PRELIMINARY PAYLOAD SPECIFICATIONS

Stratos II

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Chapter 1

Project Stratos

Project Stratos is a student project started in 2010 by the students of Delft Aerospace Rocket Engineering (DARE), a student group focused on rocketry research at Delft University of Technology in the Netherlands. The mission statement is as follows:

> *"To launch an experimental payload to 50km altitude by means of a rocket designed, built and launched by students."*

The project was started after the successes of the Stratos I rocket, that was launched in 2009 to 12.5km altitude. The rocket was launched from Esrange Space Center, Sweden to claim the European record altitude for amateur rockets. DARE is now looking to improve its own record and at the same time showing the public the uses for sounding rockets by carrying experimental payloads on board.

1.1 Delft Aerospace Rocket Engineering (DARE)

Figure 1.1: CanSat on its parachute during a DARE CanSat launchday at ASK 't Harde

DARE was founded in 2001 by a number of enthusiastic students from the faculty of Aerospace Engineering at Delft University of Technology with the aim to promote the practical aspects of rocket research among the students and to develop rocketry technology at the TU Delft.

The society grew steadily and has over the years become involved in a number of projects. These were, most notably, Stratos I, which is elaborated in section 1.2, and the CanSat project. DARE has been the provider of the CanSat launchers for the Dutch CanSat competition[1] for more than 5 years now. Since that time a large rocket family has been developed for this project. DARE has been launching from the ASK 't Harde, a military base in the northern part of the Netherlands for most of its rockets. However external launch campaigns have also been carried out namely in: Valencia, Braunschweig, Leipzig and Kiruna. In 2011, DARE has performed the first launch of a CanSat rocket on the African continent at the IAC in South Africa. Within a number

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[1] For more information on the Dutch CanSat competition, see http://www.cansat.nl/

of months after the start of the cooperation with the organizational committee, DARE had arranged the full logistics for the launch campaign of a CanSat rocket, carrying onboard 6 South-African build CanSats to 1 km altitude.

From its founding DARE has had as its main statement that the rockets launched by the members should be developed, built and tested by the members themselves as much as possible to stimulate the development of technology within the society. DARE is the leading student rocketry organization in Europe concerning the developments of rocket engines. DARE has build its expertise with solid rocket motors over the years, has made major advances in the hybrid rocket technology field in the last three years and is currently working on the first flight model of a small liquid rocket engine.

1.2 Stratos I

The Stratos I project was started by DARE to show the potential of the society to the outside world. The target was set to break the European altitude record for amateur rockets with a rocket developed by the society itself.

The rocket carried onboard an electronic flight computer that controlled the second stage ignition and performed measurements during flight. These measurements included attitude determination and GPS positioning. Data was stored on onboard storage capacity and was in part transferred to the ground by telemetry. The capsule that contained the flight computer had a single stage parachuting system to recover the capsule.

The launch was conducted in March 2009 on the Esrange Space Center in Sweden and officially reached the 12.5km mark. This is still the standing European Altitude record for amateur rocketry.

Figure 1.2: Launch of the Stratos I rocket to 12.5km from Esrange.

1.3 Stratos II

Since 2010 DARE students have been working on Stratos II, the follow-up of the Stratos I rocket. With Stratos II DARE aims for even greater heights. The goal is to reach 50km altitude with experimental payloads on board of the rocket. These payloads are provided by companies, universities or other educational instances from across Europe. The payloads have the aim to gather scientific information from the higher atmosphere or to test electronic systems. In this way DARE aims to show with the Stratos II rocket the use of sounding rockets for scientific and commercial purposes.

Over the past year the Stratos II team has made a large number of important steps forward to realize the launch of the Stratos II rocket. In November 2012 the decision was made to fly Stratos II with a single stage hybrid rocket engine. This was the result of a long internal competition between the two concurrent designs of a solid rocket concept and a hybrid rocket concept. In November 2012 both teams were at a similar development stage, confident of the systems they designed and ready to proceed to the full scale tests. However only one of the two systems could eventually fly and a decision needed to be made. After an elaborate trade-off the decision was made and all teams could focus their attention further and finalize the subsystems design around the hybrid rocket engine.

These further refinements lead the project through a rapid succession of milestones in the past half year. In the following few sections a number of the technical, but also operational aspects of the project will be discussed to give a short overview of what has been accomplished in 2013 up till now.

1.3.1 Engine development

As explained the most important design decision made in Stratos II up till now was the selection of a hybrid rocket engine to power the rocket. This concept was selected in the trade-off in November after a careful analysis of the technical aspects of both systems, but also of the non-technical aspects such as the transport and operational requirements and the motivation of the team behind the concept.

Figure 1.3: Still from the video footage of the hybrid rocket engine test at TNO in May 2013.

From November onwards the team worked hard to develop the lab scale version of the engine to the full scale system needed for Stratos. The hybrid engine uses NO as an oxidizer and a mixture of sorbitol, paraffin and aluminium powder, outperforming with ease all rocket engines developed within DARE before. It will deliver almost 10kN of thrust for over 20 seconds, enough to lift a Toyota Aygo and its driver.

The system was tested first in May this year at the laboratory of TNO in Rijswijk. The first tests were conducted in increasing steps of burn time; first just 5 seconds and then 10 seconds, both providing spectacular footage. During the 15 seconds test the combustion chamber however suffered a breach and the engine was shut down immediately without any safety risks. The cause of this failure was quickly tracked down to casting defects in the grain and a number of solutions have already been proposed.

Testing will resume again in October, using new casting techniques and extra safety measures.

After these tests the team will need to look into other operational aspects of the engine, such as the design of oxidizer filling systems, remotely controlled oxidizer feed line connections and possibly tank temperature control.

1.3.2 Payload and flight computer capsule

On top of the engine will be the payload capsule. This capsule will contain the payloads, the flight computer of Stratos and the recovery system. After the selection of the propulsion system the subteam behind this part was able to further refine their designs and to also develop the interface between the capsule and the engine. To finalize this subsystem a number of tests have been conducted over the past half year and multiple parachuting, separation and wind tunnel tests have been performed. During the summer of 2013 the team has focussed on production research and is planning to fly a fully designed capsule in September. This model will be nearly equal to what will eventually fly on the Stratos II rocket.

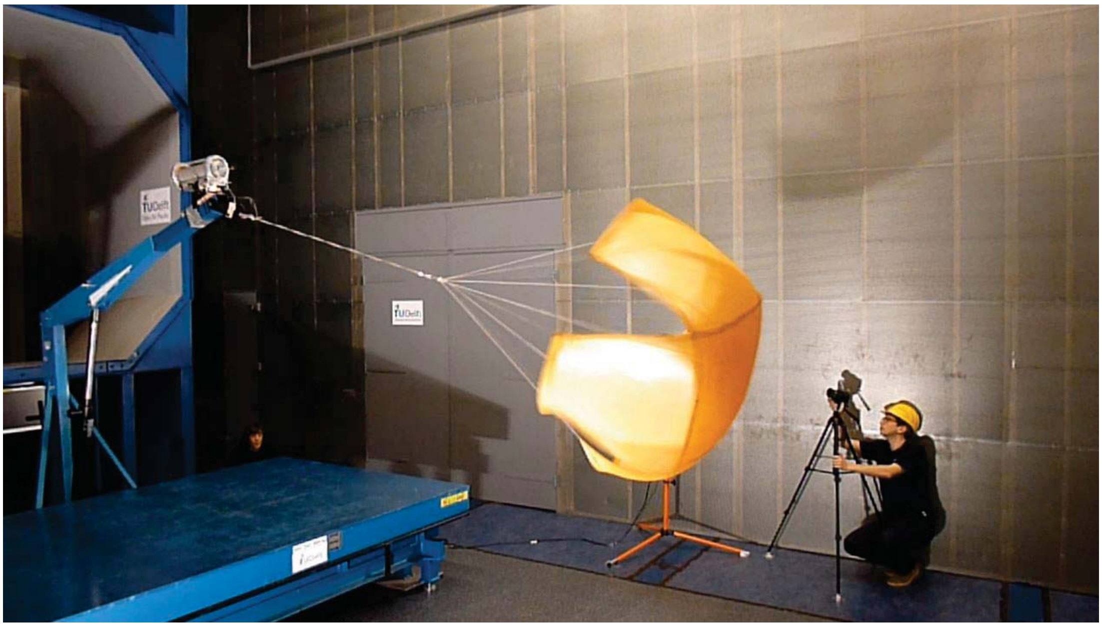


Figure 1.4: Parachute tests at the TU Delft windtunnel facility.

1.3.3 Electronics

Work on the on-board flight computer, the brain of the rocket, is progressing steadily. The main components such as the MCU and the payload controller have already been developed. Other components such as the measurement boards and the telemetry are getting the final reviews and updates before these are also ready for tests. In September a flight version of the electronics will fly as a test on board of the concept launcher. This version will consist of most of the hardware that eventually will fly in the Stratos II but will still miss certain redundancy features in the software.

1.3.4 Payloads

Since the start of 2013 contacts have been made with external parties that want to develop a payload to fly on board of the Stratos II rocket. The first payload contract to be signed for Stratos II was the agreement with the Hungarian institute for energy research. A group of students involved with this institute are constructing a small Geiger-Mller experiment to measure high energy radiation in the higher layers of the atmosphere.

The second payload is an antenna setup developed by Nijmegen University in the Netherlands, originally for an European, student build, lunar lander. This project was however cancelled by ESA. To still be able to test the antenna and to get experience with the engineering aspects of incorporating it in a real spacecraft, this antenna will be flown on board the Stratos II.

Next to these two confirmed payloads there are also negotiations underway with at two other parties, looking into an on board camera and dust particle measurements.

1.3.5 Launch sites

A major logistical hurdle is acquiring a launch site for the Stratos II rocket. A rocket going to 50 kilometres altitude cannot be launched from the Netherlands as this would bring to much risk to the dense population on the ground and the busy traffic in the air. Therefore DARE is looking for a professional launch site situated outside of the Netherlands which is able to accommodate and support a launch of this magnitude. A couple of potential launch sites have been identified and contacted. These include Esrange in Sweden and Andya in Norway (both located above the Arctic Circle). DARE has various interesting leads on non-European launch sites as well, for example White Sands Missile Range, New Mexico in the United States. This range is located in a salt-desert and has experience with student rocketry teams from the US launching there.

1.3.6 What next?

A few things that are going to happen within Project Stratos this academic year have already been mentioned. First there will be the test flight of the payload capsule and electronics in September to 1 kilometre in the Netherlands. After that will be the next tests of the Stratos II engine at TNO to achieve the full burn time and optimal performance of the engine in October.

The rest of 2013 will be used to integrate all different subsystems together and to construct the final flight model. The first months of 2014 will then see thorough reviews and testing of the whole setup and systems. Furthermore there will be a roll-out event to show the rocket to the public and finally in April / May 2014 Stratos II will be launched to 50 km altitude.

Chapter 2

Mechanical details of the Stratos II rocket

This section contains a description of the technical specifications of the Stratos II rocket that are most relevant to payload designers. The section 2.1 describes the general layout and dimensions of the rocket. Section 2.2 gives an overview of the currently expected flight path. And section 2.3 will shortly describe the capsule that will house the Stratos II flight computer, recovery system and payload bay.

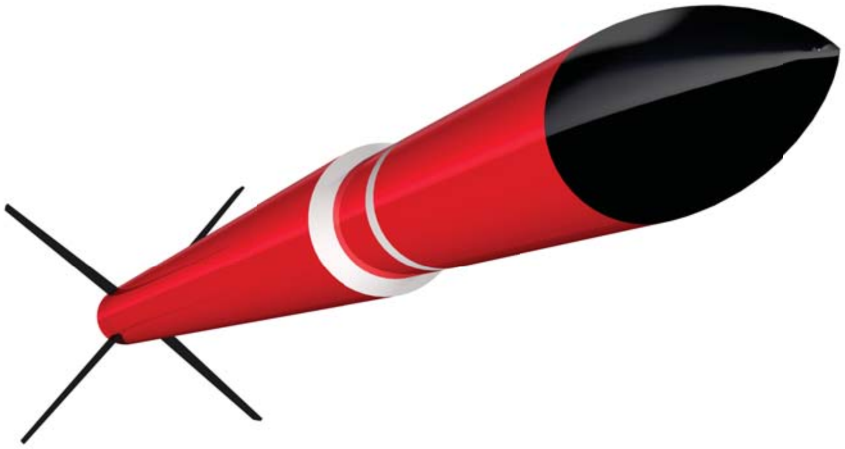


Figure 2.1: A render of the Stratos II rocket.

2.1 Rocket layout and dimensions

The Stratos II rocket consists of two main parts. The first is the single stage rocket engine using a hybrid propulsion system. The engine is called the DHX-200 Aurora (”Delft Hybrid eXperimental, 200kNs - Aurora”). The Aurora is 200mm in diameter and is 5 meters in length. The oxidizer used by the rocket is nitrous oxide (N_2O, i.e. laughing gas). N_2O is stored under it’s own vapour pressure of approximately 60bar at a temperature of $20\mathrm{deg}$C in the tank. The pressure of the vapour will force it into the combustion chamber as soon as the main valve is opened. The fuel is a mixture of sorbitol, parafin and aluminium. The usage of sorbitol is quite unique in the world and DARE is the only organisation to use it in engines of this scale. The engine system will provide approximately 10kN of thrust over a time of 20 seconds. This provides a total impuls of

200,000Ns, while burning at an average I_{sp} of 185s. During the time the rocket will be burning it will consume approximately 80kg of N_2O and around 25kg of fuel.

On top of the engine is the capsule. This capsule houses the recovery systems for the rocket, the payload bay, and the flight computer and telemetry system. The capsule is connected to the engine via a fairing that interconnects the 200mm diameter engine stage to the 160mm capsule. See section 2.3 for more details on the payload capsule.

The total mass of the rocket is approximately 190kg, with a length of 6.5 meters and a maximum diameter of 200mm.

2.2 Flight loads and accelerations

A simple simulation of the expected flight is given in figure 2.2. This can be used as an indication for the flight regimes that the rocket will pass through. More detailed figures concerning launch loads and flight path will only become known after the full scale test of the rocket motor.

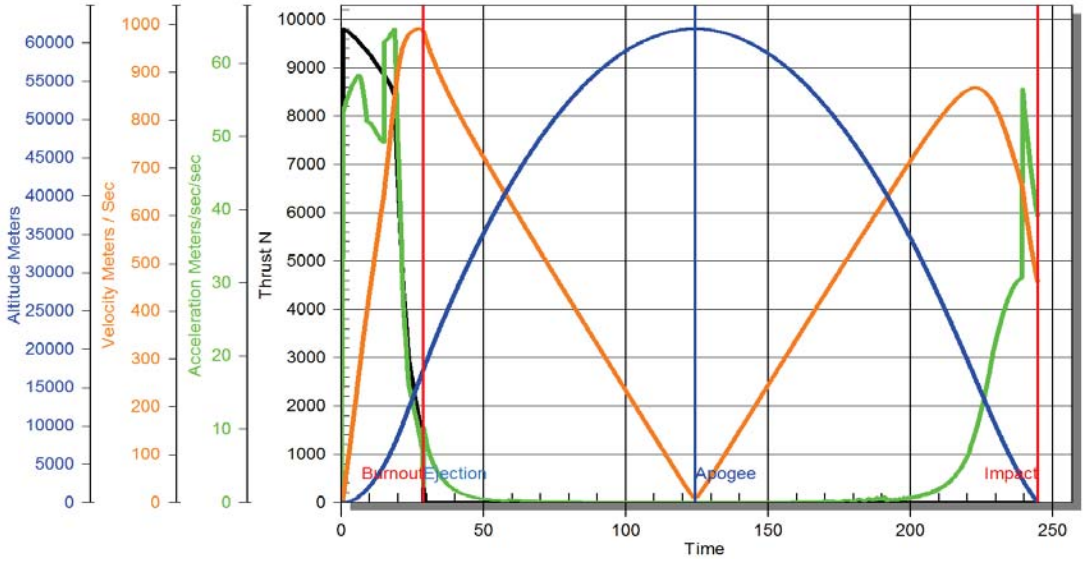


Figure 2.2: The predicted accelerations, velocities and altitudes of the Stratos II rocket during flight.

2.3 Payload capsule

2.3.1 Capsule general outline

The payload capsule of the Stratos II houses the flight computer, transmitter, payloads and recovery system. These systems are all housed in this capsule which is placed on top of the engine. The total capsule is approximately 1.5m long and 160mm in diameter. The capsule will separate from the rocket engine at apogee.

The capsule is designed in a modular way, meaning different functionalities located in the capsule are placed in their own module. Different modules are stacked on top of each other, sharing a simple interface. Due to this modular design the modules can change in length and still be connected to each other due to the same interface. This results in a simpler design and will make the handling of the capsule easier be-cause testing and integration of different modules can be done parallel. A schematic overview of the stacking of the parts is shown in figure 2.3.

The top section is the nosecone of the rocket. This houses the flight computer and the transmission antenna of the Stratos II. The nosecone is constructed out of glass-fibre with possibly a metal insert at the tip to protect against any aerodynamic heat loading. The nosecone is an optimized Von Karman shape and is approximatly 500mm long and 160mm in diameter at the base. Electrical wires are running down from this section past and into the other sections of the capsule and down to the engine.

Below the nosecone is the payload module. This section is also approximately 500mm long and 160mm in diameter. The payloads are housed in a central square construction that can fit CubeSat sized PCB's (see section 2.3.3). The side walls of this square housing are of aluminium with one side left open. Both on top and at the bottom the payload section is separated from the rest by aluminium bulkheads. The body tube for the payload section is again made of aluminium.

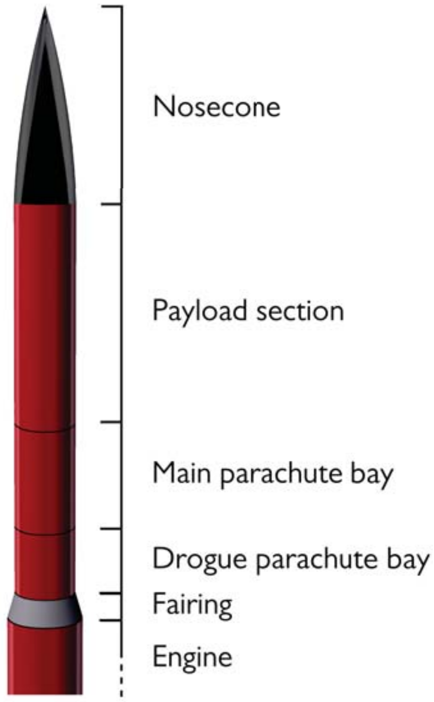


Figure 2.3: A schematic of stacking of the capsule modules.

Below the payload section follow two sections housing the main parachute and the drogue parachute respectively. Both sections are made from glass-fibre. The parachute bays are connected by a clamp-band system, and so are the engine and the bottom parachute bay. This clampband system keeps the two systems together closely but can also separate them easily by burning through a wire that holds the clamp-band under tension.

2.3.2 Separation and recovery systems

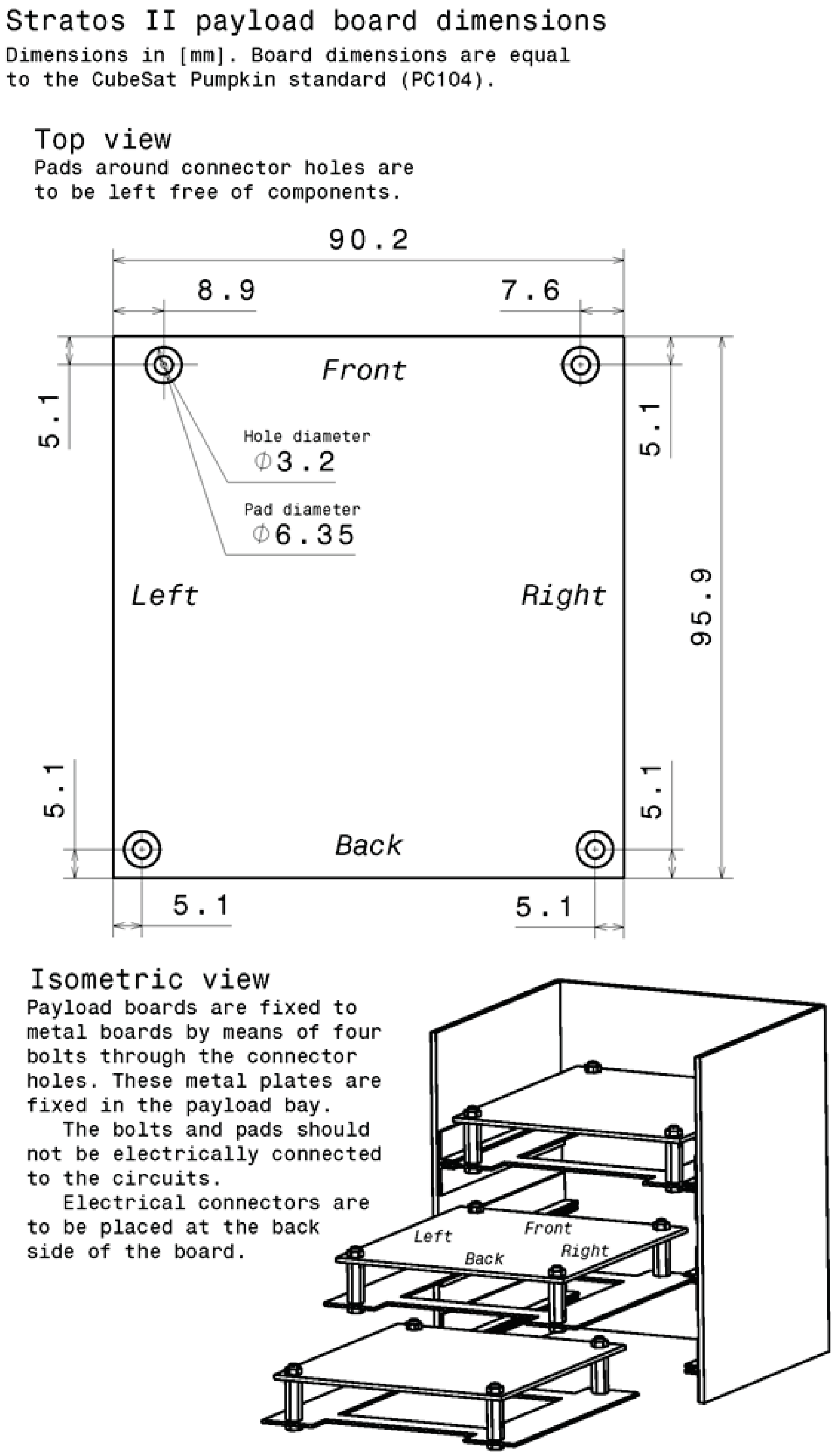
The recovery system is the system located at the bottom of the capsule. The systems consist of a separation module that decouples the capsule from the engine followed by a recovery module housing the drogue parachute. Next, a second separation module will decouple the first recovery module from the second recovery module, which houses the main parachute.

The double parachuting system is required to make sure the capsule can drift slowly to the ground but will not drift to far from the launch site. The drogue shute will be deployed at or near the apogee of the flight. The main shute will be deployed later (at approximately 2km altitude). Both these events can be expected to induce a g-load shock into the system.

A number of minutes after the landing of the capsule the Stratos II flight computer will shut the payloads down. The flight computer of Stratos will then function as a beacon to allow the team to recover the capsule.

2.3.3 Mechanical structure for the payloads

To allow for a separate development of the capsule and the payload it is chosen to use the CubeSat PCB (PC104) interface for the payloads. All payloads will be mounted on a PC104 board or have the same interface. A small connection piece will be attached to the mounting units of the PCB, this piece can slide in the payload container in the capsule. See figure 2.4.



Stratos II payload board dimensions

Dimensions in [mm]. Board dimensions are equal to the CubeSat Pumpkin standard (PC104).

Top view

Pads around connector holes are to be left free of components.

Isometric view

Payload boards are fixed to metal boards by means of four bolts through the connector holes. These metal plates are fixed in the payload bay.

The bolts and pads should not be electrically connected to the circuits.

Electrical connectors are to be placed at the back side of the board.

Figure 2.4: A overview of the payload board dimensions. Each payload consists of one board. These dimensions are compliant to the CubeSat standard. The stack of payloads will be housed in the middle of the flight capsule. The outer walls of this box are made of aluminium.

Chapter 3

Flight computer services

As the physical space and mass restrictions for the payloads are strict, the rocket provides the payloads with a number of services. The most important of these are that the rocket supplies the payload with power, data storage and a downlink.

The physical interface with the flight computer consists of a single connector, which must be a Yamaichi NFP-10A-0122BF or equivalent connector. Any equivalent connector must mate with a Yamaichi NFS-10A-0111BF and must have a locking mechanism. The specified connector may be ordered at Farnell, using order code 1143947. The pin-out for the connector is shown in figure 3.1 and table 3.1.

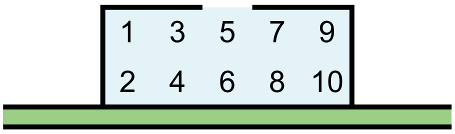


Figure 3.1: Physical pin configuration for the flight computer interface connector, viewed from the side of the payload PCB.

Table 3.1: Pin description for the flight computer interface connector.

Pins	Symbol	Description
2, 4, 6	0V	Reference voltage.
8, 10	V_{bat}	Supply voltage for the payload, provided by the flight computer.
1	MISO	Data from flight computer to payload.
3	MOSI	Data from payload to flight computer.
5	SCK	Clock for MISO and MOSI, provided by payload.
7	/SS	Slave select signal, provided by payload.
9	V_{bus}	Bus voltage for MISO, MOSI, SCK and /SS, provided by payload.

3.1 Power

As stated, the flight computer provides the payload with some power through the V_{bat}lines. The specifications for the power supply are listed in table 3.2. The maximum supply current per connector is negotiable.

Table 3.2: Payload power specifications.

Symbol	Description	MIN	NOM	MAX	Unit
V_{bat}	Supply voltage for the payload, provided by the flight computer	7.6	10.6	12.6	V
$I_{\text{max,init}}$	Maximum switch-on current, $t_{\text{on}} < 1$ second			1000	mA
$I_{\text{max,cont}}$	Maximum supply current, $t_{\text{on}} > 1$ second			100	mA

Warning: the above current specifications are actively policed using current monitors. The power supply to a payload is immediately shut off upon violation of the above rules, to ensure continuity for the other payloads.

3.2 Data

The payload may communicate with the flight computer through a Serial Peripheral Interface (SPI) compliant bus. The bus operates in SPI mode 0 (CPHA = 0, CPOL = 0), see figure 3.2. For convenience for the payload developers, the payload is the master on this bus, such that the payload may determine the SCK frequency depending on their own requirements. The bus voltage is set by the payload as well.

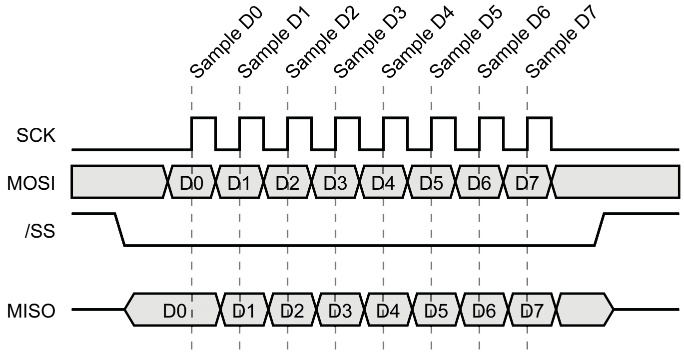


Figure 3.2: Serial Peripheral Interface protocol, mode 0.

Electrical specifications

The bus level translation is handled by four SN74LVC1T45 translators by Texas Instruments, with the payload connected to the A port.

Table 3.3: Data bus electrical specifications.

Symbol	Description	MIN	NOM	MAX	Unit
V_{bus}	Operating bus voltage, provided by the payload.	1.8		5.0	V
$I_{V_{\text{bus}}}$	Flight computer current consumption from V_{bus}, $I_{\text{MISO}} = 0$			20	µA
V_{IH}	High-level input voltage (MOSI, SCK, /SS)	$V_{\text{bus}} \times 0.7$			V
V_{IL}	Low-level input voltage (MOSI, SCK, /SS)			$V_{\text{bus}} \times 0.3$	V
I_{OH}	High-level output current (MISO)			-4	mA
I_{OL}	Low-level output current (MISO)			4	mA
V_{OH}	High-level output voltage (MISO), V_{bus} = 4.5V	3.8			V
V_{OL}	Low-level output voltage (MISO), V_{bus} = 4.5V			0.55	V

Timing specifications

Table 3.4: Data bus timing specifications.

Symbol	Description	MIN	NOM	MAX	Unit
f_{SCK}	SCK clock frequency	0		500	kHz
$t_{\text{SCK,high}}$	SCK high time	1.0			µs
$t_{\text{SCK,low t}}$	SCK high time	1.0			µs
$t_{\text{SS to SCK}}$	SS asserted to first SCK transition	1.0			µs
$t_{\text{SS to MIS(}}$	SS released to MISO hi-Z	20.0			ns
$t_{\text{byte to b}}$	Additional time between two byte transfers	0			µs

Protocol description

The data bus may be used for two purposes:

- Sending data to the flight computer for storage or transmission.
- Reading the flight state of the rocket.

All communications with the flight computer are packet based. The /SS signal is used to delimit the packets. Each packet consists of a command byte and zero or more data bytes. The command byte specifies whether the data provided is to be stored in the flight computer and/or whether it should be transmitted.

Internally, the flight computer has two first-in-first-out (FIFO) buffers, one for the to-be-stored data and one for the to-be-transmitted data. These buffers will be processed by the flight computer as fast as possible, in packets of 8 bytes. This has several implications.

- Data can be transmitted to the flight computer at any rate meeting the timing requirements in table 3.4 until the FIFO buffers are full.
- If the other payloads are not providing data at their maximum allowed rate, the data rate observed by the payload will appear to be higher than specified. It is

allowed to exploit this effect, as this does not affect the applied load balancing algorithm.

- If there are less than 8 bytes in the buffer, no data will be processed. To ensure processing of all bytes in a discontinuous data stream, append 8 dummy/pad bytes every time the stream stops for a significant amount of time.

The flight computer will report a 6-bit rocket flight state and the state of the two FIFO buffers in every SPI data transfer. If the FIFO status in the previous transfer indicates that one or both of the selected FIFOs is full, the data sent in the next SPI transfer is ignored.

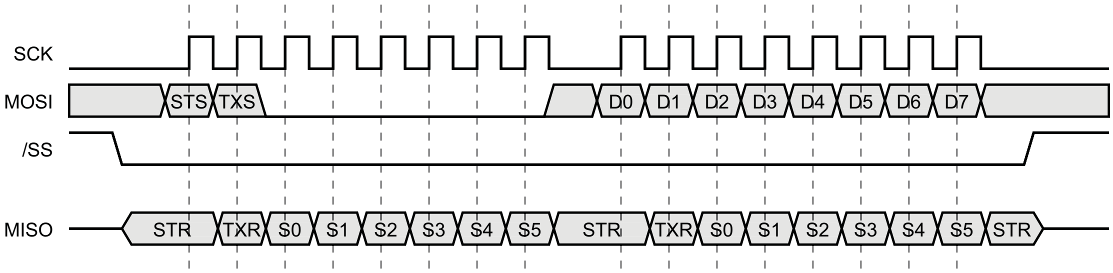


Figure 3.3: Data transfer between payload and flight computer.

Figure 3.3 shows the general case for a data transfer between the payload and the flight computer with one data byte. The symbols used are defined as in table 3.5.

Table 3.5: Description of the symbols used in figure 3.3.

Symbol	**Description**
STS	Storage select. Set to logic high to indicate that the data following the command byte is to be stored in the flight computer storage.
TXS	Transmitter select. Set to logic high to indicate that the data following the command byte is to be transmitted.
STR	Storage FIFO ready. Logic high if the storage FIFO is ready for data.
TXR	Transmitter FIFO ready. Logic high if the transmitter FIFO is ready for data.
D7..0	The data byte, which is either shifted into the selected FIFO buffer(s) or ignored, depending on the values of STS and TXS and the values of STR and TXR in the previous transmission.
S5..0	Rocket flight status. The exact definition of the status values is still **TBD** .

Chapter 4

Contact information

4.1 Delft Aerospace Rocket Engineering

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4.2 Project Stratos

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