SPUTNIX ORBICRAFT PRO

Complete CubeSat kit based on Raspberry-Pi

Product catalog

Contents:

History

Revision	Date	Description
v11	15/05/2019	Roman Zharkikh: added History table added SXC-FW4-02 description
v10	15/03/2019	Original edition

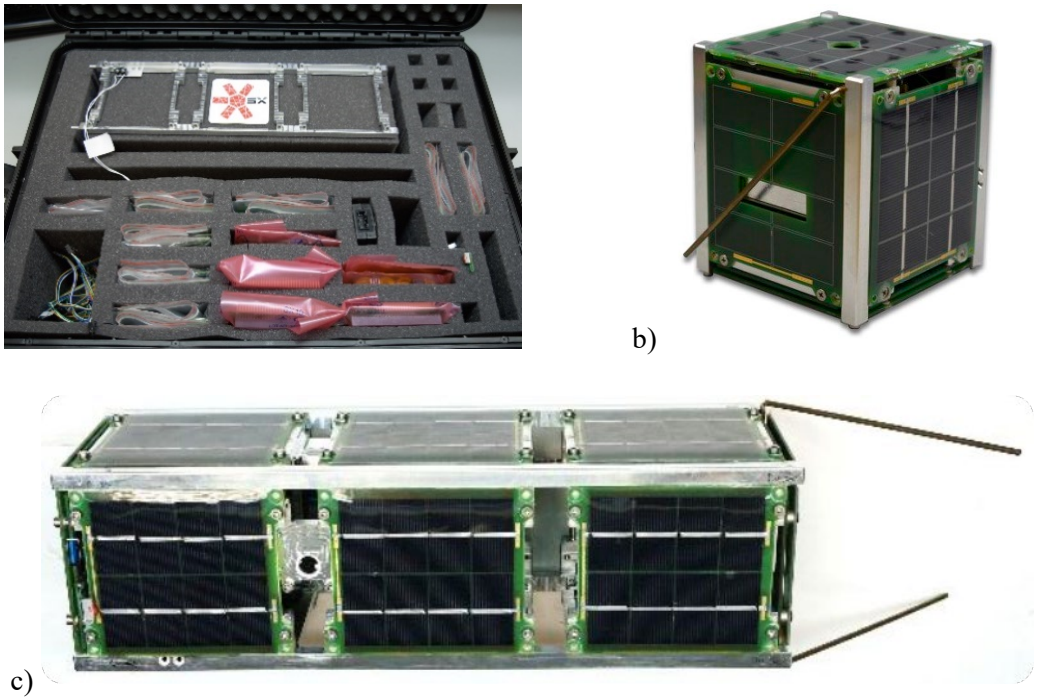
Introduction

The CubeSats are getting more popular for both educational and professional missions, but the cost of CubeSat components remains very high and uneasy to comprehend. SPUTNIX company has developed a low-cost CubeSat complete kit OrbiCraft Pro intended for university missions, the kit allows to create a satellite easier, faster, and cheaper due to standardization of its subsystems, use of commercial off-the-shelf (COTS) electronics and developed software libraries and collateral teaching material. This solution allows the scientific teams to focus on the payload and mission planning instead of developing a new satellite for each mission. The most popular CubeSat kits and their separated electronic parts have been thoroughly analyzed in order to determine common principles of the CubeSat developing and to find a way of developing satellite with lower cost, but compatible with the existing solutions.

One of the new principles in satellite engineering is using COTS components for space missions. Taking this principle into account, we chose Raspberry Pi as an On-Board Computer core and developed the whole set of compatible satellite systems. Special attention was paid to OrbiCraft programming interface - “SPUTNIX CubeSat API” - to provide the convenient way of payload integration and mission development. Also, OrbiCraft Pro keeps full API and user interface compatibility with platform's junior educational version - OrbiCraft Constructor.

Platform general description FLIGHT APPROVAL

OrbiCraft Pro satellite kit presents a set of electronic and mechanical parts for manual assembly of CubeSat-compliant spacecraft, in other words, a CubeSat construction set (Figure 1, a). When assembled, it can operate in laboratory and in open space conditions as well. Design supports both ways of usage: in a laboratory for educational purposes and on low-Earth orbits as CubeSat satellite for scientific purposes. Extremely low-cost in comparison with other available systems, at the same time, robust design allows to combine these scenarios in one product by sacrificing guaranteed in-space lifetime of a spacecraft. However, mentioned disadvantage is barely a problem for most of CubeSat educational missions for which, as NASA statistics shows, the main problem is likely to perform a successful spacecraft ejection and send a single acknowledgement to the ground control. Thereby we decided to reduce the lifetime providing an opportunity for working groups to study and practice with the very same device that afterwards can be launched to orbit and act as a part of a real space mission.



a) b) c)

Figure 1 . OrbiCraft Pro CubeSat kit: a - bare metal 3U set; b – assembled 1U unit; c - assembled 3U unit.

OrbiCraft Pro design meets the requirements of CubeSat Design Specification (CDS) revision 13. Spacecraft kit is intended for the students studying basics of spacecraft design, production, assembly, testing and operational processes. It consists of a set of separate PC/104 compliant PCB boards each of them carrying one or several satellite subsystems, cables, solar panels, and batteries. Two different form-factors are available: basic 1U and enlarged 3U, as shown on Figure 1, b and c respectively. For a 3U device an optional orientation control system is available. Possible configurations are listed in Tables 1 and 2. Should be noticed that all configurations are based on single design and can be launched at the end. The detailed specification can be found in the Appendix.

Table 1. Available OrbiCraft Pro configurations

Configuration	Educational	Experimental	Flight	Scientific
Description	Basic CubeSat kit for manual assembly and adjustments (DIY)	Assembled and verified by manufacturer CubeSat unit, ready for payload integration and testing	Assembled, verified, and calibrated by manufacturer unit, passed all qualification testing with or w/o payload.	Fully tested flight unit with installed and calibrated 3-axis orientation system and GaAs solar panels.
CubeSat 1U model (included options)	SXC1	SXC1-A (AS included)	SXC-F (AS, TF, TM included)	n/a
Options	GA1	TF, GA1	GA1	
CubeSat 3U model (included options)	SXC3	SXC3-A (AS)	SXC3-F (AS, TF, TM)	SXC3-MAX (AS, GA3, ADCS, TFF, TM)
Available options	GA3	TF, GA3, ADCS, TFF	GA3	

Table 2. OrbiCraft Pro options list

Code	Description
ADCS	3-axis orientation system including 6 sun sensors, reaction wheels module with 4 wheels and ADCS controller option for OBC
GA1	Set of 4 side and 2 end GaAs panels for 1U CubeSat
GA3	Set of 12 side and 2 end GaAs panels for 3U CubeSat
AS	Unit assembly and verification on manufacturer site
TF	Basic functional testing with protocol: PSU cycling, radio channel, electromagnetic angular velocity damping test
TFF	Testing from TF option and 3-axis orientation system examination with protocol
TM	Space qualification tests with approved protocol: vacuum, thermal and mechanical impact tests

Hardware

OrbiCraft Pro satellite has three general blocks: main electronic stack, frame assembly and solar panels as shown on Figure 2. In addition to main stack there are antenna board and service panel attached to the top and bottom respectively, both covered with corresponding solar panels.

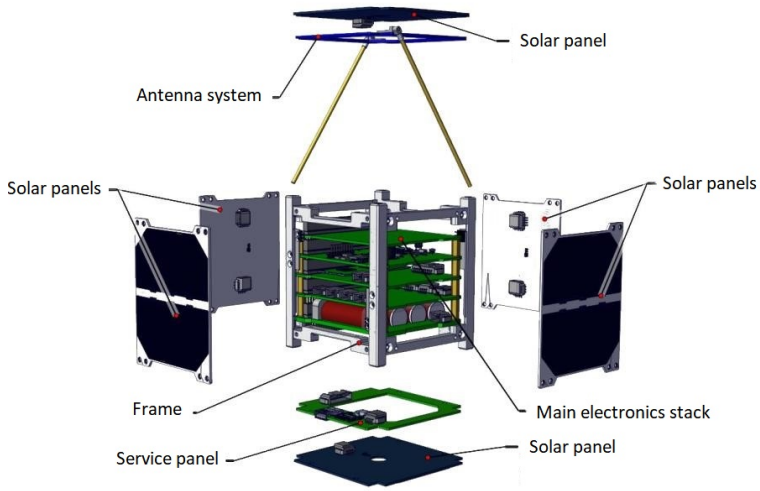


Figure 2 OrbiCraft Pro 1U assembly.

The electronic systems are modular, support variable placement order and connection of any number of electrically compatible additional PC/104 modules, such as orientation system board, different payload boards etc. All of them are assembled together in a vertical stack as shown on Figure 3. Every system is connected to a satellite network, represented with doubled CAN2.0B interface operating at 1 Mbit/s baud rate. CAN2.0B protocol stack is extended with mid-level Sputnix Unican 2.0 protocol in order to achieve robustness and convenience in telemetry and command exchange. Cable network uses PC/104 stackable connector and has additional outputs to service panel and devices, located on side panels, such as sun sensors. Service panel provides access to onboard network and battery charger interface. One of the useful feature of service panel is multiplexed two-wire debugging interface to most of PCB within electronics stack, thereby firmware can be updated or closely inspected on an assembled satellite.

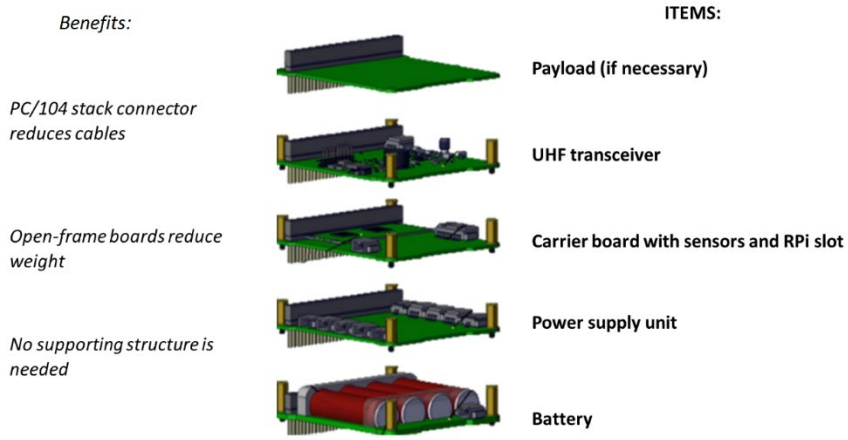


Figure 3 Main electronics stack.

Onboard computer is represented with Raspberry-Pi Compute Module model CM3 with provides compute facilities of four 1.2 GHz cores with 1 GB RAM and 4 GB ROM, but the most powerful feature of Raspberry-Pi is its well-known global community with great amount of ready-to-use solutions and code examples for any case. As a power-safe option there is an ability to delegate simple tasks, such as flight plan execution and battery management to the microcontroller located on UHF transceiver board and, thus, power-off Raspberry-Pi to reduce satellite power consumption dramatically. For data exchange with all other onboard systems the main CAN network is used, access to the bus is provided with SPUTNIX CubeSat API. This API makes messaging very easy providing ability to send and receive CAN and Unican packets by just calling corresponding functions from OS after using standard library linking procedure. Students can use C, C++ and Python languages for programing, developing satellite control applications and payload data processing as well. Raspberry-Pi computer is directly accessible via onboard removable Wi-Fi spot or by wire, which can be used to run terminal, SSH or remote desktop connections.

Payload integration is available for both OrbiCraft Pro 1U and 3U, dimensions and weight differ according to onboard empty space and available power supply. Basically, 1U allows installation of 89x95x15 mm PC/104 compatible payloads and 3U provides up to 89x95x200 mm of space. In addition to onboard CAN network payload can use extra interfaces: SPI, I2C, UART, USB which are traced directly to Raspberry module.

Power Supply Unit (PSU) has separated charger and battery PC/104 cards and provides an unique feature to replace expensive GaAs solar panels with low-cost silicon ones during educational process or for missions with low power consumption. Contrary, a silicon-based satellite can be transformed to GaAs before the launch just by replacing side PCBs and get more energy during the flight. There are two kind of side panels in OrbiCraft Pro platform, the basic ones with silicon solar cells, which provides up to 1 W per one panel, and optional with GaAs cells which allow to harvest up to 2 W per panel. There are 6 panels for 1U CubeSat and 14 – for 3U. Each solar panel also contains a built-in electromagnetic coil connected to others on the same axis in order to enforce summary field strength.

Basic functional diagram of OrbiCraft Pro's architecture is shown on Figure 4. The platform has several unified components which are used in both configurations, they are colored pale yellow. Among them there are:

- Main stack elements (Battery, Power system, Motherboard with Raspberry-Pi, UHF transceiver);
- Deployment system (Deployment switches DS-1 and DS-2);
- Antenna system;
- Service elements (Service panel with RBF switch);
- Solar panels with coils (number differs for 1U and 3U).

The 3-axis ADCS, highlighted green, consists of sun sensors set and a reaction wheels module with 4 wheels and an ADCS MCU located on the carrier board. Sun sensors are mounted on each facet of frame looking through specially designed windows on the side panels. Data connections shown blue and power ones are red.

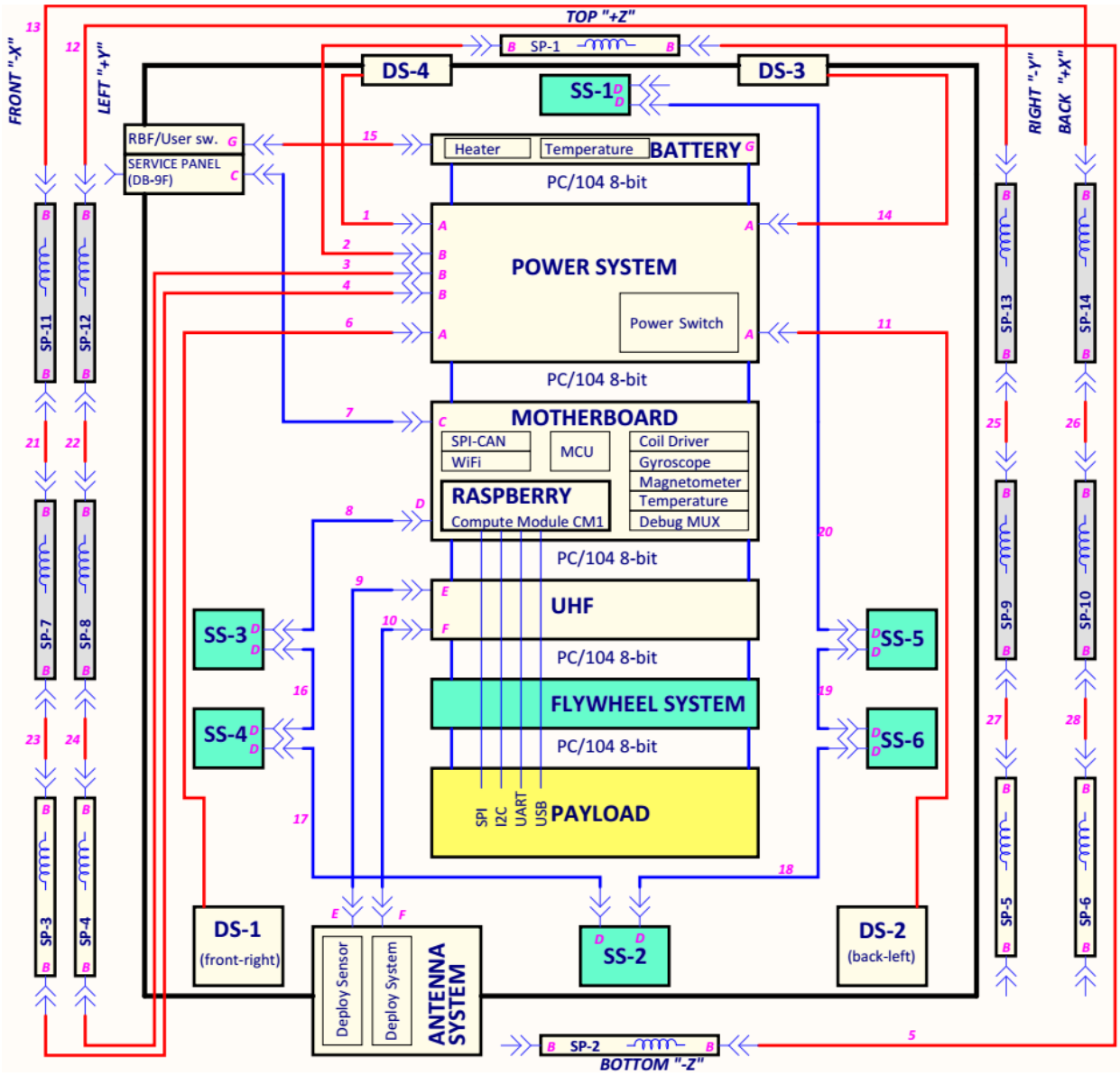


Figure 4 OrbiCraft Pro platform functional diagram.

Deployment system is located on the bottom side of satellite's frame and consists of two separation switches located on the diagonal rail's ends and a pair of separation springs on the rest rails. When satellite is in transportation mode the switches are disconnected and the whole satellite is powered off. During the ejection process from a P-POD springs push CubeSat away and switches go shorted connecting battery to power circuit. When in laboratory or on storage, the Remove Before Flight (RBF) switch can be used to power on and off the system. The problem is when RBF if frequently used, for example during study process, it can be easily damaged. To avoid this there is an additional switch on OrbiCraft's RBF which allows to power on satellite without removal RBF itself, there is a LED indication as well to prevent leaving device powered on when not used.

UHF transceiver SXC-UHF-02 FLIGHT APPROVAL

OrbiCraft Pro SXC-UHF -02 transceiver is a PC/104 stackable PCB with SMA antenna connector and auxiliary antenna deployment interface (Figure 5).

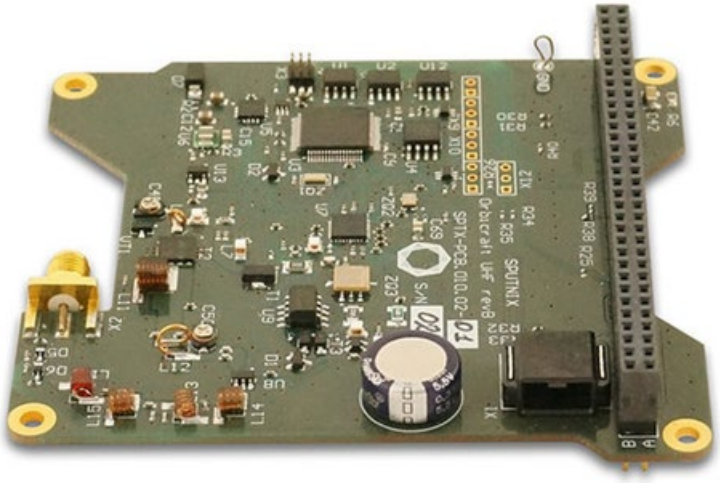


Figure 5 OrbiCraft Pro UHF transceiver.

The transceiver uses reprogrammable central frequency in 434-436 MHz range and a bandwidth not wider than 20 KHz achieving baud rate up to 9600 when in GMSK modulation mode. This speed is quite enough to exchange telemetry, commands, and data from modest payload. Maximum output power of 1 W is optimized for LEO transmissions as well as typical receiver's sensitivity of -119 dBm. UHF transceiver operates in -40..+85 degrees temperature range and weighs about 40 g. It is compatible with OrbiCraft Pro PC/104 pinout and has an additional feature of UART interface. Transceiver also runs watchdogs and a real-time clock which value is available on redundant CANx2 bus, this RTC has backup super capacitor power and keeps up ticking for about 2 weeks after main power is down.

Table 1 UHF transmitter technical data

Model: Sputnix SXC-UHF-02

Features:

- Half-duplex communication via single antenna
- Single board radio for telemetry, telecommand and beacon
- In-flight reconfigurable beacon period, datarate, frequency, call sign etc.
- In-flight firmware update via RF with backup
- Hardware and software watchdogs
- Customizable beacon message
- Ground to board bridge mode
- RTC with backup power
- Rich telemetry

Configuration:

- Operation frequency, baudrate, call sign
- Beacon contents and period
- RF connector type and orientation (on demand)
- Watchdog period

– CAN bus data rate

Properties	
Dimensions (w/o PC104 connector)	87 x 93 x 13
Mass	43g
Supply voltage	5..14V
Power consumption, max	3.5 W - transmission, 0.2 W - reception
Data interfaces	CAN2B (double), UART
Antenna interfaces	RF (SMA 50 Ohm), Antenna deployment system
Perfomance	
Operating frequency	434-438 MHz (Other ranges on request)
Output power	30 dBm (1 W)
Modulation type	GMSK
Data transfer rate	9600, 4800, 2400, 1200 bit/s
Receiver sensitivity	-119 dBm
Self telementry	Temperatures of MCU and RF, voltage, current, emitted and reflected power rate, RSSI, current time.
Datalink layer protocol	AX.25
Operationg conditions	
Operating temperature range	-40...+85°C
Storage temperature	-50..+105°C
Mechanical vibration	12 g (request full test report)
Mechanical shock	50g (request full test report)
Testing*	
Functional	QT, AT
Vibration	QT, AT (on demand)
Mechanical shock	QT
Thermal cycling	QT, AT (on demand)
Thermal vacuum	QT, AT (on demand)

**QT is performed on the design/qualification model*
AT is performed on the unit to be shipped

On-board computer SXC-MB-04

The SPUTNIX computer board SXC-MB-04 (Figure 5, b) represents a Raspberry-Pi Compute Module carrier which contains a set of devices, among them there are:

- standalone ADCS controller (option);
- gyroscope and magnetometer;
- electromagnetic coils driver unit;
- temperature sensor;
- real-time clock with backup power source;
- power system;
- central programming and debug system;
- main computer slot with appropriate power supply system.

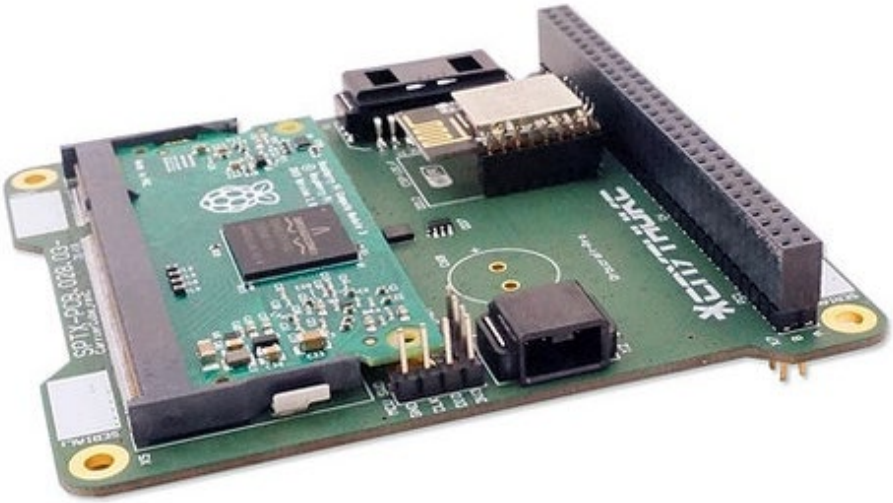


Figure 6 OrbiCraft Pro UHF transceiver.

All the onboard devices are accessible on redundant CANx2 buses as well as Raspberry, which is connected via onboard SPI-CAN converters. The main computer slot supports both Raspberry Pi CM1 and CM3 modules, the last one is basic option, but CM1 can be used to reduce power consumption at the expense of compute facilities. Should be noticed that the usage of CM3L module is not possible due it has no onboard ROM. In addition to main CAN bus there are number of Raspberry interfaces available on PC/104 connector:

- SPI with double chip select;
- High-Speed USB 2.0 port;
- I2C bus;
- UART.

Native Raspberry-Pi's camera connector is placed on carrier board for faster remote photo sensing satellite development.

System programming and debug hub provides up to 6 two-wire interfaces to the on-board devices and to external PC/104 boards using multiplexer. As the result, all the MCUs inside the assembled satellite are available for debug and flash. For Raspberry module there is removable WiFi module, USB and video interfaces for easy access.

The board with installed daughter boards weights 55 g and operates normally in in between -40..+85 degrees, but Raspberry-Pi has slightly reduced temperature range due to memory chip limitations but actual tests have shown that the whole system can operate normally in between -40..+85

degrees as well. Simple payloads, such as Arduino-based devices, can be easily powered by internal stable 5 V rail till it's supply current exceeds 200 mA.

When 3-axis ADCS is used, up to six sun sensors can be connected directly to the carrier board and on-board ADCS MCU can run the appropriate tasks autonomously using CAN interface for simple commands and telemetry.

Another low-power MCU provides CAN interfaces for sensors and manages on-board systems, additionally it runs a flight schedule to reduce power consumption of main computer module. It also can autonomously run the B-DOT stabilization algorithm using on-board electromagnetic torquers driver.

Flat and flexible hierarchy of the OBC provides satellite operational with appropriate consumption for every mode: low-power MCU only for energy harvesting, ADCS controller for idle mode and powerful Raspberry Pi compute facilities for payload operations.

Every programmable device on the OBC has a bootloader with in-flight reprogramming feature.

Table 2 On board computer technical data

Model: Sputnix SXC-MB-04

Features:

- Flat and flexible architecture: all devices have CAN bus interconnect
- Raspberry Compute Module CM1/CM3 slot
- Sensors on CAN bus: magnetometer, angular velocity, temperature, voltages and currents.
- EM torquer driver
- On board ADCS controller
- Low-power board managing MCU with B-DOT and flight plan
- Bootloaders with in-flight flash abilitu
- Rich centralized satellite debug system

Configuration:

- CAN bus data rate
- Removable WiFi module
- Raspberry CM1 or CM3 (default)
- Raspberry cooling plate
- ADCS controller presence
- RTC presence

Properties

Dimensions (w/o PC104 connector)	86.2 x 93.6 x 14
Mass	55g
Supply voltage	5..14V
Power consumption, max	0.25 W – sensors only, 0.9 W – sensors and loaded RPi (w/o WiFi)
Available power supply	5V output up to 200 mA for simple payloads Up to 650 mA for external CAN sensors
Data interfaces	CAN2B x 2 Raspberry: Camera I/F, UART, I2C, SPI (2 CS), USB.

Debug	Two-wire debug channels: on board MCU, ADCS MCU, 4 external channels on PC/104 Raspberry: removable WiFi, USB, video output.
Perfomance	
Raspberry CM3	Hardware: CPU up to 1.2 GHz quad-core ARMv8 4 GB Flash memory 1 GB SDRAM Software: API for CAN bus, code samples, program loader
Low-power MCU	Hardware: CPU Cortex-M4 16 MHz 256 KB Flash 64 KB SRAM 15 mW power consumption Software: Sensor drivers, EM-torquer driver, B-DOT, Flight plan, bootloader
ADCS MCU	Hardware: 80 MHz CPU 2 MB flash 128 KB SRAM Software: ADCS, B-DOT, Flight plan, bootloader
Power switch	3 channels up to 600mA each
EM torquer driver	3 channels up to 500mA each
Self telementry	Power voltages and currents, coils voltages and currents, magnetometer, angular velocity, temperature
Operationg conditions	
Operating temperature range	-40...+85°C (0..+60°C recommended for Raspberry)
Storage temperature	-50..+105°C
Mechanical vibration	12 g (request full test report)
Mechanical shock	50g (request full test report)
Testing*	
Functional	QT, AT
Vibration	QT, AT (on demand)
Mechanical shock	QT
Thermal cycling	QT, AT (on demand)
Thermal vacuum	QT, AT (on demand)

**QT is performed on the design/qualification model*
AT is performed on the unit to be shipped

Power supply unit SXC-PSU-03 FLIGHT APPROVAL

Sputnix Orbicraft-Pro power supply system uses power supply unit SXC-PSU-03 (Figure 5, c) module for power control in assistance with SXC-BAT-03 (Figure 5, d) battery unit for energy storage and up to 14 solar panels (typically SXC1-SPT-03 and SXC1-SPS-03) as electrical source. External battery charging rail presents on PC/104 connector and is typically traced to USB connector on the front of satellite service panel. Battery module data exchange use dedicated interface.

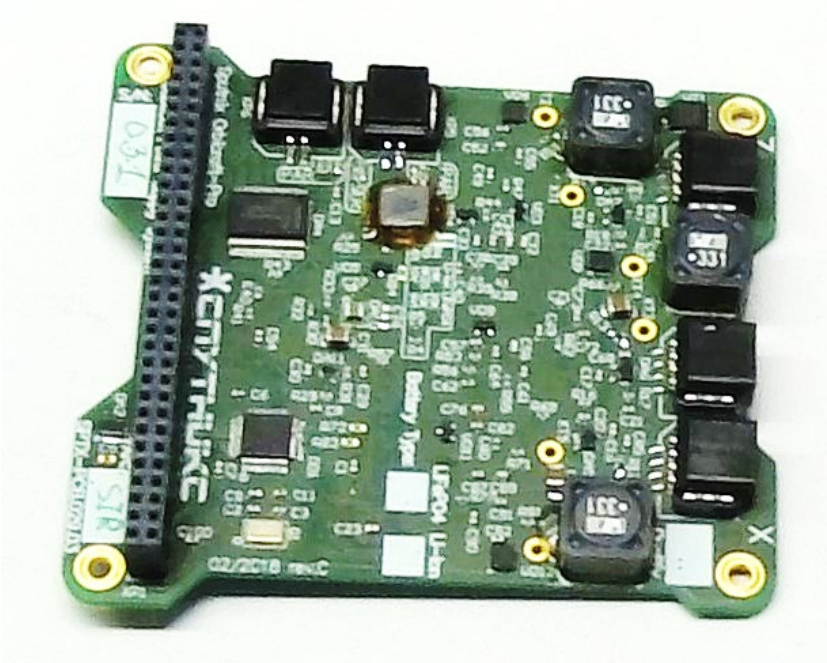


Figure 7 OrbiCraft Pro power supply unit.

Solar panels connect to 3 input channels, each per one satellite axis. PSU also supports usage of solar panels with built-in electromagnetic coils by single connector. PSU board has coils contacts traced to PC104. Satellite's solar panel on every axis are connected by cable system and have a separate connector on PSU. This makes available to enlarge coils, built into each solar panel, in a series manner to summarize their magnetic field. Overall there are three panel input connections on PSU, one per axis. The coils driver signals pass through PC/104 connector to carrier board. Charger units with maximum power point tracing support both types of photo elements: GaAs and Si, with the only condition – correct voltage level.

PSU has built-in 4-channel output power switch with current and voltage protection and telemetry on every channel. General PSU telemetry is also available on CAN bus and contains information about battery condition, input power, temperature, and fault status. In addition to 4 built-in output channels there are 3 external enable signals to drive auxiliary power switch located on carrier board, which can separately activate sensors, main computer and sun sensor devices.

There are number of battery protections provided by power supply system, including thermal sensors, heaters and switches that makes the whole system operate in satellite temperature range of about -40..+85 degrees, but for every particular flight the appropriate thermal calculations should be done and took into account.

Hardware watchdog circuit has long-term period of 25 hours (configurable) and can be reset only by command from the ground station. This exclude software dead loops of any kind. There are several software watchdogs as well acting as a software functions supervisor.

Software reliability increased with failsafe configuration memory access and built-in boot-loader with supports safe in-flight firmware updates.

Table 3 Power supply unit technical data

Model: Sputnix SXC-PSU-03

Features:

- 3 independent charger units with MPPT function
- up to 86% input converters efficiency
- Solar panels with coils support
- 4 output channels with current limits
- Failsafe output switch with timers
- RBF switch connection
- Long-period hardware watchdog circuit
- Rich telemetry

Configuration:

- Watchdogs conditions and periods
- RBF switch connection
- Battery protection levels
- External charger current limit

Properties

Dimensions (w/o PC104 connector)	96 x 89 x 14
Mass	58g
Solar panels channels	3
Solar panel type	GaAs, Si
Solar panel voltage	3..6V
Maximum solar panel current per channel	1500 mA
Maximum summary solar panels current	3000 mA
System bus voltage	8V (from solar, charger), 6.0V – 8.4V (from battery)
Output channels	4
Output channels voltage	direct from system bus
Output channel maximum power	1500 mA
Summary output current	5000 mA
Battery type	LiFePO4, Li-Ion
Battery voltage	2S
Charge voltage	4.5 … 5.5 V

Charge current limit	1.1A (default)
Power consumption, max	0.16 W – without solar power
RBF switch	Two separate RBF connectors, Separate disconnectable RTC ground
Data interfaces	CAN2B x 2 Battery UART.
Perfomance	
Low-power MCU	Hardware: CPU Cortex-M4 16 MHz 256 KB Flash 64 KB SRAM 15 mW power consumption Software: Watchdogs, RTC, MPPT, Flight plan, bootloader
Discrete hardware watchdog period	25 h (typical)
Battery heater channels	2
Maximum heater channel current	1000 mA
Telemetry	Input power voltages and currents, battery voltage and current, Output channels currents, temperature.
Operationg conditions	
Operating temperature range	-40...+85°C
Storage temperature	-50..+105°C
Mechanical vibration	12 g (request full test report)
Mechanical shock	50g (request full test report)
Testing*	
Functional	QT, AT
Vibration	QT, AT (on demand)
Mechanical shock	QT
Thermal cycling	QT, AT (on demand)
Thermal vacuum	QT, AT (on demand)

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Battery unit SXC-BAT-03 FLIGHT APPROVAL

Sputnix Orbicraft-Pro battery unit SXC-BAT-03 (Figure 8) provides electrical power storage with basic protections and sensors. Typically it's used with SXC-PSU-03 power supply unit connected by data and power interfaces. Power storage consists of two series Li-Ion cells with summary 10 Ah capacity, board is equipped with balancing circuit.

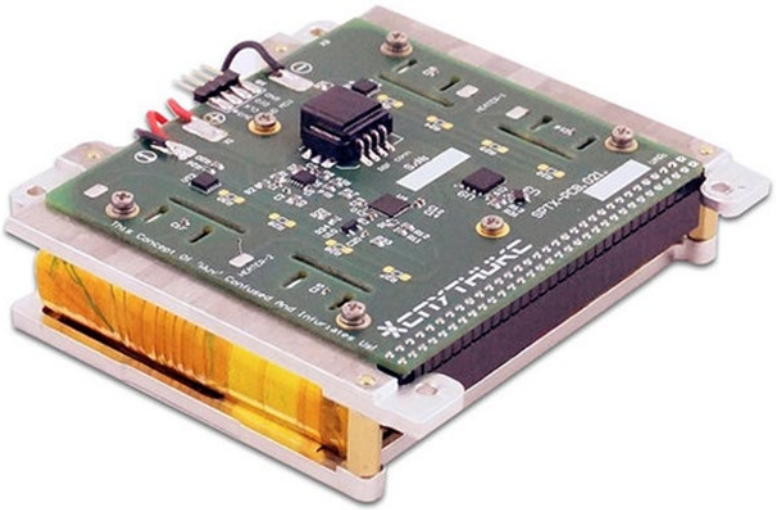

Figure 8 OrbiCraft Pro power supply unit.

Battery module supports RBF switch connection with physical bus disconnection. It also has precision voltage and temperature sensors. There are current limit protection with electrical power bus switch to prevent battery damage.

Built-in battery heaters allows to extend operating temperature range.

Table 4 Battery unit technical data

Model: Sputnix SXC-BAT-03

Features: • Large power storage • RBF switch connection • Built-in current and voltage protections and sensors • Digital interface	
Configuration: – Heaters power – Protection limits	
Properties	
Dimensions (w/o PC104 connector)	97 x 83 x 34.5
Mass	360g
Interfaces	PC104, RBF connector

Data interface	UART, 115200 8-N-1
Perfomance	
Battery type	Li-Ion
Battery voltage	2S (5.0V – 8.5V)
Capacity	10.6 AH (39.8 WtH)
Current protection limit	5.0 A
Voltage protection limits	5.0 V, 8.5 V
Battery heater channels	2
Heater resistance	40 Ohm (typ)
Telemetry	Voltage, temperature
Operationg conditions	
Operating temperature range	-40...+85°C (-20..+60 for longer battery life)
Storage temperature	-50..+105°C
Mechanical vibration	12 g (request full test report)
Mechanical shock	50g (request full test report)
Testing*	
Functional	QT, AT
Vibration	QT, AT (on demand)
Mechanical shock	QT
Thermal cycling	QT, AT (on demand)
Thermal vacuum	QT, AT (on demand)

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UHF antenna system SXC-AUH-02 FLIGHT APPROVAL

Sputnix Orbicraft-Pro UHF antenna system SXC- AUH -02 (Figure 8) provides convertion of electrical RF signal to electromagnetic waves for transmit and receive radio signals. Flexible dipole antenna design allows bending for transportation purpose and automatically deployment after launch.

Figure 9 OrbiCraft Pro UHF antenna system.

The system is equipped with RF balance system, every item has tuned SWR.

Table 5 Battery unit technical data

Model: Sputnix SXC-AUH-02

Features:

- Robust mechanical design
- Built-in RF balance system

Configuration:

- RF connector orientation

Properties	
Antenna type	dipole
Dimensions	98 x 98 x 10.5 board (98x362 deployed)
Mass	32 g
Interfaces	SMA, 50 Ohm
Perfomance	
Frequency	430 MHz – 440 MHz @ 6 dB level
Polarization	Linear
Operationg conditions	
Operating temperature range	-40...+105°C
Storage temperature	-50..+105°C
Mechanical vibration	12 g (request full test report)

Mechanical shock	50g (request full test report)
Testing*	
Functional	QT, AT
Vibration	QT, AT (on demand)
Mechanical shock	QT
Thermal cycling	QT, AT (on demand)
Thermal vacuum	QT, AT (on demand)

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Si side solar panel with coils SXC-SSS-03 FLIGHT APPROVAL

Sputnix Orbicraft-Pro solar panel SXC-SSS-03 (Figure 8) use Si photo-electric converters and has built-in electromagnetic coils.

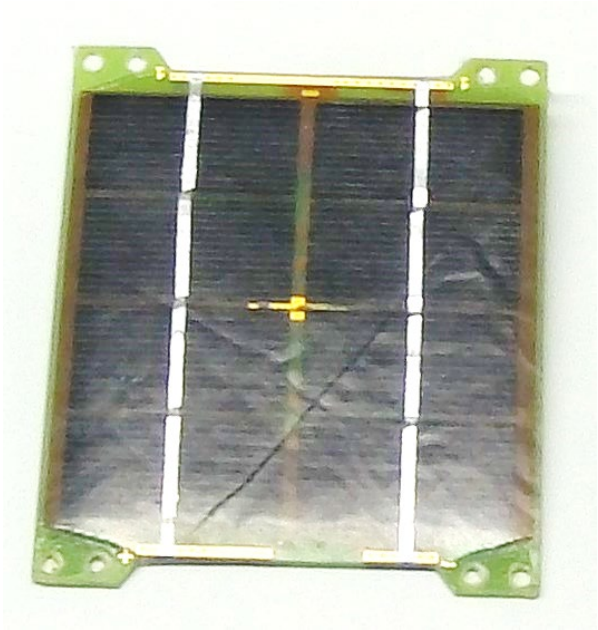


Figure 10 OrbiCraft Pro Si side solar panel with coil.

The panel is suitable for side edges of 1U CubeSats, both Sputnix and ISIS frames, several panels can be combined for 2U and 3U frames. The panel has a built-in electromagnetic orientation coil.

Table 6 Si side solar panel technical data

Model: Sputnix SXC-SSS-03

Features:

- Robust mechanical design with protective cover
- Compatible panels with SPUTNIX and ISIS CubeSats structures
- Super-diode protection circuit
- Built-in planar coil
- Scalable power and coils using several panels
- Calibration report for every item

Configuration:

- Connectors count
- Custom apertures (on demand, power degradation possible)

Properties	
Dimensions	98 x 82.6 x 8.6 mm (1.7 mm depth w/o connector)
Mass	32 g

Interfaces	Hirose GT8E connectors, scalable
Perfomance	
Cell type	Si
Open Circuit Voltage (Voc)	5.4 V
Short Circuit Current (Isc)	330 mA
Voltage at max. Power (Vmp)	4.4 V
Current at max. Power (Imp)	280 mA
Efficiency	18%
Coil equivalent area	1.9 m^2 (typ.)
Coil resistance	200 Ohm
Operationg conditions	
Operating temperature range	-40...+105°C
Storage temperature	-50..+105°C
Mechanical vibration	12 g (request full test report)
Mechanical shock	50g (request full test report)
Testing*	
Functional	QT, AT
Vibration	QT, AT (on demand)
Mechanical shock	QT
Thermal cycling	QT, AT (on demand)
Thermal vacuum	QT, AT (on demand)

**QT is performed on the design/qualification model*
AT is performed on the unit to be shipped

Si end edge solar panel with coils SXC-SSE-03 FLIGHT APPROVAL

Sputnix Orbicraft-Pro solar panel SXC-SSE-03 (Figure 8) use Si photo-electric converters and has built-in electromagnetic coils.

Figure 11 OrbiCraft Pro Si end edge solar panel with coil.

The panel is suitable for top and bottom edges of 1U CubeSats, both Sputnix and ISIS frames, several panels can be combined for 2U and 3U frames. The panel has a built-in electromagnetic orientation coil.

There is a 13 mm diameter aperture at the panel center with M2 mount holes for sun sensors or similar payloads.

Table 7 Si end edge solar panel technical data

Model: Sputnix SXC-SSE-03

Features:

- Robust mechanical design with protective cover
- Compatible panels with SPUTNIX and ISIS CubeSats structures
- Super-diode protection circuit
- Built-in planar coil
- Scalable power and coils using several panels
- Calibration report for every item

Configuration:

- Connectors count
- Custom apertures (on demand, power degradation possible)

Properties	
Dimensions	98 x 98 x 8.6 mm (1.7 mm depth w/o connector)
Mass	32 g

Interfaces	Hirose GT8E connectors, scalable
Perfomance	
Cell type	Si
Open Circuit Voltage (Voc)	5.4 V
Short Circuit Current (Isc)	300 mA
Voltage at max. Power (Vmp)	4.4 V
Current at max. Power (Imp)	250 mA
Efficiency	18%
Coil equivalent area	1.9 m^2 (typ.)
Coil resistance	200 Ohm
Operationg conditions	
Operating temperature range	-40...+105°C
Storage temperature	-50..+105°C
Mechanical vibration	12 g (request full test report)
Mechanical shock	50g (request full test report)
Testing*	
Functional	QT, AT
Vibration	QT, AT (on demand)
Mechanical shock	QT
Thermal cycling	QT, AT (on demand)
Thermal vacuum	QT, AT (on demand)

**QT is performed on the design/qualification model*
AT is performed on the unit to be shipped

GaAs side solar panel with coils SXC-SGS-03 FLIGHT APPROVAL

Sputnix Orbicraft-Pro solar panel SXC-SGS-03 (Figure 8) use GaAs photo-electric converters and has built-in electromagnetic coils.

Figure 12 OrbiCraft Pro GaAs side solar panel with coil.

The panel is suitable for side edges of 1U CubeSats, both Sputnix and ISIS frames, several panels can be combined for 2U and 3U frames. The panel has a built-in electromagnetic orientation coil.

Table 8 GaAs side solar panel technical data

Model: Sputnix SXC-SGS-03

Features:

- Compatible panels with SPUTNIX and ISIS CubeSats structures
- Super-diode protection circuit
- Built-in planar coil
- Scalable power and coils using several panels
- Calibration report for every item

Configuration:

- Protective cover (two options)
- Connectors count

Properties	
Dimensions	98 x 82.6 x 8.6 mm (1.7 mm depth w/o connector)
Mass	30 g (34 g with cover)
Interfaces	Hirose GT8E connectors, scalable
Perfomance	
Cell type	GaInP/GaAs/Ge on Ge substrate
Open Circuit Voltage (Voc)	5.3 V
Short Circuit Current (Isc)	500 mA
Voltage at max. Power (Vmp)	4.7 V
Current at max. Power (Imp)	480 mA
Efficiency	28%
Coil equivalent area	1.9 m^2 (typ.)
Coil resistance	200 Ohm
Operationg conditions	
Operating temperature range	-40...+105°C
Storage temperature	-50..+105°C
Mechanical vibration	12 g (request full test report)
Mechanical shock	50g (request full test report)
Testing*	
Functional	QT, AT
Vibration	QT, AT (on demand)
Mechanical shock	QT
Thermal cycling	QT, AT (on demand)
Thermal vacuum	QT, AT (on demand)

**QT is performed on the design/qualification model*
AT is performed on the unit to be shipped

GaAs end edge solar panel with coils SXC-SGE-03 FLIGHT APPROVAL

Sputnix Orbicraft-Pro solar panel SXC-SGE-03 (Figure 8) use Si photo-electric converters and has built-in electromagnetic coils.

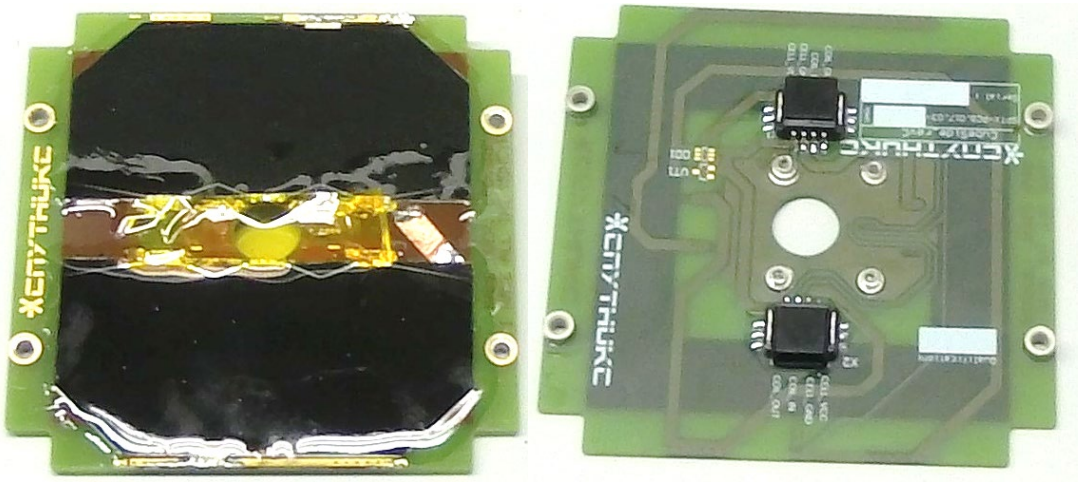


Figure 13 OrbiCraft Pro GaAs end edge solar panel with coil.

The panel is suitable for top and bottom edges of 1U CubeSats, both Sputnix and ISIS frames, several panels can be combined for 2U and 3U frames. The panel has a built-in electromagnetic orientation coil.

There is a 13 mm diameter aperture at the panel center with M2 mount holes for sun sensors or similar payloads.

Table 9 GaAs end edge solar panel technical data

Model: Sputnix SXC-SGE-03

Features:

- Robust mechanical design with protective cover
- Compatible panels with SPUTNIX and ISIS CubeSats structures
- Super-diode protection circuit
- Built-in planar coil
- Scalable power and coils using several panels
- Calibration report for every item

Configuration:

- Protective cover (two options)
- Connectors count

Properties	
Dimensions	98 x 98 x 8.6 mm (1.7 mm depth w/o connector)
Mass	32 g
Interfaces	Hirose GT8E connectors, scalable

Perfomance	
Cell type	GaInP/GaAs/Ge on Ge substrate
Open Circuit Voltage (Voc)	5.3 V
Short Circuit Current (Isc)	500 mA
Voltage at max. Power (Vmp)	4.7 V
Current at max. Power (Imp)	480 mA
Efficiency	28%
Coil equivalent area	1.9 m^2 (typ.)
Coil resistance	200 Ohm
Operationg conditions	
Operating temperature range	-40...+105°C
Storage temperature	-50..+105°C
Mechanical vibration	12 g (request full test report)
Mechanical shock	50g (request full test report)
Testing*	
Functional	QT, AT
Vibration	QT, AT (on demand)
Mechanical shock	QT
Thermal cycling	QT, AT (on demand)
Thermal vacuum	QT, AT (on demand)

**QT is performed on the design/qualification model*
AT is performed on the unit to be shipped

Service panel SXC-SP-03 with RBF switch SXC-RBF-03 FLIGHT APPROVAL

Sputnix Orbicraft-Pro service panel SXC-SP-03 (Figure 8) provides interfaces to the satellite for data exchange, debug and programming, charger connection all via single USB-like connector. The connector is USB-A 3.0 with custom pinout, though compatible with standard USB cables for charge purpose.

Figure 14 OrbiCraft Pro service panel with RBF switch.

The panel is designed to be used with Sputnix SXC-MB-04 computer, connected by cable inside the satellite, it provides convenient access to its data and power interfaces.

"Remove before flight" switch plug SXC-RBF-03 has separate socket on service panel and powers on system on removal. For easy use in laboratories RBF contains slide switch, there is a led also to prevent leaving enabled satellites unattended. RBF power connection is compatible with Sputnix SXC-BAT-03 battery unit.

Service panel supports indication for satellite state: battery connection and charge, power supply system.

Table 10 Service panel and RBF technical data

Model: Sputnix SXC-SGE-03

Features:

- Convenient USB connector
- Combined data, power and debug interfaces
- Satellite state indication
- RBF with additional slide-switch

Configuration:

- RBF switch custom design
- PC connection cable
- CAN-USB translator

Properties	
Dimensions	98 x 98 x 8.6 mm
Mass	24 g
PC interface	USB 3.0 with custom pinout
Satellite interfaces	Hirose GT8E connectors for: Power interface with RBF Data interface with on-board computer
Operationg conditions	
Operating temperature range	-40...+105°C
Storage temperature	-50..+105°C
Mechanical vibration	12 g (request full test report)
Mechanical shock	50g (request full test report)
Testing*	
Functional	QT, AT
Vibration	QT, AT (on demand)
Mechanical shock	QT
Thermal cycling	QT, AT (on demand)
Thermal vacuum	QT, AT (on demand)

**QT is performed on the design/qualification model*
AT is performed on the unit to be shipped

Sun sensor SXC-SD-01

Sputnix Orbicraft-Pro sun sensor SXC-SD-01 (Figure 8) is design for use in nano-satellites missions. CAN interface provides single cable connection and chains of sensors.

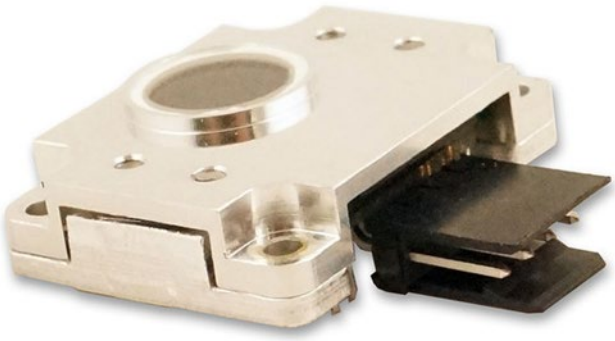


Figure 15 OrbiCraft Pro service panel with RBF switch.

PSD Sun Sensor is a two orthogonal axes digital sun sensor which. It generates the directional cosines of the angles of the direction to the sun, thus, it doesn't require any calibration. Besides, the sun sensor's size and weight are very small, as is his power consumption which is ultra-low.

Mount holes position is compatible with Sputnix solar panels.

Table 11 Service panel and RBF technical data

Model: Sputnix SXC-SD-01

Features:

- Mid-size satellites design in light and small package
- Ultra-low power CAN device
- Built-in DC converter for constant consumption

Configuration:

- Back cover removal to reduce weight
- CAN bus data rate
- Telemetry frequency

Properties	
Dimensions	28 x 23 x 11 mm
Mass	10 g (with cover)
Power supply	4-15 V

Power consumption	15 mW (in active mode)
Data interface	CAN 2.0B
Perfomance	
Field of vide (FOV)	± 60°(FOV is a cone)
Accuracy	< ± 0,5°(3**σ**)
Noise	± 0,1° (3**σ**)
Telemetry frequency	10 Hz
Operationg conditions	
Operating temperature range	-40...+85°C
Storage temperature	-50..+105°C
Mechanical vibration	12 g (request full test report)
Mechanical shock	50g (request full test report)
Testing*	
Functional	QT, AT
Vibration	QT, AT (on demand)
Mechanical shock	QT
Thermal cycling	QT, AT (on demand)
Thermal vacuum	QT, AT (on demand)

**QT is performed on the design/qualification model*
AT is performed on the unit to be shipped

Structure 1U CubeSat SXC-F1U-02 FLIGHT APPROVAL

Sputnix Orbicraft-Pro 1U CubeSat frame SXC-F1U-02 (Figure 8) designed in accordance with CuveSat rev.13 specification and supports modular satellite construction based on PC104 PCB stack with solar panels on the edges. The structure is fully compatible with all Orbicraft-Pro devices.

Figure 16 OrbiCraft Pro service panel with RBF switch.

The structure provides simple and fast assemble and requires only 8 screws, at the same time is durable base for the satellite with easy access to the devices inside and on the edges.

For container launches there is a deployment system which consists of 2 separation springs and double separation switches with interface for Sputnix SXC-PSU-03 power supply unit.

Table 12 Cubesat 1U structure technical data

Model: Sputnix SXC-F1U-02

Features:

- Very easy to assemble
- Easy access to internal volume

Configuration:

- Separation switches connectors
- Radiation protection panels (optional)

Properties	
Dimensions	CubeSat 1U
Mass	132 g
Board stack	PC/104

Perfomance	
Separation springs	2 pcs
Separation switchs	2 pcs
Operationg conditions	
Operating temperature range	-40...+85°C
Storage temperature	-50..+105°C
Mechanical vibration	12 g (request full test report)
Mechanical shock	50g (request full test report)
Testing*	
Functional	QT, AT
Vibration	QT, AT (on demand)
Mechanical shock	QT
Thermal cycling	QT, AT (on demand)
Thermal vacuum	QT, AT (on demand)

**QT is performed on the design/qualification model*
AT is performed on the unit to be shipped

Structure 1U CubeSat SXC-F3U-01

Sputnix Orbicraft-Pro 3U CubeSat frame SXC-F3U-01 (Figure 8) designed in accordance with CuveSat rev.13 specification and supports modular satellite construction based on PC104 PCB stack with solar panels on the edges. The structure is fully compatible with all Orbicraft-Pro devices.

Figure 17 OrbiCraft Pro service panel with RBF switch.

The structure provides simple and fast assemble, at the same time is durable base for the satellite with easy access to the devices inside and on the edges.

For container launches there is a deployment system which consists of 2 separation springs and double separation switches with interface for Sputnix SXC-PSU-03 power supply unit.

Table 13 Cubesat 3U structure technical data

Model: Sputnix SXC-F3U-01

Features:

- Fast assemble
- Easy access to internal volume

Configuration:

- Separation switches connectors
- Radiation protection panels (optional)
- Number of intermediate crossbeams

Properties

Dimensions	CubeSat 3U

Mass	455 g
Board stack	PC/104
Perfomance	
Separation springs	2 pcs
Separation switchs	2 pcs
Operationg conditions	
Operating temperature range	-40...+85°C
Storage temperature	-50..+105°C
Mechanical vibration	12 g (request full test report)
Mechanical shock	50g (request full test report)
Testing*	
Functional	QT, AT
Vibration	QT, AT (on demand)
Mechanical shock	QT
Thermal cycling	QT, AT (on demand)
Thermal vacuum	QT, AT (on demand)

**QT is performed on the design/qualification model*
AT is performed on the unit to be shipped

Charged particle detector SXC-SINP-CPD-01

Charged particle detector SXC-SINP-CPD-01 (Figure 8) was developed by Sputnix in collaboration with scientists from SINP (Moscow State Univercity). It is fully compatible with Orbicraft-Pro platform and can operate as payload in other satellites. Compact size and low power consumption allows installation of a detector in nano-satellites.

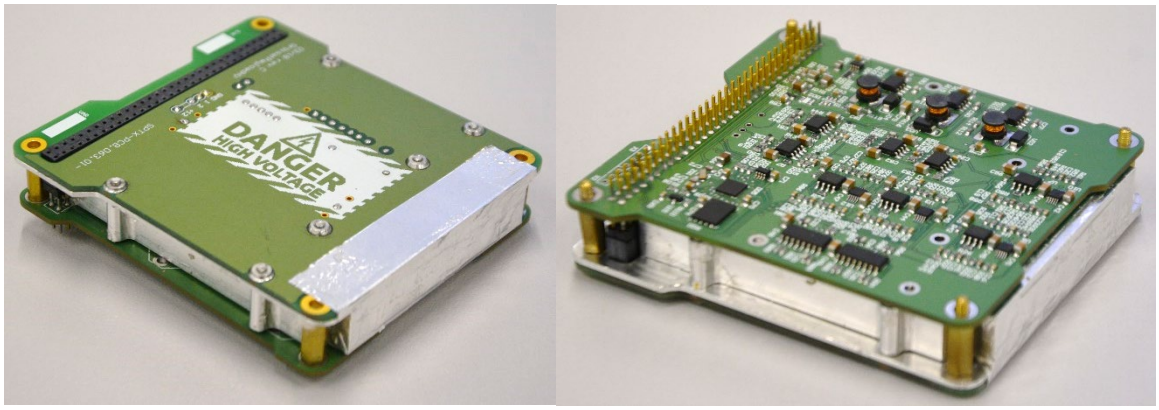


Figure 18 OrbiCraft Pro service panel with RBF switch.

Detector consists of digital and analog subsystems. Analog part use scintillator for particle detection and double photo-electronic amplifiers with high-voltage power source. Digital part use high-speed ADC and MCU for data analysis and storage. Digital and analog subsystems can be powered separately to reduce power consumption during downlink sessions. For data exchange with satellite systems CAN interface is used.

Detector provide simultaneous monitoring and single events parameters measurement. Recorded data can be accessed via satellite data bus.

Table 14 Service panel and RBF technical data

Model: Sputnix SXC-SD-03

Features:

- Mid-size satellites design in light and small package
- Ultra-low power CAN device
- Built-in DC converter for constant consumption

Configuration:

- Back cover removal to reduce weight
- CAN bus data rate
- Telemetry frequency

Properties	
Dimensions	95 x 89 x 22 mm
Mass	240 g
Power supply	6.0 – 9.0 V

Power consumption	650 mW (analog) + 100 mW (digital)
Data interface	CAN 2.0B
Perfomance	
Particle types	Gamma, electrons
Particle energy	0.3 – 3 MeV
Sensor effective area	4 cm^2
Common current monitor dynamic range	0 – 10000 cm^{-2}
Spectrum-timing analysis dynamic range	0 – 100 cm^{-3}
Time resolution	20 us
Memory size	8 MB
Operationg conditions	
Operating temperature range	-40...+85°C
Storage temperature	-50..+105°C
Mechanical vibration	12 g (request full test report)
Mechanical shock	50g (request full test report)
Testing*	
Functional	QT, AT
Vibration	QT, AT (on demand)
Mechanical shock	QT
Thermal cycling	QT, AT (on demand)
Thermal vacuum	QT, AT (on demand)

**QT is performed on the design/qualification model*
AT is performed on the unit to be shipped

Orbicraft-Pro development kit SXC-DK-01

The development kit SXC-DK-01 (Figure 19) is used for functional tests of Orbicraft-Pro components and pre-assembled electronic stack, also useful for payload development and integration process. It brings convenient access to signals and power buses for measurement and debug, provides emulation of crucial systems and sensors for stand-alone testing of separate Orbicraft-Pro boards.

Figure 19 OrbiCraft Pro Development Kit SXC-DK-01.

Development kit consists of a PCB board which has two regions, one of them can be inserted directly into main electronics stack of an Orbicraft-Pro satellite using standard PC/104 connector. It can be plugged on top, bottom or in the middle of stack. Devkit holds number of interfaces in order to provide access to any interface of assembled satellite and stand-alone boards. It also can emulate some subsystems when they are necessary for system-under-test operational.

The kit is very useful for payloads development process, because it's possible to debug payloads without fully assembled Orbicraft-Pro electronics. There are indicators for most power parameters, connectors for data interfaces and even emulations of some sensors.

Table 15 Development kit technical data

Model: Sputnix SXC-DK-01

Features:

- Stand-alone Orbicraft-Pro devices testing
- Suitable for install inside PC/104 electronics stack
- Convenient connectivity
- On-board power supply with telemetry
- Antenna deploy system emulation
- Deployment system switches emulation
- CAN-USB converters

Configuration:

– CAN bus data rate

Properties	
Dimensions	87x227 mm
Mass	300 g
Power supply	6.0 – 9.0 V
Power consumption	< 2W
Data interface	CAN 2.0B x2, USB2.0 x2
Perfomance	
Solar panels channels	3
Solar panel voltage	3..6V
Maximum solar panel current per channel	1500 mA
System bus voltage	8V (from solar, charger), 6.0V – 8.4V (from battery)
Output channels	4
Output channels voltage	direct from system bus
Output channel maximum power	1500 mA
Output channels telemetry	Input power voltages and currents, battery voltage and current, Output channels currents, temperature.
Input charger power	5.0V, 2A max
Operationg conditions	
Operating temperature range	+10...+45°C
Storage temperature	-40..+60°C

**This is a laboratory equipment and it's not intended for space usage*

Orbicraft-Pro Payload Baseboard SXC-MBB-01

The board SXC-MBB-01 (Figure 20) can be used for development of payload and other systems compatible with Orbicraft-Pro PC/104 bus. It holds a MCU with CAN driver, which grants access to the satellite bus. The vacant area of the board is 2.54mm pitch breadboard where user can place any needed components to enable payload's sensors and other periphery.

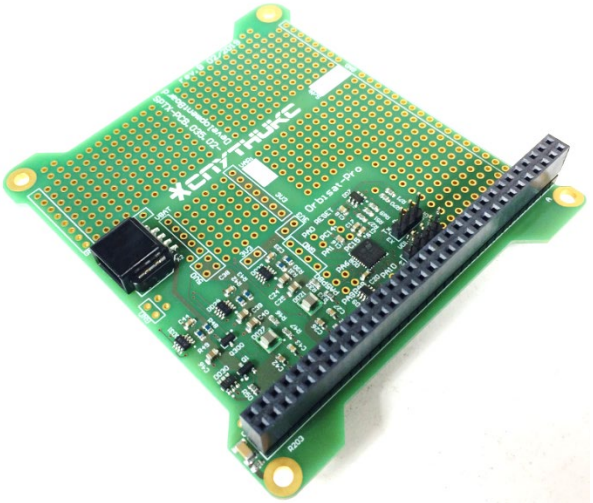


Figure 20 OrbiCraft Pro Payload Baseboard SXC-MBB-01.

The main point about SXC-MBB-01 is that it uses proven schematic and layout that is 100% compatible with the original architecture. Getting the board is also provides it's schematic.

In addition to hardware MCU can be optionally fulfilled with Sputnix basic firmware, which consists of binary bootloader with on-orbit firmware update feature, and a set of source code files, which can be customized by user to integrate the payload main function to the satellite.

There are several different devices mounted on the board:

- STM32L432KCU MCU;
- CAN-driver;
- I2C temperature sensor;
- power source for MCU and periphery with I2C current sensor;
- auxiliary power source for 2.54mm area with I2C current sensor;
- auxiliary power switch for 2.54mm area with I2C current sensor.

Table 16 Development kit technical data <u>(PRELIMINARY)</u>

Model: Sputnix SXC-DK-01

Features:

- approved MCU with CAN bus design
- user area with 2.54mm pitch
- controllable power system for user area
- board schematic provided
- firmware source files available
- bootloader available

Configuration: – firmware source files option	
Properties	
Dimensions	86.2x93.6 mm
Mass	34 g
Power supply	6.0 – 9.0 V
Power consumption	20 mW
Data interface	CAN 2.0B
Perfomance	
Power channels	3
Sensors	Temperature, Current and Voltage
Operationg conditions	
Operating temperature range	-40...+85°C
Storage temperature	-50..+105°C

Reaction wheels module SXC-FW4-02

OrbiCraft Pro SXC-FW4-02 reaction wheels module is an autonomous actuators module of four flywheels with drivers and control electronics which is designed to be integrated into 3U or larger nanosatellite (Figure 21).

Figure 21 OrbiCraft Pro reaction wheels module.

The flywheels and electronics are balanced and calibrated and provide enough momentum to rotate nanosatellite. It uses single PC/104 connection with power and CAN buses. Each flywheel driver can be driven separately with its own CAN ID.

The module is design to be used "off the shelf" with SPUTNIX SXC-MB-04-ADC controller (or later).

Table 17 SXC-FW4-02 technical data

Model: Sputnix SXC-FW4-02

Features:

- Complete 3-axis angular rate actuators for CubeSat satellite
- Easily integrates with SPUTNIX Orbicraft-Pro platform
- Four brushless DC motors with vacuum-rated bearings
- Wide power supply range
- Momentum and current control algorithms
- Voltage, Current and temperature sensors for each motor
- CAN interface for each separate driver
- Rich telemetry and commands protocol
- Bootloader with in-flight firmware update feature

Configuration:

– Increased maximum rotation speed and momentum – CAN bus data rate	
Properties	
Dimensions (w/o PC104 connector)	97 x 97 x 80 mm (< 1U)
Mass	520 g
Supply voltage	5..14V
Average power consumption	< 2000 mW (@2000 RPM)
Peak power consumption	< 8000 mW
Data interfaces	CAN2.0B
Perfomance	
Motor speed range	±6000 RPM (can be increased on demand)
Speed control accuracy	< 10 RPM
Max torque (X/Y/Z projections)	1.2/1.2/0.64 mNm (can be increased on demand)
Momentum storage (@6000 RPM, X/Y/Z 25/25/6.8 mNms)	25/25/6.8 mNms (can be increased on demand)
Self telementry	For each motor: temperature, voltage, current, RPM, momentum.
Operationg conditions	
Operating temperature range	-30...+85°C
Storage temperature	-50..+105°C
Mechanical vibration	12 g (request full test report)
Mechanical shock	50g (request full test report)
Testing*	
Functional	QT, AT
Vibration	QT, AT (on demand)
Mechanical shock	QT
Thermal cycling	QT, AT (on demand)
Thermal vacuum	QT, AT (on demand)

**QT is performed on the design/qualification model*
AT is performed on the unit to be shipped

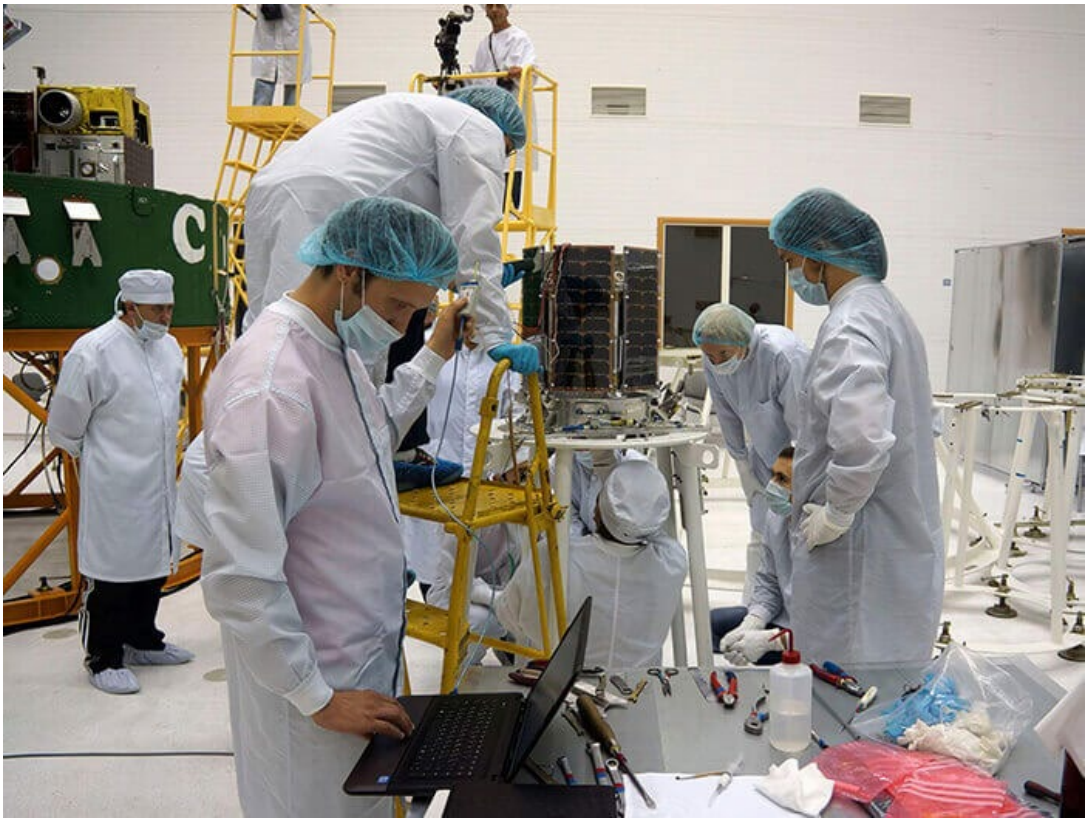
Appendix: OrbiCraft Pro kit specification

Item	Description	Quantity in SXC1 kit (pcs)	Quantity in SXC3 kit (pcs)
Battery unit	2s LiFePo4 cell 4.4 Ah	1	1
Side panel Si-cells	240mA 5V cell, 0.056nT 6V coil	4	12
End panel Si-cells	200mA 5V cell, 0.056nT 6V coil	2	2
Power supply unit	Supports Si, GaAs cells up to 3A, 4-ch output up to 1.5A each	1	1
Carrier board	Raspberry-Pi slot, magnetometer, gyro, coil control, sun sensor interface	1	1
Raspberry Pi CM3		1	1
UHF transceiver	436MHz central frequency, up to 9600 bods	1	1
UHF antenna system	435-438MHz bandwidth, deployment system with sensors	1	1
RBF switch	With slide button and LED	2	2
Service panel board	Charger, CAN bus and debug interfaces		
Deployment system	Reserved switches and double springs		
CubeSat 1U frame	With fixture	1	-
CubeSat 3U frame	With fixture	-	1
Safety hull for 1U	For transportation and storage	1	-
Safety hull for 3U	For transportation and storage	-	1
Onboard cable set for 1U	Solar panels, service panel, antenna and battery connections	1	1

Additional cables for 3U	Extra solar panels and extended antenna connections	-	1
Service cable	Provides charger, debugger and CAN access	1	1
Charger unit	2A 5V	1	1
Transportation case for 1U		1	-
Transportation case for 3U		-	1
CAN-USB converter		1	1

About SPUTNIX

SPUTNIX is the Russian private company, manufacturing high-tech microsatellite components and technologies, as well as microsatellites and cubesats based services. We are working since 2011, providing to our clients cost-effective solutions, based on microsatellite and cubesat technology, and a high level of technical support at all stages of the product life cycle. Our approach is to be attentive to the customer's wishes, to work on time and to provide flexible pricing. The core of efficient and professional SPUTNIX team are young professionals with real experiences in the design and operation of spacecraft, including microsatellites and cubesats.



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