

THE DELFI-N3XT NANOSATELLITE: SPACE WEATHER RESEARCH AND QUALIFICATION OF MICROTECHNOLOGY

S. de Jong⁽¹⁾, E. Maddox⁽²⁾, G.J. Vollmuller⁽³⁾, C.A.H. Schuurbiers⁽⁴⁾, R.A.C.M.M. van Swaaij⁽⁵⁾,
W.J. Ubbels⁽⁶⁾, R.J. Hamann⁽¹⁾

⁽¹⁾Chair of Space Systems Engineering, Faculty of Aerospace Engineering, Delft University of Technology,
Delft, The Netherlands, Sybren.deJong@student.tudelft.nl, R.J.Hamann@tudelft.nl

⁽²⁾Cosine Research BV, Leiden, The Netherlands, E.Maddox@cosine.nl

⁽³⁾National Aerospace Laboratory (NLR), Marknesse, The Netherlands, Vollmull@nlr.nl

⁽⁴⁾TNO, Delft, The Netherlands, Coen.Schuurbiers@tno.nl

⁽⁵⁾DIMES-ECTM, Delft University of Technology, Delft, The Netherlands,
R.A.C.M.M.vanSwaaij@tudelft.nl

⁽⁶⁾ISIS - Innovative Solutions In Space BV, Delft, The Netherlands, W.J.Ubbels@isispace.nl

Abstract

The Delfi-C³ nanosatellite successor, Delfi-n3Xt, is currently under development at Delft University of Technology and scheduled for launch in the first half of 2010. This improved three-unit CubeSat platform allows novel technology qualification for future small satellites and innovative scientific research. The platform is improved by implementing a high-speed downlink, three-axis stabilization and a single-point-failure free implementation of batteries in the electrical power subsystem. Apart from giving a description of the three main advancements, this paper also gives an overview of the five payloads: A microsystems technology based cool gas micropropulsion module, a multifunctional particle spectrometer, a set of hydrogenated amorphous silicon solar cells, an efficient transceiver module for nanosatellites, and a memory unit based on low-cost commercial grade flash memory cards with innovative radiation protection electronics. Although the accommodation of the five payloads in a nanosatellite of only (10 x 10 x 34) cm is ambitious, this paper shows feasibility and proves that nanosatellites are powerful instruments for the qualification of novel technology and innovative scientific research.

1 Introduction

The Delfi nanosatellite programme of the Delft University of Technology, in which more than 80 students have been participating, focuses on qualification of novel microtechnologies from the Dutch space industry [1]. The second satellite in this programme, Delfi-n3Xt, is currently in the first detailed design phase. This nanosatellite will be a three-unit CubeSat. Compared to the first satellite in this programme, Delfi-C³, Delfi-n3Xt will

additionally be equipped with batteries, an active attitude determination and control system (ADCS) and a high-speed S-band transmitter. Five innovative payloads will be accommodated for microtechnology space qualification and scientific research on space weather. Next to these mission goals, Delfi-n3Xt will be equipped with a radio amateur transponder to be used by the radio amateur community. This paper describes also the preliminary design and shows the preliminary design of Delfi-n3Xt.

2 Five Payloads

The call for payloads for this microtechnology space qualification mission resulted in thirteen proposals received from industry and research institutes. The payload assessment procedure resulted in the selection of five payloads that all can be accommodated in the nanosatellite of only (10 x 10 x 34) cm [2]. The selection is based on feasibility, educational value, services provided, innovation level and design impacts.

The five payloads that will fly on Delfi-n3Xt are:

The Cool Gas Micropropulsion system

This microsystems based thruster systems is under development by TNO, TU Delft and University of Twente.

Multifunctional Particle Spectrometer This payload is under development by cosine Research BV, which is able to capture radiation and giving the composition of it (type of particles, angle of incidence and energy).

Space Flash Memory NLR is developing a reliable and low-cost data storage solution based on COTS flash memory cards that is medium tolerant to radiation.

Hydrogenated amorphous silicon solar cells DIMES, which is part of TU Delft, does a lot of research and development on solar cells. This type of solar cell will be analyzed in space to improve lab research.

Efficient Nanosatellite Transceiver Module

ISIS BV is developing a transceiver module for future small satellites. This transceiver is based on the transceiver of Delfi-C³ and will be qualified and tested on Delfi-n3Xt.

2.1 Cool Gas Micropropulsion system - TNO, TU Delft, UTwente

The micropropulsion system that will fly with the Delfi-n3Xt mission combines several innovations resulting in a highly miniaturized system which is part of the Dutch microtechnology program MicroNed [3, 4]. These innovations concern:

- Compact storage of the propellant in solid state,
- Highly integrated feeding and thruster system based on MEMS technologies.

The micropropulsion system is designed to supply thrust for orbit and positional corrections. The engineering model of the system is given in Figure 1. Thrust is delivered by gas under pressure; the system is of the cold gas blow-down propulsion type. The gas is stored in solid condition at ambient temperature and pressure within cool gas generator grains. In Figure 1A a gas generator grain is shown indicated by number 1. The current design supports 7 such grains and with some modifications this can be increased to 15. During launch the plenum (gas storage container, indicated by 2) is unpressurized and all gas is contained within the cool gas generator grains. When thrust is required the first cool gas generator grain is ignited pressurizing the plenum with cool, pure nitrogen gas to approximately 4.5 bars. The unique feature of this gas generation process is the release of gas at ambient temperature and the storage of all heat of the decomposition reactions in the gas generator system itself. Therefore immediate stable storage conditions are obtained after each gas generator firing (i.e. no pressure drop due to cooling down of the hot decomposition gas). This unique gas storage and release technology is under development at TNO for nitrogen, hydrogen and oxygen [5]. A nitrogen gas generator, with a different functionality, is scheduled to fly with the Proba-2 mission scheduled to be launched in the second quarter of 2009.

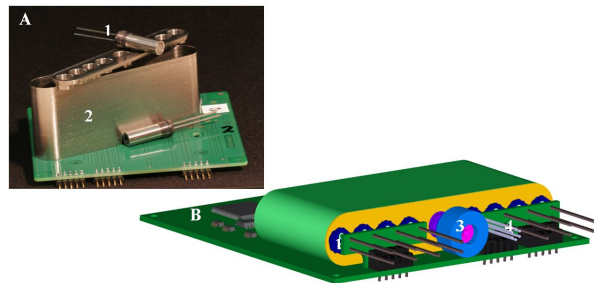


Figure 1: Engineering model (A) and a computer model (B) showing the cool gas generator micropropulsion system.

Using the valve and the nozzle short bursts of thrust can be delivered. When the plenum is depleted it can be refilled (when required) by igniting a second cool gas generator grain. In Figure 1B the microthruster system is shown with the cool gas generating grains integrated in the plenum as well as the valve with the nozzle (3) and the electrical interface (4). The high level of integration reduces the system size and mass. Currently an engineer-

ing model excluding the MEMS based integrated feeding and thruster system has been assembled and tested on functionality. A COTS valve integrated with a micro machined metal nozzle plate were used for this engineering model. The MEMS based valve and nozzle combination shown in Figure 2 is still under development at the University of Twente and is constructed using chip fabrication methodologies. The aim is to produce a valve/thruster combination measuring (15 x 15) mm in total.

In the next phase, besides implementing this new innovative valve-nozzle combination, the design will be optimized further with a focus on increasing the reliability and reproducibility, while reducing the energy requirements. The complete system will have a mass of ca. 120 g and will be (100 x 100 x 35) mm in size, which makes it an easy fit into CubeSat size satellites.

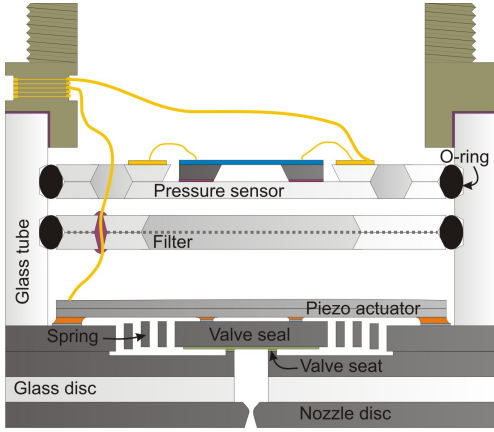


Figure 2: Schematic of thruster system (excluding electronics and the fine machined metal part).

During the Delfi-n3Xt mission the micropropulsion system will be present as a payload. The aim is to show the micropropulsion system is able to perform under space conditions and to prove that cool gas generator propulsion systems are a good and flexible option for use in small-scale satellites systems. During flight the following experiments will be conducted:

- Testing the behaviour of multiple ignitions of the cool gas generators,
- Functioning of the valve during a series of command cycles,
- Valve leakage measurements,

- Measuring the thrust and impulse bit generated.

After successful demonstration in space the payload will be further developed to become an easy-to-use off-the-shelf reliable “plug & play” component for positional control in small satellites.

2.2 Multifunctional Particle Spectrometer - Cosine Research BV

The multifunctional spectrometer (MPS) [6] has been designed as a new type of radiation spectrometer to safeguard the spacecraft and its payload and to obtain key diagnostic data. Since protons, electrons, ions and gamma-rays affect systems differently, it must have the ability to separate different particle species. Also since aging and damage effects are very much energy dependent, the device has to be spectrally sensitive over large energy ranges

The top-level instrument requirements for the MPS are listed in Table 1. The proposed base line design consists of a tracker and a scintillator. A 3D-drawing is shown in Figure 3. The tracker has two silicon pixel sensors with (30 x 30) mm active area. The area of a single pixel is (7.5 x 7.5) mm and the thickness is about 300 μm . The distance between the two sensors is 10 mm. The angle of incidence for charged particles which traverse both sensors can be reconstructed with an accuracy better than 10° . The specific energy loss (dE/dx) inside the trackers can be corrected for the angle of incidence. The total energy (E) is measured with a CsI(Tl) scintillator with the dimensions (34 x 34 x 34) mm. The CsI(Tl) scintillator is optically coupled to a large area photodiode. Particle identification can be performed by correlation of dE/dx and E .

The tracker system board is based on a Va32Ta ASIC (Application-Specific Integrated Circuit) from Ideas (Norway). This ASIC has 32 input channels with pre-amplification, shaping, sample-and-hold and an internal trigger. The readout of the ASIC is performed with a custom FPGA (Field-Programmable Gate Array) module [7].

A photodiode board has been designed and constructed. The photodiode signal is sampled and digitized at 100 MHz. The digital processing will be performed by an Xilinx FPGA. The FPGA is supported by the GR-XC3S Leon3 evaluation board from Gaisler Research (Sweden). A dedicated FPGA module has been designed and imple-

Table 1: Summary of the MPS specifications.

Parameter	Property, Value
Particle IDs	γ , e, p, ^3He , ^4He , C, N, O, Ne
Energy range of particles	Gamma-rays: 0.1 - 3 MeV
	Electrons: 1 - 20 MeV
	Protons: 1 - 200 MeV
	Alphas: 5 - 400 MeV
E resolution ($\Delta E/E$)	Gamma-rays: 10%
	Electrons: 20%
	Protons, Alphas: < 5%
Count rate	Particle counting: ≤ 10 MHz
	Particle ID mode: ≤ 1 MHz
Aperture	45°
Mass	< 1.25 kg
Power	< 1.5 W
Volume	< 1000 cm ³

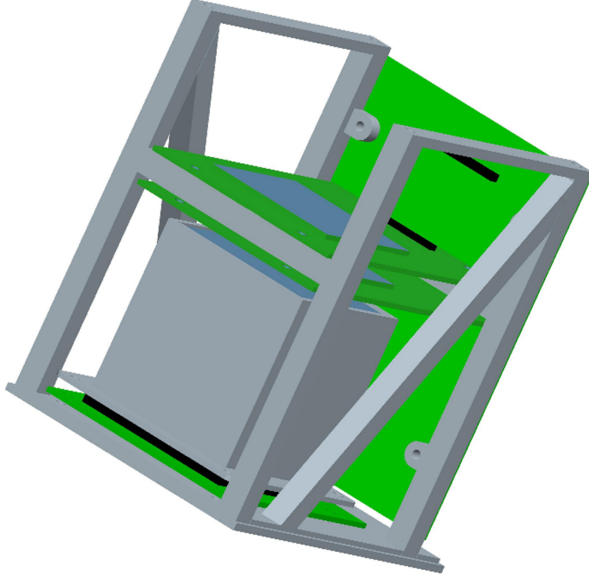


Figure 3: 3D drawing of MPS.

mented for digital filtering of the scintillator signal [7, 8]. First pulse height spectra have been recorded with this system.

The inclusion of MPS on Delfi-n3Xt is, besides an excellent test opportunity to fly and test such a device, useful for scientific reasons. Particle identification and energy reconstruction in a large energy range will be available in the low earth orbit. Regions with high particle fluxes are the Polar regions and the South-Atlantic anomaly. The correlation of particle types and fluxes as a function of the solar activity is important to study various space weather phenomena. At this orbit differences in

east and west bound fluxes are expected at equatorial regions because of atmosphere effects. To perform these measurements, the instrument should face away from the Earth at the Polar regions and should face eastward or westwards at the equatorial region. The orientation of Delfi-n3Xt should therefore be well known. Also the effect on the pitch angle of east and west bound particles can be studied. cosine is currently developing the multi-channel readout for the silicon sensors and involved in calibration tests of prototype components at accelerator facilities.

2.3 Space Flash Memory - NLR

The NLR experiment, installed on Delfi-n3Xt, is called SPLASH (SPace FLASH). In space systems, there is an increasing demand of data storage. Several space qualified memory chips are available, but their memory capacity is limited and very expensive. Especially for nano satellites, COTS memory would be of great benefit. However, COTS memory is sensitive for radiation: Single Event Upset (SEU, also known as bitflip), Single Event Latch-Up (SEL, destructive) and Total Dose (causing electrical degradation).

The NLR SPLASH system will be based on secure digital (SD) memory cards, but with additional electronics to make the storage medium immune for radiation (with a nanosatellite lifetime of maximum 2 years). For SEU, additional redundancy bits together with the data will be stored to the SD memory; upon reading the system will extract the data and correct for SEU if needed. For the higher level systems like the Delfi-n3Xt Data Handling Subsystem, the data storage will be transparent. To prevent latch-up additional miniature electronics will be implemented for protection of the SD-cards. The envelop of this system is approximately (50 x 50 x 10) mm.

During its operation, it will measure the amount of SEU and SEL events and count the amount of successful corrections. In the autonomous mode, the SPLASH controller will generate pseudo-random data and write this to the SD cards. After a certain time, the data will be read back from the SD cards and compared with the pseudo-random data. The counter results will be sent to the ground for analysis. This will not only give an indication of the sensitivity of SD memory for radiation in low orbits but, more important, also show the effectiveness of the protection electronics.

As an additional feature, SPLASH can operate in the storage mode, in which the pseudo-random data generation is disabled. In this mode SPLASH acts as a real data storage medium for the other Delfi-n3Xt experiments.

Finally SPLASH will provide a data storage system that is perfectly suitable for implementation in small satellites: cheap, modular and it can sustain radiation in low Earth orbits (LEO).

2.4 Hydrogenated amorphous silicon solar cells - DIMES

Hydrogenated amorphous silicon (a-Si:H) solar cells have great potential for application in space, because these solar cells can be produced inexpensively, are lightweight, and are relatively radiation hard. In a space environment the solar-cell performance degrades partly due to high-energy charged-particle irradiation [9, 10, 11] and partly due to the effect prolonged illumination, the so-called Staebler-Wronski effect [12]. On the other hand, at elevated temperatures the performance degradation is to some extent neutralized. For the utilization of these solar cells in space it is necessary to be able to predict their End-Of-Life (EOL) performance for a given mission in which they are exposed to electron and proton irradiation having a wide range of kinetic energies and for this reason a computer model was developed at Delft University of Technology [13].

When a-Si:H is irradiated by high-energy charged particles, defects are created in the material that will seriously affect the conductive properties [9]. Recently, it was reported that these defects are created by direct interaction of the charged particles with the lattice [14]. In order to predict the effect of this defect generation on the performance of a-Si:H solar cells a computer model was developed [13]. In this model first the change in defect density as a function of position in the solar cell was calculated. In this way a new defect density profile is obtained, which in turn is used to calculate the solar-cell performance after defect creation. This model was first successfully used to simulate the performance of a-Si:H solar cells following light soaking [14] and has since then been applied to simulate the performance degradation after charged-particle irradiation [13].

On the Delfi-n3Xt satellite a-Si:H solar cells will be mounted in order to investigate the change in per-

formance in space. The main objective of this experiment is to monitor the change in solar-cell performance during the first year of the mission and to compare the performance degradation to computer modeling results. In this way we intend to verify and improve the computer model and create a knowledge base for application of these solar cells in space. In addition, this experiment will contribute to the understanding of defect formation in a-Si:H devices. For this experiment the performance of a number of solar cells will be monitored by determining the current density versus voltage curve for a limited number of voltages. By comparing the power output of the solar cells to a reference cell, the conversion efficiency is obtained. Parallel to this experiment, solar cells will be tested in the laboratory in order to improve the computer model. This payload for Delfi-n3Xt is called the SDM experiment which stands for Solar cell Degradation Measurement experiment.

2.5 Efficient Nanosatellite Transceiver Module - ISIS BV

An efficient and modular transceiver module based on the transceiver of Delfi-C³ will fly on Delfi-n3Xt. It is called ITRX which stands for ISIS transceiver. The main improvement of this transceiver in contrast to the former version is a high efficiency power amplifier. The other intention is a highly modular interface design.

The frequency bands used by the ITRX are VHF for downlink and UHF for uplink. The data rates are 1200 bps for uplink and a maximum of 9600 bps for downlink, which can be variable. The power amplifier (PA) of ITRX will be more efficient than the PA used on Delfi-C³. The maximum transmitter power will be at least 400 mW, but the transmitter power may be varied by a command from the satellite. This is useful for situations when less power is available for transmission.

Main goal of the experiment is to qualify the highly efficient transceiver. Besides flying as a payload, the uplink receiver of the ITRX can be used as a backup command receiver for commanding the satellite. Furthermore, the transceiver will be used for ranging purposes, whereby the transceiver acts as a transponder, and range and range-rate measurements can be taken. Goals of this ranging experiment are to determine the actual accuracy

which can be obtained, to see whether Total Electron Content (TEC) models can be used to remove biases introduced by propagation of the radio waves through the ionosphere and to investigate how these measurements can aid in the orbit determination of nanosatellites, which at the moment can be relatively complex due to their small Radar Cross Section (RCS).

3 Mission

Delfi-n3Xt is scheduled for launch in the first half of 2010. After launch, the payload experiments as described in the previous sections will be conducted as soon as possible. Next to these experiments that are requested by the payload partners, other mission goals related to interesting science and radio amateur service are under consideration.

3.1 Scientific research opportunities

Once the MPS has performed the tests for qualification, MPS can be used for scientific research on the field of space weather. Opportunities are:

- Analysis of the correlation of cloud forming and incoming radiation in Earth's atmosphere,
- Analysis of radiation pattern at LEO,
- Analysis of radiation fluctuations during Solar flares,
- Statistical research of the correlation of the measured particles and radiation, solar cell degradation and event count of SPLASH.

The research on the correlation of cloud forming, radiation from space and solar activity is a controversial and not yet well-understood topic in climate change research. Several studies, e.g. [15] shows an alternative cause of the climate change in contrast to the human influence on the green house effect. This study shows that total cloud cover and solar modulated galactic cosmic ray (GCR) flux are correlated. MPS could contribute to this research field by the analysis of radiation level, type and origin.

The same scientific data could be used to analyse the radiation pattern in the orbit of Delfi-n3Xt. Interesting regions are latitudes between 45° and 85° (North and South), at the equator and the South Atlantic Anomaly. The influence of the solar activity on the radiation characteristics that can be measured is an interesting topic.

The data of SPLASH and the SDM experiment are expected to be dependent on the radiation flux that enters Delfi-n3Xt. The correlation between the data of those two payloads and the data of MPS is very interesting. The exact scientific mission goal is not set yet. The most interesting research topic will be chosen in combination with the feasibility within the tight constraints of this nanosatellite.

3.2 Amateur radio transponder

The Delfi-C³ is a great success that has been made possible by the great number of radio amateurs all over the world receiving and forwarding the telemetry. As return favor for this support and the use of amateur radio frequency bands, a linear transponder is active since the fourth month of Delfi-C³'s lifetime. Many radio amateurs are very happy with the good quality of this transponder.

Delfi-n3Xt will fly the same linear transponder. The activation of this transponder will be as soon as possible after launch. Unlike Delfi-C³, the qualification of micro technology and science mission will be performed parallel to the transponder service as long as the power budget and other technological constraints allow. As an extra return service for the radio amateur community, an S-band beacon is under consideration.

3.3 OLFAR transponder

Complementary to the amateur radio transponder, an OLFAR transponder function is under investigation. OLFAR stands for Orbiting Low Frequency Antenna for Radio astronomy. The additional receiver will receive signals via the VHF antenna in various bands below 30 MHz that will be linked down via the VHF transmitter. OLFAR is a supplemental system of the LOFAR project in Europe.

In the Northern part of the Netherlands ASTRON will build the largest radio telescope in the world for low frequencies, the Low Frequency Array (LOFAR) for radio astronomy [16]. LOFAR detects the incoming radio signals by using an array of simple omnidirectional antennas. A total of seventy-seven stations will be built within a circle of 150 km in diameter. The lower bound of the received signal frequency is limited by atmospheric constraints. RF signals below 30 MHz are unable to penetrate the atmosphere and can therefore not be received on ground. Reception of these signals outside the

atmosphere for downlink to Earth at another frequency has never done before and is very interesting for the LOFAR scientists as well as for radio amateurs receiving the signals. A relatively simple transponder function on Delfi-n3Xt could be implemented. The received signals could be transmitted by the linear transponder, so that the footprint of this experiment is low.

4 Subsystems

Six subsystems are defined to support and facilitate the five payloads. The subsystems are described in this section.

4.1 Electrical Power Subsystem

The electrical power subsystem (EPS) will power Delfi-n3Xt by the use of four solar arrays in a single plane pointed to the sun and batteries as secondary power supply and storage. The addition of batteries is a Delfi platform advancement. In Delfi-n3Xt the batteries will be used for power in eclipse and peak power deliveries during a high-speed downlink and payload peak loads. Like Delfi-C³ the EPS is decentralized: a single power bus of 12 V with switching at each board. In addition to the 12 V bus, a variable power line will be available for a new type power amplifier that will be discussed in the next section.

4.2 Communication Subsystem

The communication subsystem (COMMS) of Delfi-n3Xt [17] consists of four main parts; a primary transceiver (PTRX), the ITRX payload, a high-speed S-band transmitter (STX) and the antenna system. The PTRX is based on the transceiver on Delfi-C³. Few improvements will be made and probably a LOFAR transponder will be implemented on this transceiver. PTRX can be used as amateur radio transponder and ITRX will optionally be used for the low-speed downlink of data in this case. The UHF-band will be used for uplink and the VHF-band for downlink. STX is a Delfi platform advancement that will be able to transmit mission data at a high-speed to the ground station(s) using S-band. The data rate of this link will be at least 9600 bps but if power and technology allows, the data rate will be increased. The STX is equipped with a switching-mode power

amplifier of which the output power can be adapted to the available power. A variable power dump line (variable voltage) will be implemented to use all available power.

The antenna system consists of at least nine antennas. Four UHF uplink antennas are positioned alongside the solar panels, and four VHF downlink antennas are mounted canted turnstile at the far end of the satellite in the same way as on Delfi-C³. The high-speed S-band downlink will use one or multiple patch antennas. It is currently not defined if ground station pointing and tracking will be performed during downlinking.

4.3 Attitude Determination and Control Subsystem

An active attitude determination and control subsystem (ADCS) will point Delfi-n3Xt to the Sun to obtain maximum power from the solar panels. This active ADCS is a Delfi platform advancement and will also be able to perform ground station tracking. The ADCS will make use of a Sun sensor, magnetometers and gyros for attitude determination and magnetotorquers and reaction wheels for attitude control. The ADCS algorithms will be performed by a dedicated computer on the ADCS to keep the system modular and as autonomous as possible.

4.4 Command and Data Handling Subsystem

The command and data handling subsystem (CDHS) of Delfi-n3Xt consists of a single onboard computer (OBC) with data storage, software, the data bus, deployment control systems, satellite health sensors and local power switching on subsystems [18].

The OBC will consist of a single microcontroller and data storage. Its tasks are controlling the satellite and collecting payload and house keeping data. No full identical redundant OBC will be implemented since common mode failure can still occur and can therefore be a single-point-failure (SPF). A redundancy measure for the OBC will be placed on the primary transceiver. The telecommand interpreter on the PTRX which consists of a microcontroller will include an algorithm that is capable to control the subsystems autonomously or by ground command in case of an OBC failure.

The databus of Delfi-n3Xt will be a single 100-kbps

I²C bus. This databus will physically be a doubled. The choice for the I²C standard was mainly based on the experience and on the simplicity to implement this bus in combination with decentralized power switching and deployment systems. It is intended to use standard I²C chips (e.g. I/O expander PCF8574) for these functions. All nodes on the databus will be connected by a bus protector which is a buffer with a time out circuit. This protector will isolate a node from the bus if this node hangs up the databus.

4.5 Thermal Control Subsystem

The thermal control subsystem (TCS) of Delfi-n3Xt is assumed to be passive in the preliminary design. Only if further analysis indicates that the constraints become to stringent to cope with, active thermal control will be included.

4.6 Structural Subsystem

The structure of Delfi-n3Xt will be a similar rod system as Delfi-C³. Testing, integration and inspection was however difficult for Delfi-C³. The structure of Delfi-n3Xt will therefore be improved on the aspects of assembly and accessibility for inspection. One of the improvements are detachable side panels instead of a stack that can be slid into a tube.

5 Conclusion & Configuration

This paper shows that university nanosatellites of only (10 x 10 x 34) cm are powerful enough to space qualify five microtechnology payloads. Besides space qualification, scientific research on space weather aspects as radiation patterns in LEO will be performed parallel to presenting a linear transponder to the amateur radio community.

Figure 4 shows the preliminary configuration and layout of Delfi-n3Xt. All PCBs will be stacked using rods and the solar panels will deploy using spring-hinges at the short sides like Delfi-C³. The difference with Delfi-C³ is the configuration of the solar panels and a much denser interior shown in Figure 5.

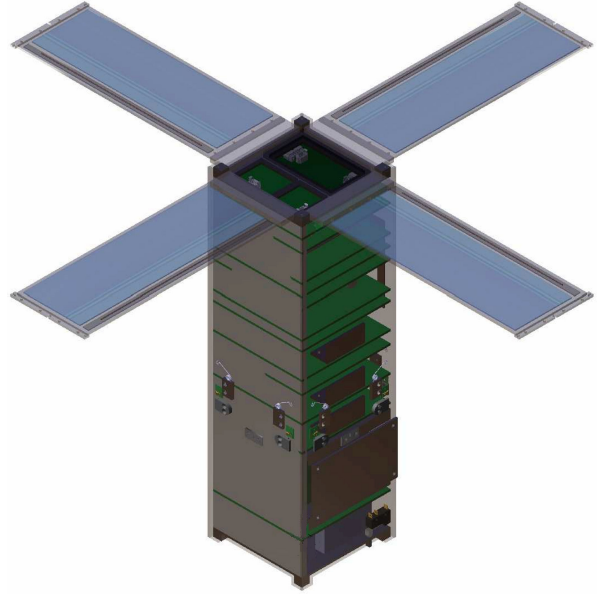


Figure 4: The external configuration of Delfi-n3Xt with deployed solar panels and undeployed VHF downlink antennas.

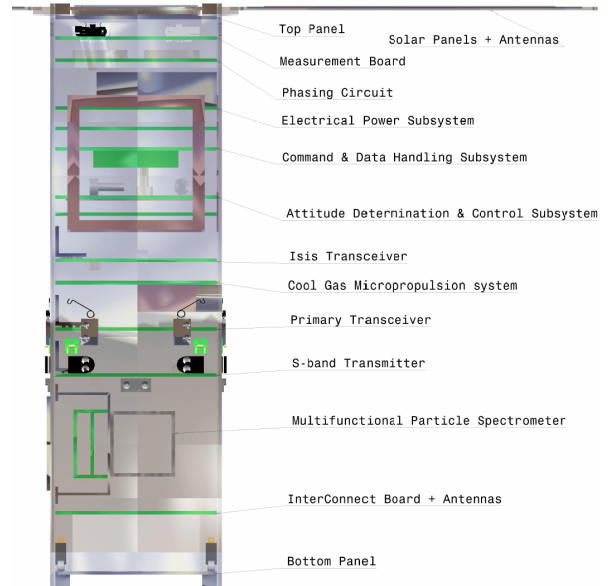


Figure 5: The internal configuration of Delfi-n3Xt.

References

- [1] R.J. Hamann, C.J.M. Verhoeven, A.A. Vaartjes, and A.R. Bonnema. Nano-satellites for micro-technology prequalification: The delfi program of delft university of technology. In *Selected contributions of the 6th IAA Symposium on Small Satellites for Earth Observations*, pages 319–330, Berlin, Germany, April 2007. Springer.
- [2] S. de Jong and R.J. Hamann. Trade-off procedure for payload selection in university small satellite projects. In *Proceedings of the 4S symposium: Small Satellites, Systems and Services (unpublished)*, Rhodes, Greece, May, 26-30 2008.
- [3] W. Jongkind. The dutch mst program microned and its cluster misat. In *Proceedings of ICMENS 2005*, Banff, Canada, 2005.
- [4] E.K.A. Gill, J.M.A. Monna, G.L.E. and Scherpen, and C.J.M. Verhoeven. Misat: Designing a series of powerful small satellites based upon micro systems technology. In *Proceedings of the 58th International Astronautical Congress*, Hyderabad, India, September 2007.
- [5] J.L.P.A. Moerel, H.M. Sanders, M.C. Louwerse, H.V. Jansen, J. Boscher, B.T.C. Zandbergen, F. La Torre, S. Kenjeres, and C.R. Kleijn. Development of micro propulsion system technologies for minisatellites in the netherlands. In *Proceedings of Space Propulsion 2008, 5th international spacecraft propulsion conference, 2nd international symposium on propulsion for space transportation*, Greece, May, 5-9 2008.
- [6] E. Maddox, A. Palacios, D. Lampridis, S. Kraft, A. Owens, D. Tomuta, and R. Ostendorf. Development of a multifunctional particle spectrometer for space radiation imaging, nuclear instruments and methods. In *Proceedings of the 9th International Workshop on Radiation Imaging Detectors*, volume 591, pages 121–124, June, 11 2008.
- [7] D. Lampridis, E. Maddox, S. Moon, S. Kraft, J. Elstak, and J. Rotteveel. Development of a multifunctional particle spectrometer for space radiation imaging, nuclear instruments and methods. In *Proceedings of the 4S symposium: Small Satellites, Systems and Services (unpublished)*, Rhodes, Greece, May, 26-30 2008.
- [8] D. Lampridis, S.D. Cotofana, and S. Kraft. High speed reconfigurable computation for electronic instrumentation in space applications. In *Proceedings of the 2007 IEEE/PRORISC Workshop*, Veldhoven, The Netherlands, November 2007.
- [9] J.R. Srour, G.J. Vendura, D.H. Lo, C.M.C. Toporow, M. Dooley, R.P. Nakano, and E.E. King. *IEEE Trans. Nucl. Sci.*, 2624(45), 1998.
- [10] J.E. Granata, T.D. Sahlstrom, P.E. Hausgen, S.R. Messenger, R.J. Walters, and J.R. Lorentzen. In *Proceedings of 31st IEEE-PVSC*, volume 607, 2005.
- [11] K.R. Lord, M.R. Walters, and J.R. Woodyard. The dutch mst program microned and its cluster misat. In *Proceedings of 23rd IEEE-PVSC*, volume 1448, 1993.
- [12] D.L. Staebler and C.R. Wronski. *Appl. Phys. Lett.*, 292(31), 1977.
- [13] A. Klaver. *Irradiation-induced degradation of amorphous silicon solar cells in space*. Delft University of Technology, Delft, The Netherlands, phd thesis edition, December 2007.
- [14] R.A.C.M.M. Van Swaaij and A. Klaver. *Non-Cryst. Solids*, 2462(354), 2008.
- [15] N. D. Marsh and H. Svensmark. Cosmic rays, clouds and climate. *Space Sci. Rev.*, 94:215–230, 2000.
- [16] S. Zaroubi and J. Silk. Lofar as a probe of the sources of cosmological reionization. *Monthly Notices of the Royal Astronomical Society: Letters*, 360(1):L64–L67, April 2005.
- [17] M. de Milliano and C.J.M. Verhoeven. Towards the next generation of nanosatellite communication systems. In *Proceedings of the 59th International Astronautical congress 2008 (unpublished)*, Glasgow, Scotland, September 2008.
- [18] S. de Jong, G.T. Aalbers, and J. Bouwmeester. Improved command and data handling system for the delfi-n3xt nanosatellite. In *Proceedings of the 59th International Astronautical congress 2008 (unpublished)*, Glasgow, Scotland, September 2008.