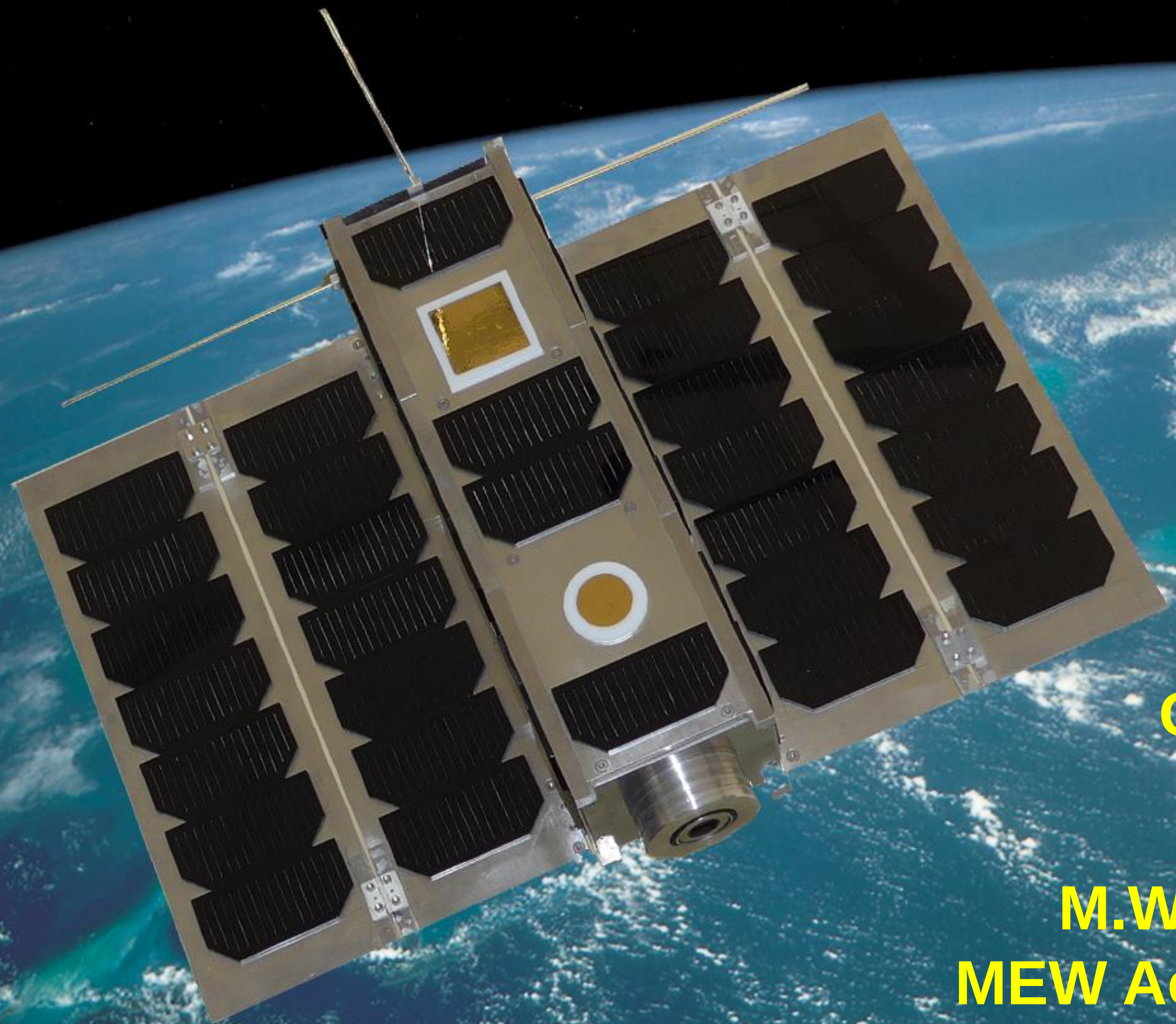
THE OPS-SAT NANOSATELLITE MISSION



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TU Graz

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MEW Aerospace

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ESA

Contents

Background & Motivation (1)

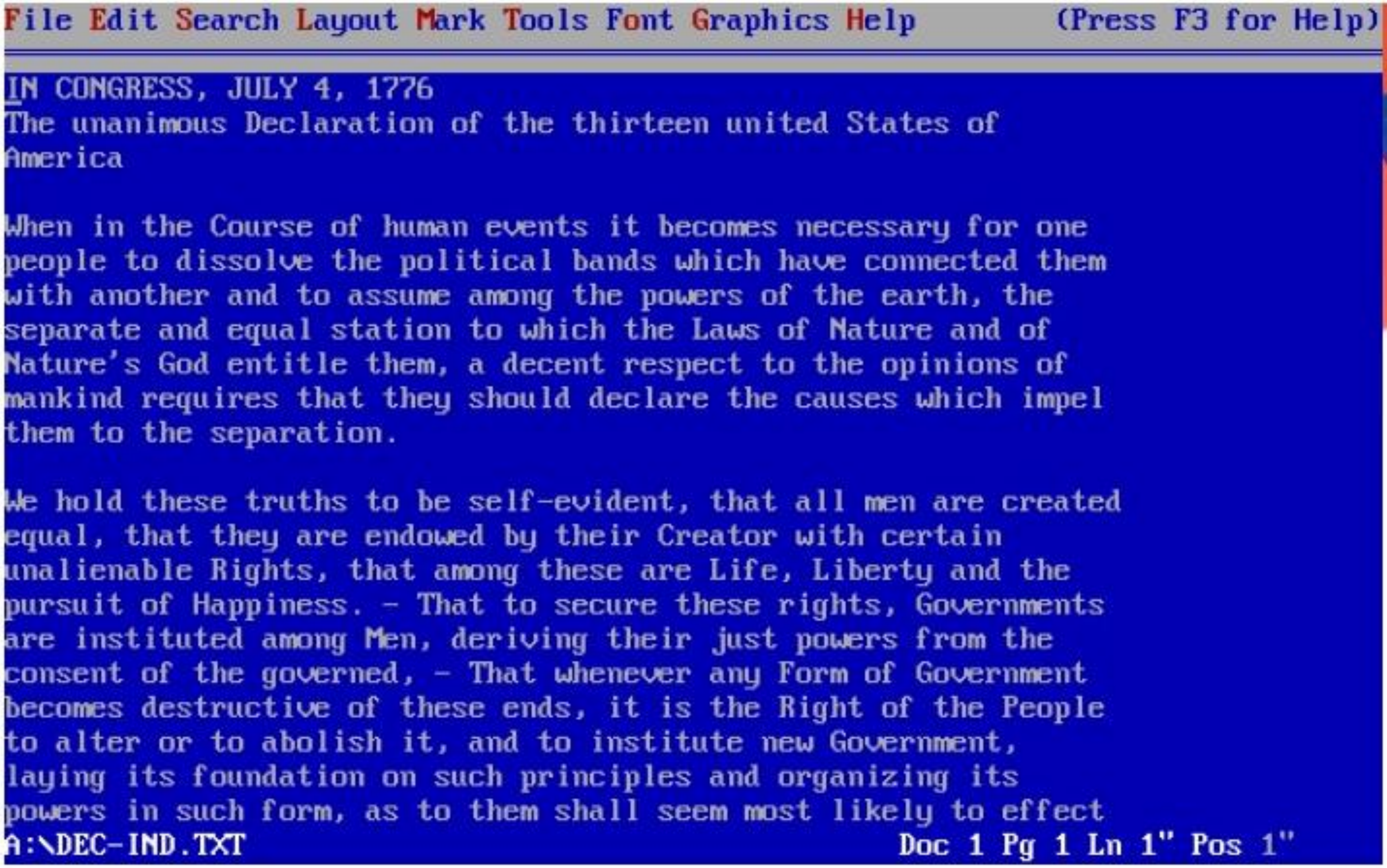
- New ideas are generated by ESA and European industry for evolving mission control
- Patents, studies, prototypes & breadboards are produced
- But the majority do not make it near a real mission

- Why ….
  - Has never flown - will never fly problem
  - Risk aversion: healthy when dealing with large missions but not for innovation

Background & Motivation (2)

- In 2011 ESOC‘s Advanced Operations Concepts Office had an idea to change the current situation
- A low cost, in-orbit demonstrator for mission control based on a COTS CubeSat bus - OPS-SAT
- In January 2012 a CDF Study funded by GSP (with CNES participation) declared the idea feasible
- In May 2013 an Open Call for OPS-SAT Experiments was run by ESA
  - Over 100 experiment ideas from 17 ESA member states
  - OPS-SAT Open Day in June 2013 attracted 100+ guests
- 2 parallel Phase A/B1 studies kicked off in 7/2013
- Phase B2/C/D/E1 contract kicked off in 02/2015

A Quiz



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IN CONGRESS, JULY 4, 1776
The unanimous Declaration of the thirteen united States of America

When in the Course of human events it becomes necessary for one people to dissolve the political bands which have connected them with another and to assume among the powers of the earth, the separate and equal station to which the Laws of Nature and of Nature's God entitle them, a decent respect to the opinions of mankind requires that they should declare the causes which impel them to the separation.

We hold these truths to be self-evident, that all men are created equal, that they are endowed by their Creator with certain unalienable Rights, that among these are Life, Liberty and the pursuit of Happiness. - That to secure these rights, Governments are instituted among Men, deriving their just powers from the consent of the governed, - That whenever any Form of Government becomes destructive of these ends, it is the Right of the People to alter or to abolish it, and to institute new Government, laying its foundation on such principles and organizing its powers in such form, as to them shall seem most likely to effect

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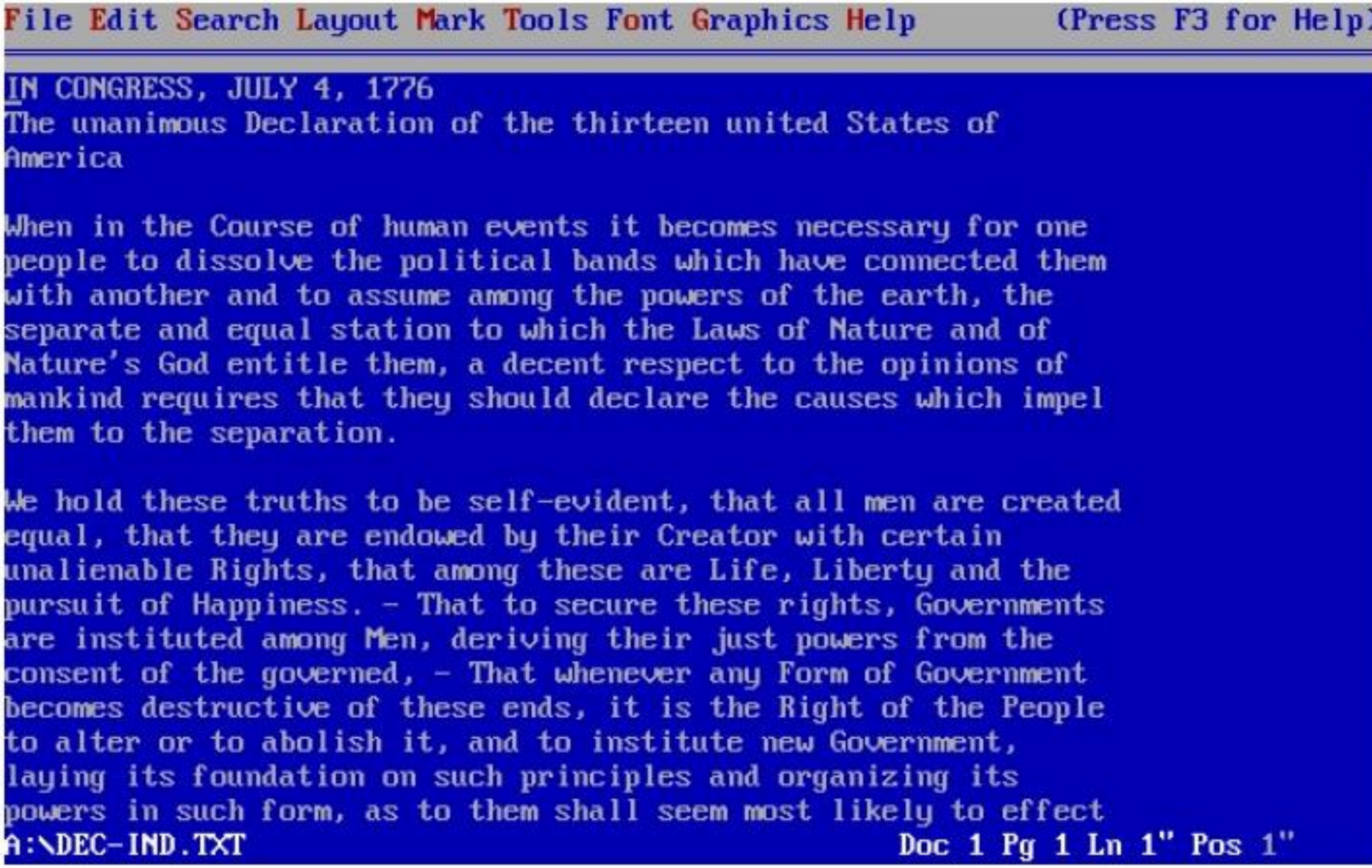
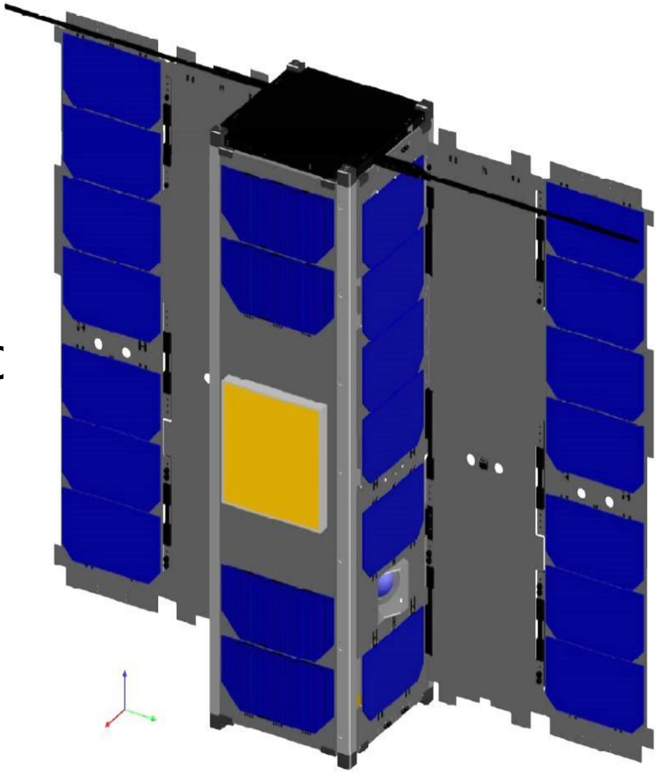
A Quiz



Packet Utilisation Standard: ESA PSS-07-101 Issue 1 May 1994

OPS-SAT Mission Statement

“OPS-SAT is a safe, hard/software laboratory, flying in a LEO orbit, reconfigurable at every layer from channel coding upwards, available fc authorised experimenters to demonstrate innovative new mission operation concepts.“



Mission Requirements (1)

- OPS-SAT: Experimentation with on-board and ground software by offering a safe and reconfigurable environment for execution of software experiments relevant for ESA's future mission operation needs

- OPS-SAT shall be a nanosatellite compliant with current nano-satellite volume and mass limitations, using reliable COTS components

- OPS-SAT shall be compliant with an existing and proven launch adaptor interface

Mission Requirements (2)

- Lifetime of at least one year in orbit and be compliant with space debris guidelines on re-entry.

- Spacecraft: power and thermally safe even if tumbling, robust against SEUs, latching events or faulty experimental software.
-
- Payload: at least two processors running at 500MHz or more, capable of running Linux and a Java Virtual Machine, 500MB RAM and 10GB solid storage, one or more reconfigurable FPGAs

Mission Requirements (3)

- Payload accepts upload and verification of new software images to be executed.

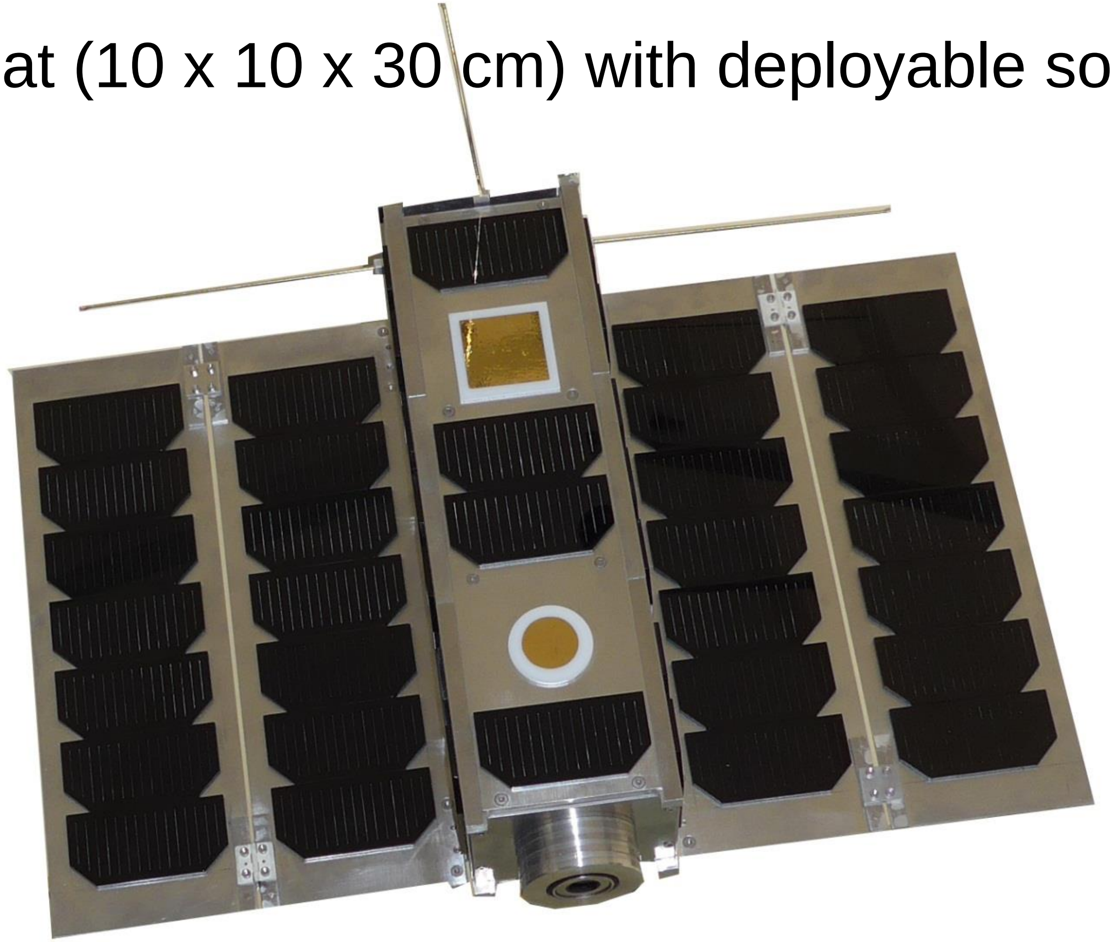
- Software experiments shall have open access to all on-board resources and systems unless justified due to safety.

- At least one configuration on board and on ground shall be representative of an ESA mission

- S-Band rates: of at least 256 kbps (uplink) and of 1 Mbps (downlink)

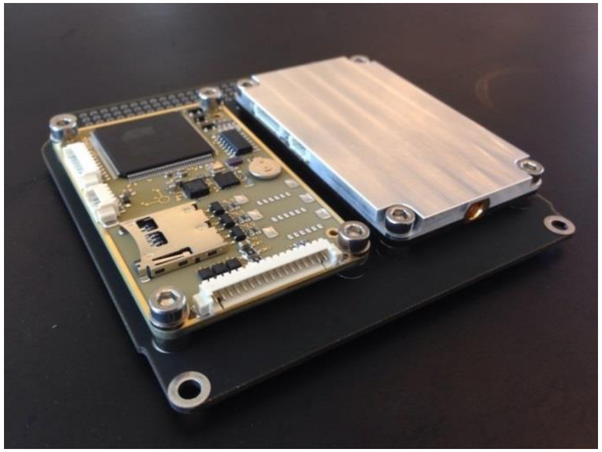
OPS-SAT

Triple CubeSat (10 x 10 x 30 cm) with deployable solar arrays

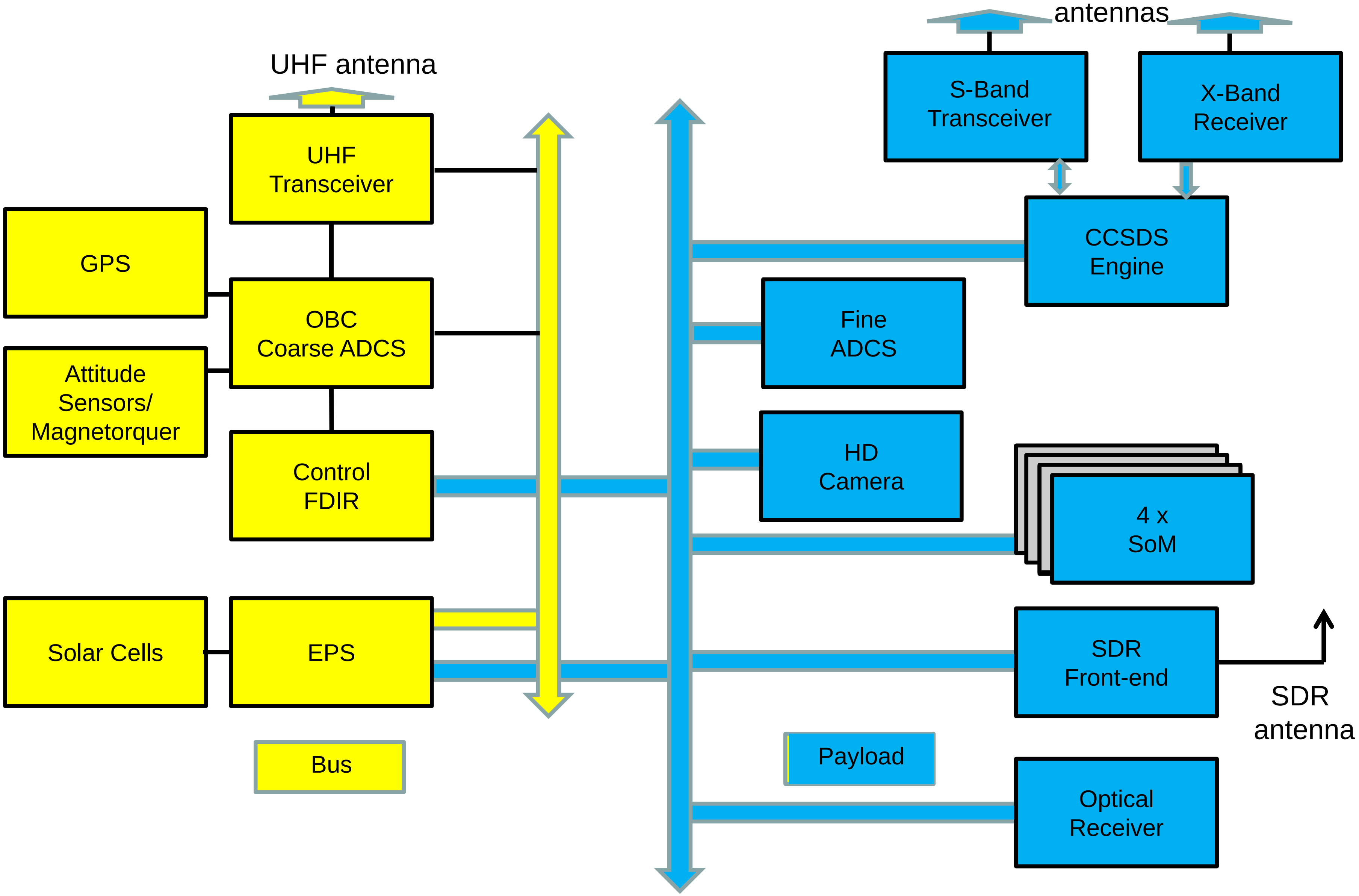


Detailed Definition

- Bus: CubeSat COTS components
  - OBC with GPS
  - FDIR computer
  - UHF communications system
  - Coarse ADCS system
  - Electric Power System (EPS)
    - Deployable solar arrays (30 W)
    - Batteries
    - Charge/discharge regulators



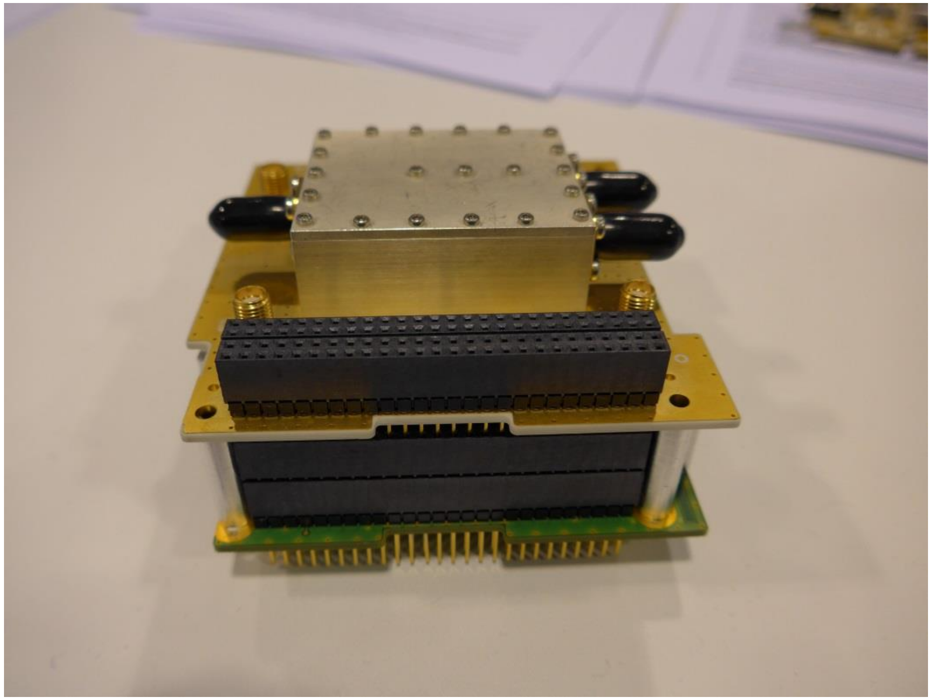
Source: GOMSPACE



antennas
UHF antenna
S-Band Transceiver
X-Band Receiver
UHF Transceiver
CCSDS Engine
GPS
OBC Coarse ADCS
Fine ADCS
Attitude Sensors/ Magnetorquer
HD Camera
Control FDIR
4 x SoM
Solar Cells
EPS
SDR Front-end
SDR antenna
Bus
Payload
Optical Receiver

S-Band Transceiver

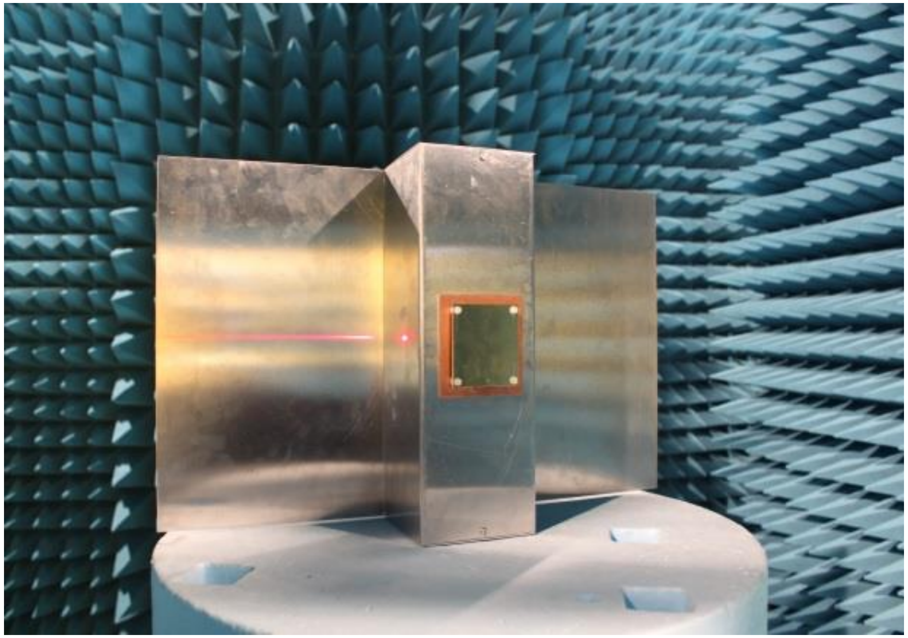
- Regulated telemetry spectrum
- Uplink data rate: 256 kbit/s
- Downlink data rate: 1 Mbit/s

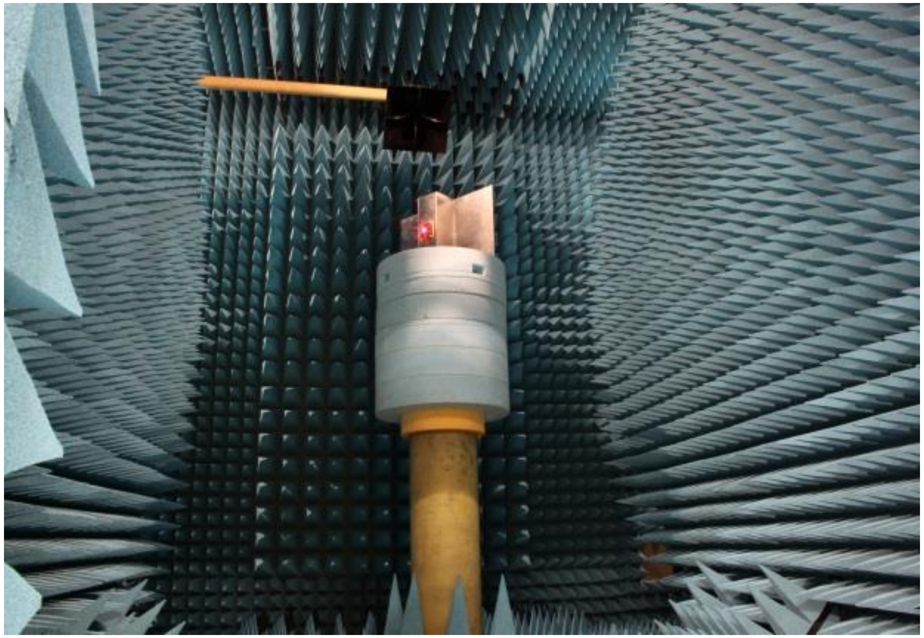


Source: Syrlinks

Antenna Tests

- 2 patch antennas on opposite faces of spacecraft

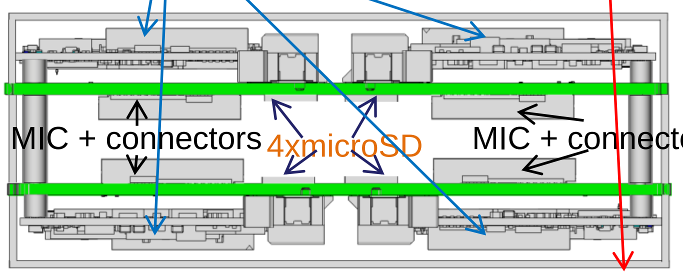




Main Payload
Processing Platform Hardware

- 4 x System on Module
- Altera Cyclone V SoC

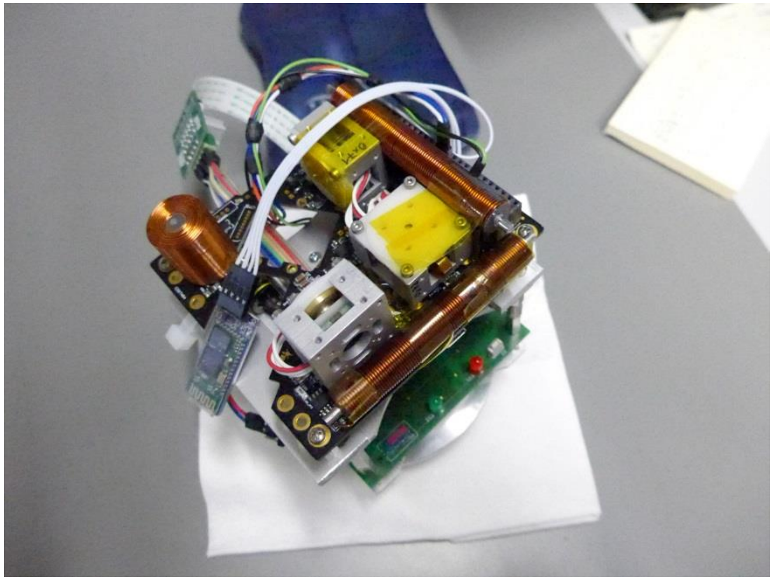
- Memory
  - 1 GB DDR3 RAM (ECC!)
- Mass Memory
  - external 8 GB Industrial SD-Cards (SLC)



Source: Critical Link

Payloads

- Fine attitude control system with star sensor and 3 reaction wheels

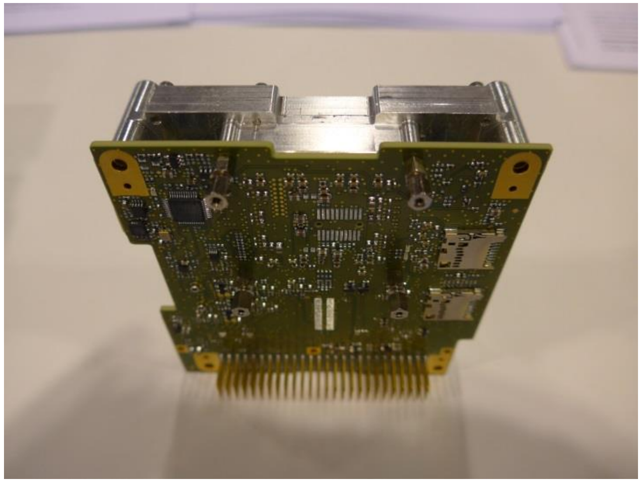


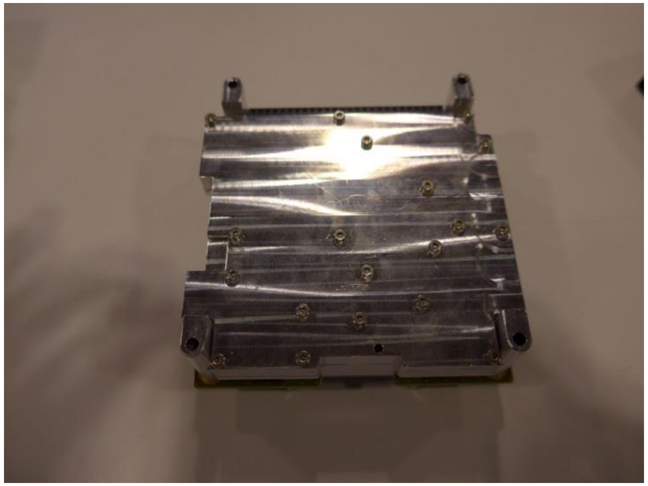
Source: BST

- HD-Kamera with 50 – 60 m ground resolution

Payloads

- X-Band transmitter (50 Mbit/s)



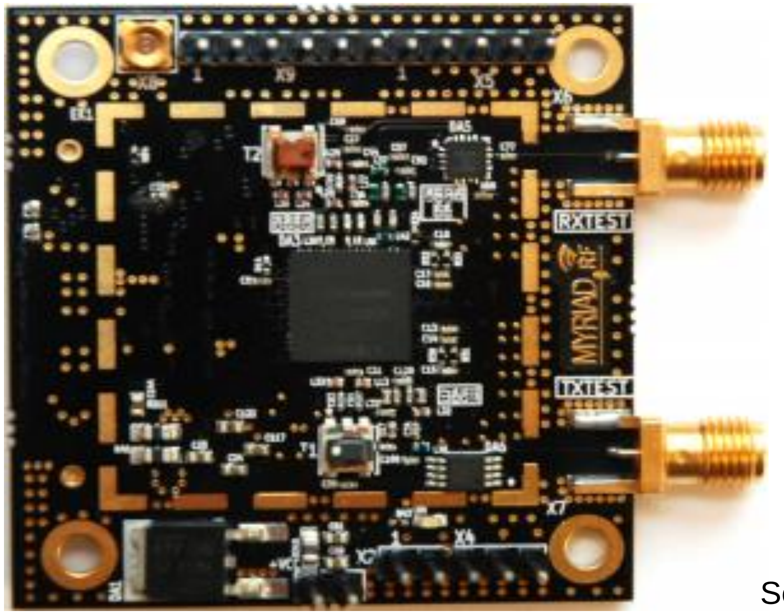


Source: Syrlinks

- Software-Defined Radio („spectrum analyser in the sky“)
- Optical receiver
- Optical retro-reflectors (position determination from ground)

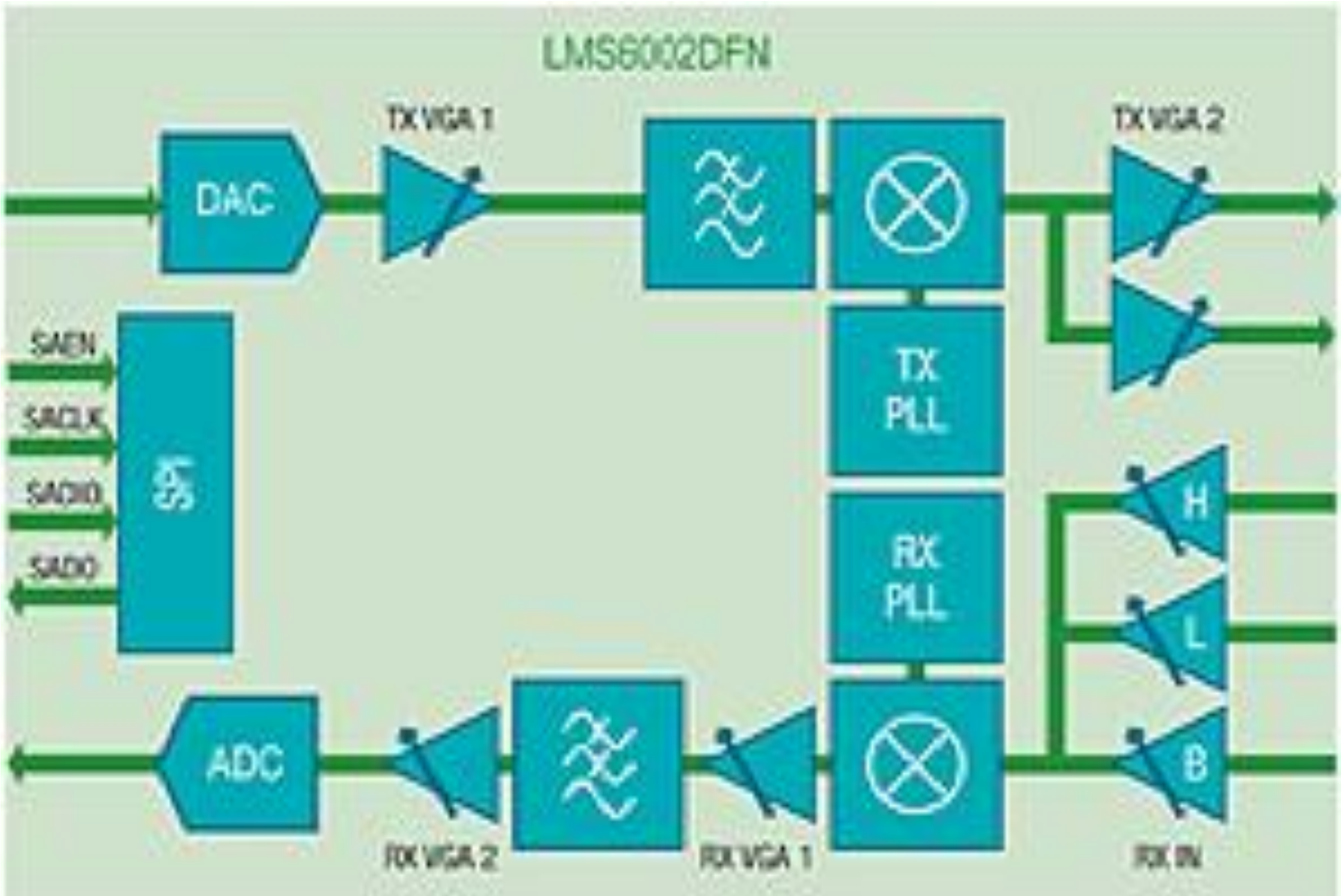
Software-defined Receiver

- RF front-end interfacing with processing platform
- Frequency range: 300 MHz – 3.8 GHz
- RX / TX capabilities



Source: Myriad RF

RF Front-end

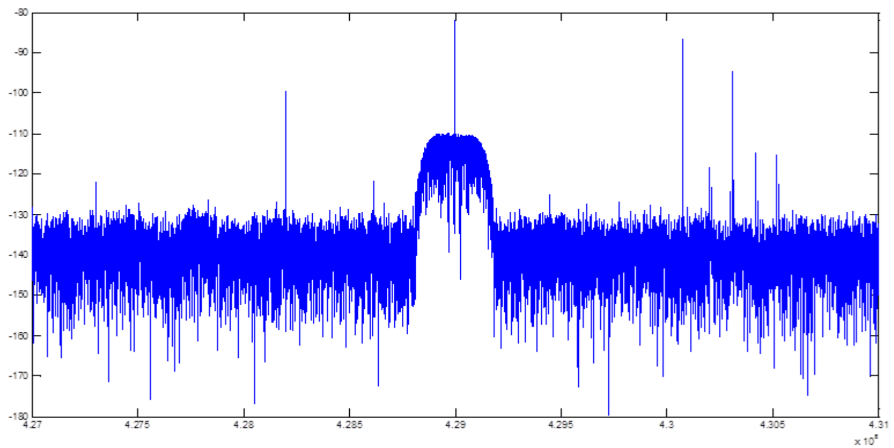


Source: Myriad RF

12 bit ADC /DAC
28 MHz bandwidth

SDR Experiments

- Spectral monitoring & signal localisation
- Rationale: strong interference in some bands (430-440 MHz)



- ADS-B signal detection from Space (1090 MHz)
- GALILEO/GPS/GLONASS/BEIDOU signal monitoring

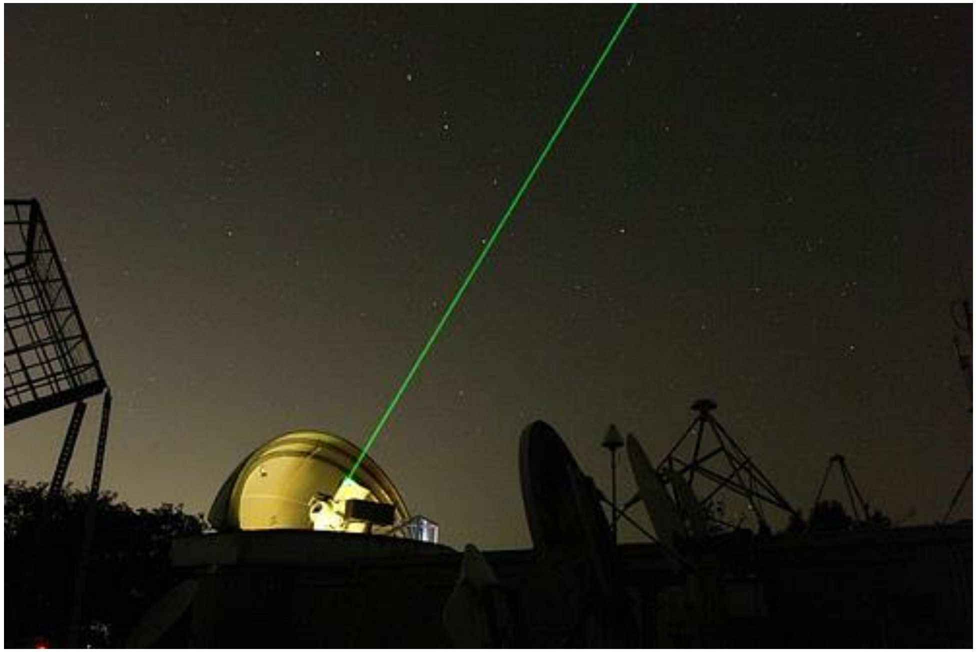
  (1575, 1278, 1207,… MHz)

Optical Uplink

- Optical communications advantageous:
  - No interference
  - Very high bit rates
  - Favourable link budgets
  - Problem: fog and cloud cover
- Standard: SILEX on ARTEMIS, EDRS, SENTINELs
- Power/volume/mass limitations on a nanosatellite
- Uplink system feasible

Laser Station Graz

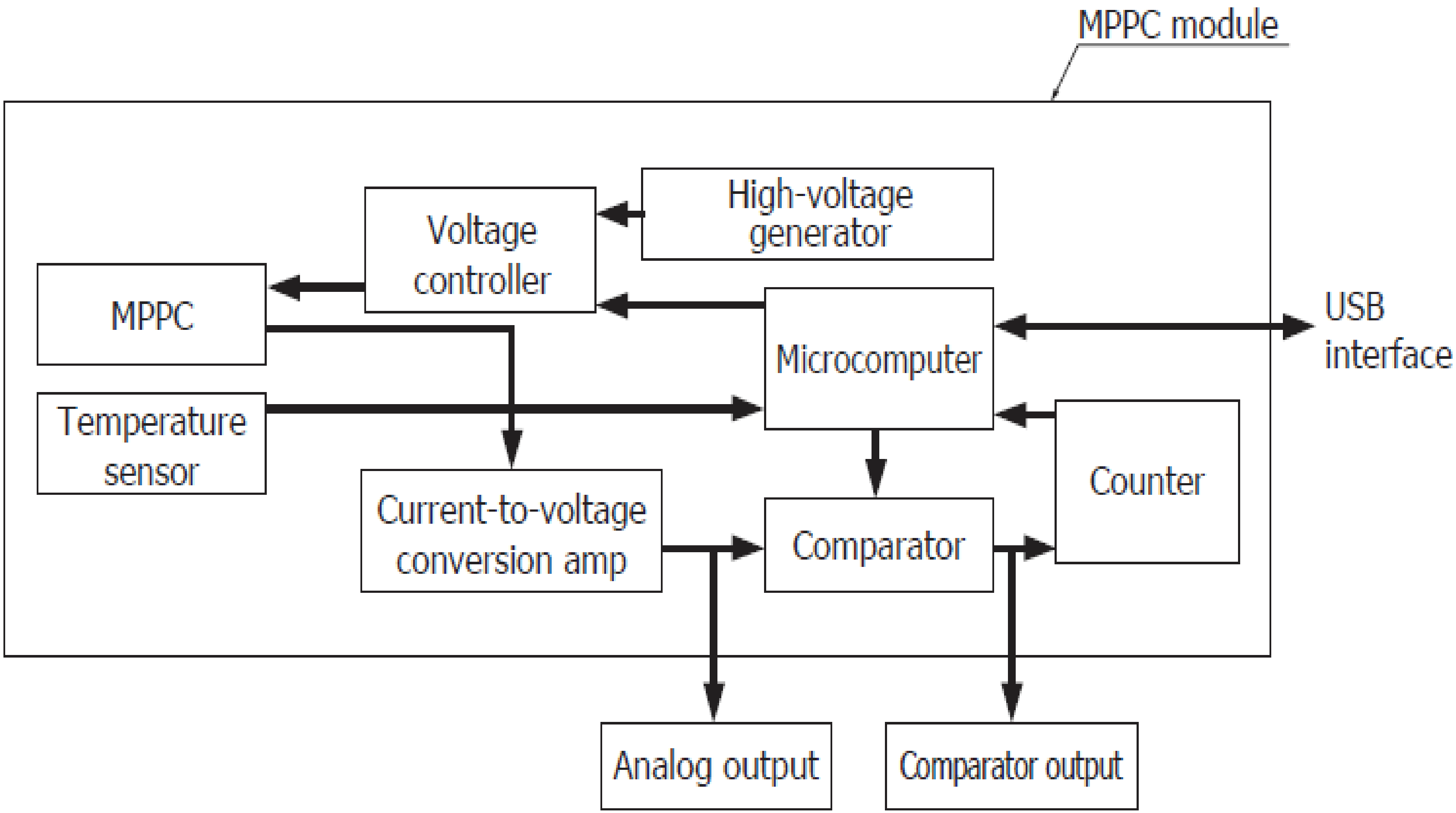
- Laser tracking station for geodedic research
- Pulse Laser (kbit/s)
- Can be used as a PPM transmitter



Source: IWF/OEAW

Optical Front-end

Detector: array of 400 avalanche photo diodes



Optical Link Budget

Laser Energy	300 µJ
Pulse Duration	10 ps
Pulse repetition Frequency	2 kHz
Pulse Power	30 MW
Transmitted Beam Divergence	20 arcsecond
Total Transmission (including Atmosphere)	0.1
Effective Tx Telescope Diameter	5.5 mm
Effective Spot Size at receiver (1000 km Distance)	193 mm
Receiver Aperture	50 µm * 50 µm
Space loss	$1.782 \cdot 10^{-27}$
Tx Antenna Gain	$1.049 \cdot 10^{9}$
Rx Antenna Gain	$8.73 \cdot 10^{4}$
Received Power per Pulse	492 nW
Number of Photons per Pulse	13.1
Photon Energy	$3.74 \cdot 10^{-19}$ J

Optical Experiments

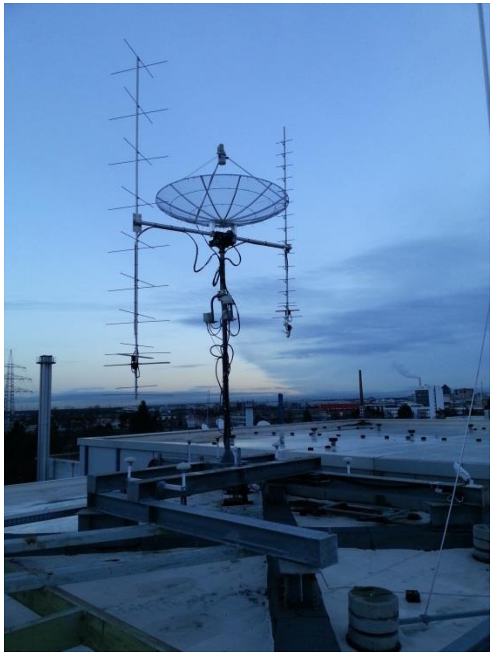
- Low data rate, but…
- Uplink of cryptographic key for RF downlink
- Hardly interceptable
- One-time pad method (not breakable)
- Never done before in satellite communications

Realisation

- Phase A/B1 completed in January 2014
- Phase C/D started in February 2015
- FAR: Q1 2017
- Launch: Q3 2017
- Experimental phase: 1 - 2 years

OPS-SAT Operations

- Fully compatible with CCSDS standard
- Ground infrastructure of ESA (ESTRACK): S- / X-Band
- OPS-SAT operated as any other ESA mission
- Test of new protocols



Source. ESA

Consortium

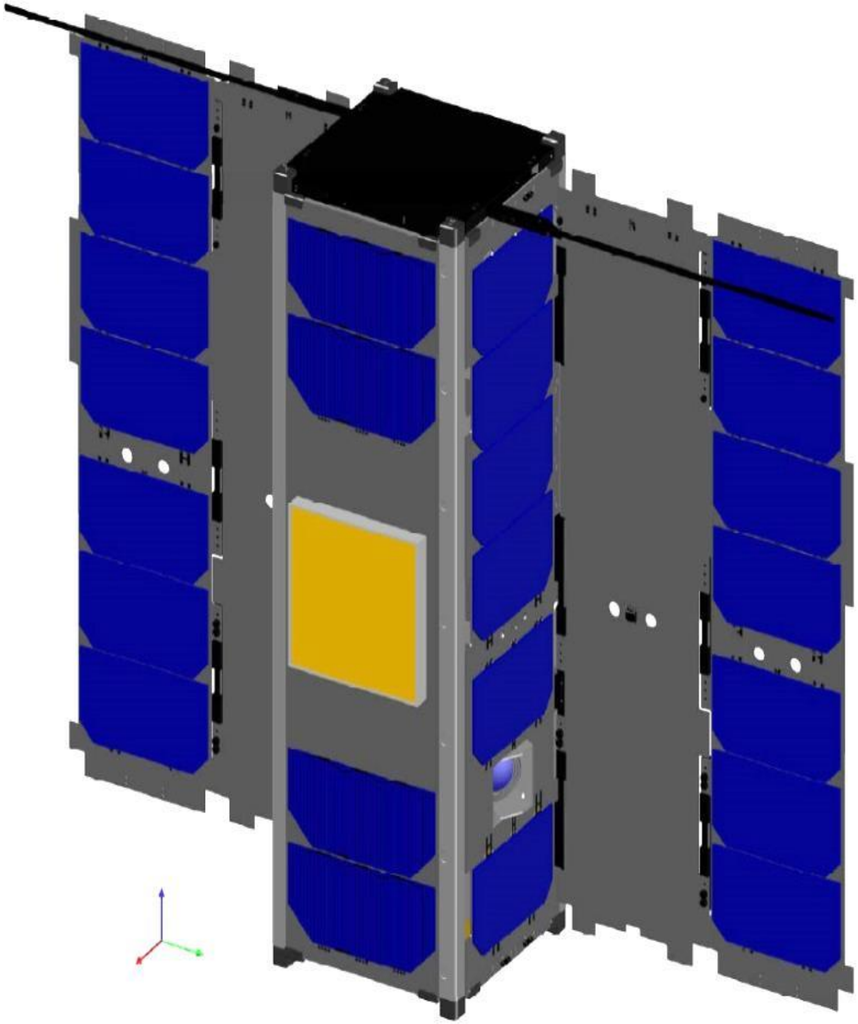
- TU Graz (Prime Contractor)

<u>Subcontractors:</u>

- Berlin Space Technologies (D)
- GMV (PL)
- GOMSPACE (DK)
- MAGNA STEYR Aerospace (A)
- MEW Aerospace (D)
- Space Research Centre, Warsaw (PL)
- UniTel IT-Innovationen (A)

Summary

- OPS-SAT offers a unique opportunity to test, demonstrate and validate novel operational concepts in flight
- Experimenters will have the opportunity to change flight/ground software and reconfigure flight/ground hardware during this mission
- We have designed a mission that can allow this to take place with minimal risk and at minimal cost
- S-/ X-Band payload, SDR and optical communications experiments demonstrates new opportunities for small satellite missions



Thank you for your attention!