Multi-purpose 6U Platform

TECHNICAL INFORMATION SUMMARY

NA-M6P-G0-R0

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Contents

1. M6P (Multi-purpose 6U Platform) Introduction

Standard configuration of the platform is optimized for IoT, M2M, ADS-B, AIS, other commercial and emergency communication applications as well as scientific missions. Hardware layout allows the maximization of volume available for the payload. It also ensures robust power properties and thermal control for sensitive payloads, such as measurement and sensing instruments. To ensure the practical reliability of the platform, radiation-resistant components and design implementations have been incorporated to support critical systems such as the Flight Computer, Payload Controller, Electric Power System and Communication System. The platform is optimized to have a nominal 5 years operational lifetime in a Low-Earth Orbit (LEO) environment.

The M6P platform optionally might include a propulsion system capable of performing high-impulse maneuvers such as orbital deployment, orbit maintenance, precision flight in formations, orbit synchronization and atmospheric drag compensation, resulting in new opportunities for unique Customer missions and significant savings on constellation maintenance costs. The propulsion unit also provides satellites with decommissioning utility at the end of mission, meeting the space debris mitigation requirements of ESA and NASA.

NanoAvionics also provides M6P-optimized launch support for PSLV (India). Company also has access to Rocket Lab Electron (New Zealand), SpaceX Falcon 9, Soyuz, Vega, Long March, Orbital Sciences Antares and Atlas V launch vehicles. Activities cover technical aspects related to flight preparation of the spacecraft, including integration with the deployer to be provided or supervised by NanoAvionics before delivery to the launch pad, and on-site prior to launch.

Furthermore, NanoAvionics support includes the coordination of logistics and arrangement of mission-specific documents. As a flight-ready satellite contains mission-specific hardware, the launch opportunity shall be discussed in more detail covering each particular mission's case.

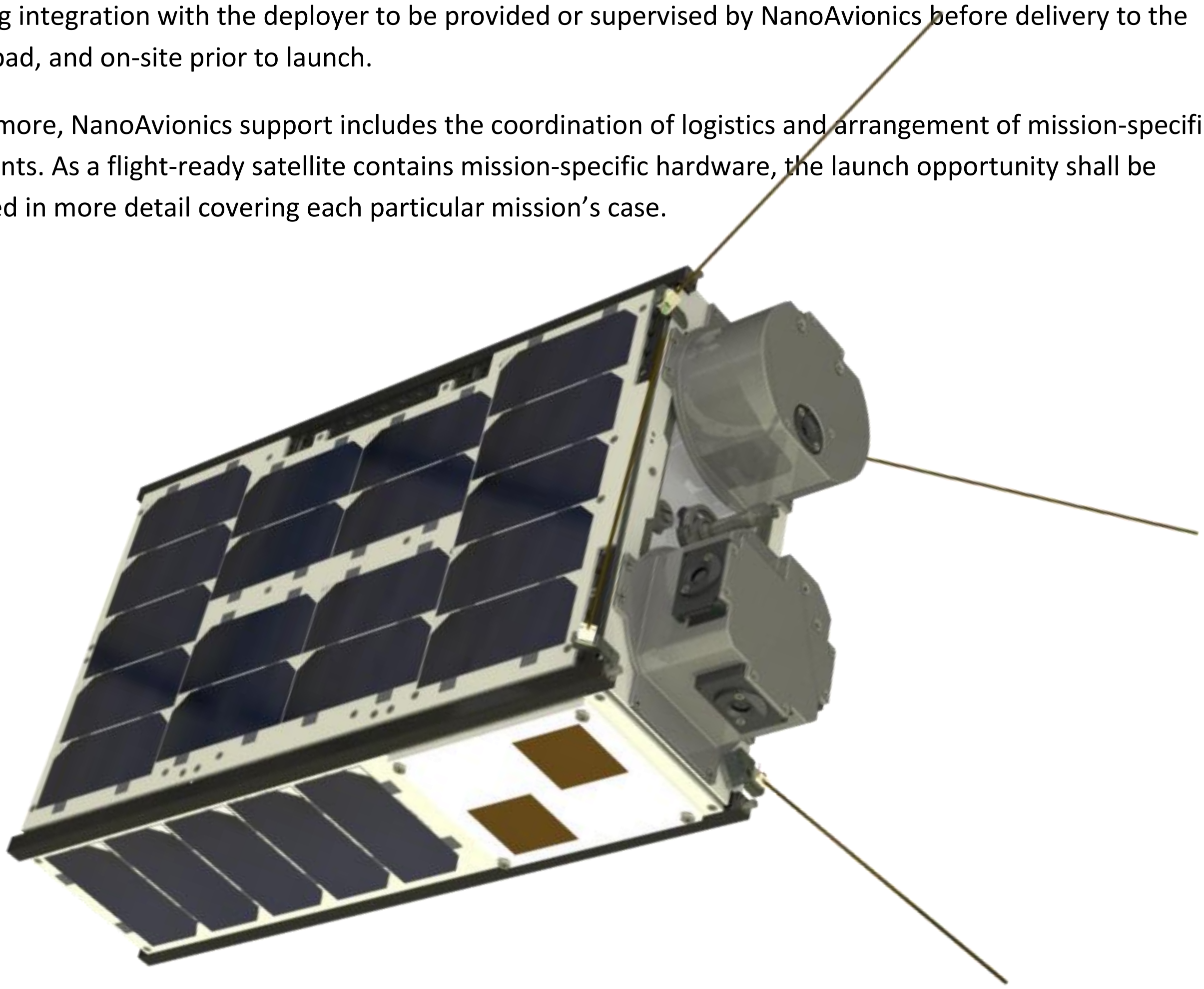

Figure 1. Multi-purpose 6U Platform (M6P)

2. M6P Platform Features

Subsystem	M6P Platform Specifications
General Features	• Total empty platform mass: 5000 g • Payload volume: up to 4U • M6P platform is already pre-integrated (mechanically, electrically and functionally tested) and pre-qualified to be ready for instant payload integration. Therefore, final flight acceptance and flight readiness procedures are minimized for the Customer. • Default operation of M6P platform during satellite mission is implemented at command level by execution of uploaded scripts. • A sophisticated mission code can be prepared by the NanoAvionics team according to separately agreed terms and conditions. • A payload integration service can be performed by the NanoAvionics team according to separately agreed terms and conditions.
Payload Interfaces	**Refer to:** *5. M6P Payload Installation*
Payload Controller (PC)	• ARM 32-bit Cortex™ M7 CPU with clock speed up to 400 MHz (configurable) • Double-precision FPU • 1 MB of internal RAM • 2 MB of internal FLASH memory • 2x512 KB of FMC-connected FRAM • 256 MB of external NOR-FLASH for data storage • 2x512 KB of FRAM (SPI) for frequently changing data storage • Integrated RTC • microSD NAND memory up to 16 GB (SDIO) • Three on-board PWM controlled H-bridges • PWM Outputs • FreeRTOS • In-orbit firmware update • Firmware power-on-check and restore • RFS – redundant record-based file system • CSP support • Self-Diagnostics • Dynamic CPU frequency control • User-friendly console
Payload Communication	**IQ-wireless Slink PHY S-Band Full-duplex Transceiver** (default) • Frequency Uplink: 2025-2110 MHz • Frequency Downlink: 2200-2290 MHz • Bitrate (uplink): up to 256 kb/s • Bitrate (downlink): up to 20 Mb/s • Modulation: BPSK (Uplink) & QPSK (Downlink) • Linear output power: up to 27 dBm **Syrlinks EWC27 X-Band Transmitter** (optional) • Bitrate: 3-50 Mb/s in flight configurable or 100 Mb/s fixed

	• Frequency Downlink: 8025-8450 MHz • Modulation: OQPSK or QPSK • Output power: 30-33 dBm • Contains LVDS interface **Large platform's housekeeping data packets can be requested also**
Power System NanoAvionics "EPSH"	• Input, output converter efficiency: > 90 % • Battery cells balancing • Configurable thermal control system • Supported data interfaces: CAN with CSP protocol support, UART for configuration • Integrated RTC with backup power supply • Fail-safe design: in case of total microcontroller malfunction EPS will go to emergency mode and selected emergency channels will keep satellite operational **Outputs (Over-current protected):** • 4 regulated voltage rails: 3.3 V; 5 V; (3 V – 18V configurable); (3 V – 18V configurable) • 10 regulated configurable – 3.3 V / 5 V / 3 - 18 V • Unregulated with switch: battery voltage 6.4 - 8.4 V • Max channel output current: 3 A • Max 3.3 V rail output: 20 W • Max 5 V rail output: 20 W • Max 3 - 18 V rail output: 20 W • Max unregulated (V_{Bat}) output: 75 W **Inputs:** • 4 MPPT converters (8 channels) with integrated ideal blocking diodes • Voltage: 2.5 - 18 V • Max input power per converter: 25 W • Max charging power for standard battery (2 cells): 10 W • Max charging power with extended battery pack (4 cells): 30 W **Batteries:** • 8 cells, 7.4 V, 12800 mAh, 92 Wh
Solar Panels (GaAs)	• Triple junction GaInP/GaInAs/Ge epitaxial structure solar cells • 30 % efficiency • NASA-qualified low out gassing solar cell adhesive • Magnetically clean circuit design without current loops to avoid spontaneous satellite spin up due to parasitic magnetic dipole effects • Silicone applied over solder joints for atomic oxygen protection • Integrated magnetometers and temperature sensors • Please see *3.* • *M6P Platform Power* Configurations for power input and average power available for the payload
Flight Computer (Including ADCS functionality)	• ARM 32-bit Cortex™ M7 CPU with clock speed up to 400 MHz (configurable) • Double-precision FPU

<table>
<tr><td>NanoAvionics
“SatBus 3C2”</td><td>

1 MB of internal RAM
2 MB of internal FLASH memory
2x512 KB of FMC-connected FRAM
256 MB of external NOR-FLASH for data storage
2x512 KB of FRAM (SPI) for frequently changing data storage
Integrated RTC
microSD NAND memory up to 16 GB (SDIO)
On-board magnetorquers drivers
PWM Outputs
FreeRTOS
In-orbit firmware update
Firmware power-on-check and restore
RFS – redundant record-based file system
CSP support
Self-Diagnostics
Dynamic CPU frequency control
User-friendly console
Mission planner with time-scheduled script/task execution support
Telemetry logging

ADCS sensors:

Inertial and Magnetic Sensors System
Fine Sun Sensors
Star-Tracker

Actuators:

Reaction Wheels System
Integrated Magnetorquers

Attitude control type: 3-axis stabilization
Attitude pointing accuracy ranges (pointing/knowledge), depends on the final platform parameters:

Default: 1°-2.5° / 0.8°-2.3°
Increased accuracy (with additional precision IMU): 0.5°-1° / 0.3°-0.8°
High accuracy (with Star tracker): 0.2°-0.5° / 0.05°-0.3°

Stability accuracy (Jitter):

± 0.004°/s (at f > 0.1 Hz)

Attitude maneuver ability: 3-10°/s
Operational modes:

Detumble mode
Velocity vector pointing mode
Nadir pointing mode
Sun maximum power tracking
Earth target tracking according to geodetic coordinates
Nadir/one axis sun-tracking
User supplied (ECI) vector tracking

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<tr><td>Reaction Wheels
System (SatBus RW)</td><td>
One Reaction Wheel Maximum torque:

3.2 mNm

One Reaction Wheel Maximum momentum storage:

20 mNms

Power consumption:
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	• Idle: 135 mW • Steady state (1000 RPM): 450 mW
Magnetorquers "SatBus MTQ"	• Nominal magnetic dipole strength of X, Y and Z axis magnetorquer coils @ 3.3 V: 0.9 Am^2 • Power consumption of X, Y and Z axis magnetorquer coil @ 3.3 V: 585 mW
GPS System SkyFox Labs "piNAV-L1"	**Position accuracy:** ± 10 m **Velocity accuracy:** ± 10 cm/s **Time Accuracy:** ± 100 ns (if pulse-per-second signal is used)
Command, Control and Telemetry NanoAvionics "SatCOM UHF"	• Dual modular redundant UHF communication system • ARM 32-bit Cortex™ M4 CPU with clock speed up to 72 MHz (configurable) • External interfaces: 3xUART, CAN, GPIO • Frequency range: 430 - 440 MHz (UHF) • Modulations: 2-FSK (including G3RUH) • Deviation: 3 kHz • Compatibility with AX.25 radio packet protocol • Bit rate range: 4800-9600 • RX sensitivity @ 9600 bit: -118 dBm (10% BER) • Maximum RF output power: +33 dBm (2 W) • UHF beacon allows payload housekeeping data fragments to be included into the data packets
Umbilical Connector	Umbilical connector is surface-mounted therefore shall be placed according to deployer specifics, to be accessible in case there is a requirement for the final check after integration. It contains the following interfaces through 16-pin connector: • Main Satellite CAN Bus • Payload CAN Bus • Battery Charging • EPS Kill Switch Reset (KSR) – must be shorted to ground to reset • EPS Kill Switch Override (KS) – must be shorted to ground to engage Note: the same umbilical connector is being used to interface through the test chambers used by NanoAvionics.
Remove Before Flight Pin	Remove Before Flight connector is surface mounted therefore shall be placed according to deployer specifics to be accessible.

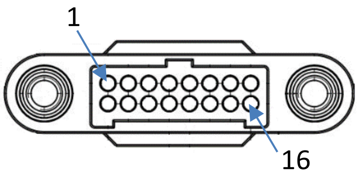

Figure 2. Umbilical Connector

Pin Designation							
1	2	3	4	5	6	7	8
GND	**KSR**	**GND**	**KS**	**GND**	**CAN_PL**	**EMPTY**	**EMPTY**
9	10	11	12	13	14	15	16
CAN_L	**GND**	**CAN_H**	**GND**	**CHARGE +**	**CAN_PH**	**EMPTY**	**EMPTY**

Table 1. Pinout of the Umbilical Connector

Interaction between subsystems containing the M6P platform is described in *Figure 3. M6P Architecture Diagram.*

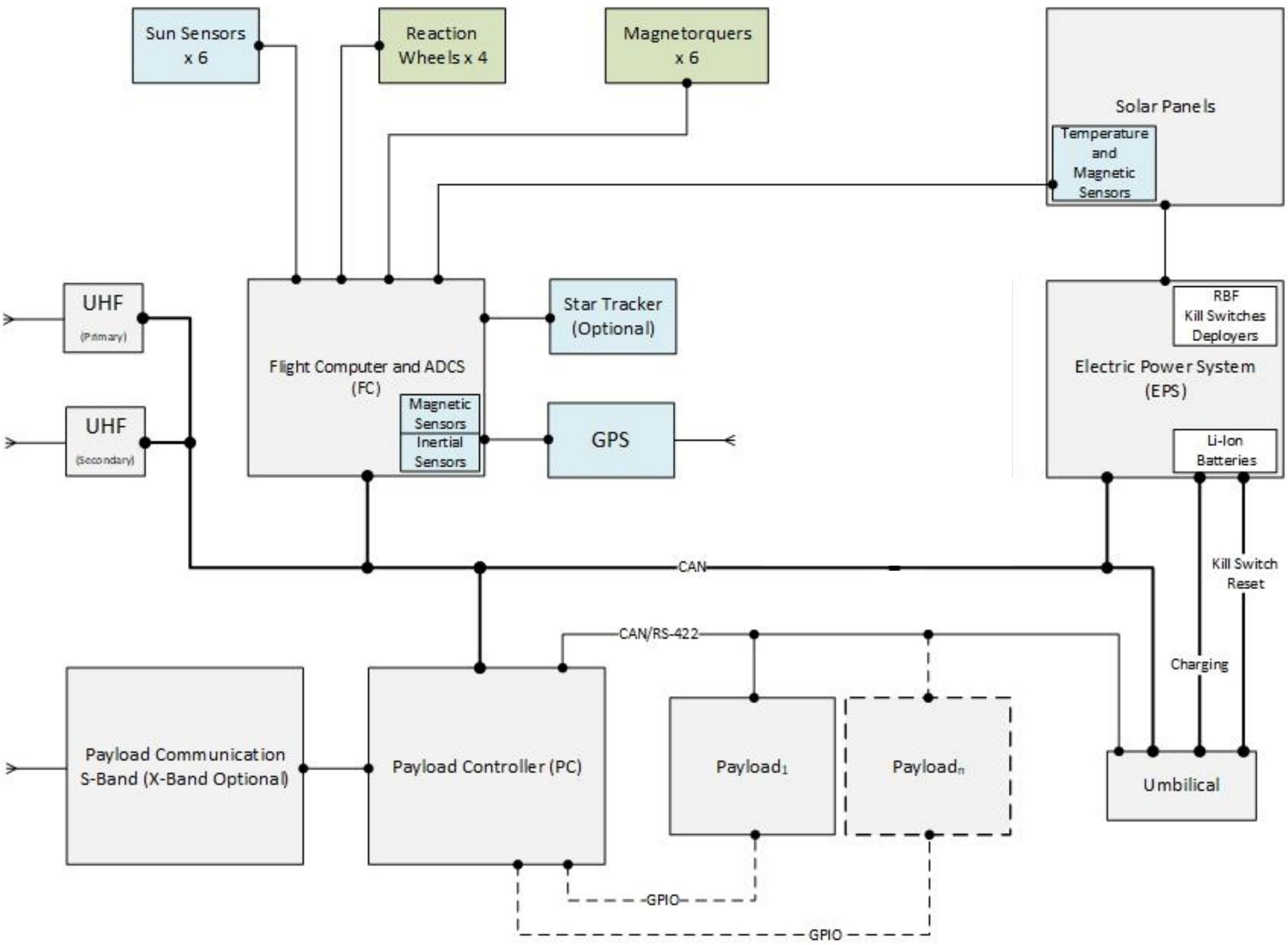

Figure 3. M6P Architecture Diagram (it might vary according to the final Customer's requirements)

3. M6P Platform Power Configurations

The configuration of solar panels is fully dependent on mission requirements. Therefore, for the configuration estimation the Customer shall provide NanoAvionics with inputs such as:

1. Desired orbit parameters
2. Payload specifications (power and duty cycle)
3. Payload thermal requirements
4. Preliminary information on ground/orbital objects pointing (if any)
5. Other critical data which could have an impact on power and thermal configuration

Example power options available practically to handle thermal loads through excess heat dissipation are within the ranges represented

Figure 4 *and Figure 5.* Examples provided includes but not limits possible panel configurations for the M6P platform.

Note that average power available for payload highly depends on the CubeSat orbit and Customer mission requirements.

Detailed information on power configurations and available power budgets is provided in the document:

- *M6P Electric Power Resources*

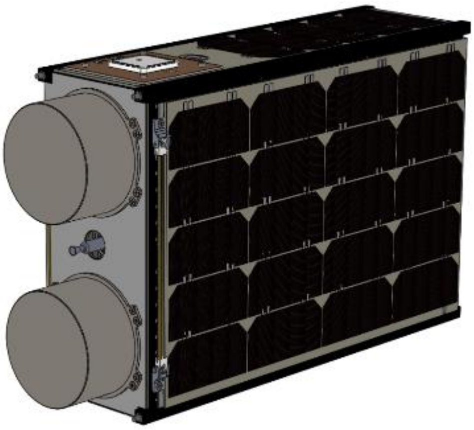

Figure 4. Default: no deployable panels configuration giving up to 9.5W OAP for payload

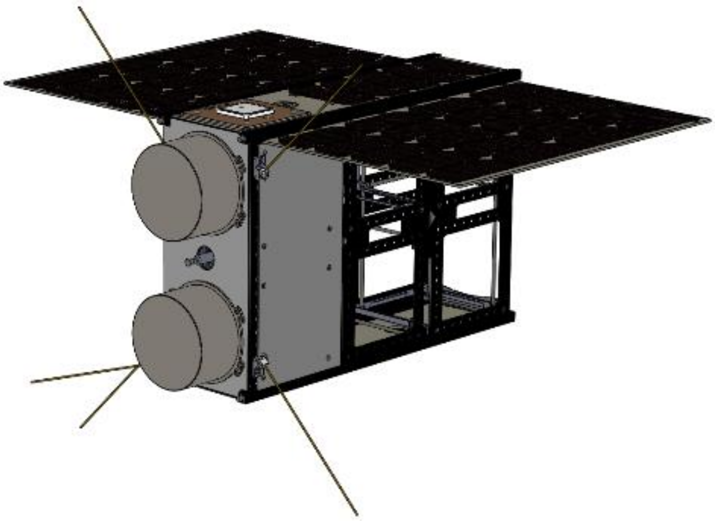

Figure 5. High power deployable panel configurations giving up to 29W OAP for payload

4. M6P Software Overview

The NanoAvionics system runs the open source FreeRTOS real time operating system, which is "light weight", reliable, relatively simple and easy to use. The kernel is designed specifically for integral embedded systems and provides a full set of task scheduler, resource management and synchronization features.

Implemented software solutions allow the Customer to save integration time and reduce mission risks. Solutions are capable of maintaining the platform and are flexible to build additional functionality and features specific to the Customer's mission.

Satellite Platform Software (SPS) covers:

1. Flight Computer (FC) (includes attitude control and determination) subsystem;
2. Payload Controller (PC);
3. UHF radio subsystem (COMM);
4. Electrical Power System (EPS);
5. Propulsion (Engine) Control Unit (ECU) subsystem.

All configurable functions and telemetry of containing subsystems are accessible using CSP protocol over CAN bus during the mission and text console over UART during development. SPS API features:

- Platform telemetry acquisition and storage
- Platform configuration
- Real-time clock
- Hardware diagnostic
- Attitude determination and control
- Position estimation from TLE
- Magnetic and Sun vectors estimation
- UHF radio downlink/uplink
- CSP protocol support
- Power distribution control
- File transfer
- Sending the beacon packets
- Collecting and sending real-time telemetry packets
- Executing scripts
- SPS can be configured by NanoAvionics for each mission including additional functions, if requested by Customer
- NanoAvionics' integrated Command Line Interface (CLI) allows fast diagnostic out-of-the box, configuration and telemetry readout using a human-friendly text-command interface

5.1 Mission Code Development

A firmware for satellite platform's FC, COMM, EPS and ECU subsystems come flashed and ready to use or in compiled image files of HEX or similar format.

Software for the PC along with detailed defined command list and Software ICD document are provided. NanoAvionics can support the Customer with no additional charge for 2 working weeks if some of the functionality needs to be adjusted to properly operate the Payload. However, the Customer is responsible for the Payload software development and implementation of the requirements provided by NanoAvionics.

Also, Software ICD contains instructions for the Customer to initiate collection of telemetry and configuration settings of all M6P subsystems over CSP network. The Customer's Payload mission software can request all available satellite platform data covering EPS telemetry to orientation and position in space.

If Customer requires to develop the PC software alone NanoAvionics can support the Customer for 2 working weeks with no additional charge. Any flashing and debugging requires Serial Wire Debug (SWD) debugger. The recommended debugger is ST LINK/V2 and recommended integrated development environment (IDE) is KEIL uVision. ST LINK/V2 debugger tool can be provided together with the platform if required. Though Customer can use any other IDE and debugging tool, NanoAvionics can only provide support setting up the recommended IDE and debugger.

5.2 CubeSat Space Protocol (CSP)

Majority of the NanoAvionics systems communicate using the CSP – an efficient open-source protocol stack developed specifically for network-centric nano-satellite systems.

CSP is a small network-layer delivery protocol designed for nano-satellites. The protocol is based on a 32-bit header containing both network and transport layer information. The implementation is written in C and is ported to run on FreeRTOS and POSIX and threads-based operating systems such as Linux.

The CSP enables distributed embedded systems to deploy a service-oriented network topology. The layering of CSP corresponds to the same layers as the TCP/IP model. The implementation supports a connection-oriented transport protocol (Layer 4), a router-core (Layer 3), and several network-interfaces (Layer 1-2).

Key features include:

- Simple API similar to Berkeley sockets
- Router core with static routes. Supports transparent forwarding of packets over e.g. spacelink
- Support for both connectionless operation (similar to UDP) and connection-oriented operation (based on RUDP)
- Service handler that implements ICMP-like requests, such as ping and buffer status
- Support for loopback traffic. This can e.g. be used for inter-process communication between subsystem tasks
- Optional support for broadcast traffic if supported by the physical interface
- Optional support for promiscuous mode if supported by the physical interface
- Optional support for encrypted packets with XTEA in CTR mode
- Optional support for HMAC-authenticated packets with truncated SHA-1 HMAC

5.3 Attitude Determination and Control Software

NanoAvionics' Attitude Determination and Control System (ADCS) framework is a software package that implements algorithms and functions required to facilitate attitude determination and control of nano satellites employing a magnetometer, inertial sensors, sun-sensors, in some cases high precision Inertial Measurement Unit (IMU) and Start Tracker for attitude determination. In addition, platform is equipped with GPS receiver to acquire global position and orbital parameters. Reaction wheels and magnetorquers are employed for actuation.

The information below provides an overview of the different elements included in the ADCS on-board firmware:

- Orbit propagation
- Geomagnetic field model
- Eclipse & Sun position
- Spacecraft dynamics and kinematics
- Sensors calibration
- Kalman filter (position and attitude determination)
- Control algorithm
- B-dot for de-tumbling

The ADCS code will start up in detumbling mode until upload of the satellite two-line element (TLE) is performed during the satellite commissioning or acquisition of the GPS signal, before initiating more advanced control modes.

The code under this framework will be tailored and improved by NanoAvionics to support the specific mission tasks, including specific modes to reach optimal capabilities of the ADCS according to the particular mission case. The control modes are distinguished as following:

- Detumble mode
- Velocity vector pointing mode
- Nadir pointing mode
- Sun maximum power tracking
- Earth target tracking according to geodetic coordinates
- Nadir/one axis sun-tracking

User supplied (ECI) vector tracking

Detumbling is performed by use of magnetorquers, which interact with the Earth's magnetic field to create a torque. This will eventually slow the spacecraft's angular velocity and damp oscillations down to a point where a transition to a more advanced attitude control mode is made.

Determination is performed by collecting data from the following sensors:

- Inertia and magnetic sensor system
- Sun sensors
- GPS

The sensors' data is fused by the Kalman filter, determining the spacecraft's position and attitude. An obtained attitude quaternion is used as input data for attitude control algorithms, which drive the reaction wheels to achieve the required pointing direction. Magnetorquers are also used to de-saturate the reaction wheels.

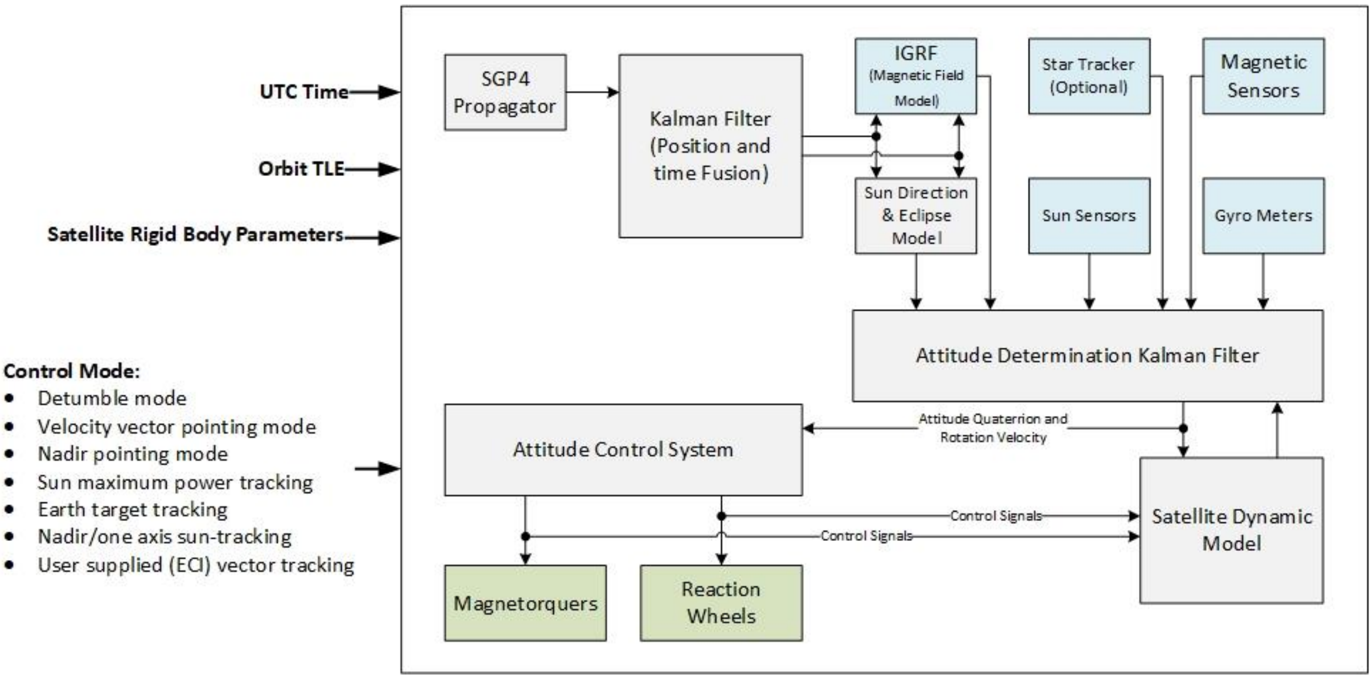

Figure 6. ADCS System Architecture

For more technical information please see the following documents:

- *M6P Platform (Rideshare) Software Interface Control Document*

5. M6P Payload Installation

The M6P platform allows easy and fast integration of the payload through standardized electric, data, software, mechanical and thermal interfaces. It is strongly recommended that the installation be supervised by NanoAvionics engineers to ensure smooth and reliable operations in orbit as well as safe orbital insertion of the satellite to start the mission successfully.

The mechanical brackets and harness needed to accommodate the payload instruments are provided by NanoAvionics to ensure proper operational conditions. Thermal control, power and data interfaces are connected under the guidance or recommendations of the NanoAvionics team.

Additional qualification, EM compatibility or functional testing might be performed if required by the Customer or launch provider for safety or flight acceptance reasons.

The platform enables Customer to use up to 5U for the payload, which is mechanically fastened to the structure using internal mechanical nodes. The layout of the platform allows exposure of the payload instruments to the exterior of the satellite or to keep them covered under the side panels.

5.1 Payload Interfaces – Data and Power

All signals and power channels are available on Molex Pico-Lock type connectors.

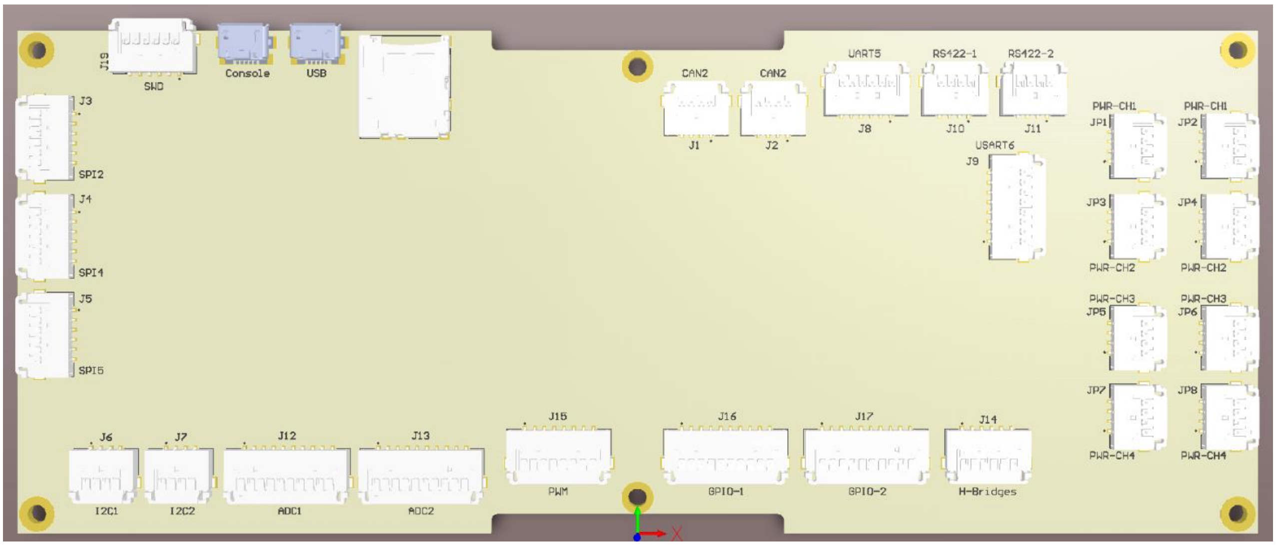

Figure 7. Payload Interface Board

Table 2. Command and Data Interfaces

Serial	I/O
Primary: • CAN • RS422 x 2/ UART Optional: • SPI x 3 • I2C x 2 • USART	• ADC x 14 • PWM up to 6 • Power PWM (H-bridge) x 3 • GPIO x 16

5.2 Payload Interfaces – Mechanical Layout

The platform package also includes all required harness (wires and connectors) to connect the payload and prepare the flight software through programming/debugging/umbilical interfaces which allows debugging, software upload and charging of the satellite when fully integrated.

During the entire integration process, whether it is held at the Customer's premises or at NanoAvionics, it is strongly recommended to follow NanoAvionics' recommendation and guidance through the entire process.

For more technical details please see following documents:

- *M6P Platform-Payload Interface Control Document*

6. Launch and Logistics

NanoAvionics offers a piggyback-launch opportunity to Low Earth Orbit (LEO) with the Indian Polar Satellite Launch Vehicle (PSLV) and Rocket Lab Electron due to its favorable conditions. NanoAvionics' service includes a complete launch package taking care of all aspects related to launch, logistics of the satellite, and satellite-deployer-launch vehicle integration. The complete launch package service contains:

- Securing the launch opportunity on one of the suitable upcoming launches with a possibility to switch the launch time 6 months before agreed time with no additional charges;
- Arrangement of launch deployer;
- Technical interface control (ICD) – arrangement and coordination of technical interfaces, equipment, and documentation required for the launch acceptance;
- Logistics coordination and support – coordination of Satellite and Ground Support Equipment logistics to the launch site and facilitating travel of personnel to and from integration facilities from Chennai airport as well as equipment re-export if needed;
- Launch vehicle integration – final satellite flight preparation campaign and, if required, satellite fueling operations. Final checkout of the satellite and integration with the launch vehicle at the launch site;
- Provision of the satellite orbit and attitude data at injection and commissioning support.

More technical information is available in document:

- *M6P Launch Information*

7. Ground Station and Mission Operations

NanoAvionics offers support for Customers in the preparation and implementation of a mission plan, including Ground Station (GS) communications after satellite commissioning. However, if the Customer prefers to go through the entire process independently, NanoAvionics is ready to help solve any related issues. NanoAvionics has extensive experience operating satellite platforms in an optimal manner, in terms of working positions involved and mission data handling, as well as taking into account data and power constraints while using payload instruments on-board the satellite. The NanoAvionics-provided GS kit features full hardware and software compatibility with any of NanoAvionics' platforms as well as all platforms and communication equipment provided by NanoAvionics is compatible with Leaf Space and KSAT infrastructure.

Customer access the Mission Control Software (MCS) and controls the Ground Station through defined Application Programming Interface (API). Graphical User Interface (GUI) is being developed by the Customer itself or NanoAvionics may provide mission specific interface under the separate agreement. All satellite operations are performed using a web-based access.

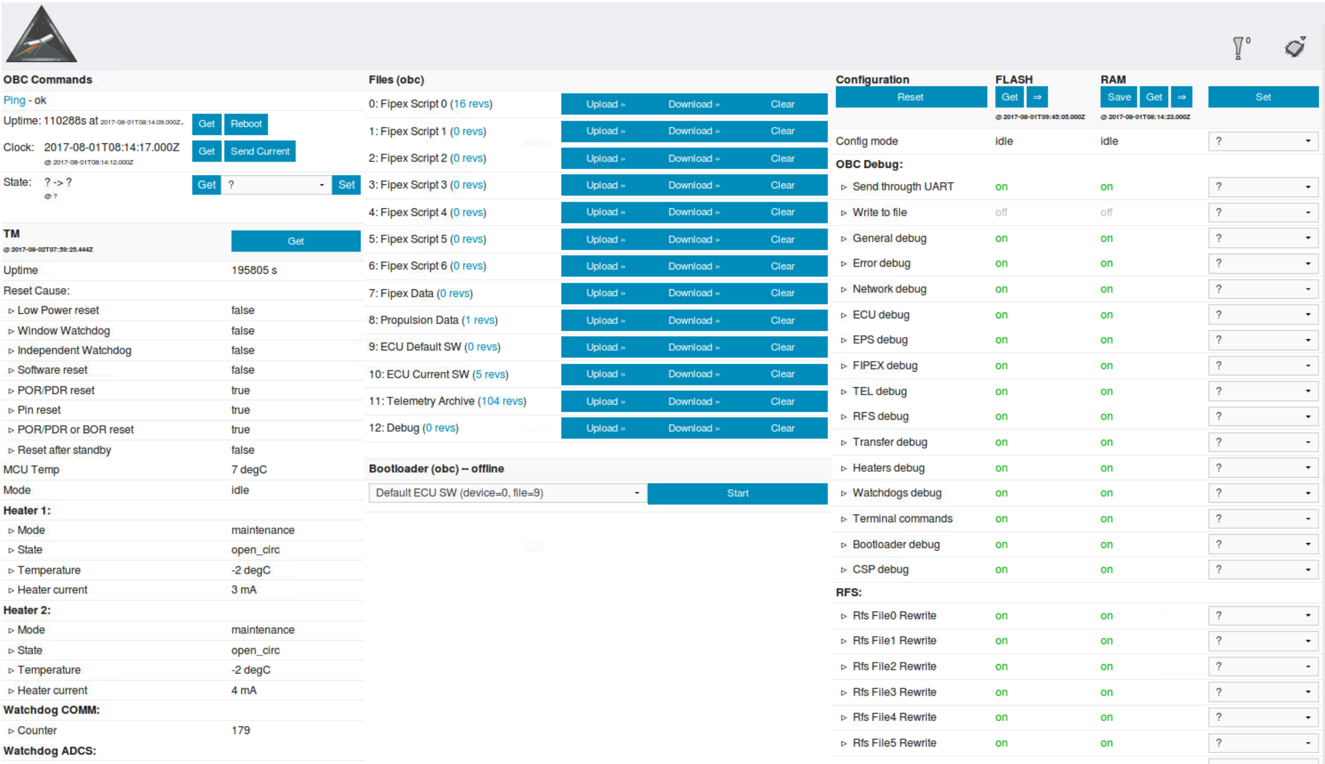

Figure 8. LituanciaSAT-2 GUI example (Flight Computer Control and Telemetry Window Fragment)

Typical ground station hardware provided or owned by NanoAvionics includes an antenna tower for on-the-roof mounting and a radio equipment rack, which can be installed indoors at a distance of up to 20 meters from the antenna. The rack includes a computer containing all the software required for satellite tracking, antenna rotation and radio control.

The ground station kit hardware set:

- Antenna tower with two UHF and one S-Band antennas
- Antenna rotator controller for azimuth and elevation
- 2 x NanoAvionics UHF radios (same type as in satellite platform)
- S-Band TRX
- SDR receiver
- UHF Tx power amplifier
- UHF Rx Low Noise Amplifier (LNA)
- UHF Rx/Tx switch
- Power Supply
- Ground Station Computer
- Firmware and drivers

For more technical details on Mission Control Software (MCS) and Application Programming Interface (API) please see following document:

- *NanoAvionics MCS API Description*

8. List of Referenced Documents