TAUSAT (3U) PLATFORM TO SUPPORT SCIENTIFIC MISSION

1. Introduction

This document describes a Nano-Satellite platform and payload to support an educational radiation/measurements scientific/comm mission. The document provides an overview of the technical aspect of the mission.

1.1. Requirements and constraints

The solution shall be compatible with a 3U platform while reusing a maximum of systems included in the Duchifat 3 platform. A VHF/UHF communication would be baselined, but it is required to consider an upgrade towards S-band to enhance the downlink capabilities. It is understood that for optical missions an upgrade of the ADCS capabilities (relative to Duchifat 2) will be required to provide higher pointing accuracy. The use of deployable solar panels should be avoided to keep the platform as simple as possible. Some of the requirements and constraints already identified at this stage are listed in Table 1-1.

Table 1-1 Preliminary requirements provided by the Herzliya Space Center

1	The instrument shall be an optical camera for

vegetation monitoring 2 An integrated platform shall be delivered by

Jan 2018 to the Herzliya Space Center 3 The platform shall be a 3U CubeSat with a

maximum re-use of the Hoopoe system 4 A solution based on body-mounted solar panels is

preferred 5 The platform shall provide 3-axis attitude control 6 A payload data transmitter (PDT) in S-band should

be used to maximize the scientific return 7 Subsystems with proven flight heritage preferred

2. Reference orbit

Given the current incertitude of the target orbit, all the calculations are carried out for a Sun- synchronous orbit with the following parameters.

Table 2-1: Parameters of reference orbit

Inclination ~98o LTAN 10:30:00 Altitude 600 km

3. Technical overview

3.1. Variants and configuration

A 3U platform has been baselined to support a camera. A single ground station located at a latitude of 32o, is assumed, offering about 34 min per day of downlink time. In order to be able to take a sufficient amount of images an S-band downlink is used. This offers the possibility to transmit up to 80 Mbit of data per day.

The number of images that can be taken per orbit, day or week depend highly on the CONOPS (concepts of operations). For this performance analysis, it is assumed that the same number of images is taken during each orbit and all the pictures are downloaded on the day they are taken. The resulting performance is shown below.

Table 3-1: Performance of proposed system

Number of Pictures per day (8 bit RAW) 4.5 45 Number of Pictures per day (10 bit RAW) 3.6 36 Duty Cycle (average per orbit) ~0.005% ~0.05%

**The Gecko camera offers JPEG2000 compression, below a factor of 10 no significant data loss occurs.*

The duty cycles are still very low, alternatively a higher data volume can be collected during 1 orbit, whereby subsequent orbits are used for transmission of data only (see Figure 3-1).

Figure 3-1:Snap & transmit CONOPS (left) versus image only (right).

Using the second concept, the available power can be used for imaging only and the camera can take up to 36 images. The data volume can be downloaded in about a week as Table 3-2 shows.

Table 3-2: Results for alternative CONOPS Data collected
638 Mbit Storage capacity used 0.5% Pictures taken 36 29
Mission time to download 8.0 days

To give a first idea of the satellite layout, a preliminary configuration has been made of both the baselined 3U and its upgraded version including S-band downlink capabilities. The different subsystems will be mechanically integrated in a stack and electrically connected through a CubeSat Kit Bus Connector (CSKB connector).

Figure 3-2: Preliminary satellite layout using a 3U platform.

A 3U platform without deployable solar panels offers sufficient power for the payload given the limited download capability of an S-band transmitter and one ground station.

3.2. Overview of the 3U platform

The key element of a mission is the space segment, consisting of the payload and avionics. The included components are listed in Table 3-3.

Table 3-3: Space segment components

Mechanical	ISIS 3-unit CubeSat structure
Power	GomSpace P31U/BP4
	ISIS Solar Panel set Top, bottom and side panels
Communication	ISIS TRXVU VHF/UHF Transceiver
	ISIS deployable antenna system
	ISIS S-band transmitter

2 units for data link optimization

Cobham patch Antenna CDHS ISIS On-Board Computer Including FM Daughter board

IGIS, Harnessing, ABF connector ADCS CubeADCS Y-Momentum

Coarse sun sensors Integrated in ISIS solar panels Payload Gecko Camera

Table 3-4 shows an overview of the key specifications of the proposed satellite. Please note that the numbers include estimated payload parameters unless indicated differently.

Table 3-4: Space segment specs overview Form Factor [U]

[cm]

3U ~10x10x30 Max. mass [kg] TBD Might influence launch cost Power generated [W] 3.43 OAP (orbit average power) Power Consumed by platform [W] 3.07 OAP (excl. payload consumption) Data Storage [GB] 16 Integrated in imager Downlink Speed [kbps] Max. 9.6 Over UHF Uplink Speed S-band datalink [kbps]

Over VHF [kbps]

Payload downlink

3.3. Power generation and storage

In this section both the power generated by the solar panels, and the power consumed by the avionics and the payload are discussed.

1.2 100

Figure 3-3 Attitude and configuration used for the power analysis.

The solar cells have a nominal efficiency of 29%. To include temperature and degradation losses as well as panel assembly losses, an overall panel efficiency of 28% is assumed (after a one-year mission). Furthermore, the day with the worst-case beta angle is used.

The satellite has solar panels mounted on all its faces. The orbit average power generated by the solar panels is 3.43W. Figure 3-4 shows the generated power profile over one orbit. In the sunlit part of the orbit the peak power generated is ~6.3W.

Figure 3-4 Generated solar panel profile over one orbit.

The used power is depicted in Table 3-5. All assumptions regarding duty cycle are listed in Table 3-5. Furthermore, a system margin of 10% is taken on the entire system to account for unforeseen design changes to the system (note that only about one in three orbits is used to transmit the data).

Table 3-5: Average satellite consumed power

Power EPS 0.21 W 5% 100% 0.22 W AOCS CubeADCS 3-axis 1.50 W 5% 100% 1.58 W CDHS ISIS-iOBC 0.38 W 2% 100% 0.39 W

Communication

TRxVU 3.50 W 2% 3.3% 0.12 W Antennas (2x) 0.07 W 2% 100% 0.07 W TXS 4.00 W 2% 3.3% 0.13 W Payload Camera 4.00 W 2% 0.1% 4E-03 W Subtotal 2.51 W System margin 10% EPS efficiency 90% Total consumed power 3.07 W

The consumed power assumes an average orbit with one ground-station pass every tree orbits (~10min of contact time every three orbits averages out to a duty cycle of about 3.3%). This results in an average power consumption of 3.07 W. The total power budget can be met by the current setup (without deployable solar panels). The camera duty cycle used here is that of the alternative CONOPS representing the worst-case scenario from a power consumption perspective (taking up to 36 pictures per orbit).

The GomSpace P31U is proposed for the functions of storing and distributing the power. This EPS is one of one the most commonly used in CubeSat missions. It was used in particular on the Hoopoe 2U CubeSat.

Figure 3-5: GomSpace P31U EPS and BP4 battery pack

3.4 ADCS

The CubeSpace ADCS is proposed that is able to provide three-axis stabilization and control and fits within volume-limited designs. The system employs attitude sensors, magnetic torque rods, and either a momentum wheel (Y-Momentum version, proposed in the entry-level platform) or three reaction wheels (3-axis version, proposed in the high-performance platform).

Both variants has several modes
available:

- **Detumbling**: The CubeSpace ADCS is capable of detumbling from initial rates <100 deg/s using B-dot. This will bring the satellite into a slow tumble around the orbit normal axis. - **Nadir pointing**: Mode where one face of the satellite is pointing towards the Earth. - **Tracking**: Mode which tracks a point on the Earth, defined by its longitude and latitude - **Sun Tracking**: Mode in which one side is oriented to the Sun to maximize power generation.

An overview of the performance of these modes, for both variants, is given in Table 3-6.

Table 3-6: Overview of the ADCS performance parameters

Detumbling Maximum detumble rate <100 deg/s
Nadir pointing Pointing accuracy < 5 deg < 1 deg Tracking Slew rate 1.5 deg/s
Pointing accuracy < 5 deg < 1 deg

Figure 3-6: CubeADCS with three reaction wheels

The CubeADCS has flight heritage since 2014 (QB50 Precursor satellites). The second generation of system has flown in 2015 (De-Orbit Sail) and a dozen of models of the newest revision will be in orbit within a few months as part of the QB50 constellation.

Figure 3-7: CubeADCS in Y-Momentum version (fine sensors can be removed)

3.5 Communication

The communication system can be divided into two separate systems. One providing the up- and downlink for satellite command and housekeeping data and a second system for downlinking the payload data (i.e. imagery taken by the camera) at a higher data rate.

- **Telemetry, Tracking & Command** As a baseline, the TT&C capability of the platform is provided by the ISIS UHF/VHF transceiver, together with two ISIS deployable antenna systems (ISIS Ants). The combination of these 2 antennas (one turnstile for downlink and one dipole for uplink) is the results of our experience and analysis to optimize the reliability of the data link.

Figure 3-8: ISIS TRXVU (left) and antenna system (right)

The TRXVU is ISIS' newest generation of radio and has flown for the first time in 2016, with more to come as one of the baseline transceivers for the QB50 Constellation. The ISIS

Antenna System (AntS) is ISIS' oldest product and has been flown since 2010 with more than 30 systems in orbit today.

- Amateur radio The TRXVU in Duchifat 3 will include an analog radio amateur transponder, using FM modulation at the uplink and downlink.

3.6 CDHS

The main component of the CDHS is the ISIS on-board computer (OBC). This powerful and versatile computer provides various interfaces either accessible on the main board or through a customizable daughter board. The following interfaces are available: I2C, SPI, RS- 232, RS-422 and RS-485.

The other component included in the CDHS is the ISIS Generic Interface System (IGIS) that is the central node for the satellite harness and includes a connector to access to the battery charging interface, the power bus, the data bus and the debug port on the OBC.

Figure 3-10: ISIS OBC (left) and IGIS (right)

The ISIS OBC has been used in

operations since 2014 (QB50 Precursor satellites) and the IGIS since 2013 (Triton-1).

3.7 Thermal aspects

Due to the limited storage and operating temperature ranges of the Gecko camera, the installation of an active thermal management system may be required.

4 Flight heritage summary

An overview of the flight heritage of the proposed hardware is given in Table 4-1.

Table 4-1: Equipment list for ISIS platform.

Mechanical	ISIS 3U CubeSat structure	Flight proven
Power	GomSpace P31U/BP4	Flight proven
	ISIS Solar panel set	Flight proven
Communication	ISIS TRXVU	Flight proven
	ISIS AntS	Flight proven
CDHS	ISIS iOBC	Flight proven
	IGIS + Harness	Flight proven
ADCS	CubeSpace ADCS	Flight proven