Microsatellite Buses MP42

Technical Overview

NA-MP42-TO-R000

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1 Microsatellite Buses MP42 Introduction

Hardware and software of NanoAvionics satellite buses MP42, MP42H and MP42D, as well as mission operations infrastructure, are established on baseline architecture and mission-specific "building blocks" for flexible, time & cost-efficient integration, resulting in wide applicability, reliability, repeatability and manufacturability.

MP42 buses are highly versatile – their performance capabilities are optimized for remote sensing, high data throughput & complex communications missions, emergency communications, and fundamental research missions. All requiring minimal reconfiguration.

All of the MP42 subsystems have been flight-proven during these different types of missions. Latest technological developments have been implemented to ensure the practical reliability of the platform. Critical systems such as the Flight Computer, Payload Controller, Electric Power System, and all others are 20krad radiation-tolerant. MP42 enables high payload data downlink speed – up to 1 Gbps downlink on the X-Band, while intersatellite link ensures uninterrupted real-time communications (LEO-LEO and LEO-GEO options available).

MP42 buses can include a propulsion system that enables the satellite to perform high-impulse maneuvers such as: orbital deployment, orbit maintenance, precision flight in formations, orbit synchronization, and atmospheric drag compensation. It results in an extended satellite orbital lifetime uncovered new opportunities for the unique customer missions and significant savings on constellation maintenance costs.

Figure 1. Microsatellite Bus MP42

2 MP42 Buses Features

Satellite Bus	General Features
MP42	• Total empty bus mass: from 45 kg (depends on configuration). • Maximum satellite mass: 120 kg* (depends on configuration and Payload Mass Properties). • MP42 Payload Envelope: 490 x 480 x 350* mm (*satellite height is highly adjustable to customers payload requirements, up to 1300 mm).
MP42H	• Total empty bus mass: from 18 kg (depends on configuration). • Maximum satellite mass: 40 kg* (depends on configuration and Payload Mass Properties). • MP42 Payload Envelope: 280 x 325 x 280* mm (*satellite height is highly adjustable to customers payload requirements, up to 1300 mm).
MP42D	• Total empty bus mass: from 70 kg (depends on configuration). • Maximum satellite mass: 220 kg* (depends on configuration and Payload Mass Properties). • MP42 Payload Envelope: 740 x 730 x 500* mm (*satellite height is highly adjustable to customers payload requirements, up to 1300 mm).

Subsystem	Satellite Buses Specifications
General Features	• MP42 Buses are 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 MP42 Buses 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.

Payload Controller 2.0	• Zynq®-7015 SoC family device featuring ARM Cortex™-A9 processor mated with Artix®-7 based programmable logic.
	• Maximum frequency 866 MHz.
	• 74K Programmable Logic Cells.
	• 256 KB on-chip RAM (processor) and 36 Kb block RAM (programmable logic).
	• 32 MB of external NOR-FLASH for Boot (2× 16 MB chips, QSPI).
	• 3× 512KB of FRAM (SPI) for frequently changing data storage.
	• 2 × 512MB of RAM (DDR3).
	• Integrated RTC.
	• microSD NAND Memory support (up to 4× microSD).
	• PetaLinux operating system.
	• In-Orbit firmware update.
	• Firmware Power-on-check and Restore.
	• RFS – Redundant Record-based File System.
	• A number of Payload dedicated interfaces:
	  ○ 1x Ethernet (with integrated magnetics).
	  ○ 2x CAN Interfaces.
	  ○ 4x RS422/UART.
	  ○ 2x SPI.
	  ○ 1x UART (Debug).
	  ○ 2x I2C.
	  ○ 1x USB 2.0.
	  ○ Up to 34 x LVDS, GTP, GPIO.
	• CSP Support.
	• Self-Diagnostics.
	• Dynamic CPU Frequency Control.
	• User-friendly Console.
	• TRL9

<table>
<tr><th>Subsystem</th><th>Satellite Buses Specifications</th></tr>
<tr><td>NanoAvionics Electrical Power Supply
“EPS” 2.0</td><td>
• Zynq®-7015 SoC family device featuring ARM Cortex™-A9 processor mated with Artix®-7 based programmable logic.
• Maximum frequency 866 MHz.
• 74K Programmable Logic Cells.
• 256 KB on-chip RAM (processor) and 36 Kb block RAM (programmable logic).
• 32 MB of external NOR-FLASH for Boot (2× 16 MB chips, QSPI).
• 3× 512KB of FRAM (SPI) for frequently changing data storage.
• 2 × 512MB of RAM (DDR3).
• Integrated RTC.
• microSD NAND Memory support (up to 4× microSD).
• PetaLinux operating system.
• In-Orbit firmware update.
• Firmware Power-on-check and Restore.
• RFS – Redundant Record-based File System.
• A number of Payload dedicated interfaces:
    o 1x Ethernet (with integrated magnetics).
    o 2x CAN Interfaces.
    o 4x RS422/UART.
    o 2x SPI.
    o 1x UART (Debug).
    o 2x I2C.
    o 1x USB 2.0.
    o Up to 34 x LVDS, GTP, GPIO.
• CSP Support.
• Self-Diagnostics.
• Dynamic CPU Frequency Control.
• User-friendly Console.
• TRL9
</td></tr>
<tr><td>Flight Computer (Including ADCS functionality) NanoAvionics “SatBus 3C2”</td><td>
• ARM 32-bit Cortex™ M7 CPU with clock speed up to 400 MHz (configurable);
• Double-Precision FPU;
• 1 MB of Internal RAM;
• MB of Internal FLASH memory;
• 2×512 KB of FMC-connected FRAM;
• 256 MB of External NOR-FLASH for data storage;
• 2×512 KB of FRAM (SPI) for frequently changing data storage;
• Integrated RTC;
• microSD NAND memory up to 32 GB;
• 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;
• TRL9;

ADCS Sensors:
• High precision Inertial Measurement Unit (IMU);
• Magnetic Sensors System;
• Albedo-free Fine Sun Sensors;
• Star Trackers;
</td></tr>
</table>

Subsystem	Satellite Buses Specifications
	Actuators: • Reaction Wheels System; • Integrated Magnetorquers; Attitude Control type: 3-axis stabilization; Attitude pointing accuracy ranges (pointing/knowledge) depends on the final bus parameters: • Up to 0.05° / up to 0.01°; Attitude maneuver ability (Slew rate):* • Up to 5°/s; Operational modes: • Sun pointing mode; • Nadir pointing mode; • Velocity pointing mode; • Ground geodetic coordinate pointing mode; • Client defined pointing mode. *Final satellite bus specifications highly depend on the configuration.

2.1 MP42 Architecture Diagram

The interaction between subsystems comprising the MP42 buses is described in Figure 2:

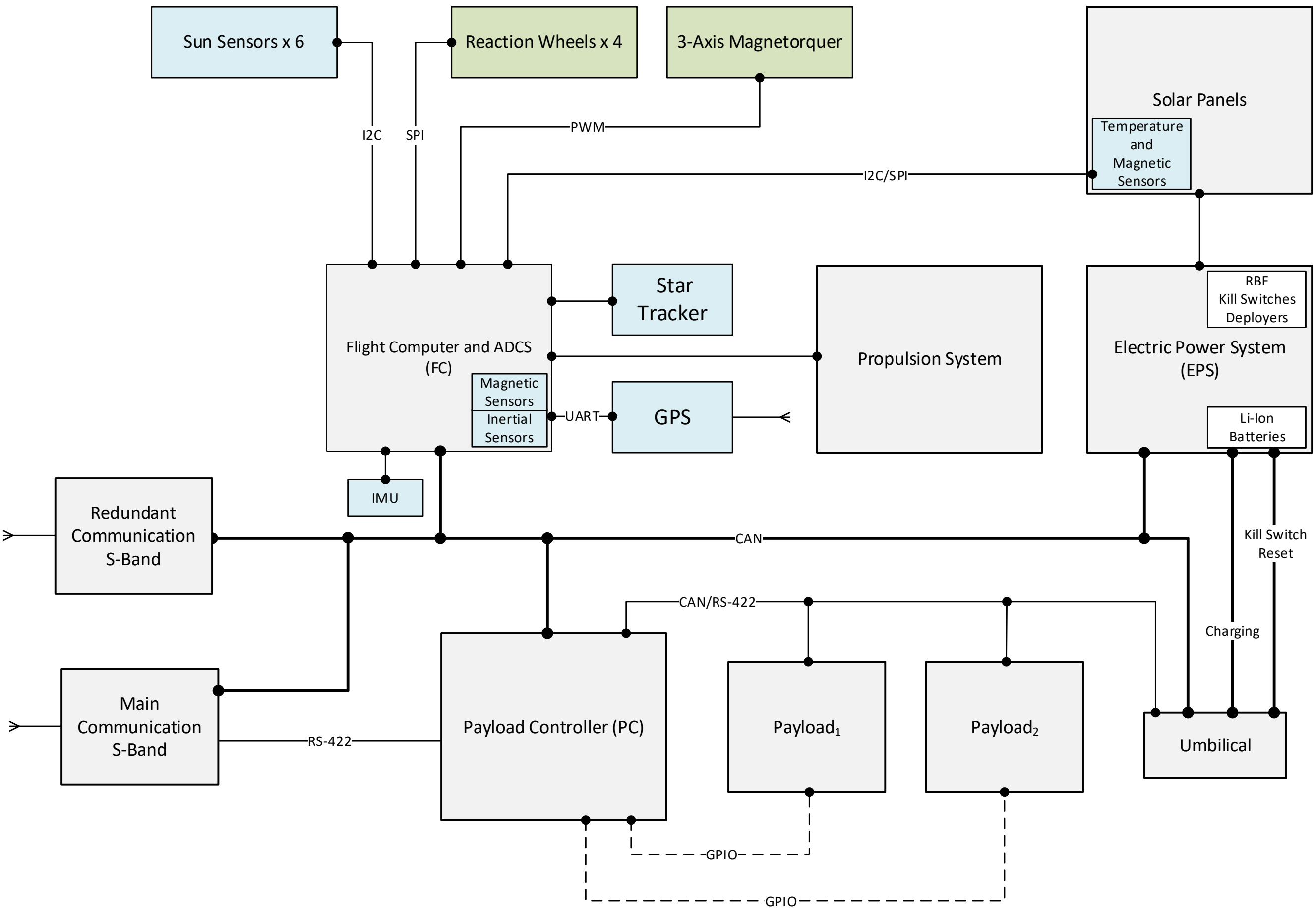

Figure 2. MP42 Architecture Diagram (may vary according to the final Customer's requirements)

3 Qualified Design

The MP42 buses and its comprising electronic and mechanical subsystems have been designed following the requirements of EUROPEAN COOPERATION FOR SPACE STANDARDIZATION (ESA ECSS) of European Space Agency and IPC-A-610 class 3 standards.

NanoAvionics follows the protoflight model philosophy as described in ECSS-E-HB-10-02A to qualify the design.

This approach is applied to projects whose characteristics are:

a. no critical technology is employed in the design,
b. qualified products are extensively used, and
c. compromise is permitted to reduce cost by accepting a moderate level of risk.

The pure protoflight approach is based on a single model (protoflight model: see Figure 3) to be flown after it has been subjected to a protoflight qualification and acceptance test.

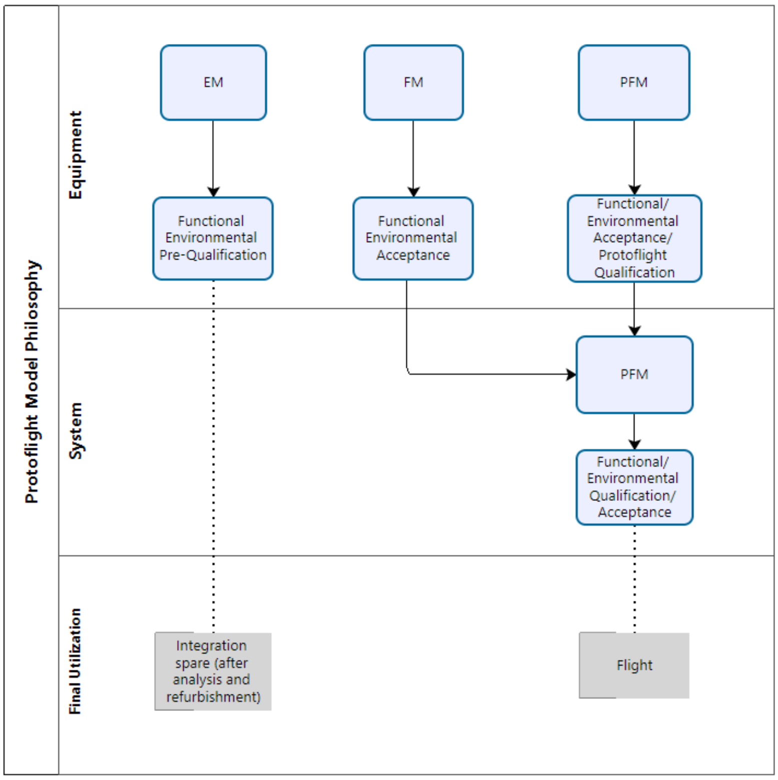

Figure 3. Protoflight model philosophy

Design of each subsystem of the bus has been qualified by thermal vacuum cycling, vibration and shock testing following National Aeronautics and Space Administration GENERAL ENVIRONMENTAL VERIFICATION STANDARD (NASA GEVS GSFC-STD-7000A) levels. Overall, our design is based on these ECSS standards and handbooks:

- ECSS-E-ST-10-02C Verification
- ECSS-E-ST-10-03C Space Engineering: Testing
- ECSS-E-ST-10-04C Rev.1 Space environment
- ECSS-E-ST-20C Rev.1 Electrical and electronic
- ECSS-E-ST-20-08C Rev.1 Photovoltaic assemblies and components
- ECSS-E-ST-31C Thermal control
- ECSS-E-ST-32C Rev.1 Structural general requirements
- ECSS-E-ST-32-01C Rev.1 Fracture control
- ECSS-E-ST-32-02C Rev.1 Structural design and verification of pressurised hardware
- ECSS-E-ST-32-08C Rev.1 Materials

- ECSS-E-ST-33-01C Rev.2 Mechanisms
- ECSS-E-ST-35-01C Liquid and electric propulsion for spacecraft
- ECSS-E-ST-50C Communications
- ECSS-E-ST-50-05C Rev.2 Radiofrequency and modulation
- ECSS-E-ST-60-30C Satellite attitude and orbit control system (AOCS) requirements
- ECSS-E-ST-35-06C Rev.2 Cleanliness requirements for spacecraft propulsion hardware
- ECSS-E-ST-32-02C Rev.1 Structural design and verification of pressurised hardware
- ECSS-E-HB-10-02A Verification
- ECSS-E-HB-32-25A Mechanical shock design and verification handbook
- ECSS-E-HB-32-26A Spacecraft mechanical loads analysis handbook (edited)
- ECSS-E-ST-35C Rev.1 Propulsion general requirements
- ECSS-E-ST-35-01C Liquid and electric propulsion for spacecraft
- ECSS-Q-ST-20C Quality assurance
- ECSS-Q-ST-10C Rev.1 – Product assurance management
- ECSS-Q-ST-70-08C Manual soldering of high-reliability electrical connections
- ECSS-Q-ST-70-38C Rev.1 Corrigendum1 High-reliability soldering for surface-mount and mixed technology
- ECSS-Q-ST-70-28C – Repair and modification of printed circuit board assemblies for space use
- ECSS-Q-ST-70-26C Rev.1 – Crimping of high-reliability electrical connections

Electromagnetic Compatibility (EMC) testing at the bus level has been performed qualifying robustness against adverse effects of electromagnetic interference from external sources, internal subsystems or the electromagnetic environment of space.

All subsystems of proposed satellite bus have been radiation tested under 20 kRad Total Ionizing Dose (TID). Additionally, mechanically complex subsystems such as reaction wheels have been tested by accelerated lifetime tests to qualify proper functionality.

Design qualification testing reports of MP42 can be disclosed to the Customer if requires.

The most importantly all of the hardware provided by NanoAvionics has been flight proven in space during the numerous missions.

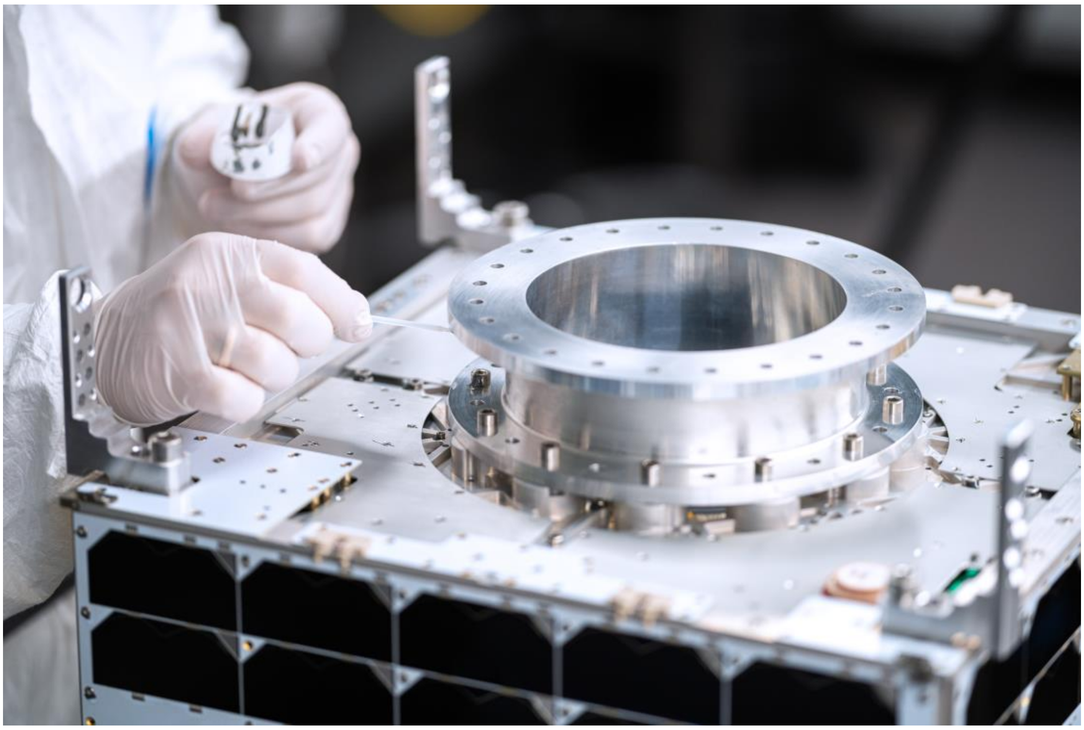

Figure 4. MP42 Satellite Bus

4 Quality Control Features

High industrial standards and procedures are applied to control the quality of NanoAvionics electronics, mechanical systems and software.

Electronic subsystems assembled and qualified in accordance to the IPC-A-610 class 3 by IPC certified specialists applying the requirements for each individual electronic component containing the systems. 3 dimensional Automatic Optical and X-Ray inspection is performed for each of the assembly.

Mechanical components are subject to measurement checks for tolerance control. Incoming and outgoing items inspection is performed at NanoAvionics to minimize the risk of faults and failures due to the discrepancy of the components.

For traceability purposes each system has a unique number indicated, where the serial number refers to a unique item list and the technical documentation of the product. Incoming/outgoing inspection documentation can be released to the Customer if required.

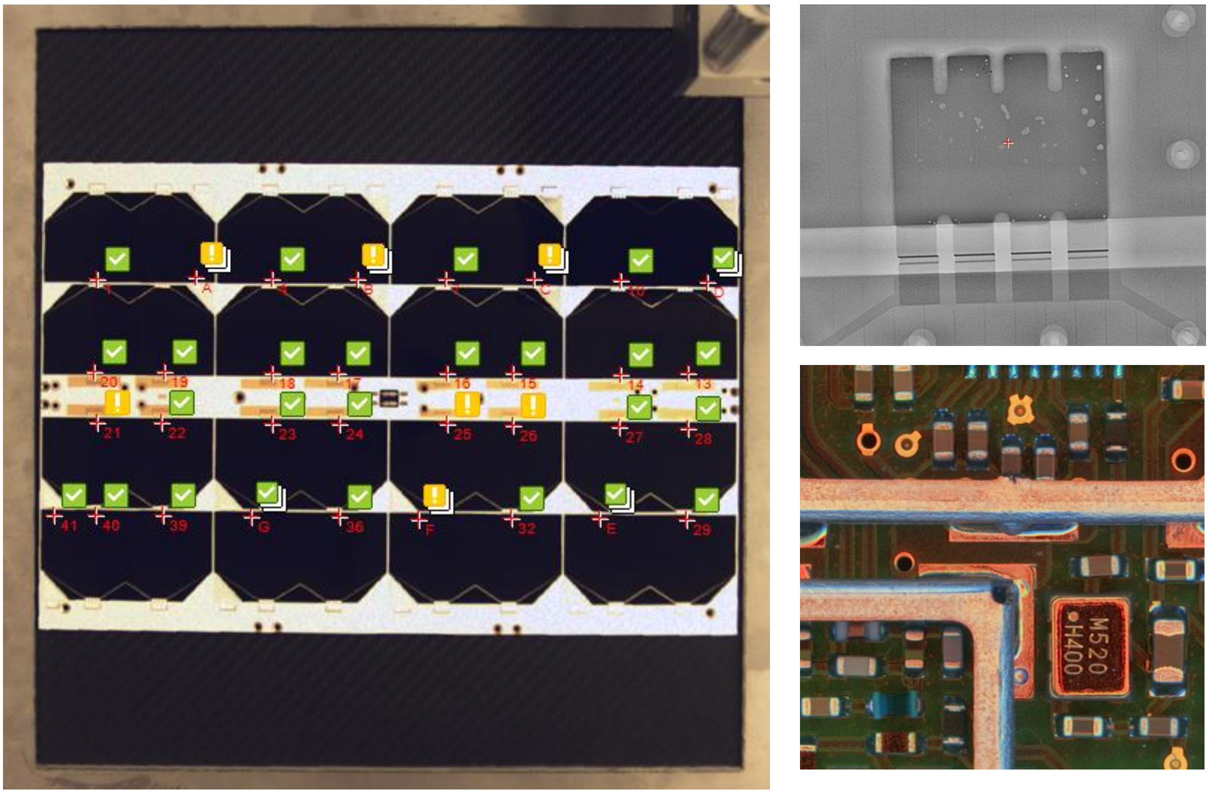

Figure 5. Optical and X-Ray inspection of electronic components and soldering quality

Final MP42 bus assembly is conducted following the predefined assembly plan, standard and customized component list, customized configuration sheets. Internal subsystems are assembled and integrated into the frame structure sequentially, verifying their functionality as per designed parameters and mechanical properties. After complete assembly MP42 bus undergoes functional testing which is being performed following European Space Agency EUROPEAN COOPERATION FOR SPACE STANDARDIZATION (ESA ECSS) guidance. NanoAvionics also follows the documentation list and content suggested by ECSS standard for nano and micro satellites development.

Finally, NanoAvionics follows quality control procedures by ISO 9001. The company is certified since 2018.

5 Ground Station and Mission Operations

NanoAvionics has extensive experience in operating satellites in an optimal manner, taking into account data and power constraints, while using payload instruments on-board the satellite. The company's satellite operations center offers cost-effective support for satellite operations, while ensuring the highest standards of data security. To meet demanding customers' missions' requirements, NanoAvionics have developed powerful mission control software which is capable of handling multiple satellite missions.

The company provides global coverage using its extensive ground stations network, which includes NanoAvionics owned ground stations in Denmark, Lithuania and the USA, as well as commercial partners' ground stations in over 200 locations around the globe (KSAT, LeafSpace, AWS and others).

Figure 6. NanoAvionics used Ground Station network

Mission Control Software (MCS) provided by NanoAvionics is compatible to any of above-mentioned options. Customer's access MCS and controls the Ground Station or access the external ground station networks through a defined Application Programming Interface (API). The Graphical User Interface (GUI) is to be developed by the Customer itself. If required, NanoAvionics may provide a mission specific interface under the separate agreement. All satellite operations are carried out through the established internet (TCP/IP) connection, ensuring confidentiality of the Customer data.

6 Disclaimer

The information in this document is subject to change without notice and should not be construed as a commitment by NanoAvionics, Corp. NanoAvionics assumes no responsibility for any errors that may appear in this document.