LituanicaSAT-1:
lessons learned from the first Lithuanian satellite mission

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Background story

What do You need to start building a real satellite?

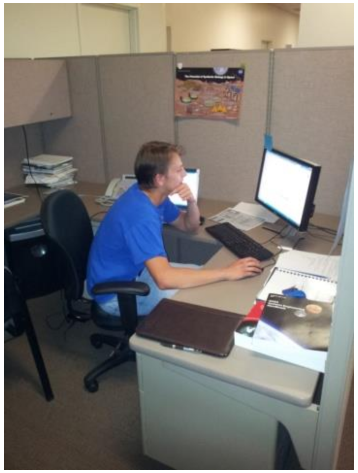
To drink a cup of coffee with a right guys in a right place!

Photo Credit: V. Buzas

Background story

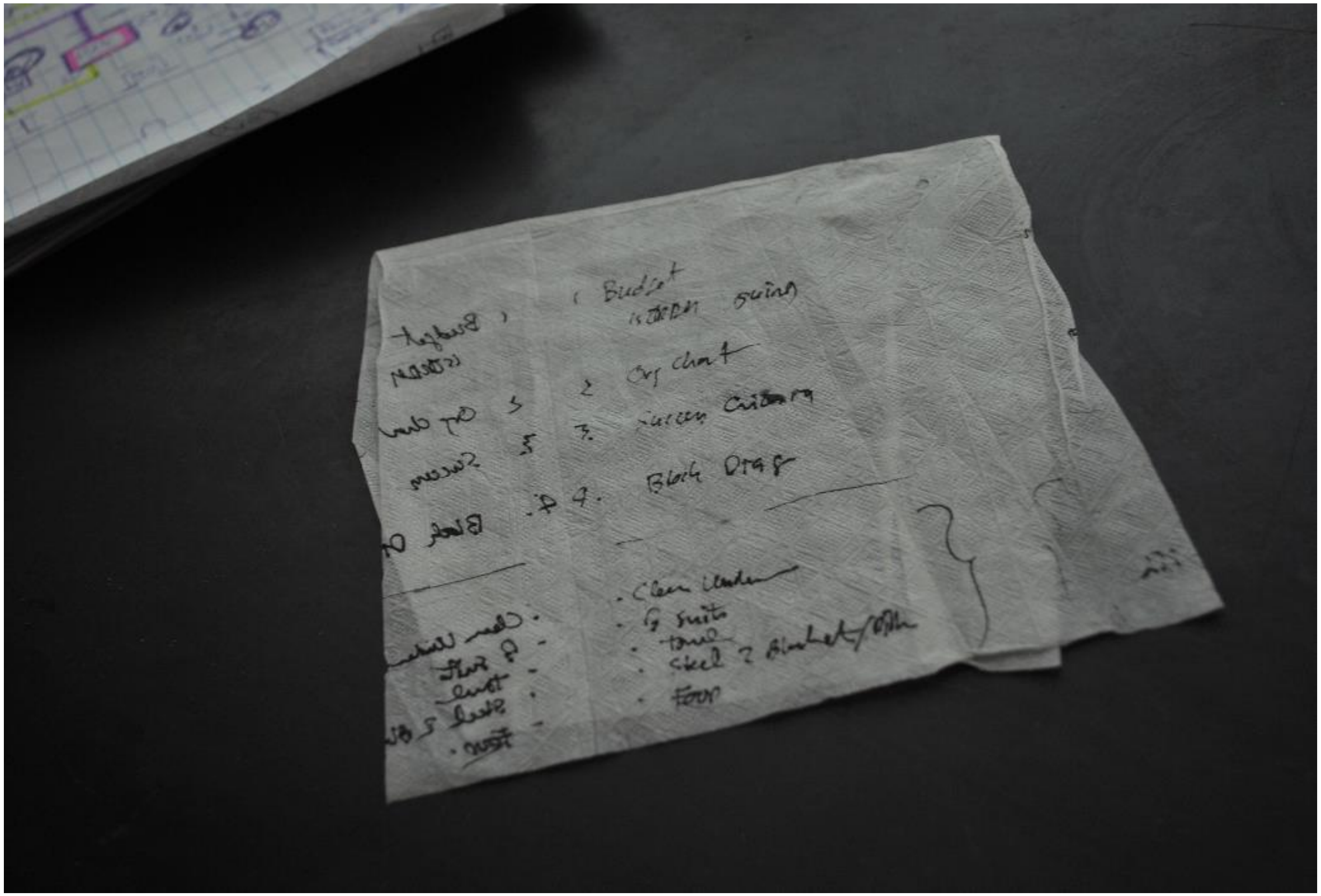
Our secret ingredients for a successful mission:

- **Work hard**
- **Do teambuilding**
- **Have passion in what you are doing**



Background story

….and don’t forget to use coffee brakes visely



Mission Statement (or plan on nampkin)

- **To build and launch first Lithuanian satellite** of 1U standard CubeSat size
- To develop infrastructure and gain know how joining industry and academia
- To honour the **80th Anniversary** (July 15, 2013) of the flight across the Atlantic by Lithuanian pilots Steponas Darius and Stasys Girėnas.

Project Managment

INOVATYVŪS INŽINERINIAI PROJEKTAI

VILNIAUS UNIVERSITETAS · 1579 · UNIVERSITAS VILNENSIS

NANORACKS

NASA

LRT

DELFI

LT LAB Optimal solutions

FLTECHNICS YOUR RELIABLE MRO PARTNER

LRMD

premet precizika - met sc

MP

DHL

LAZERA

Refra® Refrigeration & Air Conditioning

FIMA

SERTIKA

onlinemedia

HUB

MP Dental

standa

WEB SYSTEMS

GPH a Nexans company

ZOOMBOOK.LT

Mission Objectives

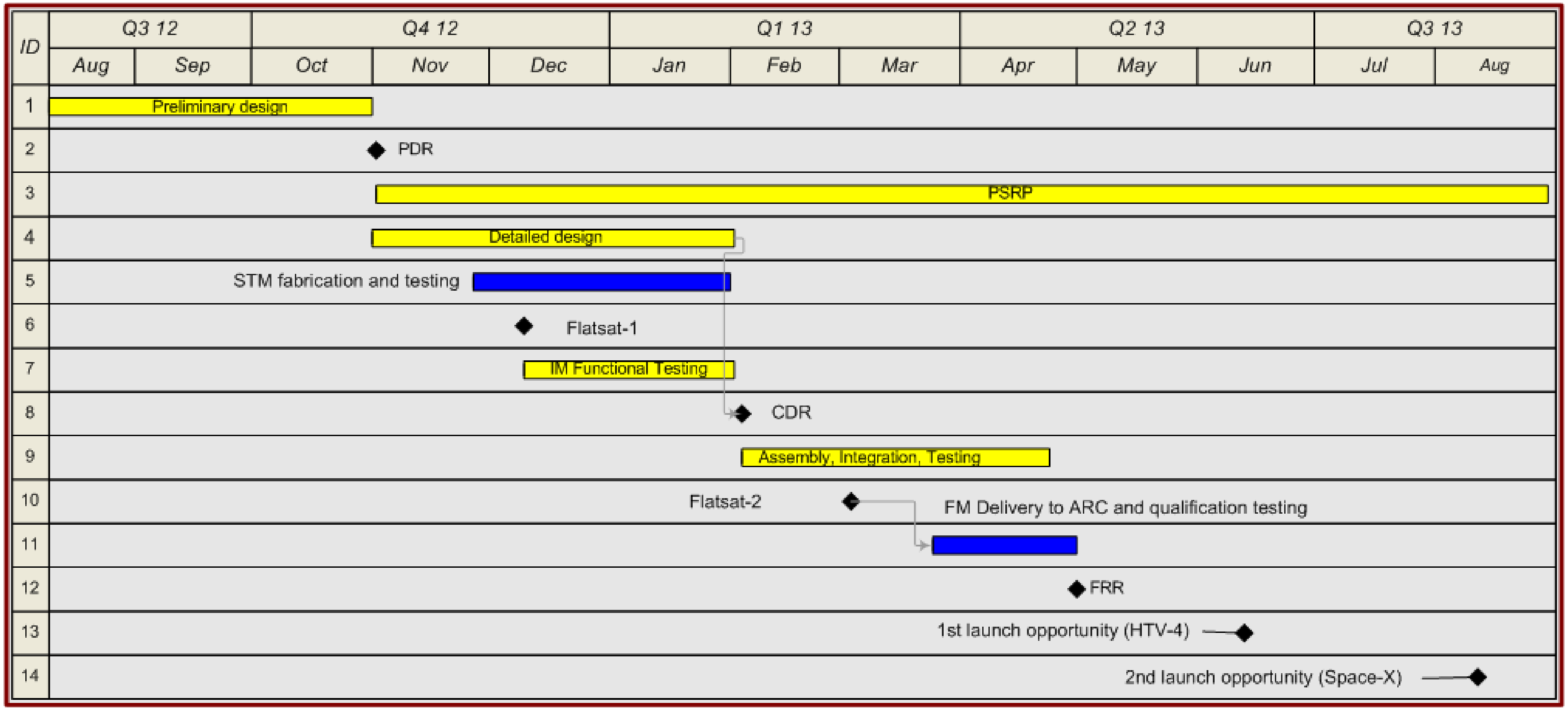
- **Primary Mission Objective**
  - To build and launch a first Lithuanian 1U size cubesat and send Lithuania's first message from space
- **Secondary Mission Objectives**
  - To provide university students and young engineers knowledge & real hands-on experience in satellite engineering
  - To develop and test in space cubesat on board control and data handling sub-system
  - To take pictures using on-board camera and downlink to the ground station
  - To test an amateur radio FM voice repeater.

Mission Success Criteria

- **Minimum Success Criteria**
  - NASA PSRP approval and delivery of the cubesat to the ISS
  - Launch cubesat from ISS by the JEM Remote Manipulator System (JEMRMS)
  - System initialization and antenna deployment after time-out
  - Transmit telemetry data (RF Morse code beacon or packet radio)
- **Nominal Success Criteria**
  - Establish two-way communication with ground station
  - Turn on the FM voice repeater
- **Comprehensive Success Criteria**
  - Take pictures with camera and downlink data to the ground station

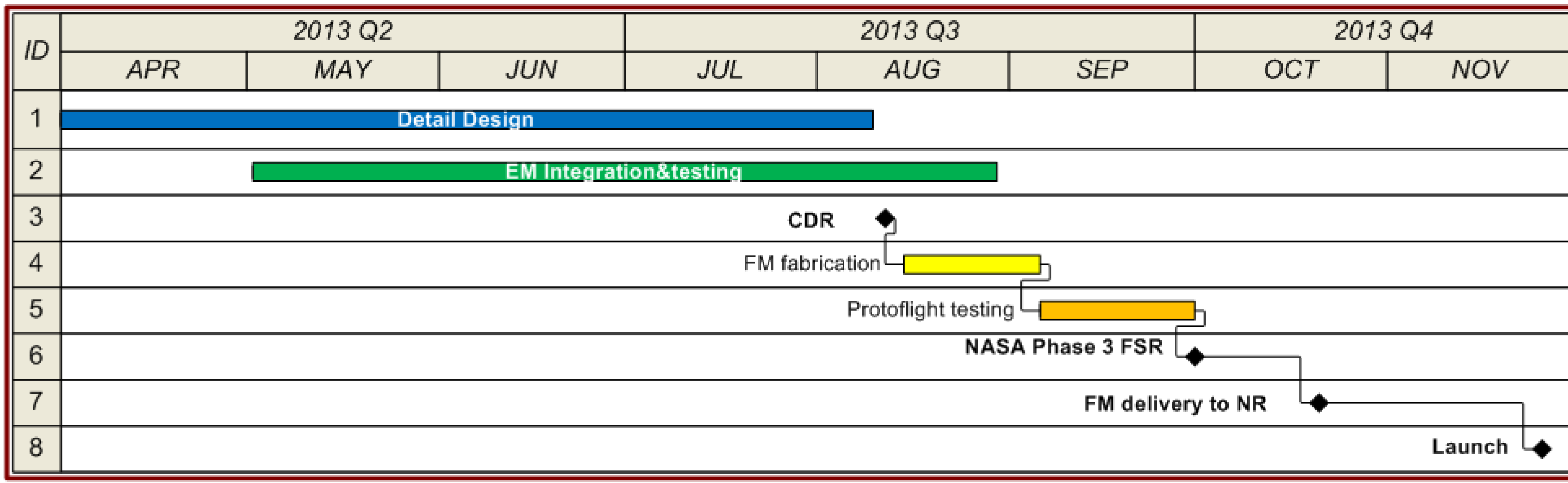
Schedule – Baseline 1

Very optimistic!



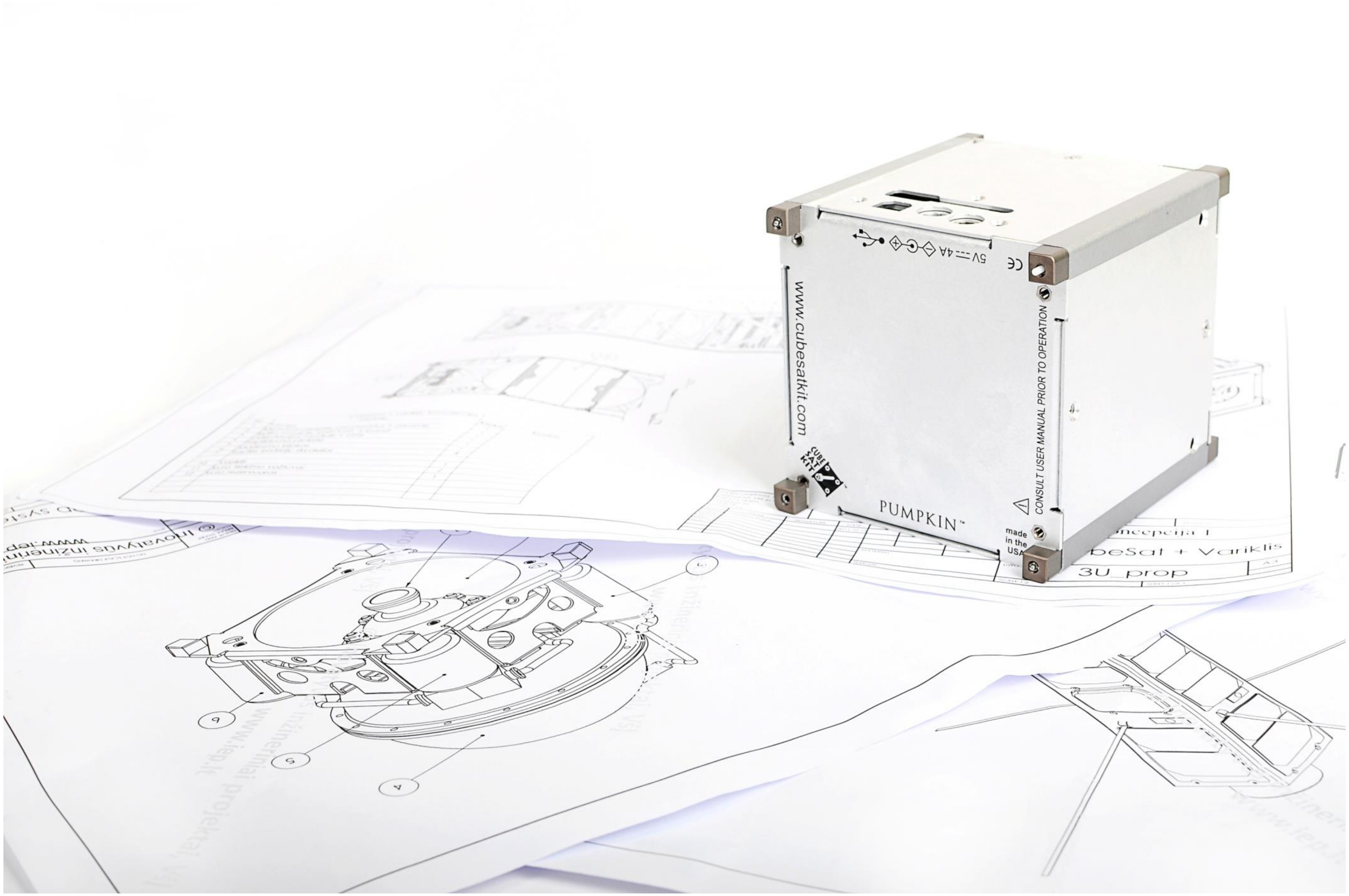
Schedule – Baseline 2

More realistic but still tight…



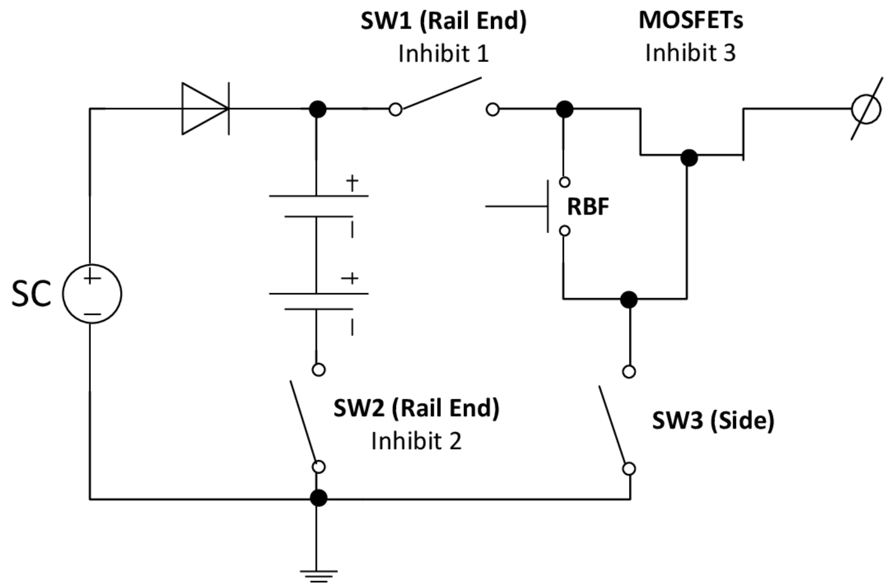
Legend:
EM – engineering model
FM – Flight model
CDR - *critical design review*

System Design



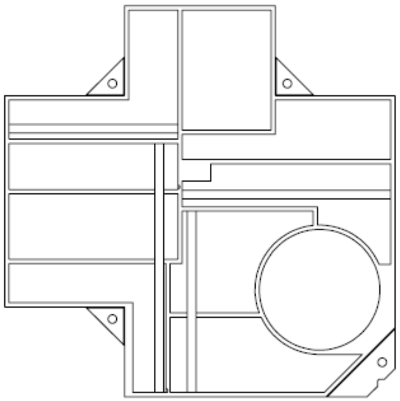
EPS

- GomSpace P31u as power management board
- expensive but reliable
- Design compatible with ISS safety requirements - but individual testing was needed
- Kill switch circuit had to be modified IAW NASA requirements

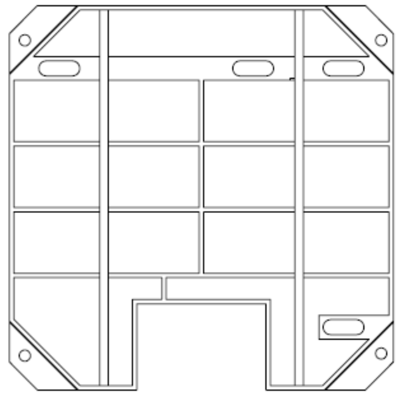


EPS – solar arrays

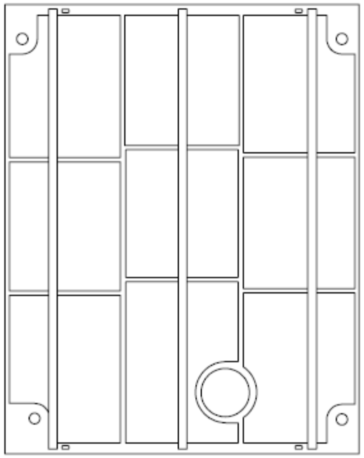
+Z



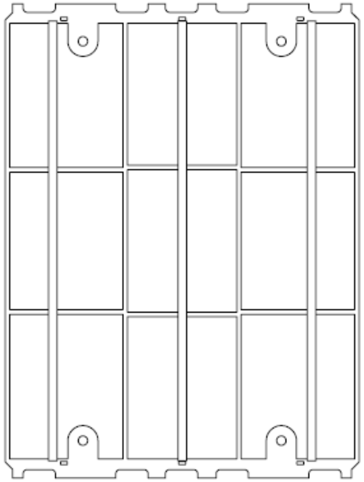
-Z



-X

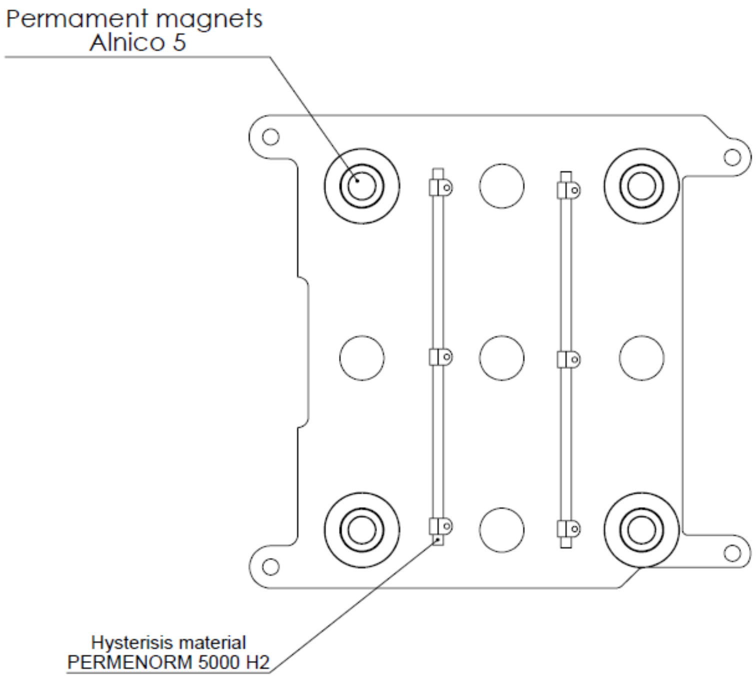


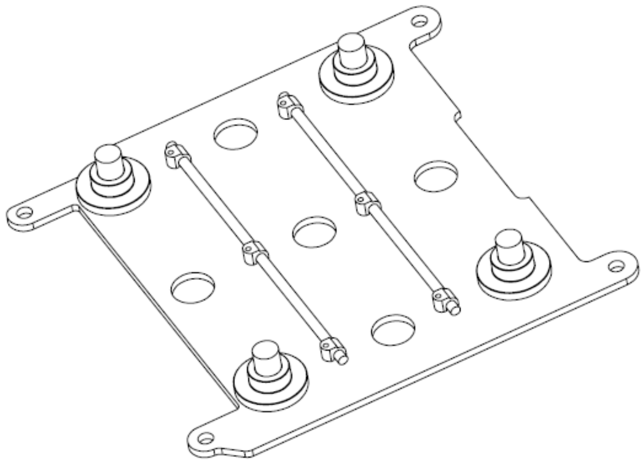
+Y, -Y, +X



LituanicaSAT-1 Si based Solar Array				
Panel	No of cells	I, A	U, V	P, W
+Z	9	0.15	4.5	0.75
-Z	9	0.15	4.5	0.75
-X	9	0.23	4.5	1
+Y, -Y, +X	9	0.26	4.5	1.2

ADCS

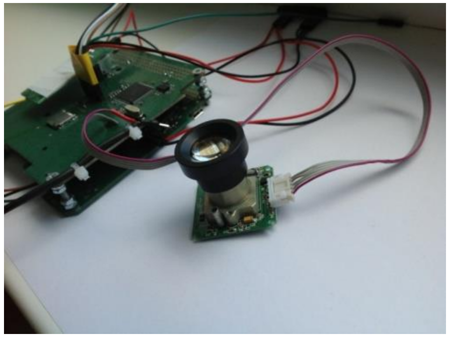




- Passive attitude control system:
  - Permanent magnet(-s): AlNiCo-5, dipole strength 0.6 A/m2 (z axis)
  - Hysteresis rods: PermeNorm 5000 H2, 0.075 cm3 (x and y axes)

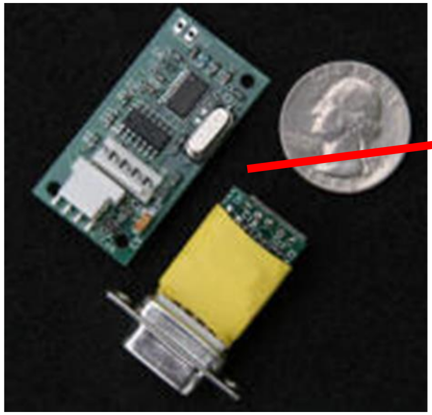
OB&DH

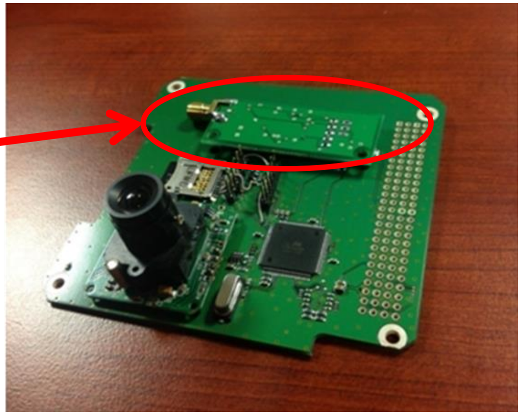
- ARM Cortex-M4F Primary flight computer:
  - Performs power management
  - Reads and logs attitude and inertial sensor data
  - Receives and interprets telecommands from main communications transceiver
  - Sends telemetry to main communications transceiver
- Arduino ATMega 2560 secondary computer:
  - Controls the On board camera
  - Stores pictures in SD card flash memory
  - Controls the radio beacon
  - Routes EPS housekeeping data to the radio beacon



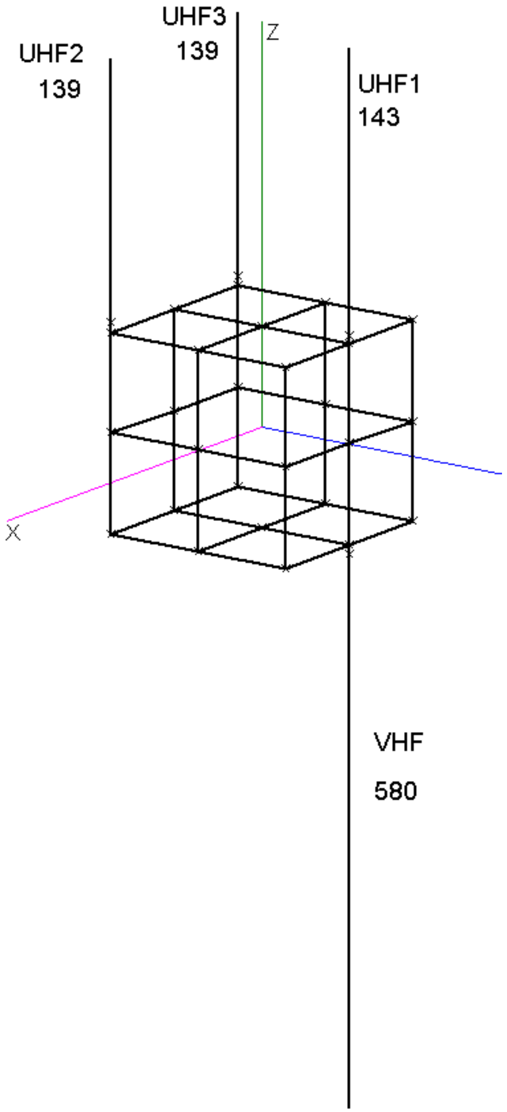
COMMUNICATIONS - hardware

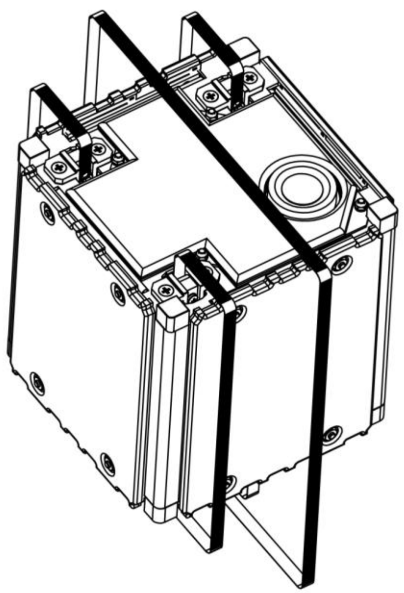
- COTS FSK/GMSK transceiver Helium-100,
  - 9k6 baud
  - 2W RF output power
- FM beacon – “Big Red Bee”
  - 100 mW output RF power
  - Flight heritage on ITupSAT-1 (>4 years in orbit)

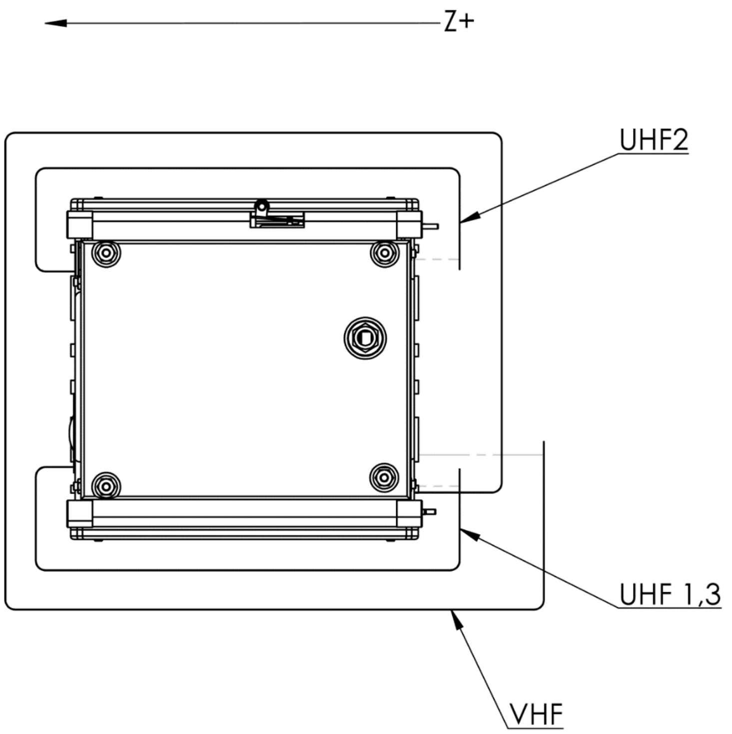




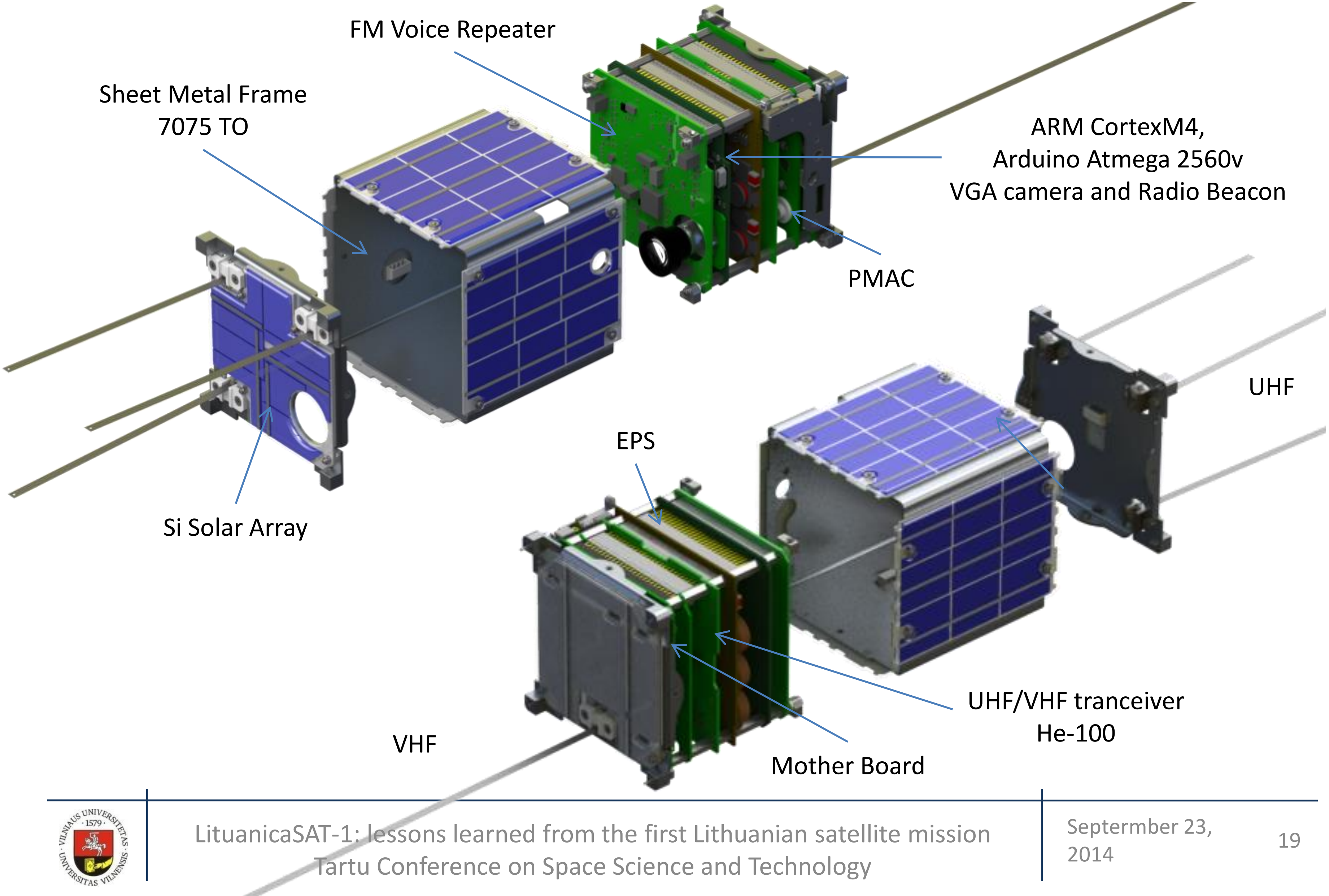
Antenna challenge







Structure


FM Voice Repeater
Sheet Metal Frame
7075 TO
ARM CortexM4,
Arduino Atmega 2560v
VGA camera and Radio Beacon
PMAC
UHF
EPS
Si Solar Array
UHF/VHF tranceiver
He-100
VHF
Mother Board

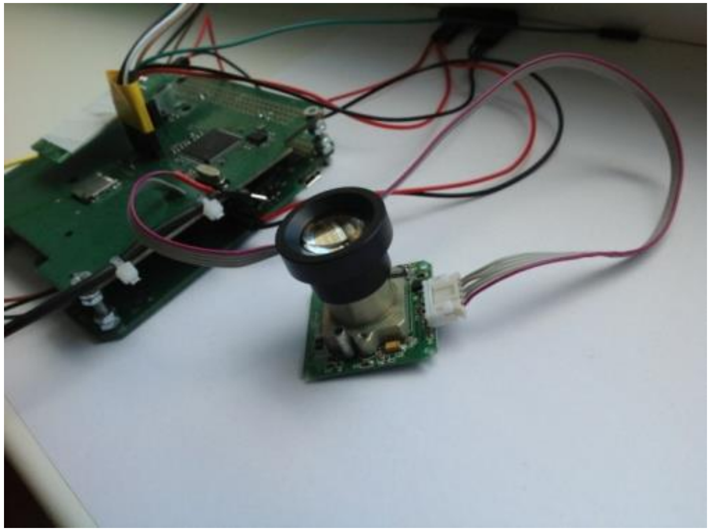
Payload – On Board Camera

- Main requirements:

  Low mass, low power consumption, image processing, convenient interface, compatibility with Arduino controllers.

Selected option is LinkSprite JPEG Color Camera:

- JPEG image compression
- 3,3 - 5V power supply
- Size 32X32mm
- Current consumption: 80-100mA



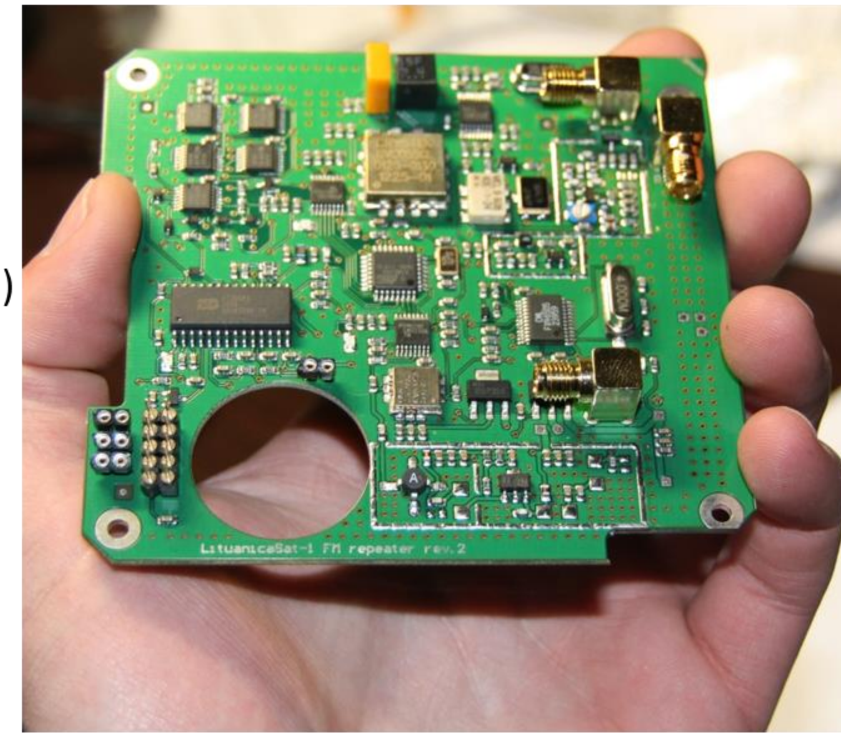
Considered options:

- The GomSpace NanoCam C1U
- PX4FLOW Smart Camera*

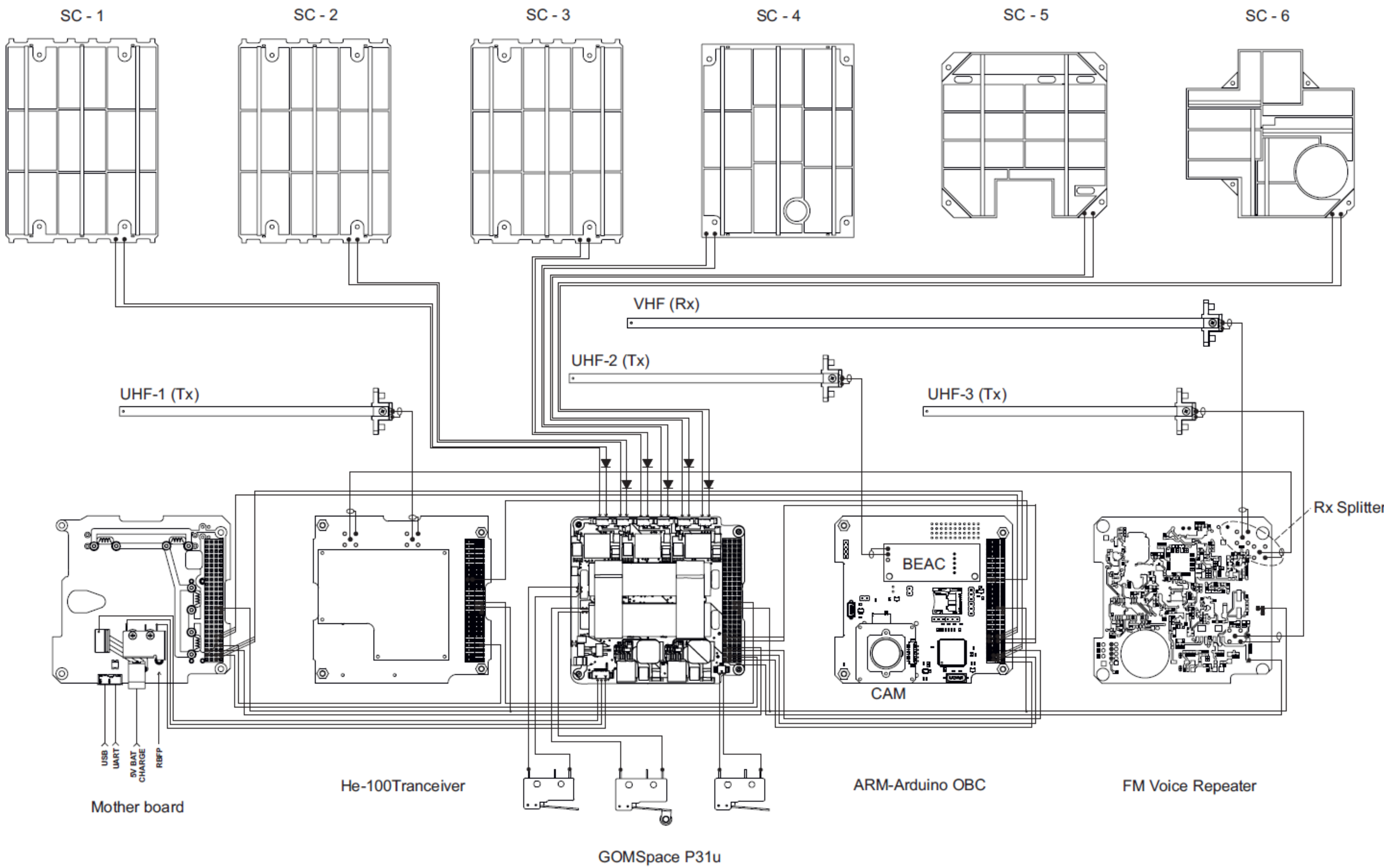
Other options were mostly rejected due to unavailability of Convenient interface and image compression possibility

Payload – FM transponder

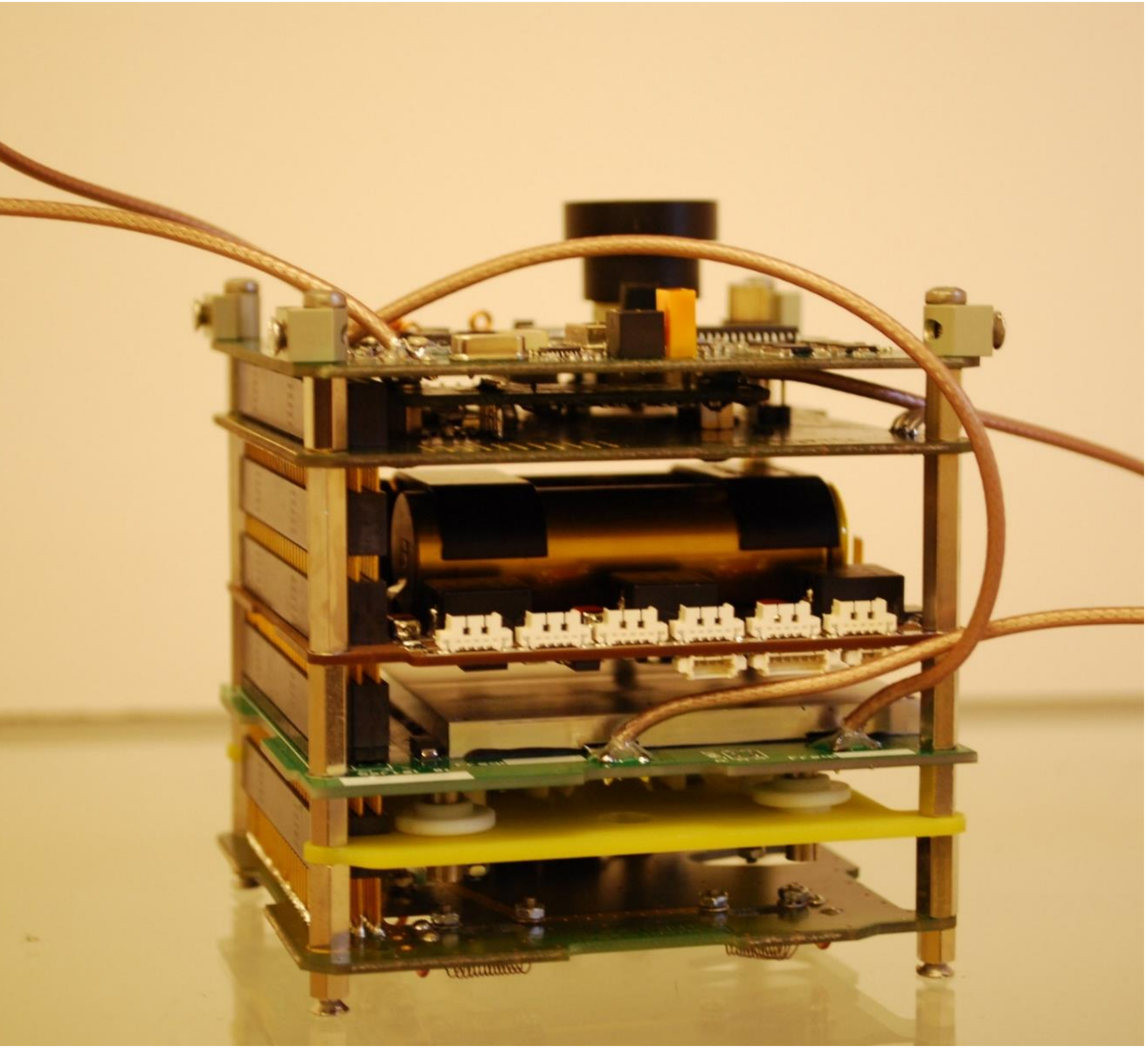
- The FM repeater is designed for placement in low Eearth orbit 1U Cubesat satellite.
- The main purpose is to widen the areal for amateur radio communications
- Operating temperature: -20° C to 70 ° C
- Weight (approx): 70 g
- Receiver system:
  - Dual conversion superheterodyne
  - 1st IF: 21.4 MHz, 2nd IF: 455 KHz
  - Frequency: 145.800-145.999 MHz
  - Receive sensitivity 0.18 uV (12 dB SINAD)
  - Selectivity: 12kHz
- Transmitter system:
  - Frequency: 435.000-438.000 MHz
  - RF Power Output: 150 mW
  - Modulation: F3E (FM)
  - Max deviation: ±6 kHz
  - Spurious emission: -60dB
- Activation: 67 Hz CTCSS tone

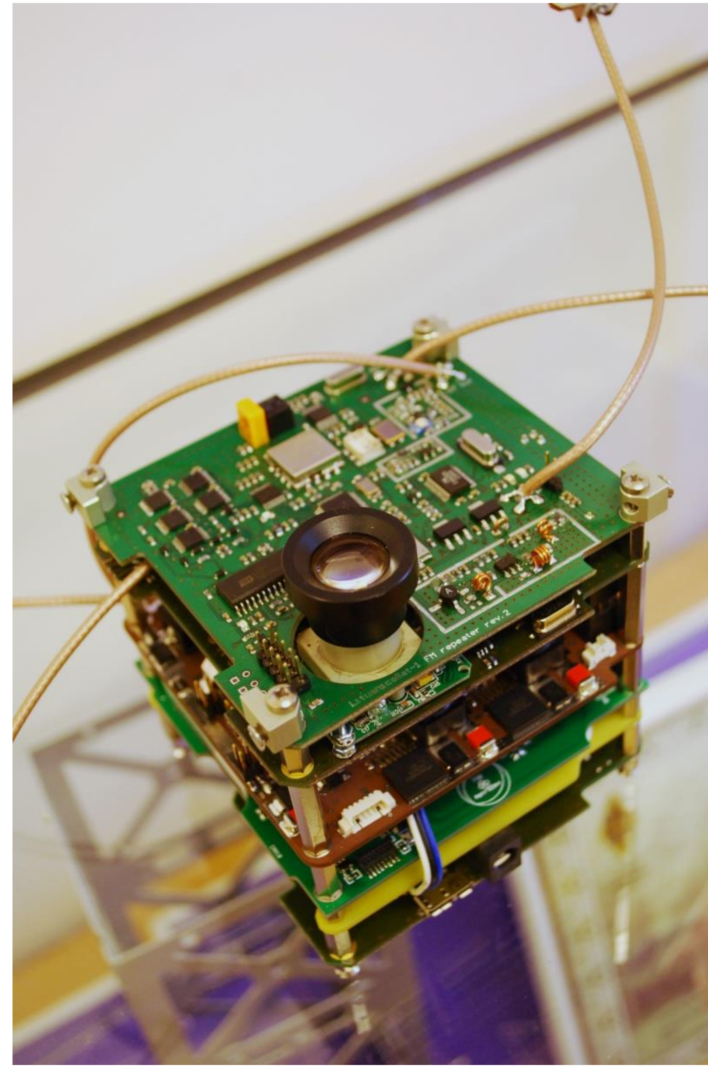


LituanicaSAT-1 Electric Diagram



Protoflight model integration





Mission Operations

Launch and early operations

LITUANICA SAT-1

2014 01 09 20:07 EET

Start of the International Space Station commercial resupply mission ORB-1 (rocket carrier Antares, cargo spaceship Cygnus 2, launch pad 0Z Wallops island Virginia, USA)

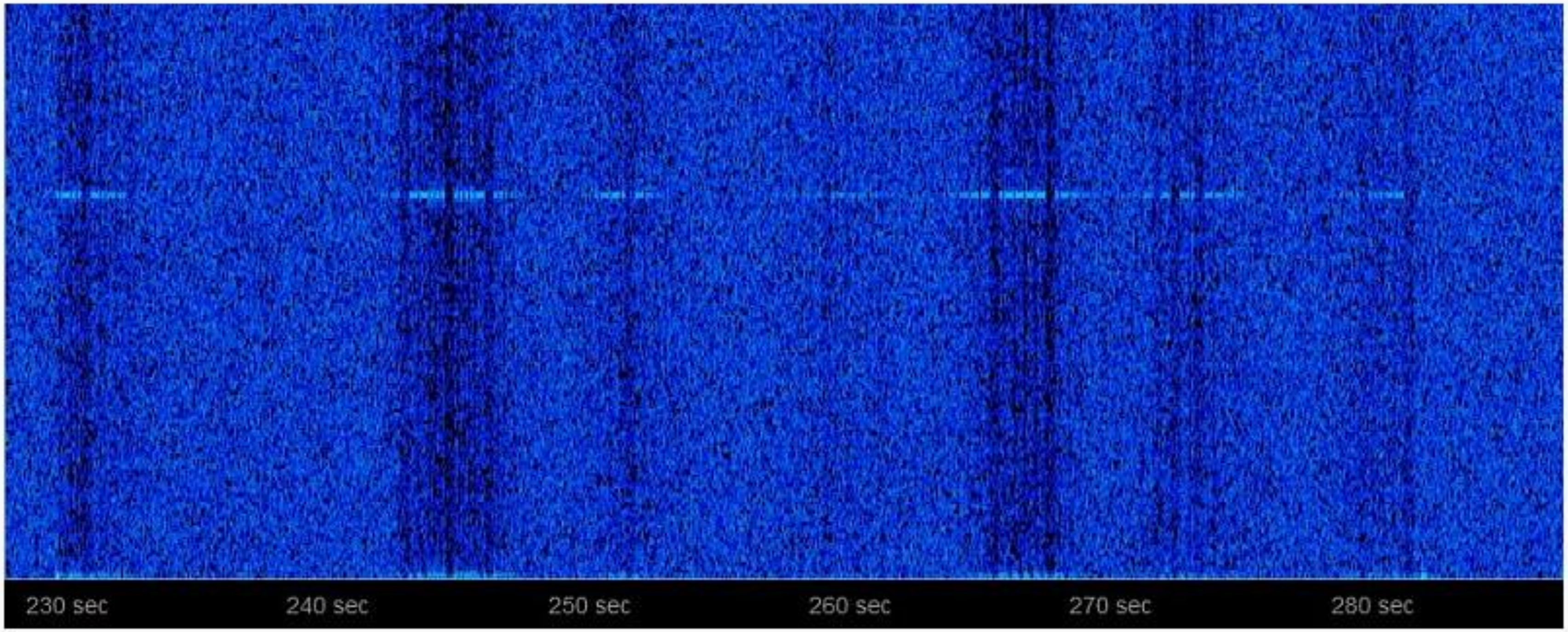
Photo Credit: V. Buzas

Deployment from ISS: 2014 02 28 7:30 UTC

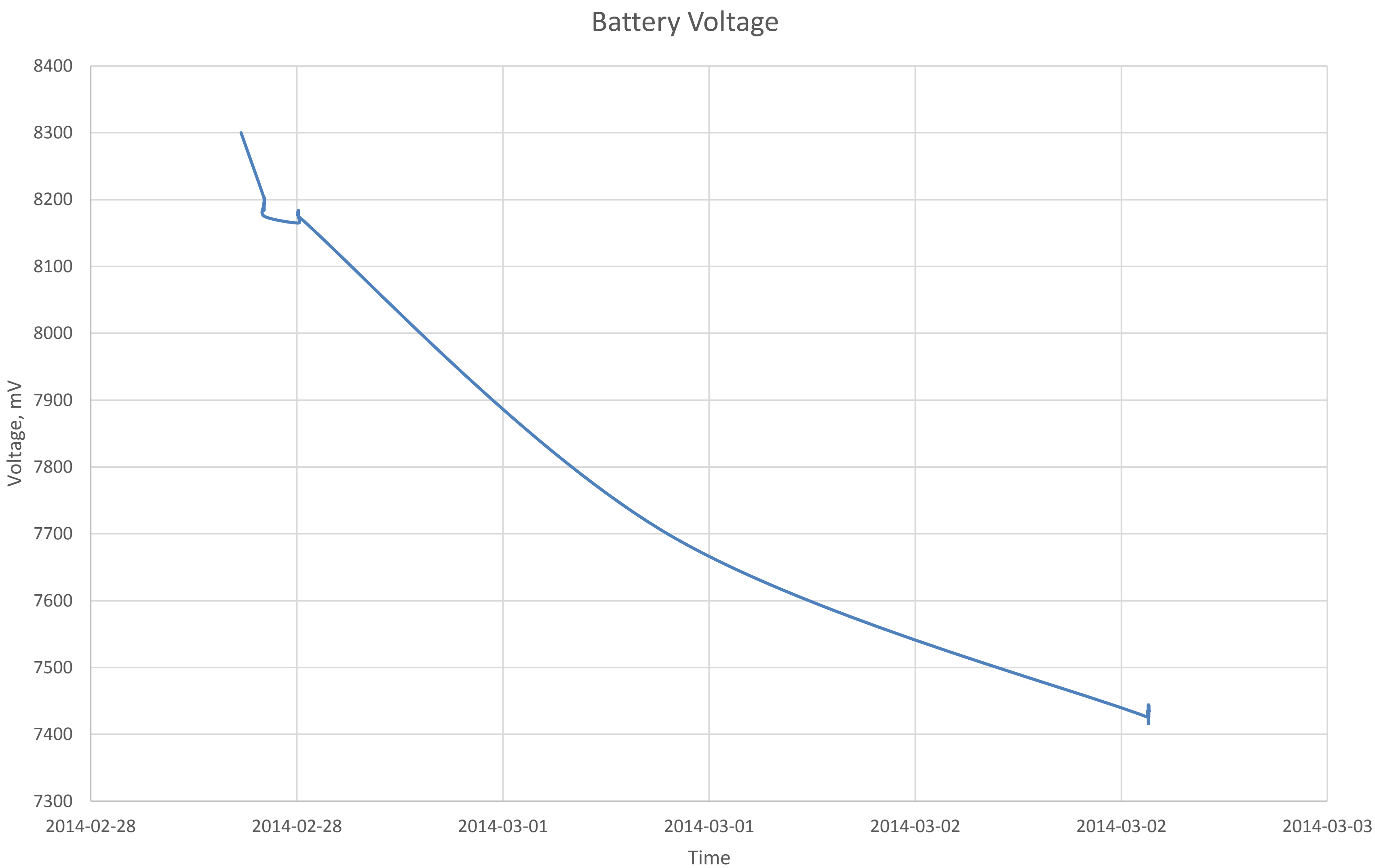
First orbit telemetry

FM beacon signal heard by DK3WN on 28/02/2014 08:45:00 UTC, 3 deg elevation pass:

LY5N.....83 C021 0112 TN05 S63

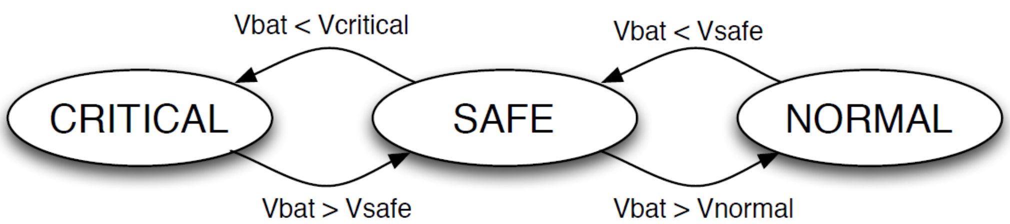


Early power problems



EPS fault analysis

- Abnormally low photo current from solar panels identified as the root cause of the failure
- Solar panel voltages appeared to be nominal
- EPS under voltage protection prevented from critical failure but did not solve the problem

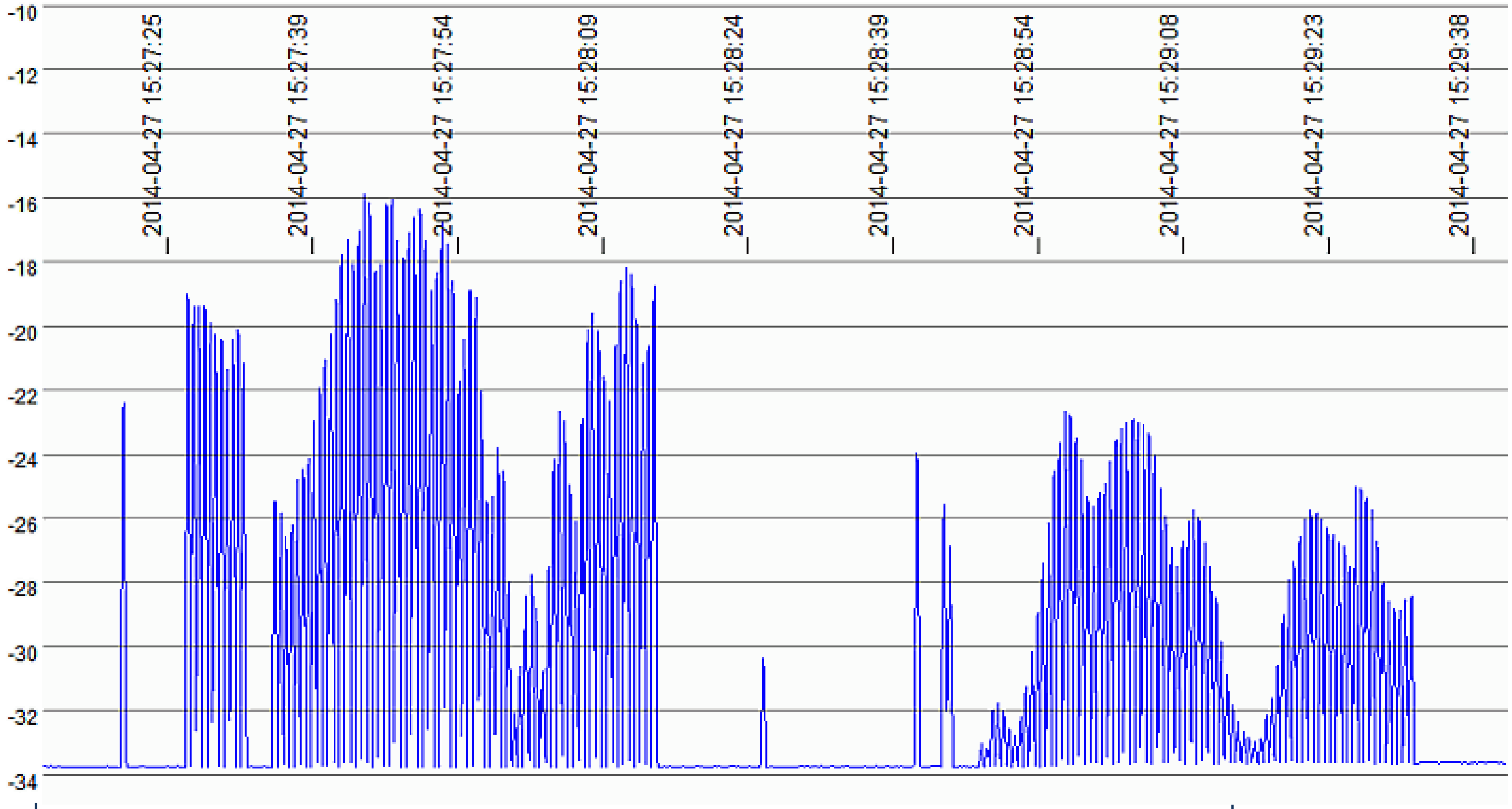


Software level setpoints	**Voltage level (V)**
Vnormal	7.4
Vsafe	7.2
Vcritical	6.5

- Solution: turn off the FM beacon (proved to be not so simple as it sounds)

COM troubleshooting

- Uplink budget proved to be less favorable than estimated during design (reliable uplinks were possible only using RF amplifier with 100W of output power)
- Downlink and uplink instability due to tumbling and spinning



First mission success

Successful transponder test

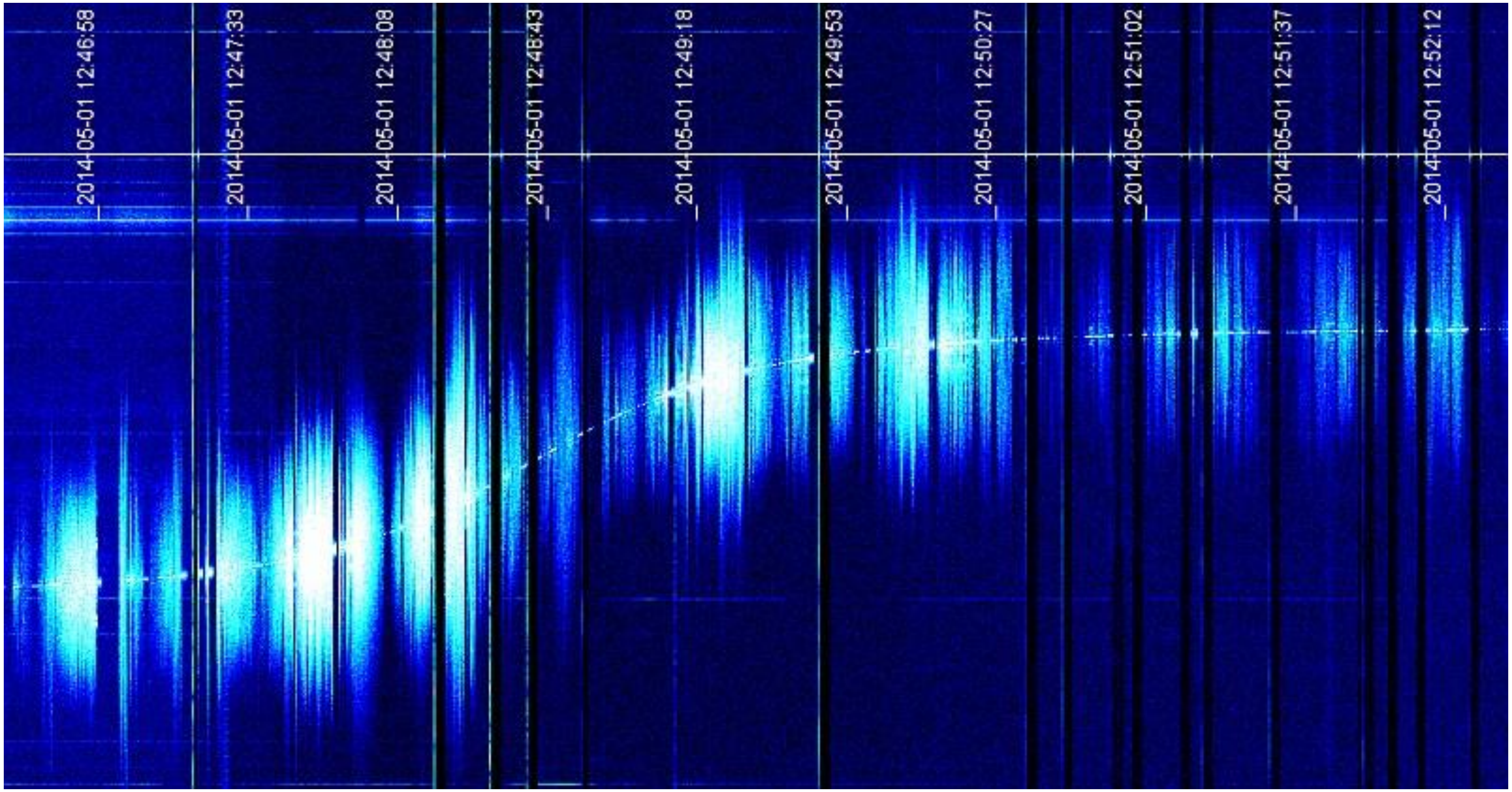


Image credit: Mike Rupprecht (url: http://www.dk3wn.info/p/?p=44725)

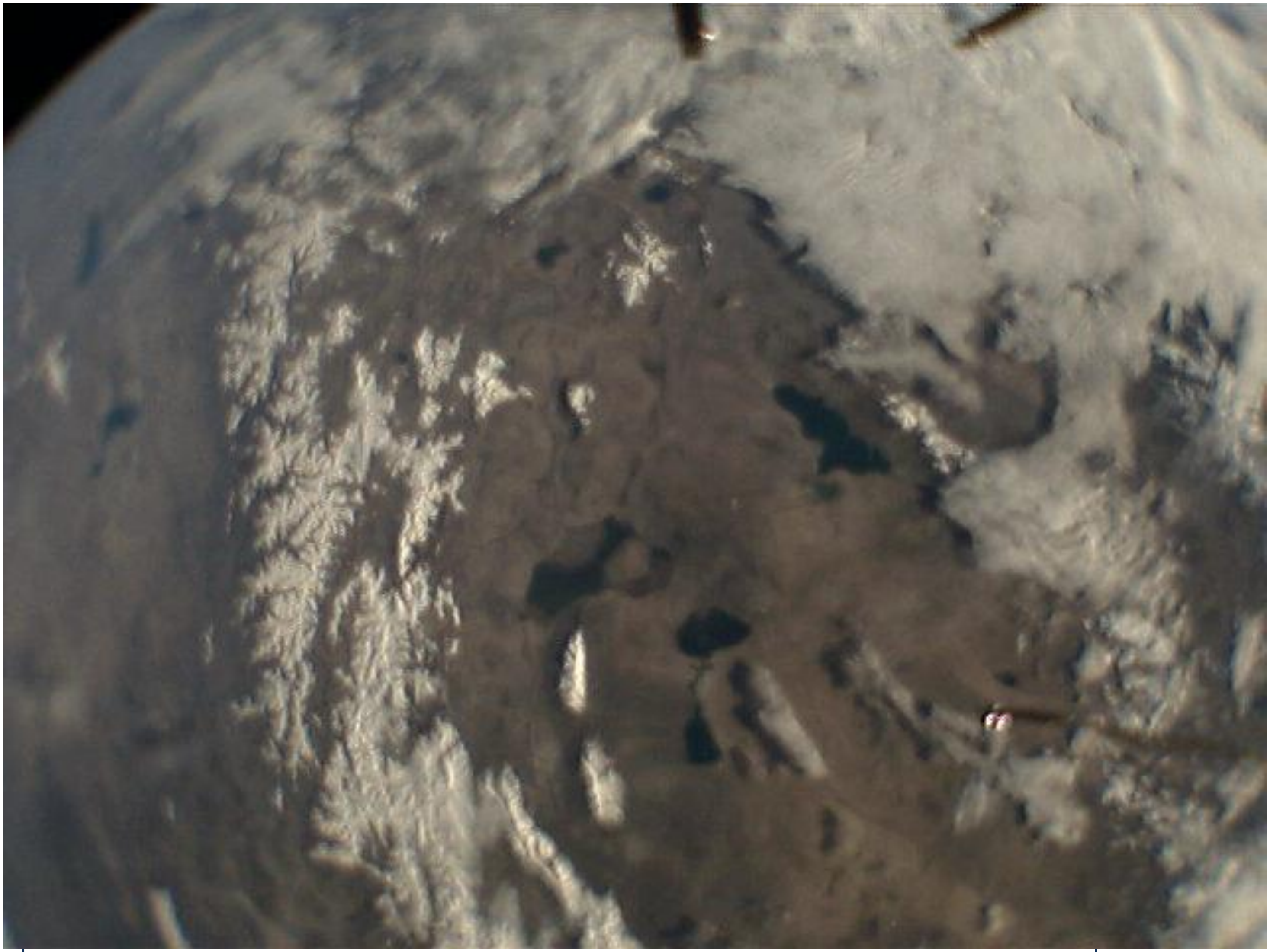
Feedback from radio amateurs

LITUANICA SAT-1

First picture from space

First glimpse at the Earth

Spying over Mongolia



Lessons Learned

- Understand your stakeholder expectations
- Be prepared for budget overruns
- Avoid Protoflight philosophy
  - Risky (if something goes wrong – you are in a big trouble)
  - Impossible to perform troubleshooting after launch
- Software integration and testing will take more time than you expect
- Most of the problems in orbit can be avoided by thorough testing on ground
- Keep your documentation up to date and use it

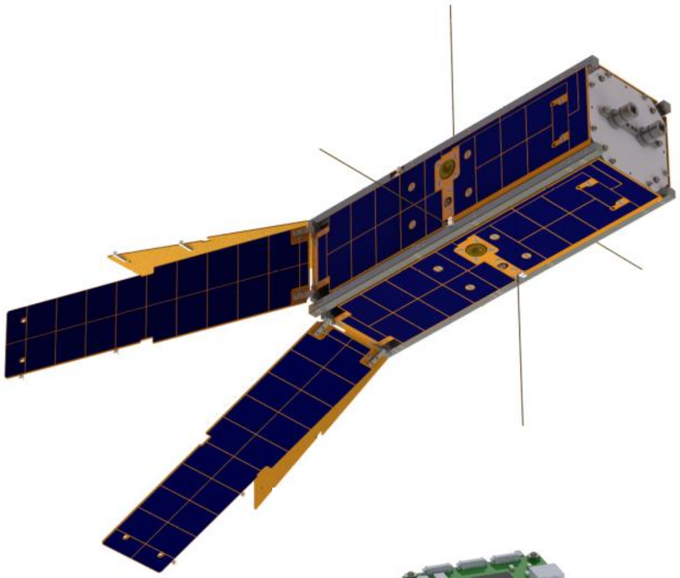
LituanicaSAT-2

Mission Objectives:

- To perform international science mission exploring lower thermosphere;
- To find new scientific and industrial partners for future collaboration;
- Technology demonstration of green propulsion system for CubeSat (deltaV = 150 m/s);
- To advance space science and technology in Lithuania;
- To develop commercial space grade nanosatellite components.

Project status:

- Flight Accepted;
- Detailed design completed and budget secured;
- Currently in phase C/D



LituanicaSAT-2 visualization (Above)
CubeSat propulsion system to be tested on LituanicaSAT-2 (Below)

Your questions

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