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**SMALL SATELLITE MISSIONS SYMPOSIUM (B4.)
Design and Technology for Small Satellites - Part I (6.A)**

OPTIMIZED THREE-UNIT CUBESAT STRUCTURE FOR DELFI-N3XT

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Abstract

For the Delfi-n3Xt mission, follow-up to CubeSat Delfi-C³ [1] of Delft University of Technology, several concepts concerning the Structural Subsystem (STS) have been analysed. One of the main objectives is to reduce the time needed for assembly, integration and testing, and to improve handling capabilities. Lessons learned from Delfi-C³ have been taken into account in a trade-off between several candidate design options.

A brief description of the structure of Delfi-C³ is given. Afterwards the candidate options for the STS of Delfi-n3Xt are discussed, followed by the final structure selection and implementation.

1 Introduction

Since the first CubeSat was designed and built, many followed. Their structure designs reveal a variety of possibilities, although some designs have constraints, e.g. by the use of a bought-out CubeSat kit. Based on the lessons learned from the first three-unit CubeSat of Delft University of Technology, Delfi-C³ (see Figure 1), several options for the structure have been investigated for the successor, Delfi-n3Xt. The structure of Delfi-n3Xt is to accommodate the five technological and scientific payloads [1] as well as the subsystems of Delfi-n3Xt.

Main issues from the Delfi-C³ have been the amount of time needed for assembly, integration and testing of the Printed Circuit Boards (PCBs) into the structure in relation to the restrictions set by the bought-out structure. A substantial number of adaptations and custom designed parts have been implemented as replacement for the standard kit parts of the bough-out structure. Furthermore a lot of time in the development phase was spent for the mounting, integration and testing of the PCBs.

The structural subsystem is an important subsystem in any satellite, providing support and protection to payloads, mechanical and electronic subsystems. An

optimum structure is not only able to accomplish the functions during mission life, but is also better to handle during the development of the satellite. The structural subsystem of the nanosatellite, Delfi-n3Xt, should allow for a smooth and more time-efficient assembly, integration and test. This also results in a reduction of risks during handling.

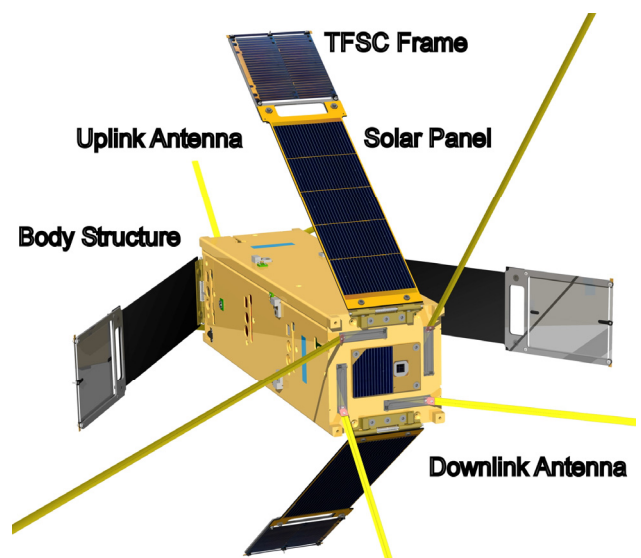


Figure 1 - Delfi-C³ flight impression

2 Delfi-C³

Delfi-C³ makes use of a bought-out CubeSat structure [3], consisting of a primary and secondary structure (see Figure 2). The primary structure consists of a tube chassis and top and bottom panel. The secondary structure consists of four rods and midplane stand-offs for better performance in stiffness. When the tube chassis is installed, there is very little access to the inside structure.

Integration and assembly took a lot of time for Delfi-C³. Delfi-C³ had a specific order for the integration of the PCBs. When a PCB from the middle of the stack had to be removed, the complete stack had to be disassembled. To reduce the time for assembly, integration and testing of PCBs and accessibility to the structure, concepts for the structure of Delfi-n3Xt have been explored.

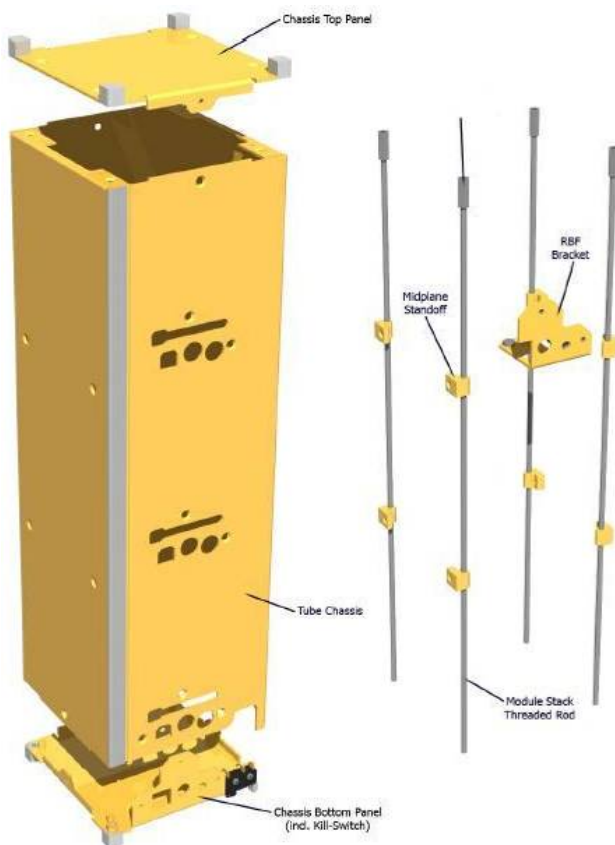


Figure 2 - Delfi-C³ primary and secondary structure

3 Design options

The known issues from Delfi-C³ have been focus points in a Structural Subsystem (STS) trade-off. The trade-off has been done between six different options, namely:

1. Card bus system
2. Rod system with detachable side panels

3. Male-female connectors with detachable side panels
4. Rod system with PCB side panels
5. Male-female connectors with PCB side panels
6. PCB box

The different options will be discussed from section 3.1. to 3.5.

For Delfi-n3Xt, a body fixed reference frame is used (see Figure 3). The reference frame is on the centre line of the satellite, beginning from the support feet at the bottom panel of the satellite. The Z⁺-axis is defined along the long side of the satellite in direction of the top panel. The X⁺-axis is the side where the system bus has attachments to the stack.

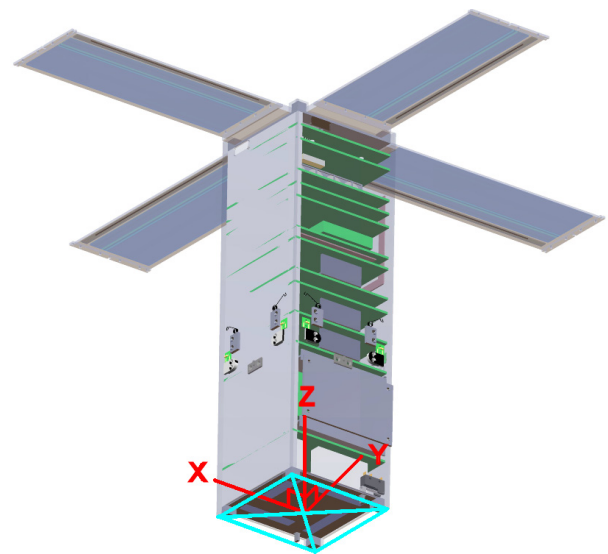


Figure 3 – Definitions used for Delfi-n3Xt

3.1 Card bus system

This option concentrates on the quick interchangeability of PCBs. An impression of this system is shown in Figure 4. Via the X-side panels the PCBs slide into the structure, where they are clamped to the sides. On the X⁺-side the PCBs are connected via a system bus. The system bus can be a cable or a panel with slots for the connectors. The X⁻ side is used to check whether the cable or structure is connected correctly. A separable X⁺- and X⁻-panel make the inner structure more accessible, therefore a cable is preferred above a slotted panel. The PCBs can be integrated and removed independently of each other from the structure. Disadvantageous for this system are the stiffness and stress for the PCBs during tests and launch. High mass with respect to the other options is also a drawback.

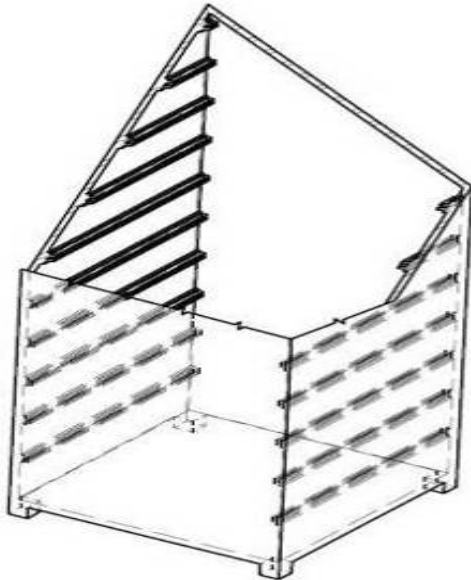


Figure 4 - Impression of card bus system

3.2 Rod system with detachable side panels

This option is a variation to the rod system of the Delfi-C³, but aims for better accessibility. The secondary structure consists of rods where the PCBs are stacked upon (Figure 5), but to have better accessibility after integration in this situation, unlike Delfi-C³, the X- and Y-side panels can be taken off. This means that removing PCBs for separate testing, modifications and/or replacing PCBs in this system is still time-consuming.

Advantageous for this option is that there is work-experience with a rod system and that the distance between PCBs can be easily varied with different bus lengths.

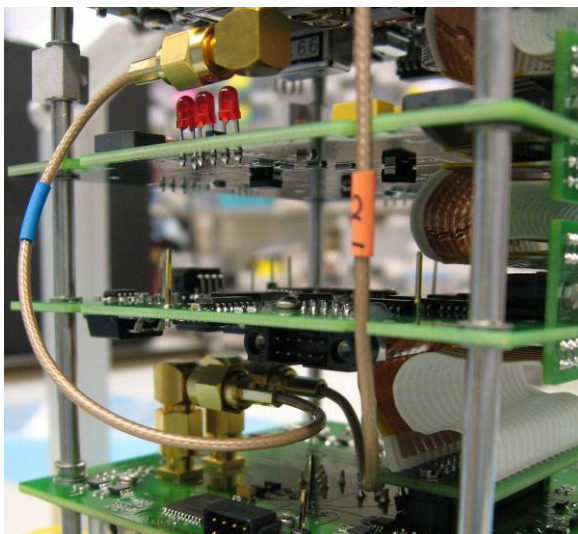


Figure 5 – Detailed view of rod system

3.3 Male-female busses on PCB

This option is similar to the mentioned rod system, but instead of rods is worked with male-female, non-electrical connectors. These connectors decrease the time needed for interchanging PCBs. A male connector is put on the Z⁺- and Z⁻-side of the PCB, after which a female connector is screwed on (Figure 6).

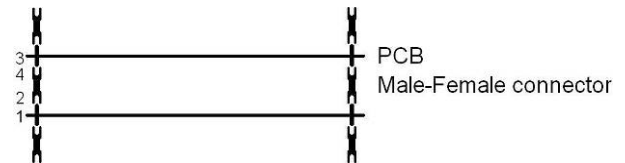


Figure 6 - Detailed view of male-female connector system

The busses can be chosen to appropriate lengths as needed. Also a standard length can be chosen for modularity.

For this system detachable X- and Y-panels are an option. This not only makes the structure interchangeable, but also better accessible.

3.4 Stack with PCB side panels

This option can be combined with the rod system and the male-female connectors. The PCBs are not the outer structure, but are protected by an outer structure. By orienting PCBs in Z-direction, more room can be created for payloads. Since a three-unit CubeSat is assumed, there is a possibility to have ribs on one third of the length of the satellite and on two third. This way the PCBs can still have a square form. For interference reasons (mechanically or electronically) the PCBs placed normal to the Z-axis have to be reduced in size. Having a stack with PCB side panels reduces the accessibility compared to the rod and male-female system.

3.5 PCB box

The idea of the PCB box is that the PCBs have their own frame on the X- and Y-sides, which makes that the PCBs can be piled together via a rod system, as shown on Figure 7. If more space is needed due to larger payload, the frame of the PCBs needs to be reduced in height. Also the stack lacks accessibility and needs disassembling when needing a PCB from the stack. On the other side the handling risk is less, due to the framework on each PCB.

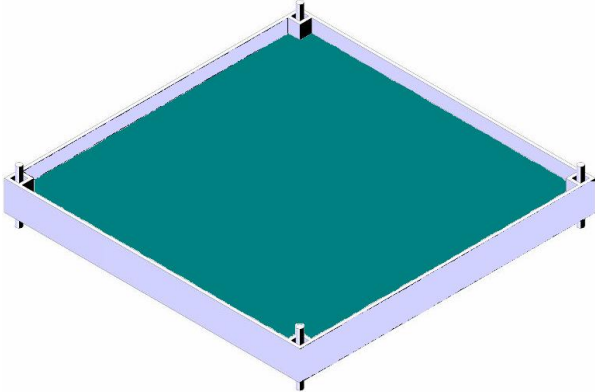


Figure 7 – Detailed view of PCB box

4 Trade-off

The six options discussed have been traded on several criteria. Not only general criteria, such as accessibility and Assembly, Integration and Testing (AIT) have been taken into account, also Delfi-n3Xt specific criteria as mounting of outer parts and structural interference due to payload. The criteria can be found in Table 1. The trade-off showed no clear winner for the best structure, however the rod and male-female connector system scored clearly better than the other options. Having experience with the rod system in the Delfi-C³ project and foreseeing problems with stiffness of the stack with the male-female connector system, in a team discussion the rod system was favoured.

The number of side panels which will be made detachable is still to be determined. Unlike Delfi-C³, Delfi-n3Xt will make use of a symmetrical rod layout for PCBs. Delfi-C³ used the PC/104 [4] standard, making use of the commercially available PC/104 systems.

Table 1 - Criteria for the Delfi-n3Xt STS

Performance
Interference due to payload
Structural subsystem mass (outer structure and items for fastening PCBs to structure)
Stress
Stiffness
Structural manufacturability
Handling
Accessibility
Assembly, integration and testing of PCBs and connectors
Substitution of PCB
Mounting of outer parts
Flexibility in design
Varying PCB distance in Z-direction
Miscellaneous
Heritage

Since for Delfi-n3Xt all electrical boards will be custom made, this standard is not necessary. Making the PCB rod layout symmetrical has further advantages in usable space per PCB.

5 Delfi-n3Xt

Delfi-n3Xt implements more and bigger payloads and more advanced subsystems than Delfi-C³. To verify all payloads and subsystems fit in a three-unit CubeSat, drawings for each subsystem have been made. Components and subsystems known from Delfi-C³ have been implemented, likewise volumes and masses as defined by payload partners and team members. Integration of all subsystems into the drawing (see Figure 8) showed that it is possible to put all subsystems as defined within the envelope of (100 x 100 x 340.5) mm, according to three-unit CubeSat specifications [4].

The largest impact comes from the Multifunctional Particle Spectrometer (MPS) payload. This payload has a large effect on the total mass of the satellite and relatively high in Z-direction. The current preliminary design specifications are 60 mm in height and 0.5 kg.

At the moment all the subsystem fit into the structure. However the MPS being so heavy, it requires its own supporting structure. To minimize obstruction of measurements and obstruction to other subsystems, the MPS has been put low on the Z-axis. This leaves only an antenna board and bottom panel below the payload. This is about one third of the total height of the satellite. While the rest of the satellite will be integrated onto rods, the structural support for the MPS is still to be determined.

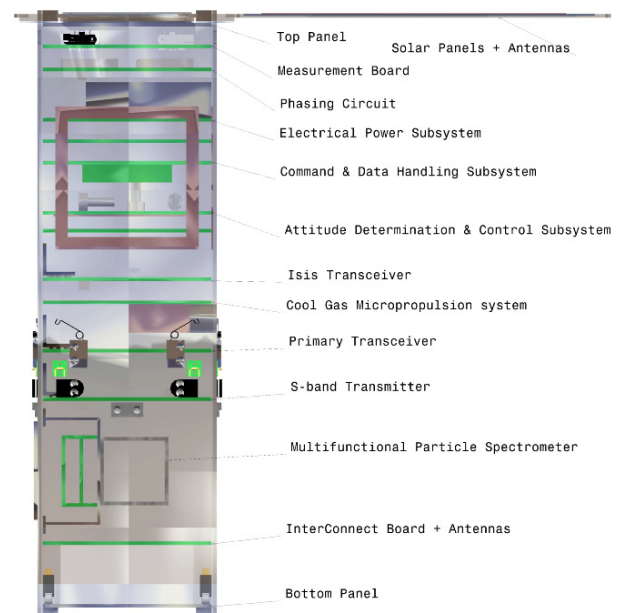


Figure 8 - Delfi-n3Xt layout

Other subsystems with considerable mass are the batteries and the micropropulsion system. What the effect on the centre of mass is due to these subsystems together with the solar panels, is to be determined.

6 Conclusion

For Delfi-n3Xt an option for the structural subsystem has been sought, which should allow for a smooth and more time-efficient assembly, integration and testing than for Delfi-C³. Options considered for the structure have been a card bus system, a rod system with detachable side panels, male-female busses on the PCB, stack with PCB side panels and a PCB box. A trade-off showed that the rod system is the best option for Delfi-n3Xt. For two third of the satellite, rods will be implemented; the integration to the structure of the last third is to be determined. An important difference with Delfi-C³ is that one or more panels are detachable.

Furthermore it is shown for Delfi-n3Xt that all payloads and subsystems fit into the envelope of a three-unit CubeSat.

With a structural subsystem chosen, the project will advance into determining the number of detachable side panels, detailing the integration of the stack to the outer structure and making more advanced drawings for payloads and subsystems.

7 References

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- [3] <http://www.pumpkininc.com/>
- [4] <http://www.pc104.org/>
- [5] <http://www.cubesatkit.com/>