\mu PS$) with gas produced by cold gas generators. Developed by TNO in collaboration with TU Delft and University of Twente, the Netherlands (see Figure 9). The key characteristics are: a fixed thrust level, selectable at manufacturing between 6 and 150 mN. The N_2 propellant is stored in cool gas generators (CGG), which require 11 W ignition power for ~10 s. Gas generator characteristics: 8 mm diameter, 20 mm long, mass: 2 grams, 0.1 normal liters of nitrogen per gas generator. The mass is less than 140 grams and its dimensions are 90 x 90 x 21 mm. The unit is not

pressurized at launch and therefore very safe. *[9, Muller 2009]*

Figure 9 Prototype of micro-propulsion experiment

- Low cost in-orbit verification of lab research on 14 hydrogenated amorphous silicon solar cells for degradation by radiation. I-V curves and temperature are measured. The experiment (SDM) is being build by DIMES.

In Delfi-n3Xt an of-the-shelf fine sensor, provided by TNO, will be used to acquire the attitude towards the sun. Beside an offer is being considered to fly a set of four micro sun sensors as an optional experiment. These can be combined with the fine sun sensor into a common housing and can be used as a redundant set.
For coarse sun sensing on all side of the satellite redundant sets of photo diodes will be mounted. With al these sun sensors together delivering data, proper control algorithms need to be implemented.

As an optional payload another experiment crossed our path, being a prototype for Orbiting Low Frequency Array. OLFAR transfers low frequency signals from deep space, which can not penetrate the atmosphere of the Earth. The possibility of implementation is currently being investigated
The experiment might not take more room on a PCB than 30x30 mm and will use available communication lines of the satellite. Power usage is almost negligible. The experiment is under development at the Faculty of EEMCS.

CONCLUSIONS

Delfi-C^3 has been a challenging and interesting project for students, university and Dutch industry. Its objectives were fully met. Students had the opportunity to get hands-on experience on a real space project. With these experiences in their pocket many students were in the position to obtain more easily a job in industry.

With the Delfi-n3xt project as follow-on new challenges are set to gain more and new experiences also in other fields of operating a satellite in space, e.g. 3-axis attitude control, operation in eclipse, higher data rate, satellite pointing in relation to payload needs and ground tracking requirements.

The excellent relationship with industry partners, institutes and sponsors shall be maintained to the benefit of all parties.

ACKNOWLEDGEMENT

The author wishes to acknowledge all project members, partners (Dutch Space, MicroNed, SystematIC Design, NLR, TNO Science and Industry) and sponsors, which made Delfi-C^3 a success. Many of them and new partners are already busy with its successor.

ABBREVIATIONS AND ACRONYMS

ADCS	Attitude Determination & Control Subsystem
AWSS	Autonomous Wireless Sun Sensor
BEng	Bachelor of Engineering
CDHS	Command & Data Handling Subsystem
CGG	Cool Gas Generators
DIMES	Delft Institute of Microsystems and Nano-electronics, The Netherlands
DS	Dutch Space B.V. Leiden, The Netherlands
EDAC	Error Detection And Correction
EECMS	Electrical Engineering, Mathematics and Computer Science
GENSO	Global Educational Network for Satellite Operations
I^{2}C	Inter-IC communication
ISIS	Innovative Solutions In Space B.V. Delft, The Netherlands
ITRX	ISIS Efficient Configurable Transceiver
MPS	Multifunctional Particle Spectrometer
MSc	Master of Science
NLR	National Aerospace Laboratory, NLR Flevoland, Marknesse, The Netherlands
OLFAR	Orbiting Low Frequency ARray
POD	Pico satellite Orbital Deployer
PSLV	Polar Satellite Launch Vehicle
RAP	Radio amateur Platform
RASCAL	Radio Amateur Satellite Caller Autonomous Logger
RD	Reference Diode
SDM	Solar Degradation Measurement
SPF	Single Point Failure
SPLASH	Space Flash Protection Experiment
T3µPS	Micro-Propulsion System
TFSC	Thin Film Solar Cell
TNO D,S&S	TNO Defense, Security and Safety Rijswijk, The Netherlands
TNO S&I	TNO Science and Industry Delft, The Netherlands
TUD	Delft University of Technology, The Netherlands
UTC	Coordinated Universal Time
UTIAS SFL	University of Toronto Institute for Aerospace Studies Space Flight Laboratory, Canada
X-POD	Experiment Pico-satellite Orbital Deployer
µSS	Micro Sun Sensor

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