GOLIAT

University of Bucharest CubeSat Project

Coordinator: Romanian Space Agency (ROSA)

Contents

- Mission definition
- Science payload
- Mechanical and Subsystems
- Status
- Follow-up

Mission Definition

Mission objectives

- University of Bucharest’s student team trains to design and build satellites
- Project for scientific purposes: electronics, optics and nuclear
- First Romanian satellite intended to draw youth interest for space science

Team and support

- Romanian Space Agency (ROSA) - coordinator
  - Support through the CEEX GOLIAT project (2005-2007)
  - University of Bucharest – **Student team members**
  - Institute of Space Sciences Bucharest – Scientific advisor
  - University Politehnica Bucharest – **Student team members**
  - CCSS BitNet Cluj, Romania – Ground Station
  - ELPROF SA Romania – Quality Testing facilities

- Project senior advisors
  - Marius-Ioan PISO, Research Professor (ROSA)
  - Dumitru HASEGAN, Research Professor (Institute of Space Sciences)
  - Dumitru Dorin PRUNARIU, Cosmonaut (ROSA)
  - Mircea RUSU, Professor, University Bucharest

Student Team

- 5 undergraduate students

  Corina Dumitru- University of Bucharest - Physics
  Marius Trusculescu- University of Bucharest - Physics
  Lorand Istvan- University of Bucharest - Physics
  Iulian Busu- University Politehnica of Bucharest, Electric Engineering
  Alex Iancu- University Politehnica of Bucharest, Electric Engineering

- 1 master level student

  Mugurel Balan- University of Bucharest - Physics

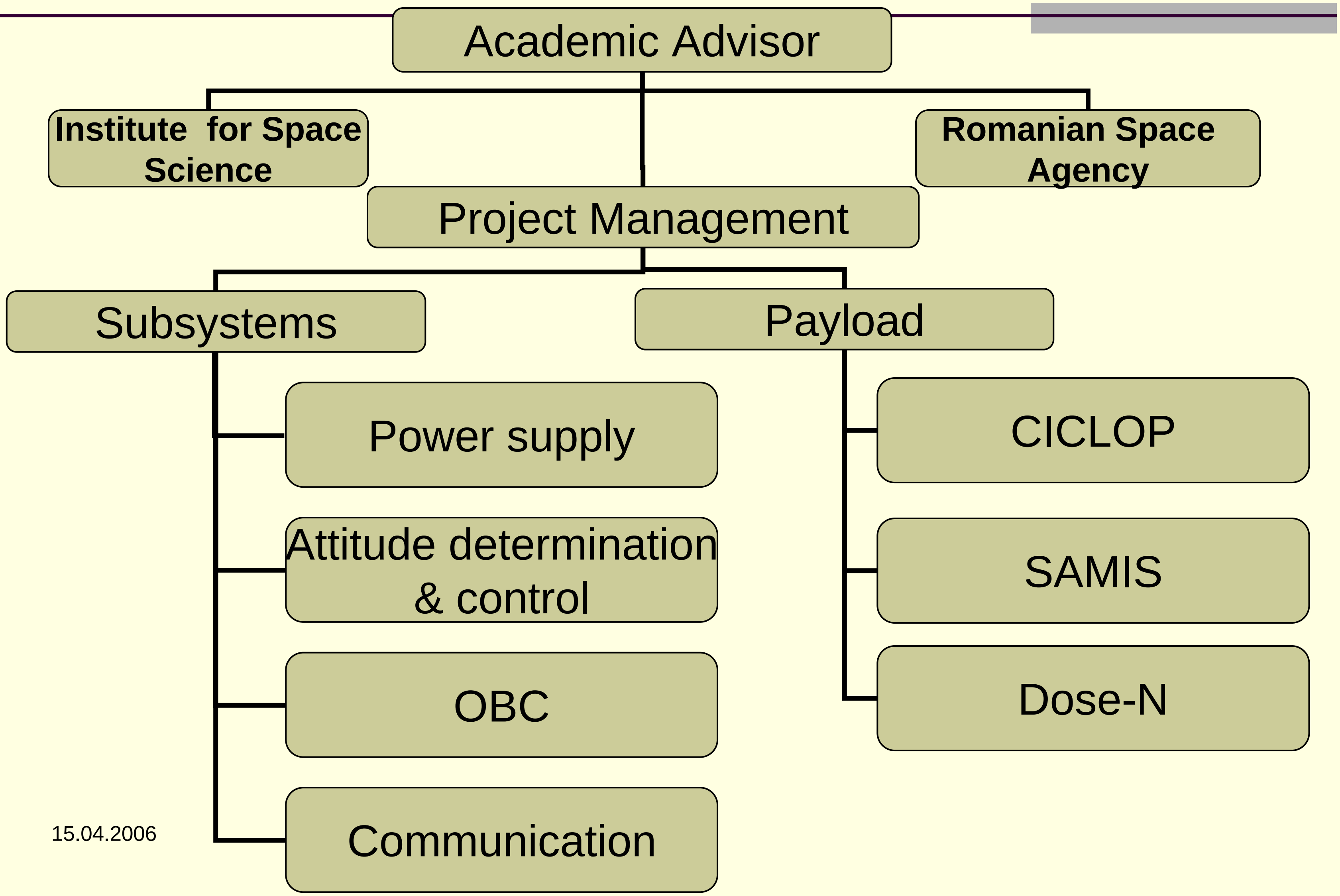
- 1 PHD student

  Irina Stefanescu- University Politehnica of Bucharest – Aerospace Engineering

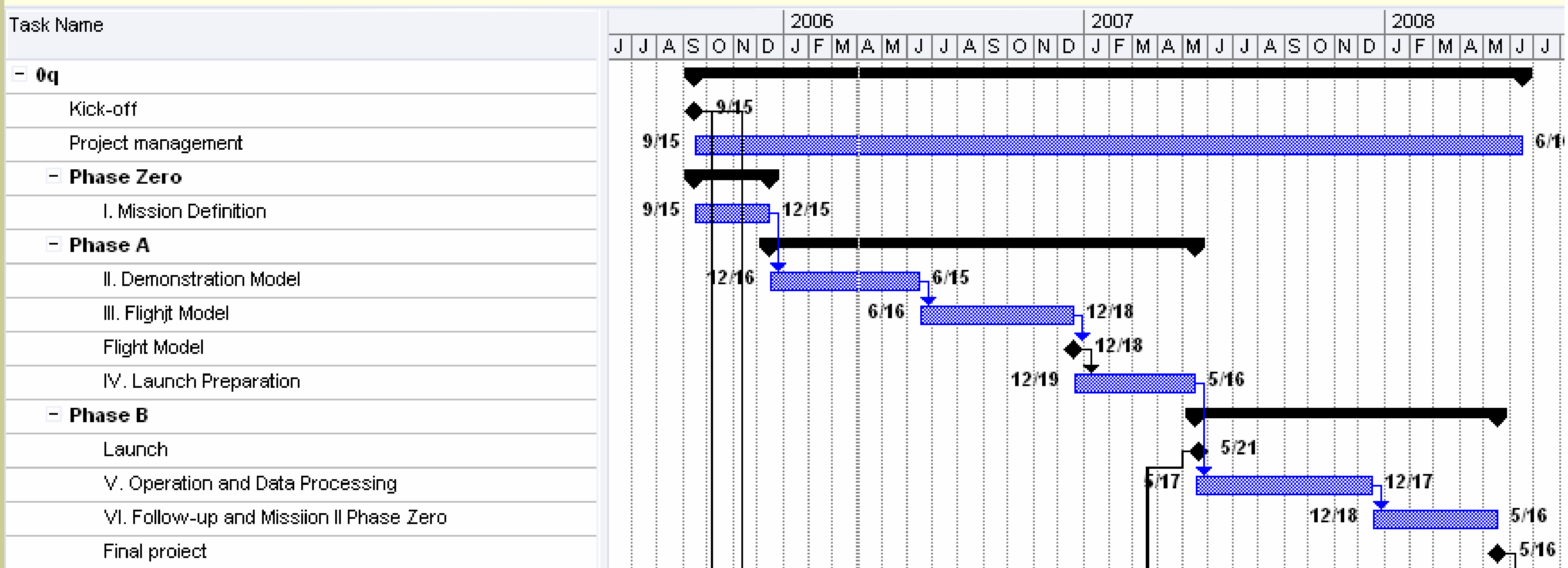
- 2 research assistants

- Marian MOGILDEA– Institute of Space Science, Space Engineering
- George MOGILDEA– Institute of Space Science, Space Engineering

Project Organization



Time Line



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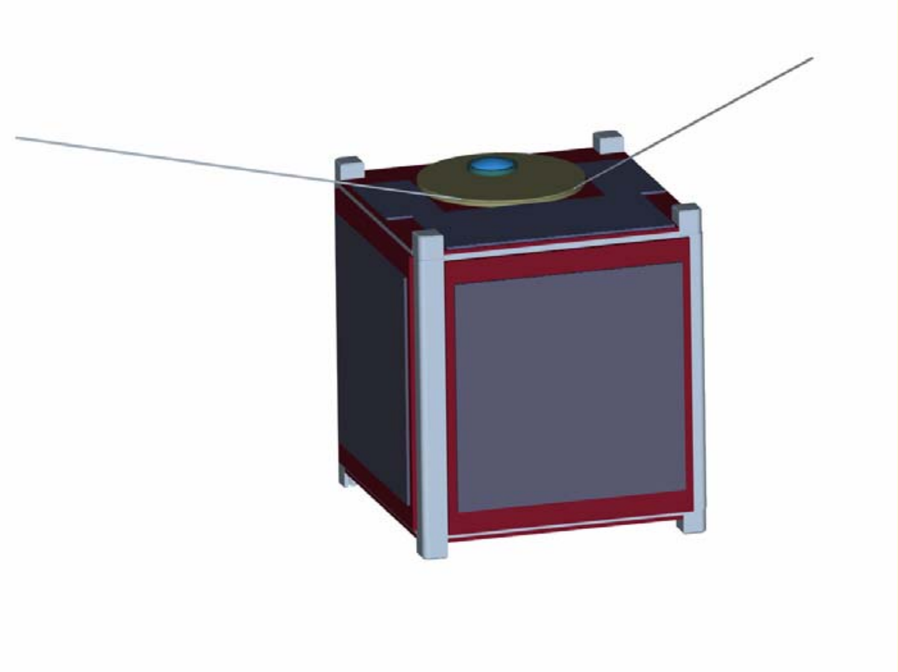
Mission Concept

- Develop
  - science instruments
  - functional components
- CubeSat type - 100 mm cubic shape
- Weight less than 1 Kg
- P-POD launch



Science payload

Science

- CICLOP- Earth Observation Camera
- DOSE-N experiment for measuring the total radiation dose
- SAMIS- micrometeorites detection platform

CICLOP
Earth Observation Camera

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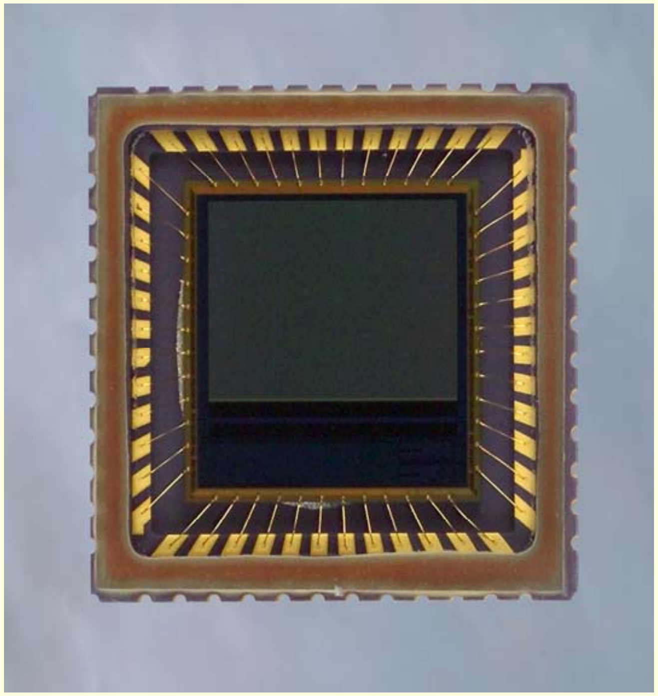
CMOS Sensor Preview

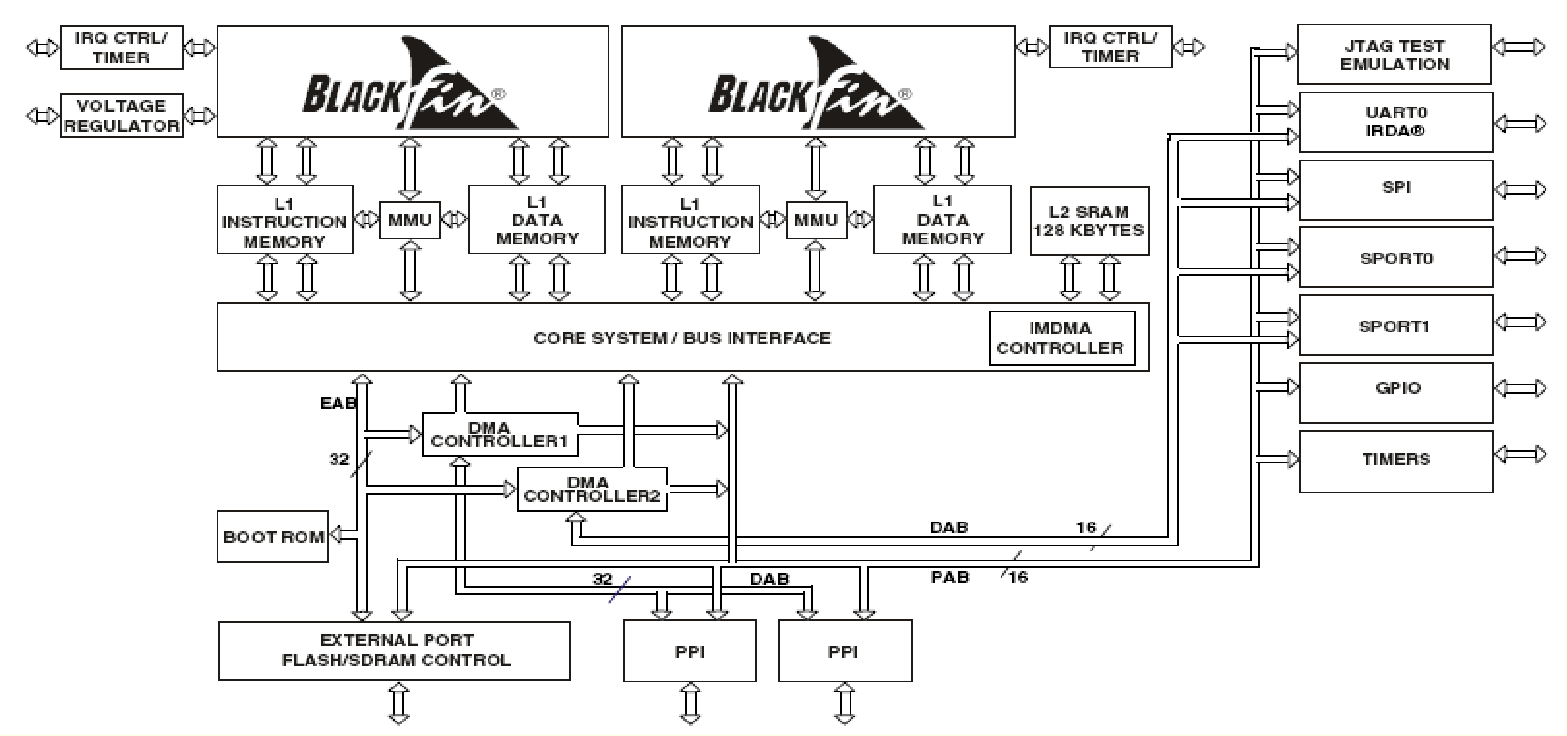
- Flexible programming via I2C compatible serial interface
- Single master clock: 10 to 36 MHz operation
- Architecture 4T4S pixel CMOS architecture with PIXELUX technology
- Digital Video Output10 bit parallel Bayer Raw
- Optical Size7.0 mm (H) 5.2 mm (V) 8.8 mm (diagonal) 1/1.8" optical format
- Operating Temperature -10°C to 60°C
- Effective image areaActive: 7.00 mm (H) x 5.24 mm (V) 1/1.8" optical format
- Dynamic Range52 dB
- Maximum Frame Rate 6 fps @ Max rezolution/ 30 fps @ VGA



5 **MP CMOS Sensor**
Power supply : Analog 3.3V ±5%
Power Dissipation: 150mW dynamic
500µW standby

Processor

- ADSP-BF561 High Speed



FEATURES

- Up to 750 MHz Dual Symmetric High Performance Blackfin Core
- 328 KBytes of On-chip Memory
- Each Black fin Core Includes:

  Two 16-Bit MACs
  Two 40-Bit ALUs
  Four 8-Bit Video ALUs
  40-Bit Shifter
- RISC-Like Register and Instruction Model for Ease of Programming and Compiler-Friendly Support
- Advanced Debug, Trace, and Performance- Monitoring
- 1.4 V ± 50 mV core VDD with On-Chip Voltage Regulation
  3.3V Tolerant I/O
- 297-Ball PBGA Package

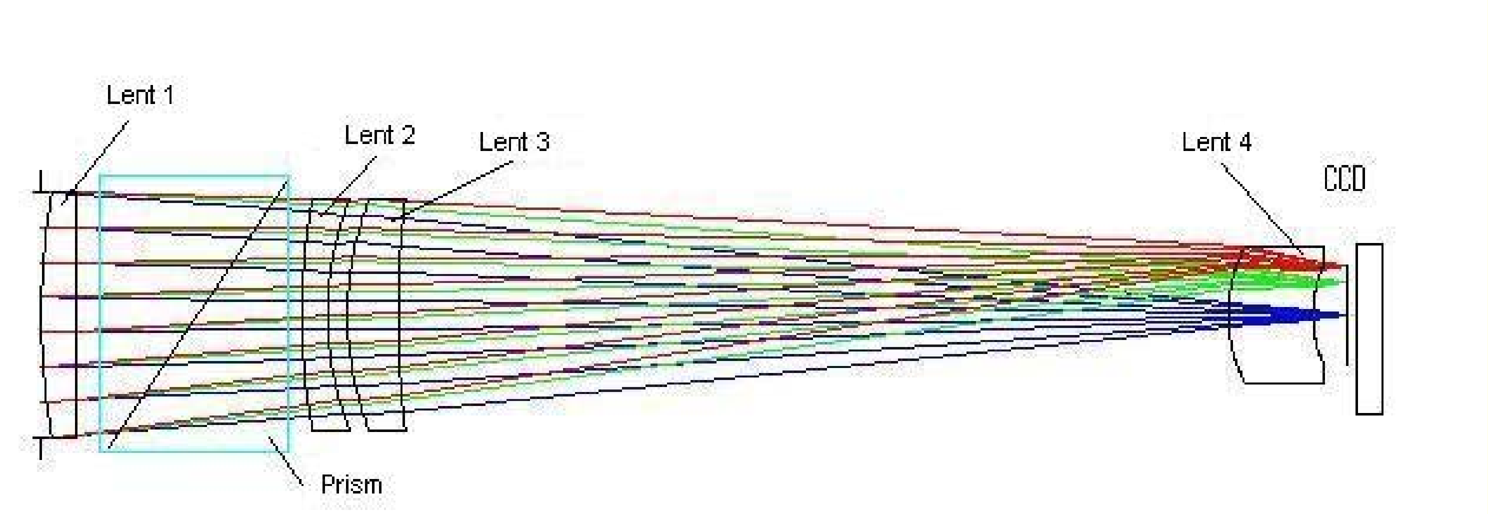
PERIPHERALS

- Two Parallel Input/Output Peripheral Interface Units Supporting ITU-R 656 Video and Glueless Interface to ADI Analog Front End ADCs
- Two Dual Channel, Full Duplex Synchronous Serial Ports Supporting Eight Stereo I2S Channels
- Dual 16 Channel DMA Controllers and one internal memory DMA controller
- 12 General Purpose 32-bit Timer/Counters, with PWM Capability
- SPI-Compatible Port
- 12 Timers/Counters with PWM Support
- UART with Support for IrDA
- Dual Watchdog Timers
- 48 Programable Flags

External memory of the camera

- Intel 8Mb Norflash

Lens-mount



Overall performance

- Focal distance – 70 mm
- Solid Angle - 6˚
- Expected picture area 50 x 70 Km
- 70 Km expected swath
- Pixel area 25 x 28 m
- 5 Mp image

SAMIS

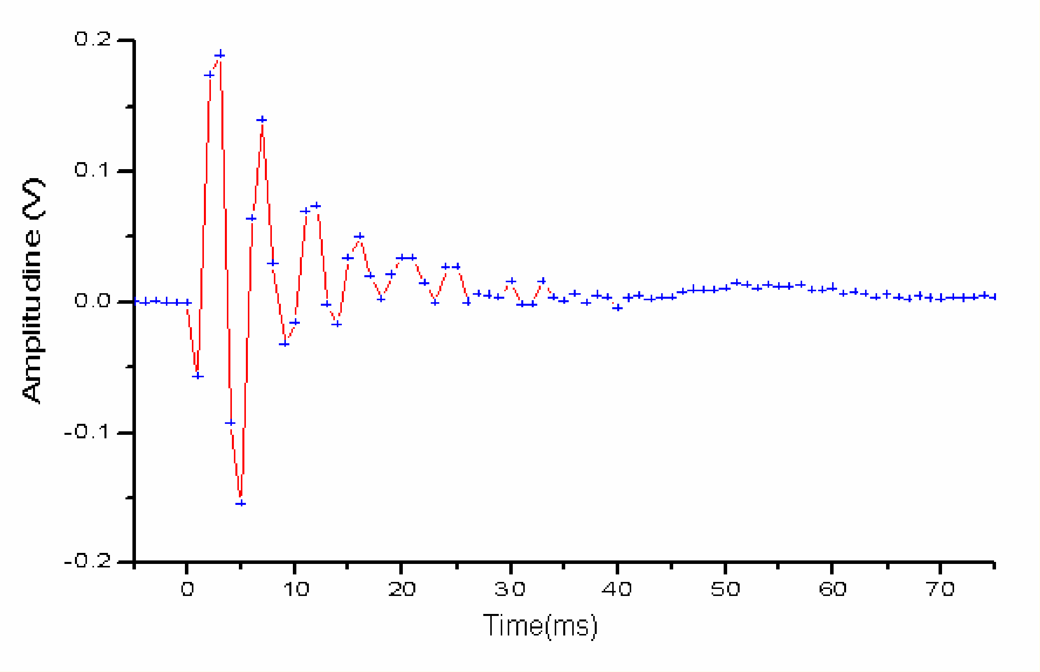
Micrometeorites

SAMIS

- A study on the micrometeorites in Low Earth Orbit
- Determines the impact of micrometeorites with the satellite
- Analyzes the energy of the impact

Detection

- PZT impact sensor
- Generates a pulse upon deformation of the element
- The amplitude of the pulse is proportional to the force of the impact
- By calibrating the detection chain we can find out the energy of the impact



Acquisition board

- A digital to analog converter
- The experiment necessities generate the requirements of the acquisition board
  - High sampling rate (to monitor impact phenomenon)
  - High resolution-12 bits (a wide range of signal)

Experimental assembly

- The sensor generates a voltage signal
- The signal is conditioned
- A data acquisition board is recording the conditioned signal
- Based on the signal to noise ratio the pulse is selected to be stored or ignored
- The data is stored in the memory of the satellite to be later transmitted by the telecommunication subsystem

Dose-N

X and Gamma radiation dose gradient

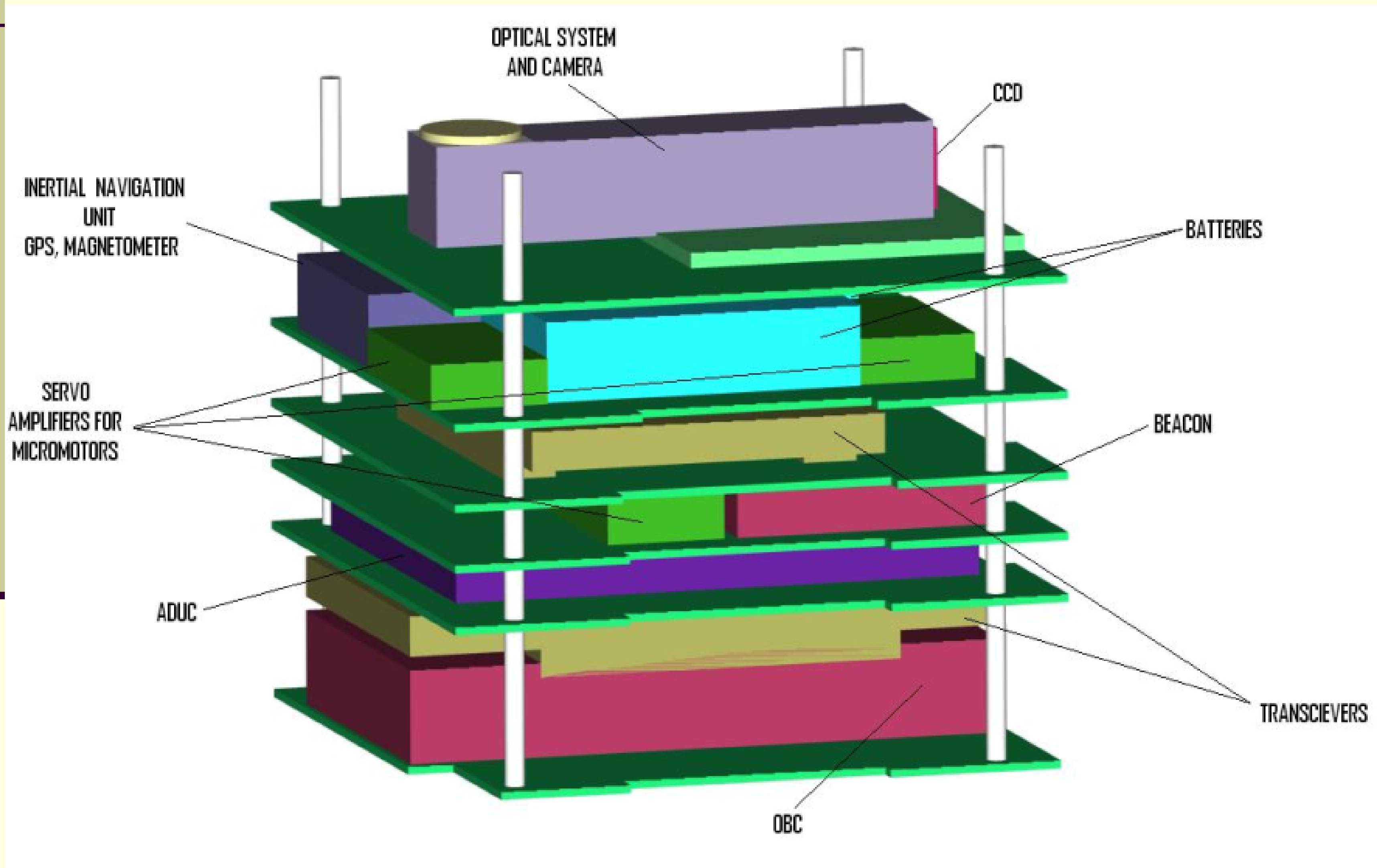
Experiment: DOSE-N

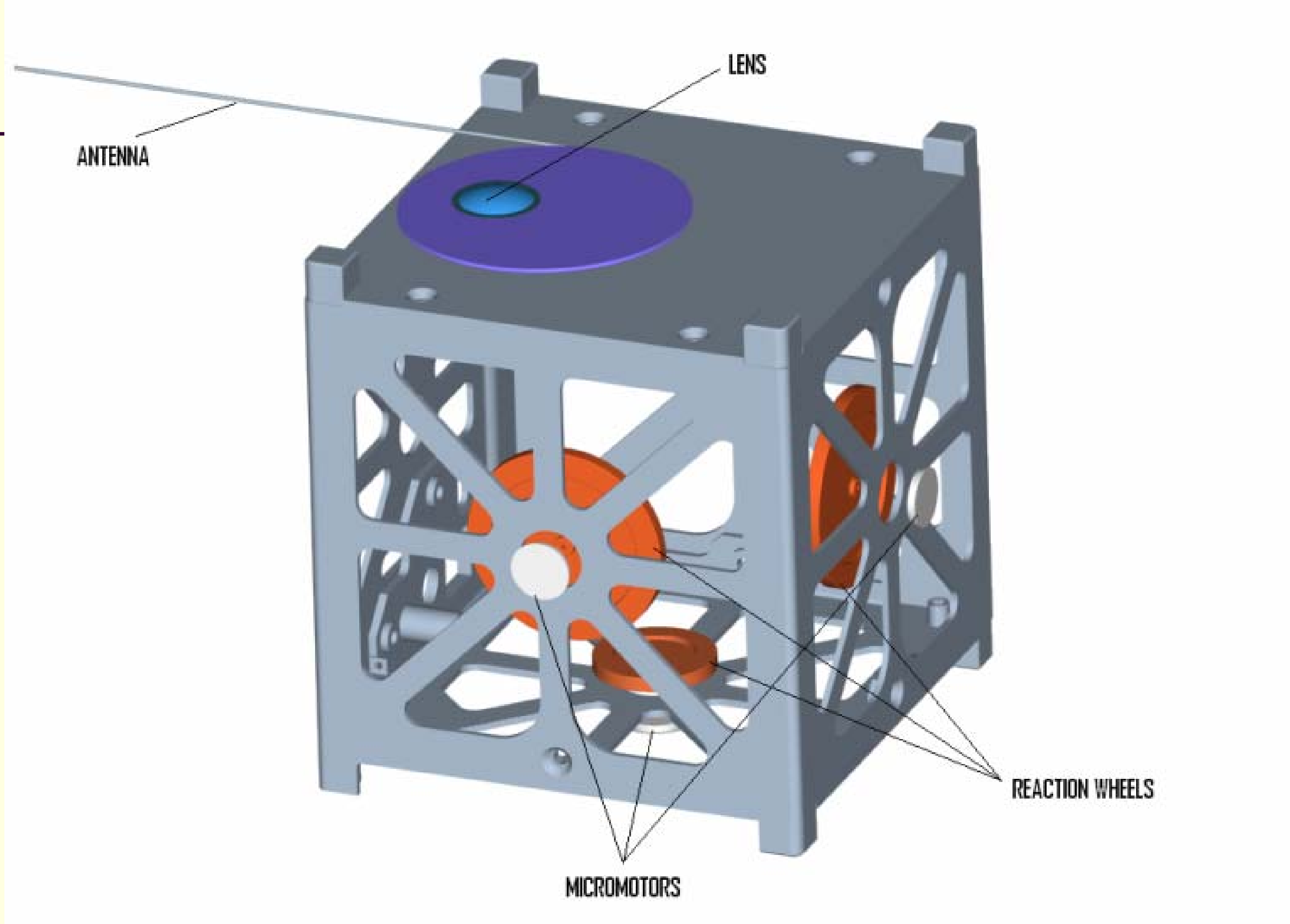
- The purpose of experiment:
  - The measurement of the total dose of cosmic ray.
  - The total dose it will be measured for each angular grade, it means 360 measurements during the 90 minutes of a complete rotation of the micro satellite around the Earth
- Results:
  - The total dose's gradient function of coordinates (latitude, longitude) and time, at altitude of around 500 km (the future GOLIAT Low Earth Orbit).

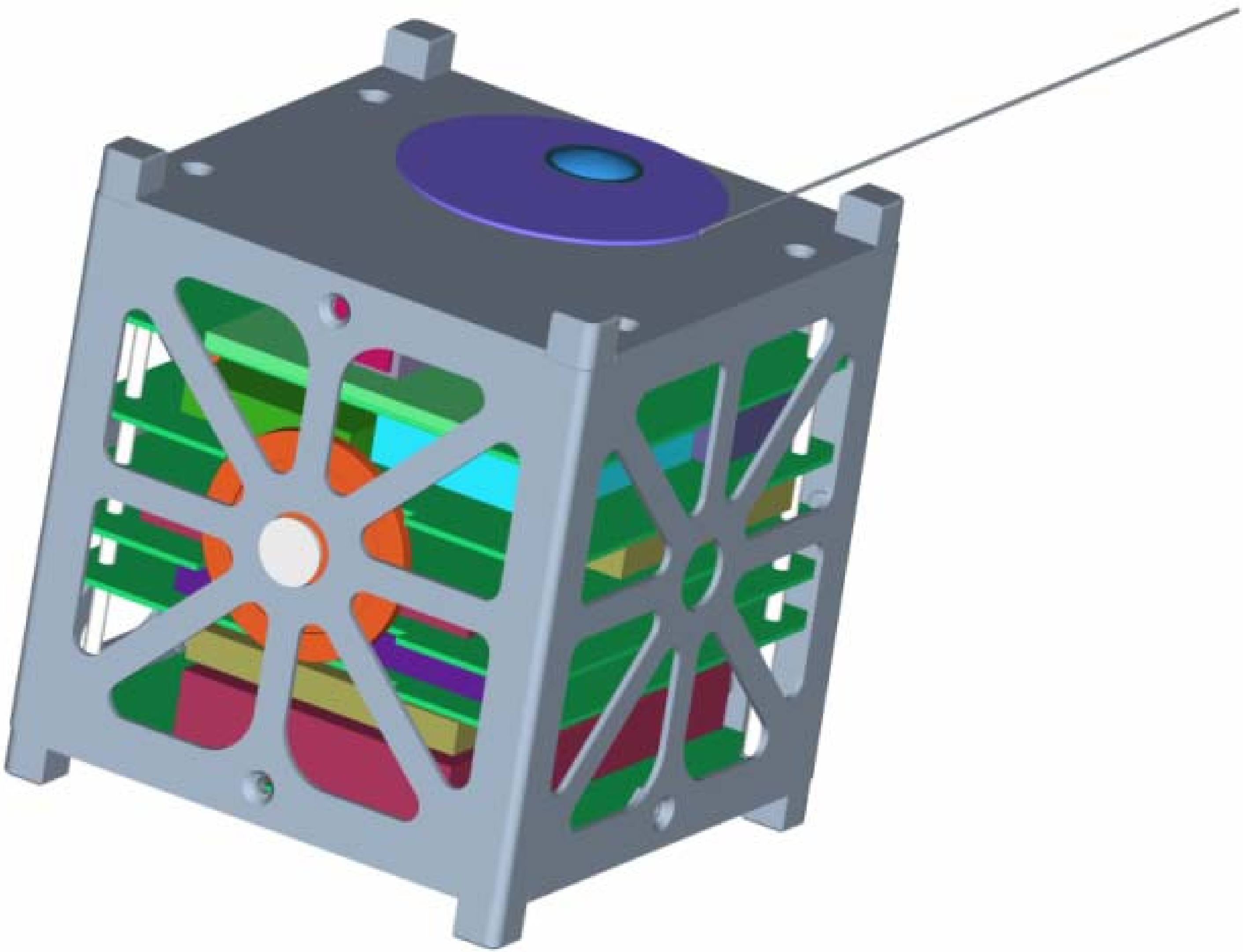
Dosimeter operational principle

- A semiconductor sensor (diode PIN) is used for cosmic radiation detection
- Semiconductor sensor dosimeter will measure X and gamma radiation
- The diode generates an analog voltage signal when gamma or X radiation interacts with it
- The analog signal is amplified before it is transmitted to the Digital to Analog converter.

Mechanical and Subsystems


OPTICAL SYSTEM
AND CAMERA
CCD
INERTIAL NAVIGATION
UNIT
GPS, MAGNETOMETER
BATTERIES
SERVO
AMPLIFIERS FOR
MICROMOTORS
BEACON
ADUC
TRANSCIEVERS
OBC


LENS
ANTENNA
REACTION WHEELS
MICROMOTORS



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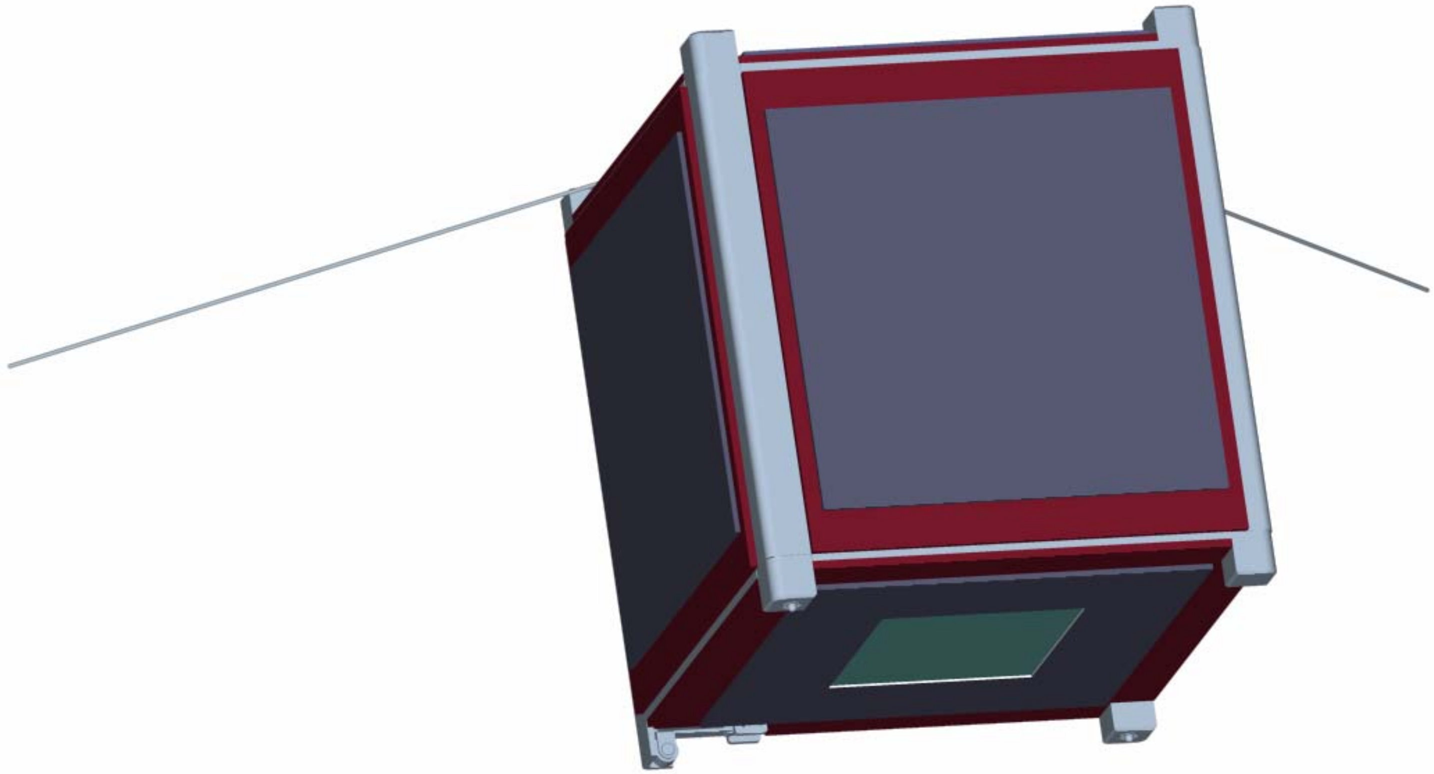
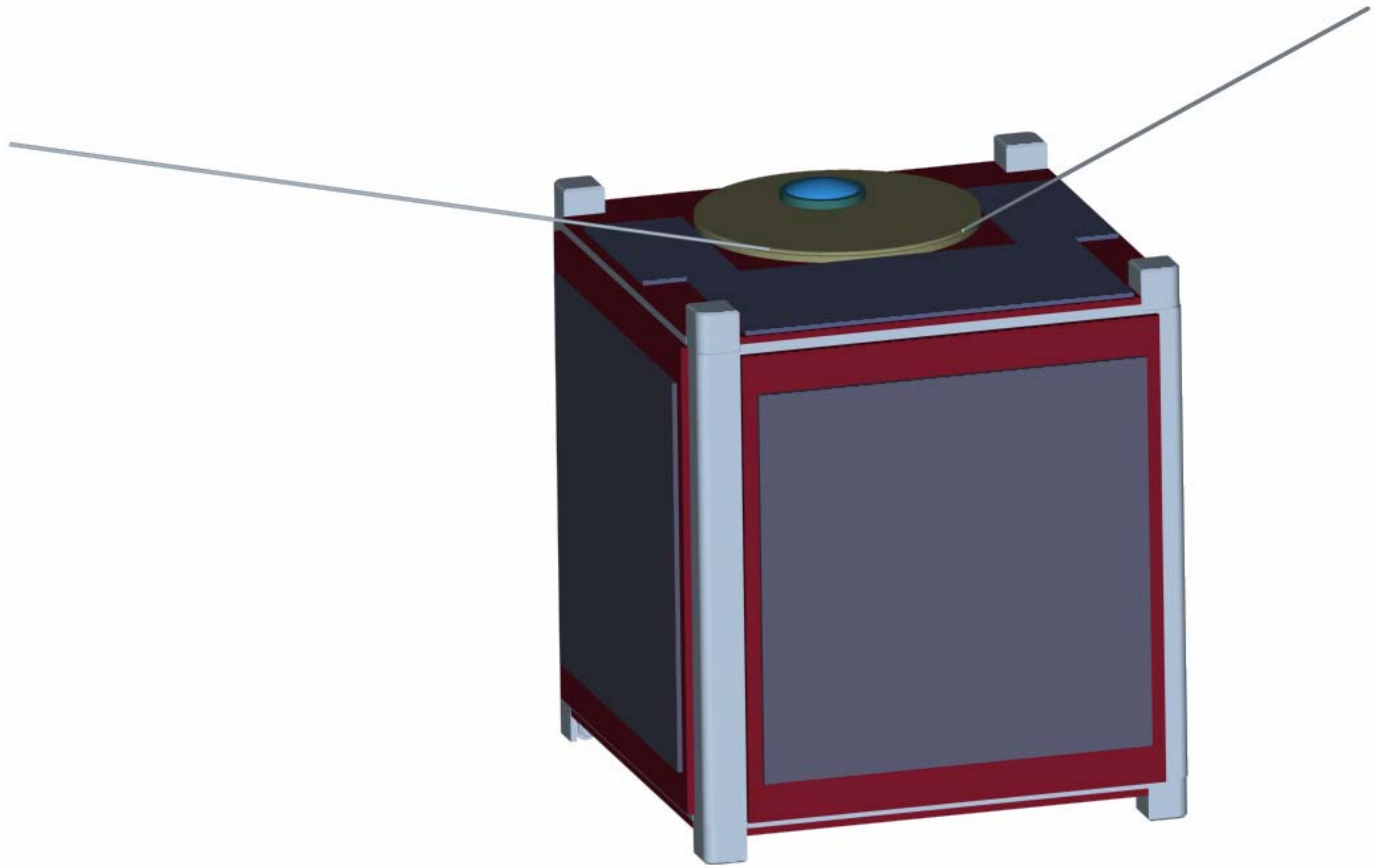
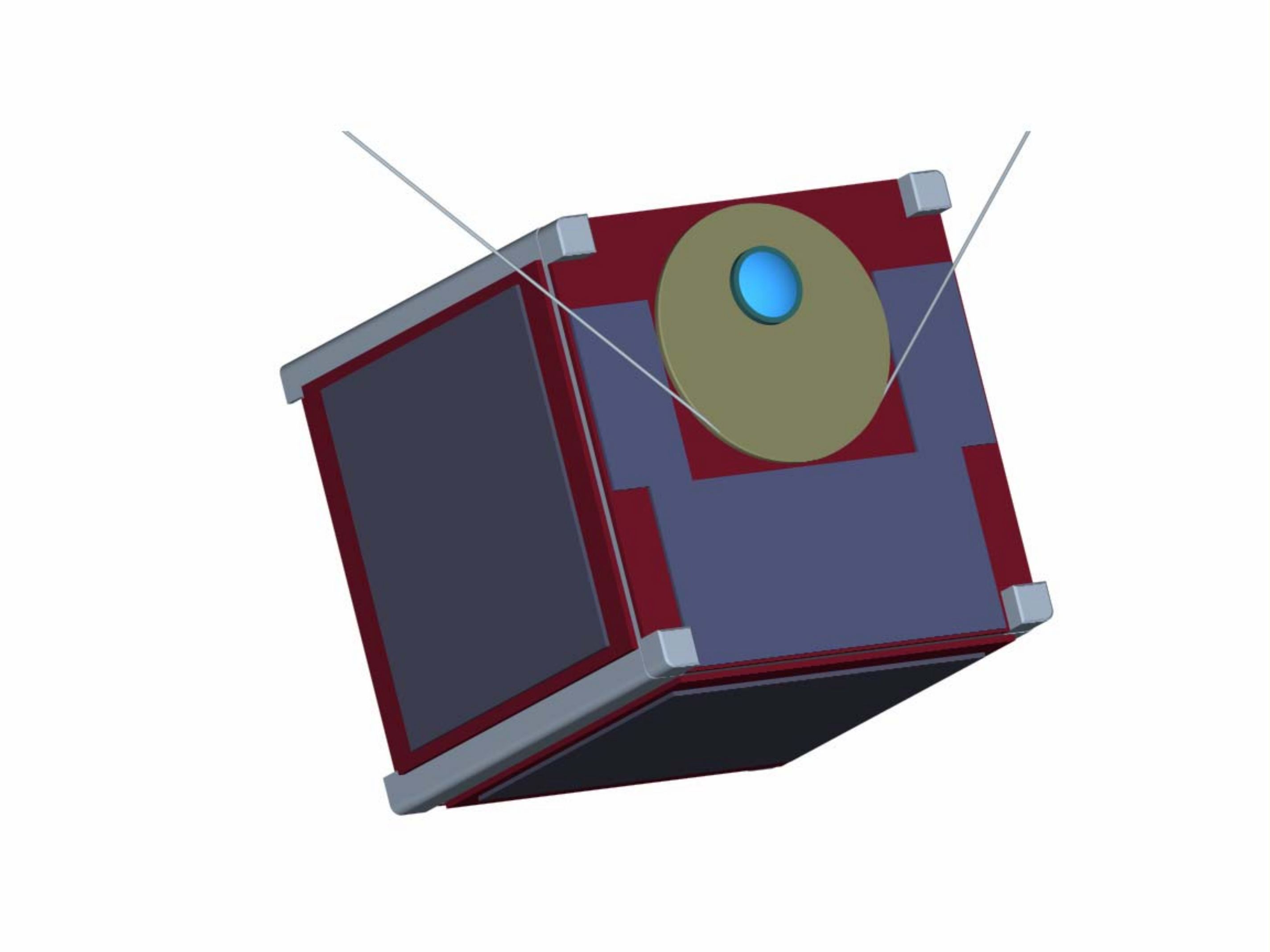
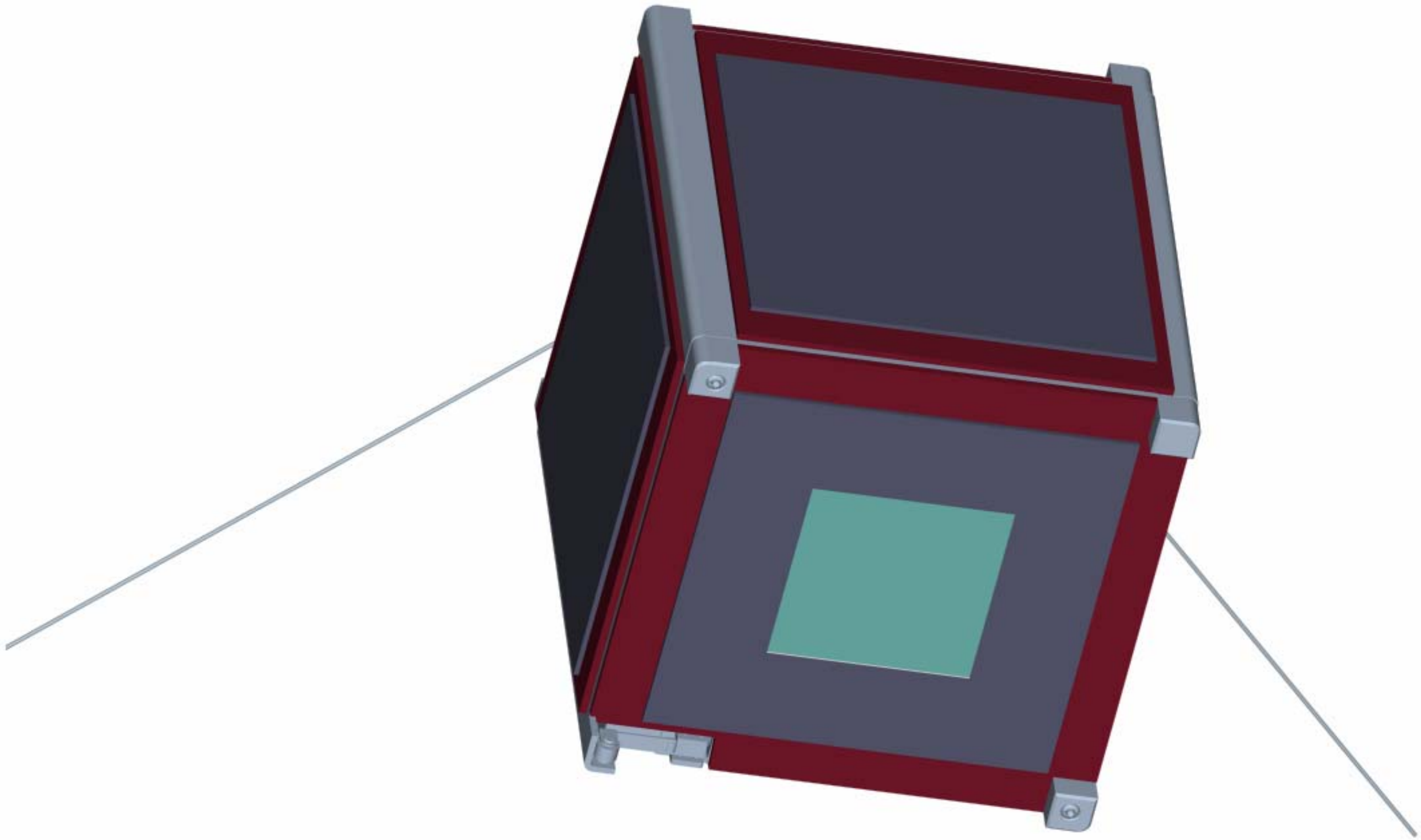








Subsystems

- Attitude determination & control
- Power supply
- OBC
- Communication
- Ground station
- Data processing

Attitude determination & control

Methods used in attitude determination

- Measurement of the Earth magnetic field using a Magnetometer.
- The IGRF is used to determinate the attitude of the satellite.
- GPS/INS to know the position, necessary for IGRF

Magnetometer

EXPECTED FEATURES

- Small size
- Low power consumption < 200mW
- High accuracy < 1 grd.
- Operation under a wide range of temperatures
- 3-axis digital compass, magnetoresistive technology

GPS

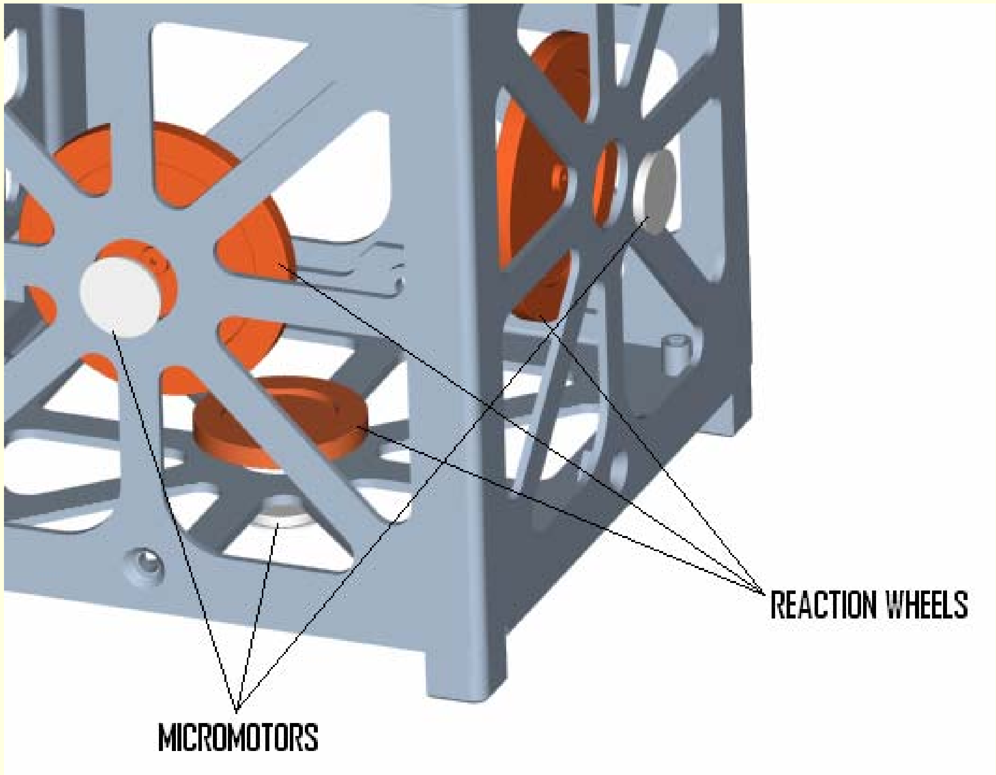
EXPECTED FEATURES

- Compact, small size
- Low power consumption
- With integrated accelerometer (3-axes) and magnetometer (3-axes).
- Operation under a wide range of temperatures

Attitude control

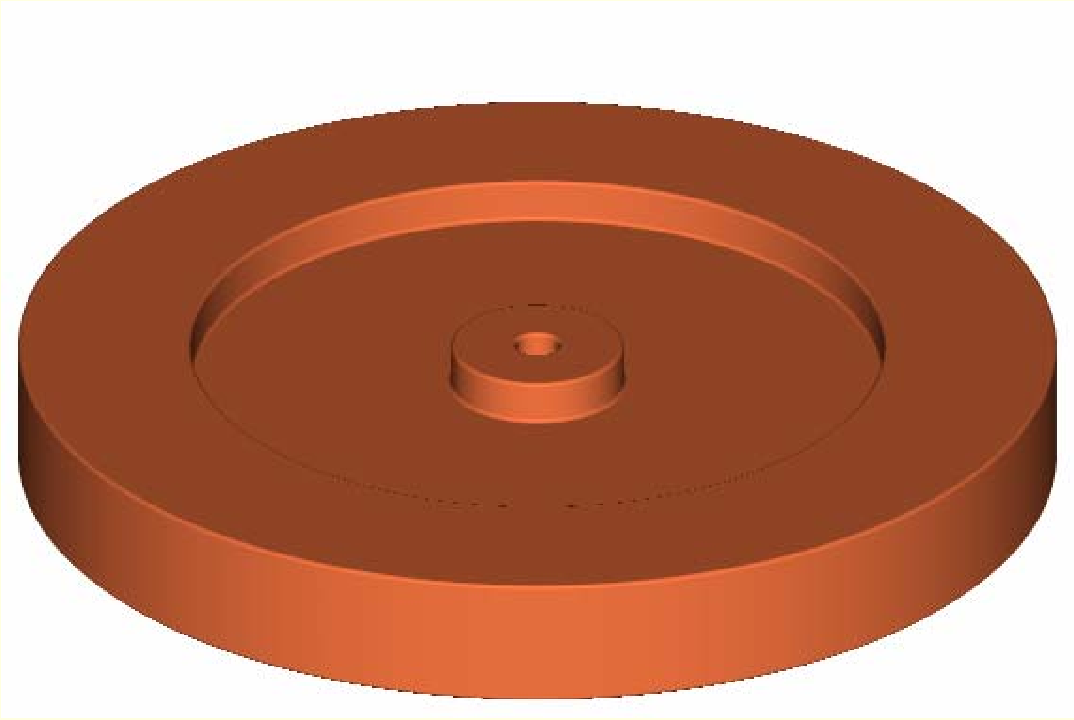
- The attitude of the satellite will be controlled by using three reaction wheels

- Each micromotor is fixed in the hole, from the center of a face
- The reaction wheels are spinning in the inner space of the CubeSat



Reaction wheels

- Iz = 5.28 Kgmm^2
- M = 21g
- D= 40 mm

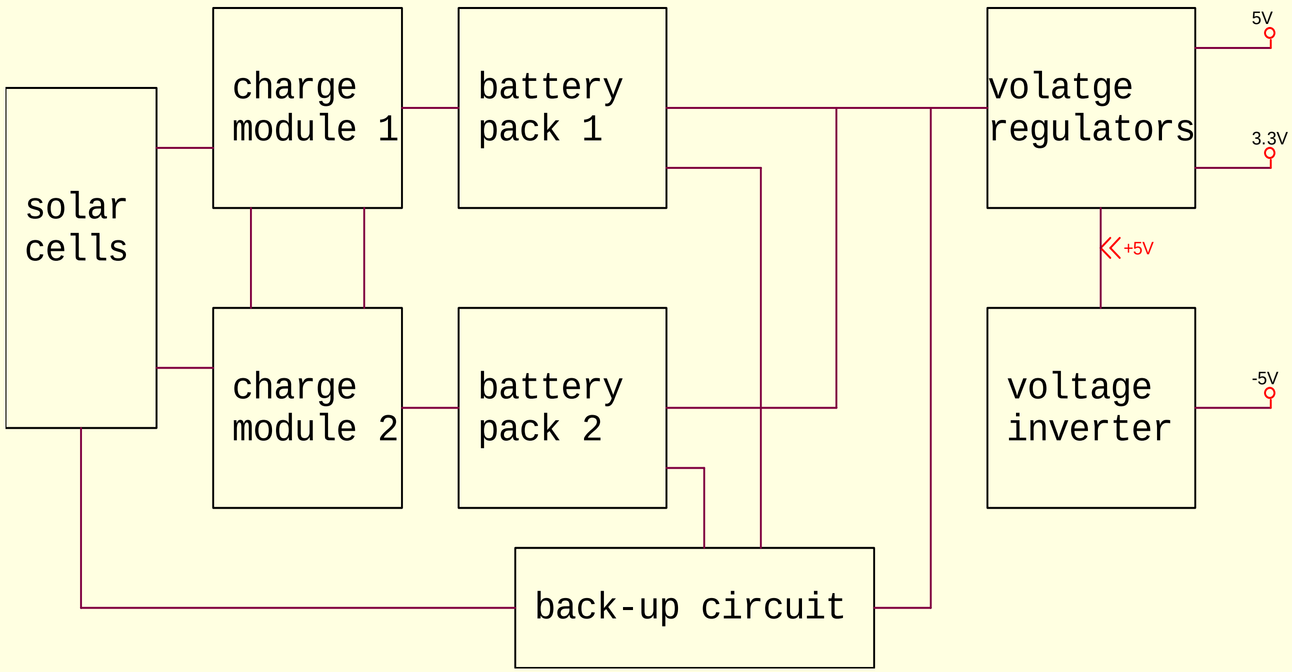


Micromotors

- The torque and the speed of each micromotor are adjustable
- The servo amplifiers controls the torque and the speed between the limits
  - M (0 – 0.14mNm)
  - n (0 – 20000 s^-1)
- Using the maximum torque we can rotate the satellite with 180 degrees in maximum 30s.

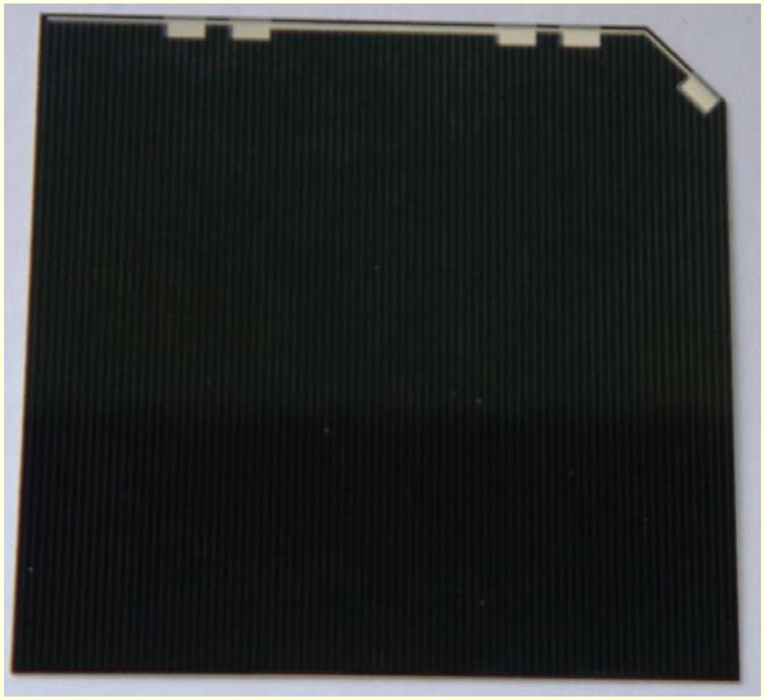
Power Supply

Block Diagram



Solar Cells

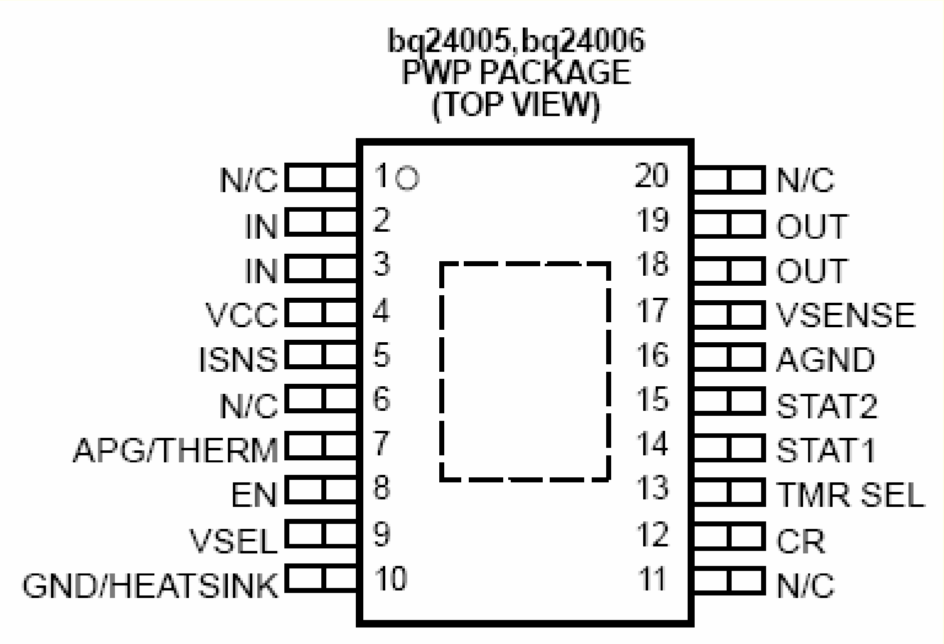
- Triple junction solar cells.
- 4 covered interconnected cells
- Output- 2.3 V/ cell
- 23.5 % Efficiency
- 41 x 42.4 mm cell area
- 70 % coverage
- 1.8 W expected power



Solar Cell

Charge Modules

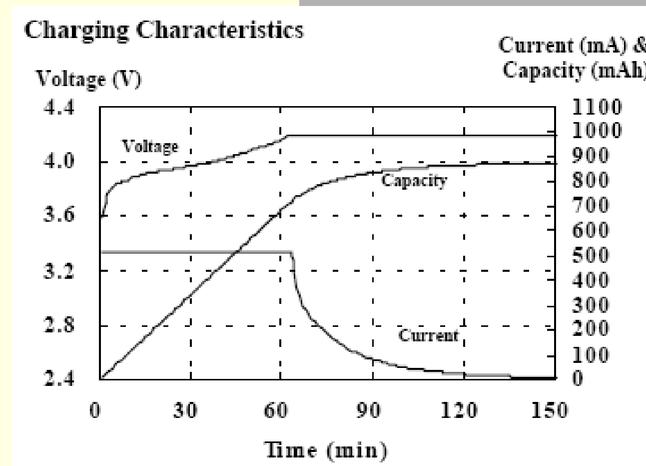
- **Integrated Voltage and Current Regulation with Programmable Charge Current**
- **Safety-Charge Timer During Preconditioning and Fast Charge**
- **Integrated Cell Conditioning for Reviving**
- **Deeply Discharged Cells and Minimizing Heat**
- **Dissipation During Initial Stage of Charge**
- **Low-Power Sleep Mode**

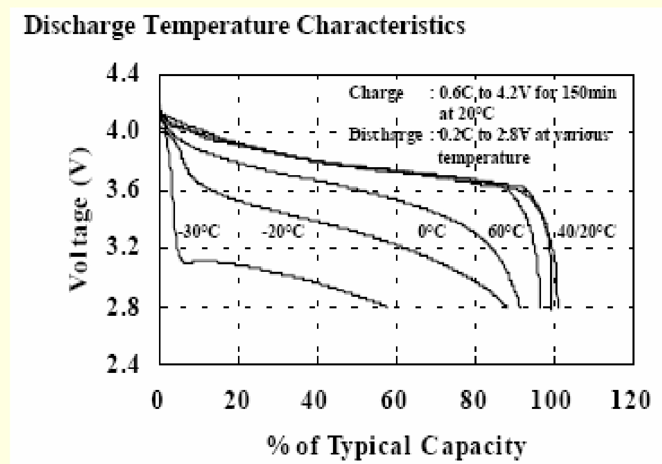


Batteries

Capacity : Typical: 860mAh (at 20C)

- **Nominal Voltage : 3.7V**
- **Weight : Approx. 21g**
- **Dimensions:**
  Width = max. 34.0mm
  Height = max. 50.4mm
  Thickness (shipment) = 5.5mm
- **Standard Discharge :**
  172 to 860mA to 2.8V





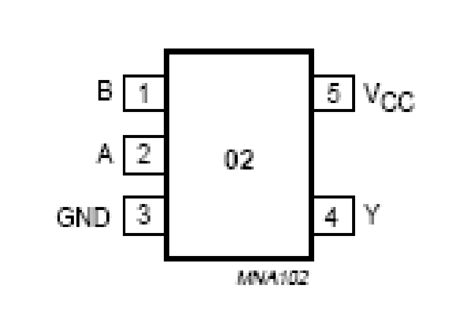
Voltage Inverter

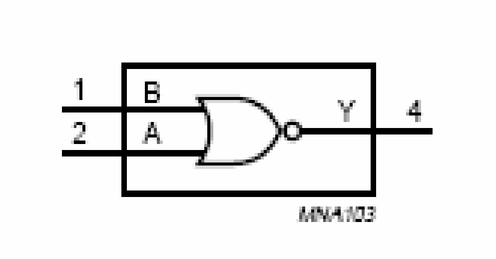
- **TPS 60400- Charge pump**
  Voltage Inverter

- **Inverts Input Supply Voltage**
- **Up to 60-mA Output Current**
- **Only Three Small 1-μF Ceramic Capacitors**
- **Needed**
- **Input Voltage Range From 1.6 V to 5.5 V**
- **PowerSave-Mode for Improved Efficiency**
- **at Low Output Currents (TPS60400)**
- **Device Quiescent Current Typical 65 μA**
- **Integrated Active Schottky-Diode for**
- **Start-Up Into Load**
- **Small 5-Pin SOT23 Package**

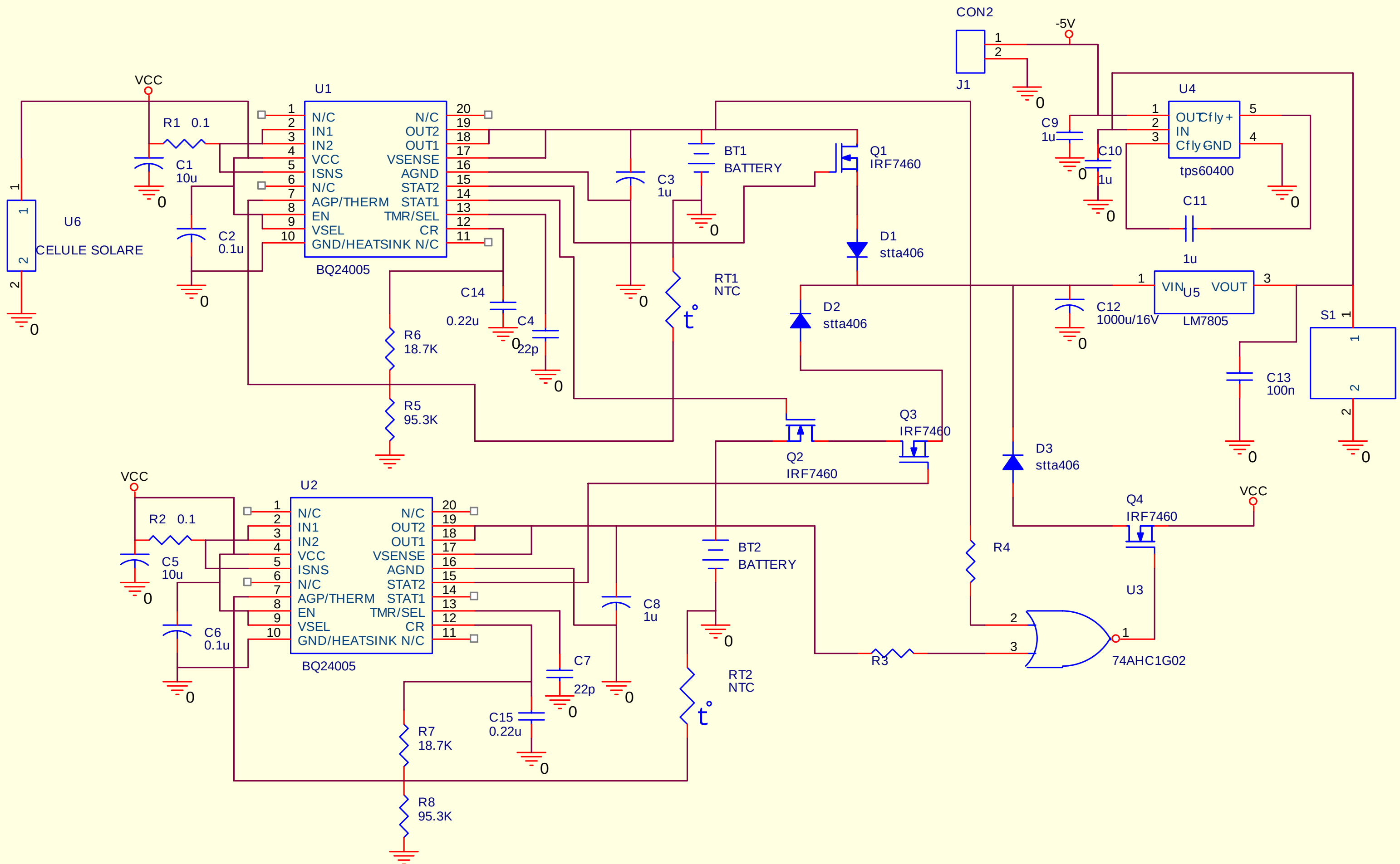
Back-up circuit

- **2-input NOR gate**
- Symmetrical output impedance
- High noise immunity
- Low power dissipation
- Balanced propagation delays
- Very small 5-pin package
- Output capability: standard
- Specified from -40 to +125 °C.





Electronic diagram



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On Board Computer

On Board Computer Tasks

- ADC task

The goal of the ADC is to collect experimental data from the payload.

The ADC task collect data with an 1MSPS speed in 12bit register and stores data into memory.

This task is divided in two subtask: SAMIS and DOZE-N.

SAMIS is scheduled to run for five minutes and then it stops. After SAMIS stops DOZE-N starts and runs for one minute. After DOZE-N stops SAMIS starts and continues the cycle.

DOZE-N stores all the data that pass a certain limit. SAMIS collect samples of data and verifies if at least a value (from a sample) is greater then a given value and if is so the whole sample is stored into memory.

On Board Computer Tasks

- CICLOP task

  The goal of this task is to handle the picture taken process, to compress the picture in a JPEG format and to store the picture to memory.

- BOOT task

  This task determines if a new software is uploaded on the CubeSat main memory. Determines the boot sector for ADUC microcontroller and for MSP microcontroller.

On Board Computer Tasks

- DATA STORAGE task

  This task schedules the writing on the main flash memory and handles the whole data storage of the CubeSat.

- DOWNLOAD task

  The goal of this task is to send the data collected in main memory to the transceiver that handles data transfer and communication with ground station. It calculates the beacon signal and send those bits to the beacon transceiver.

- UPLOAD task

  The Upload task stores the new software received from the ground into main memory of the CubeSat and informs the MSP microcontroller that a new version is ready to use.

On Board Computer Tasks

- ATTITUDE task

  This task is divided in two sub task: DETERMINATION and CONTROL

  The attitude determination task calculates the position of the CubeSat and the orientation angle. The attitude control task compares the output given by determination task with tabular data and commands the CubeSat orientation in the desired position. This task have to send the position data to the transceiver and it needs to be synchronized with CICLOP, SAMIS and DOZE-N task.

On Board Computer Tasks

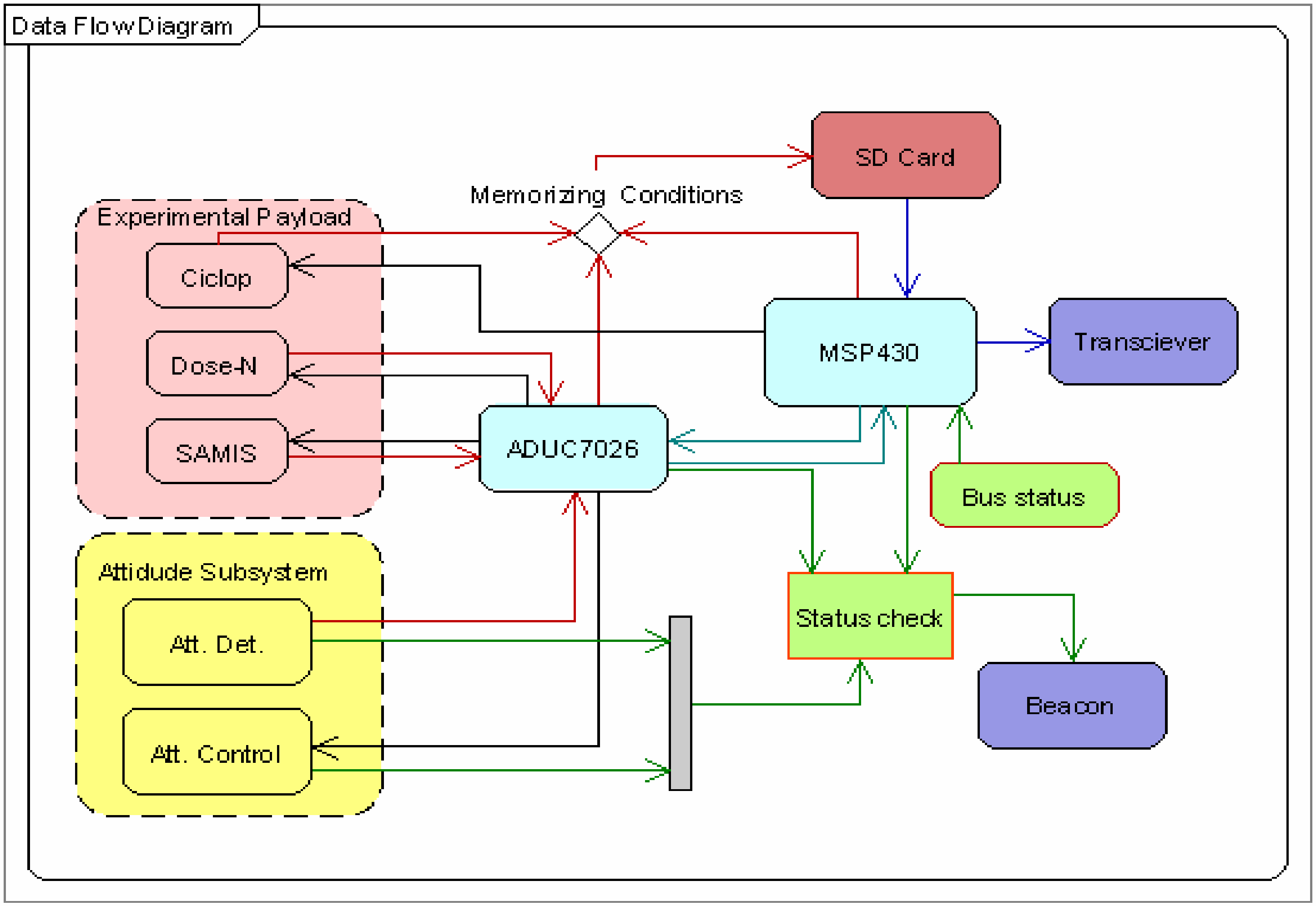
- CONTROL task

  This task creates a communication protocol between all the on board computer task. Decide when a tasks have the permeation to read/write from/to main memory. Schedules the SAMIS and DOSE-N tasks, synchronies the ADC tasks with attitude determination task. The CONTROL task decides when CICLOP takes pictures.

  An important function is that the CONTROL task resets the Watch-dog-timer for all the microcontrollers on the CubeSat.

  The communication interface between the CubeSat components is a serial interface I2C or SPI. This task creates the rules for the serial interface: clock rate, direction of data transfer master and slave components and performs different calculation to determine the data integrity.

Data flow diagram



Communication

Functions:

- Download Data and Telemetry from the Satellite
- Upload commands for reprogramming the flight computer

Communication

2 Transceivers Architecture:

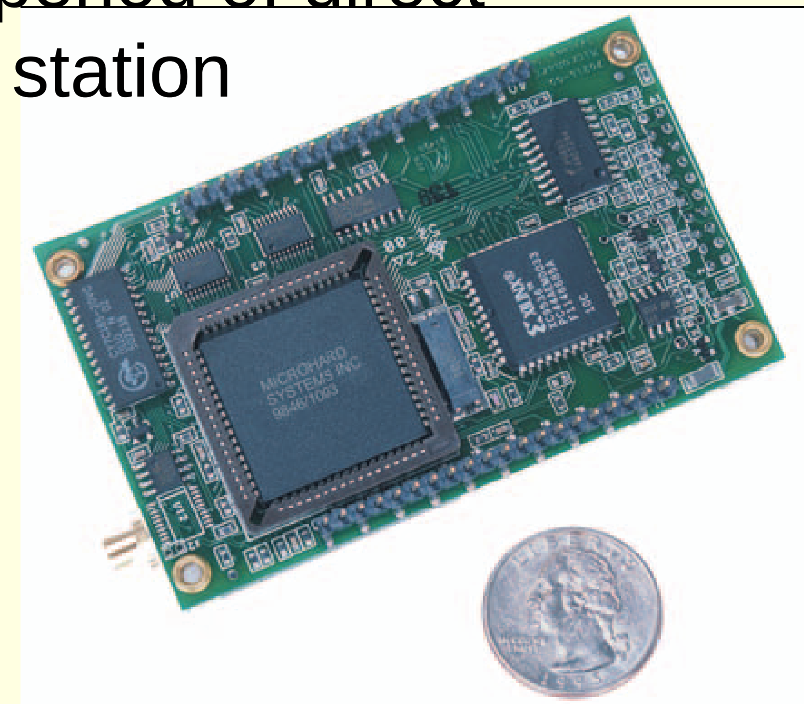
- One for data transmission
  - 2400MHz
- One for telemetry
  - 450MHz

Beacon

- Operates in the 434.79-438MHz band
- Continuously transmitting
- Transmits:
  - Identification of the satellite
  - Telemetry data and diagnosis of the subsystems
- 100mW output power
- 1200bauds
- Only transmitting mode (projected)
- Back-up for uplink

Main data link

- 2400Mhz transceiver
- Downlink of experimental data
- Uplink commands into the on board computer
- Transmitting only for the period of direct connection to the ground station
- 1W output power
- Programmable bit rate



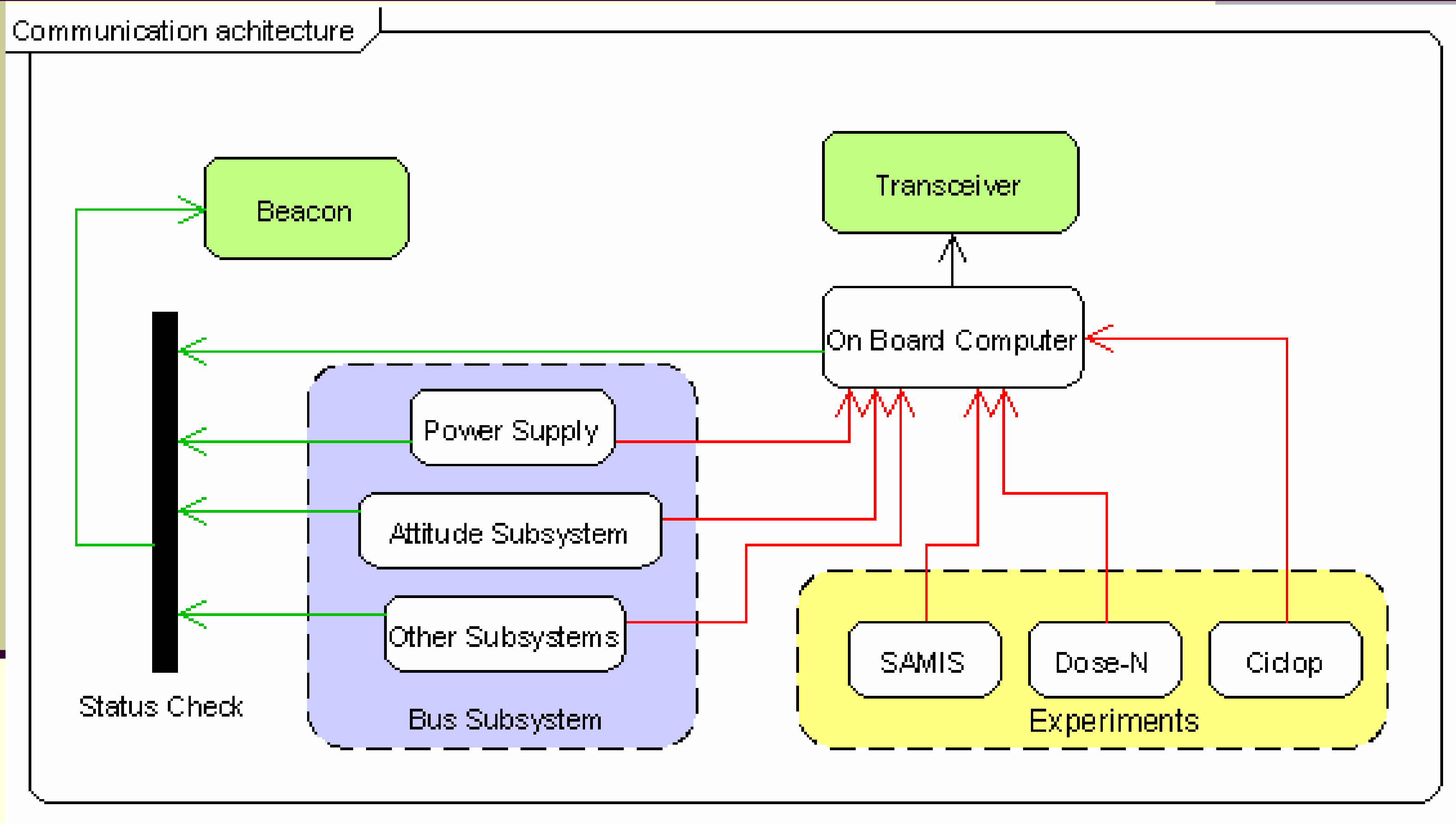
Transceiver for main data link

- 2.4000 - 2.4835 MHz
- Adjustable output power 100mW-1W (100mW steps)
- Will be used at 1W output power (projected)
- Will transmit data from the experiments
- Form Factor suited for CubeSat satellites

Antenna

- 2 dipole antennas
- 438MHz antenna require deployable mechanism
- The deployable mechanism must run independent from all the other subsystems
- Further antenna testing could lead to redesign

Communication architecture



Ground Station

- Tracking the Satellite
- Monitor Telemetry data
- Download Data from the payload
- Reprogram the On Board Computer
- A larger parabola dish (4 – 6 m) to be used for the GOLIAT mission is under consideration as support by ROSA and BitNet

Data Processing

- Payload data-contains 3 data packages:
  - SAMIS experimental data & time
  - Dose-N experimental data & time
  - Ciclop pictures & time
- Diagnosis data-contains correlated tabular data of:
  - Temperatures
  - Voltages
  - Currents
  - Position & Time
- Beacon-contains:
  - Identification of the satellite
  - Minimal diagnosis data

Status of the GOLIAT Mission

- Components procurement to be finished before July 2006
- Engineering model to be assembled during autumn 2006
- Mechanical, Electrical and Thermal tests to be performed during winter 2006
- Flight model t.b.a. during winter 2007
- Launch to be negotiated and scheduled for 2007

Follow up

- RO Second generation nanosatellite missions
  - Tethered satellites
    - Two tethered CUBEsatellites – a double and a single cube
  - Nanosatellites formation flying in a networked environment
    - Several nanosats connected through a commercial WiFi – like system
    - Running network data processing – GRID architecture
    - Specialized satellites (scientific, server, communication)

Thank you for your attention!

- Expected results!