Nanosatellites for Technological and Science Missions

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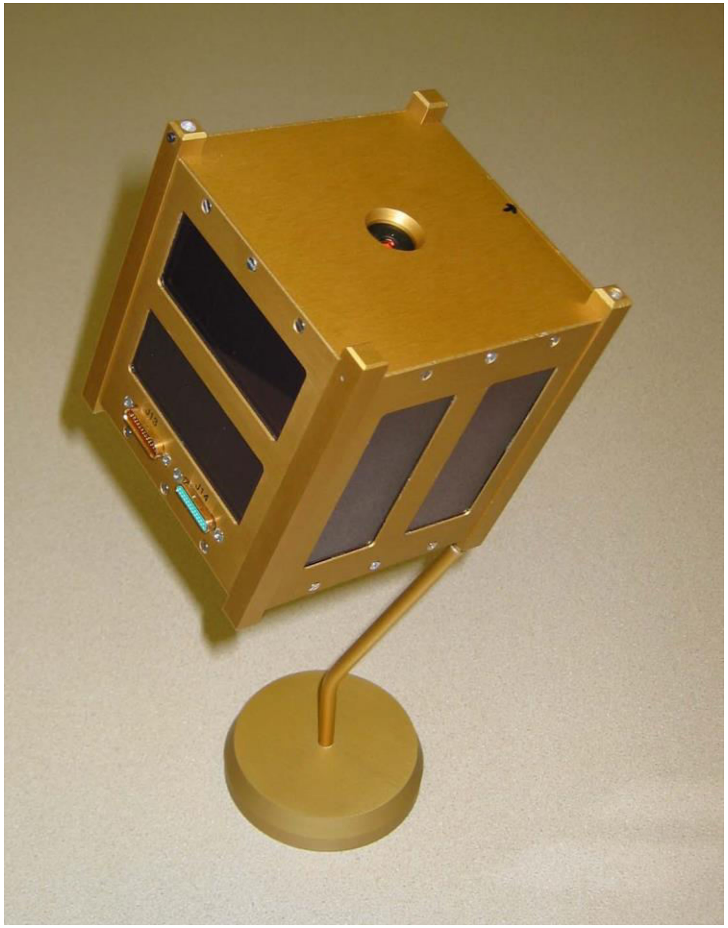
Contents

- Introduction to CubeSats and nanosatellites
- Trends in nanosatellite technology
- CubeSat Missions
- Technology for future astronomy mission
- Summary

CubeSats

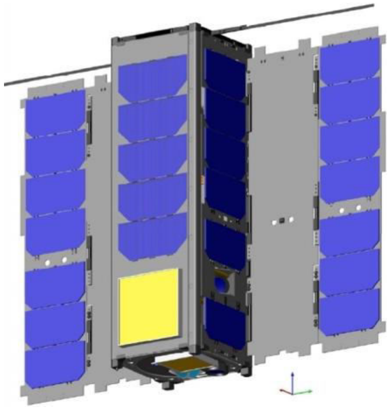
- Cubesat concept introduced by Bob Twiggs and Jordi Puig-Suari in 1999
  - small (10x10x10 cm, 1 kg – Picosatellite)
  - low cost
  - short development time
  - ideal for education.
  - involvement in all phases of Space project



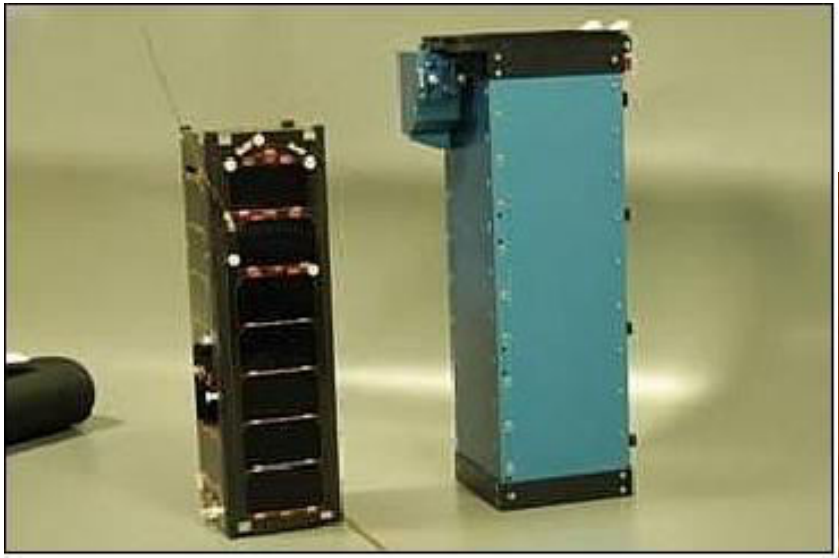
Nanosatellites

- First CubeSats launched in early 2000
- By now: > 800 nanosatellites launched
- Record in 2017: 104 on a single PSLV launcher
- Exponential increase in recent years
- Standard deployers important
  - XPOD, P-POD, ISIPOD, Nanoracks (from ISS)
- Standardized launcher interfaces

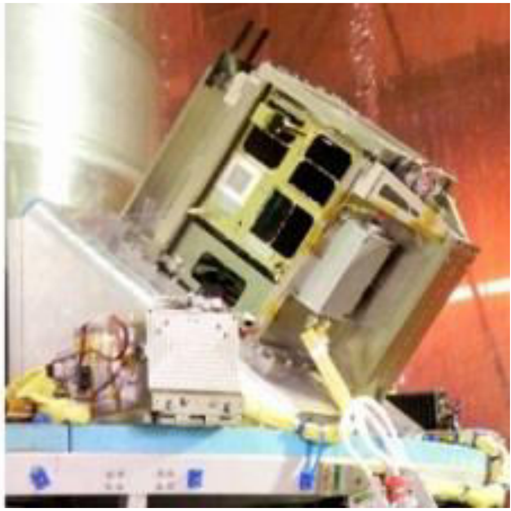
- Initially mostly 1U, 2U, 3U CubeSats
- Trend to larger nanosatellites 6U, 8U, 12U
- Nanosatellite classification 1…10 kg mass



Deployers

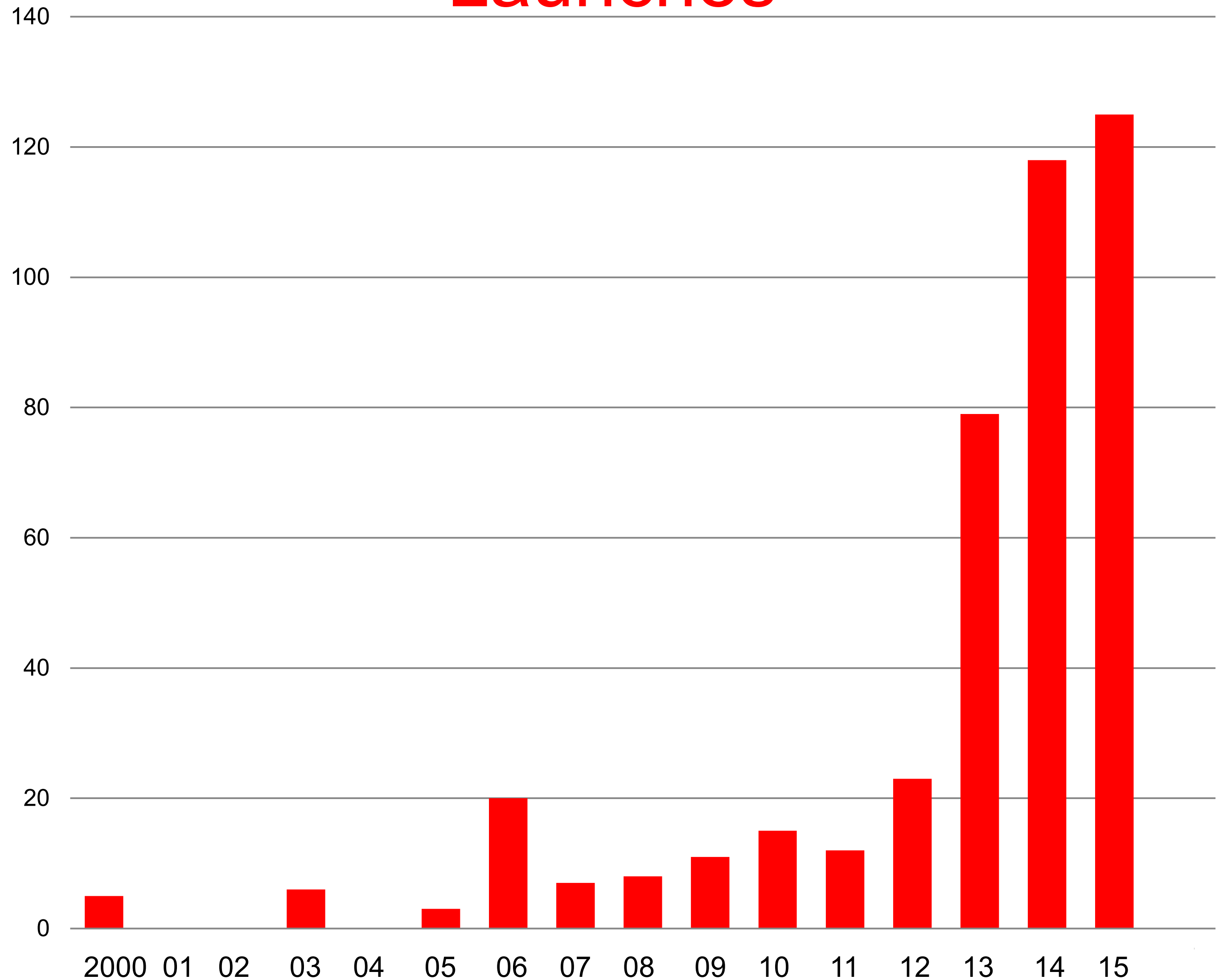


Source:ISIS



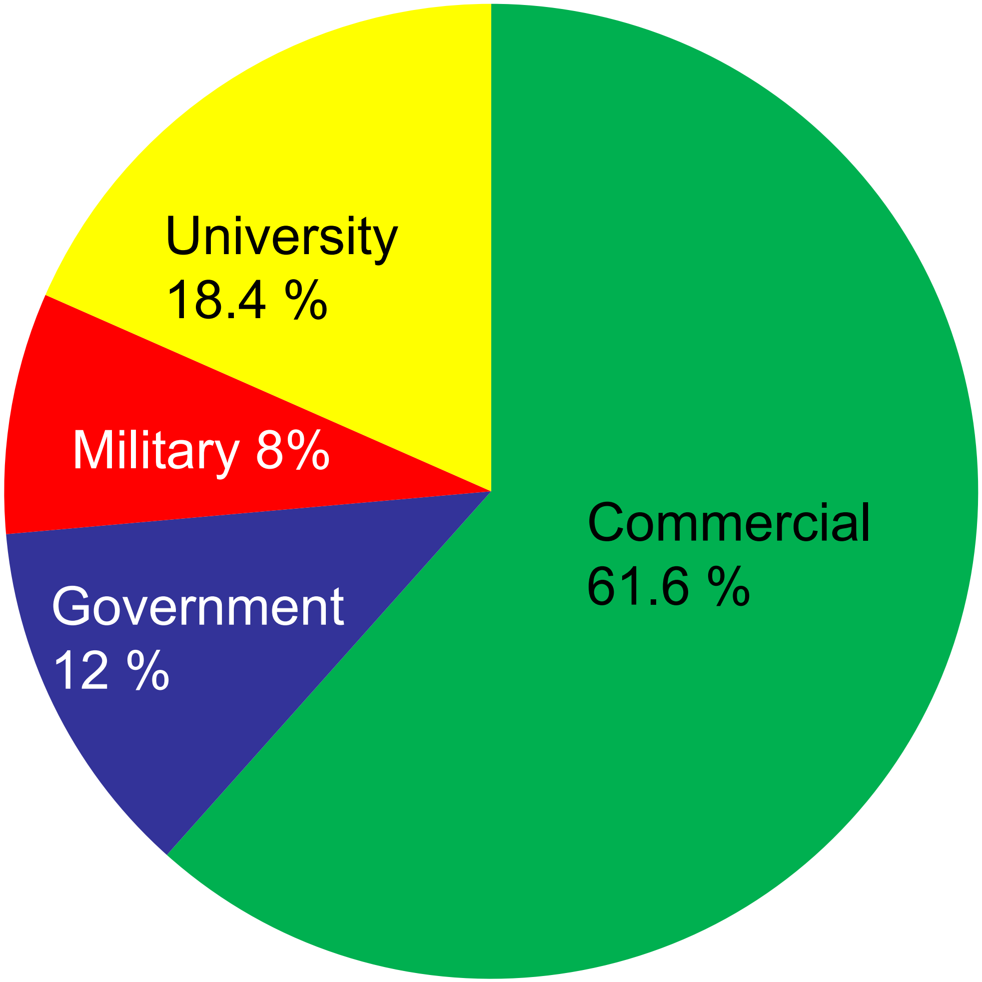
Source: ISRO

Launches



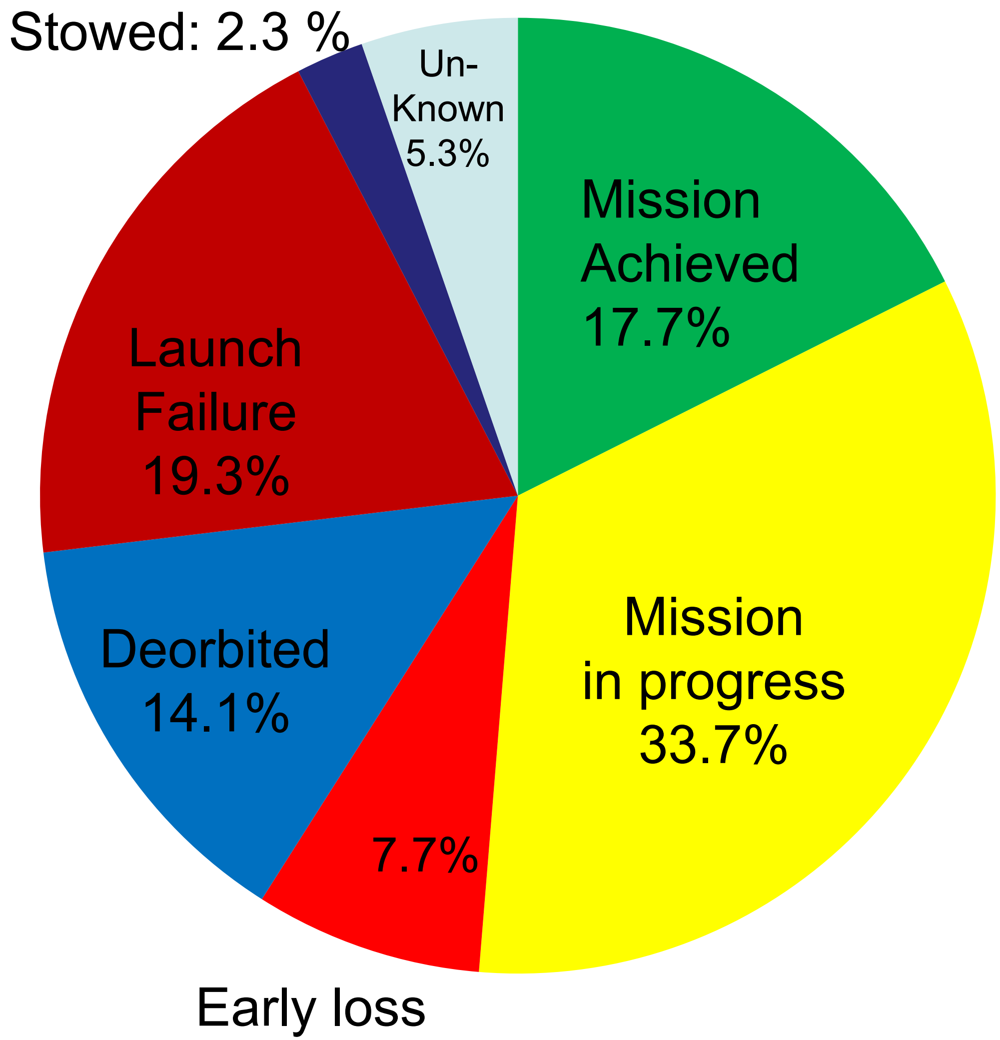
Source: M.Swartwout

CubeSats in 2015



Source: M.Swartwout

Mission Statistics



Source: M.Swartwout

Success Rate

- In beginning failure rate of about 50 %
- Lack of experience of students‘ teams
- Insufficient system level testing

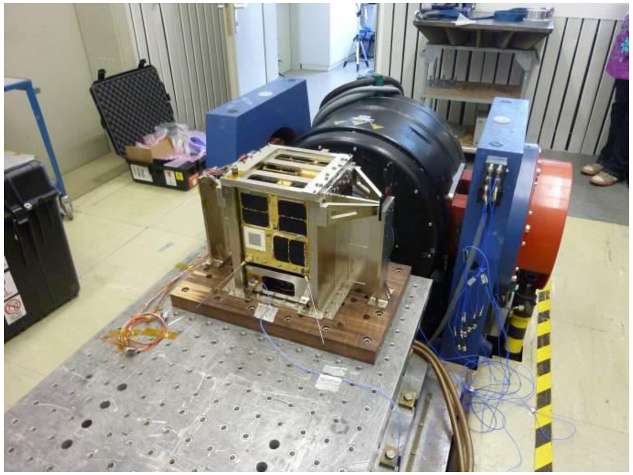
- Success rate has improved since:
- Commercial activities
- Space Agencies and industry became involved

Quality Assurance

- ECSS Standard too heavy for nanosatellite missions
  - Time-consuming
  - Costly
- ESA has introduced standards tailored to nanosatellite missions (used e.g. in OPS-SAT project)
- Commercial entities take a PQ/QA approach different from traditional Space projects
  - Higher risk
  - If spacecraft fails - replenished

Mission Success: Testing!

- Environmental tests on unit and system level: thermal, thermal-vacuum, vibration, EMC, open-field tests
- Burn-in tests (1000 hours on BRITE)
- Do not compromise on testing!!!



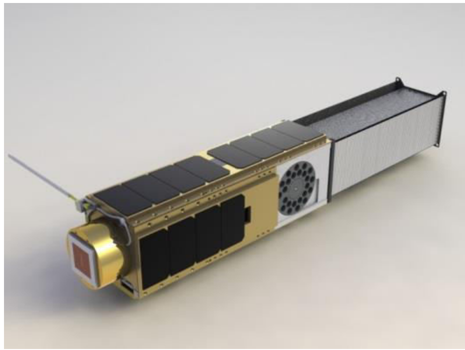
Communications

- Telemetry mostly in VHF (145 MHz) and UHF (430 MHz) amateur radio bands
- Low data rates (kbit/s)

- S-Band (2.2 GHz) so far less used
- Higher frequency bands available (C, X, Ka)

Space Missions

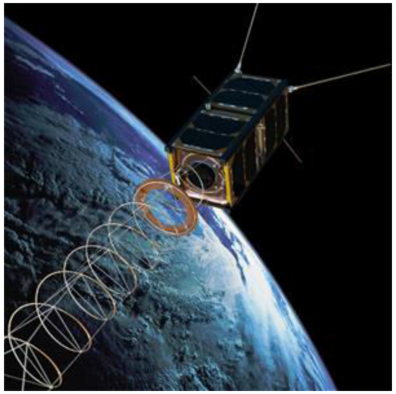
- Astrobiology
- Astronomy
  - BRITE
  - CANIVAL-X (NASA): formation flying, virtual telescope
- Atmospheric Science
- Biology
- Pharmaceutical Research
- Earth Observation
  - Planet Labs (commercial)



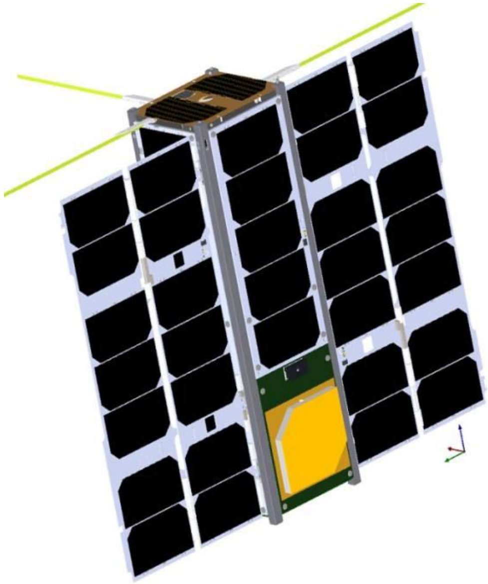
Source: NASA

Space Missions

- Space Weather
- Telecommunications
  - AIS (UTIAS, SPIRE- commercial)
  - ADS-B monitoring
  - Messaging
  - Amateur Radio
- Material Science
- Technology
  - OPS-SAT



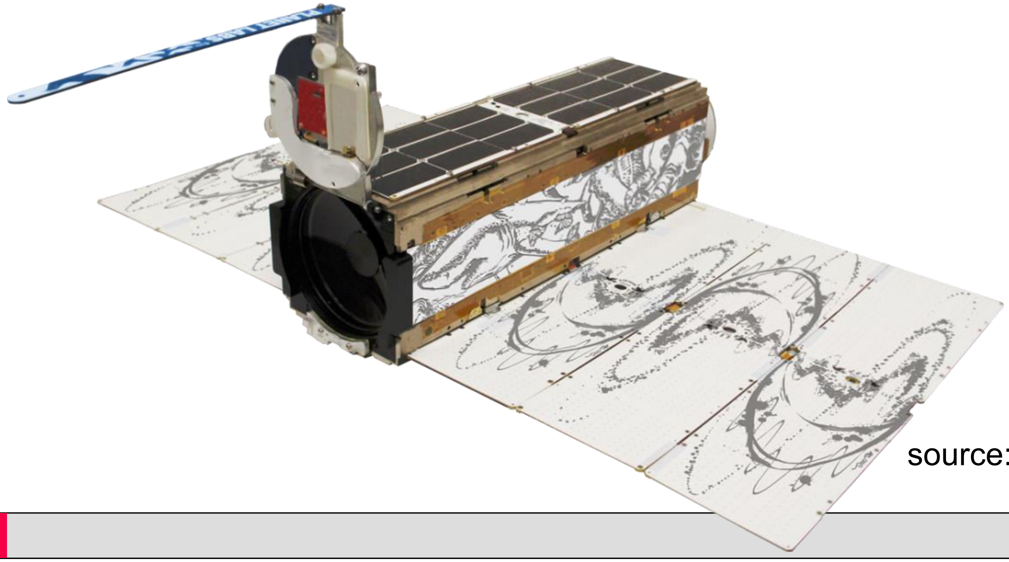
Source: GOMSPACE



Commercial Services

Planet (Labs)

- constellation of 196 CubeSats (in orbit)
- 3U CubeSat, mass: 5 kg
- Service: remote sensing with ~ 3.2 m ground (DOVE) resolution
- Daily revisit time
- camera with 90 mm aperture



source: PlanetLabs

SPIRE

- constellation of ~ 50 CubeSats (3U)
- 26 Lemur satellites in orbit
- Applications:

  Detection of AIS signals (Automatic Identification System)

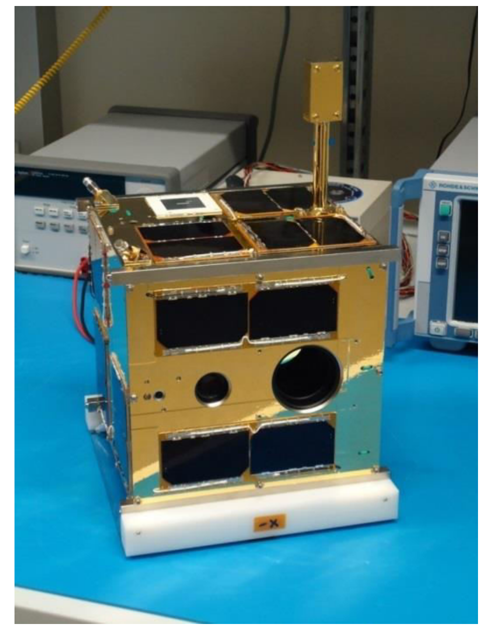
  Improving maritime safety

  GPS Occultation (weather forecasting)

Source: spire.com

BRITE (BRIght Target Explorer)

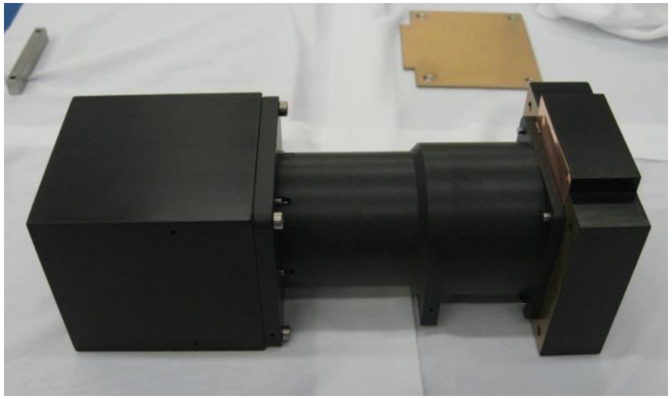
- World‘s first nanosatellite constellation dedicated to asteroseismology
- 5 spacecraft
  - Austria
  - Poland
  - Canada



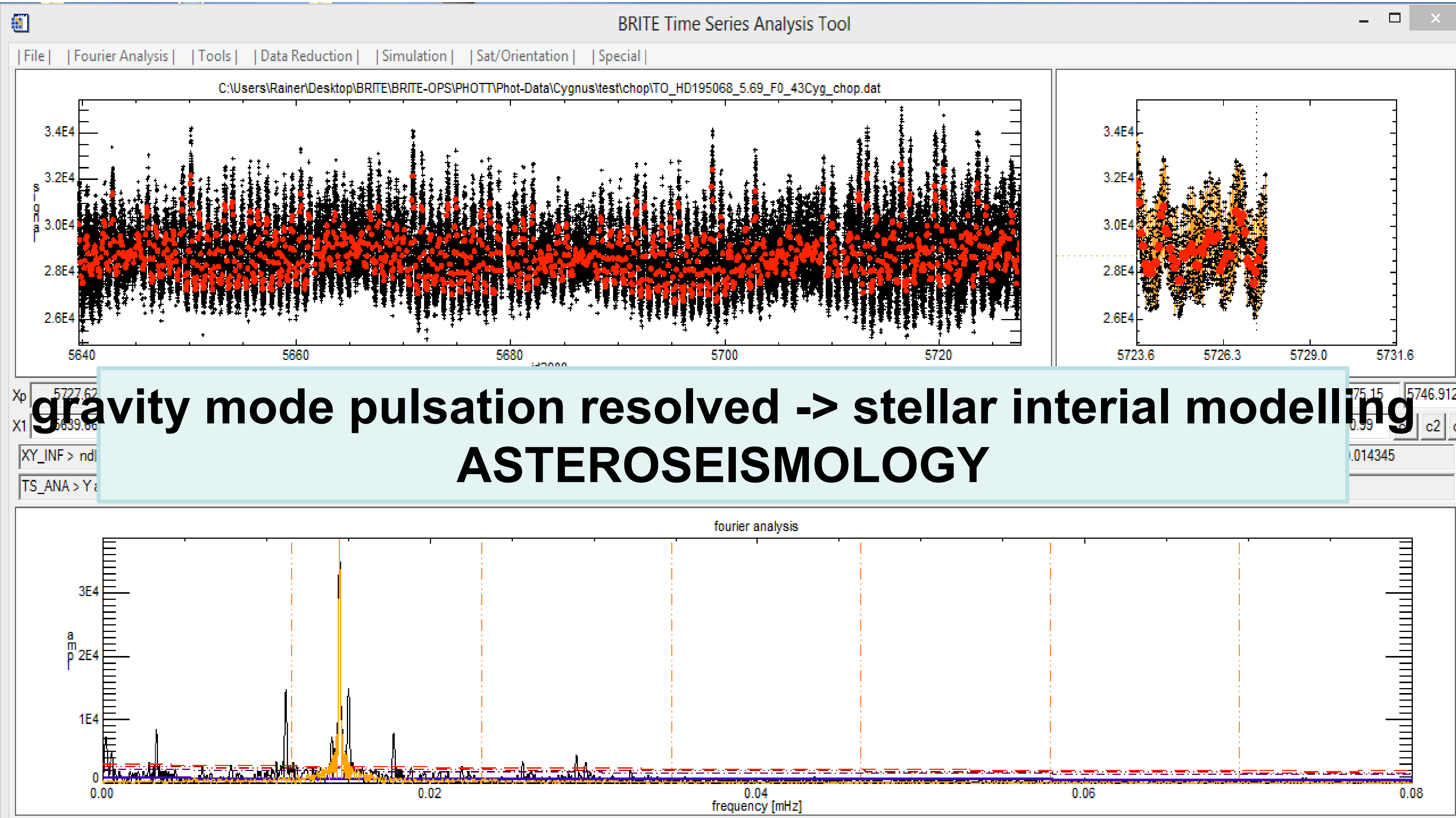
- Austrian BRITEs 4+ years in orbit
- Demonstrates that demanding science mission is possible with low-cost spacecraft

Scientific Goal

- Photometric measurement of brightness and temperature variations of massive luminous stars (up to visual magnitude 4)
- Observations: 6 months typ.
- High duty cycle
- 2-colour (blue and red)
- 24° field of view



Pulsating star:43 Cyg mag(V)=5.69 F0

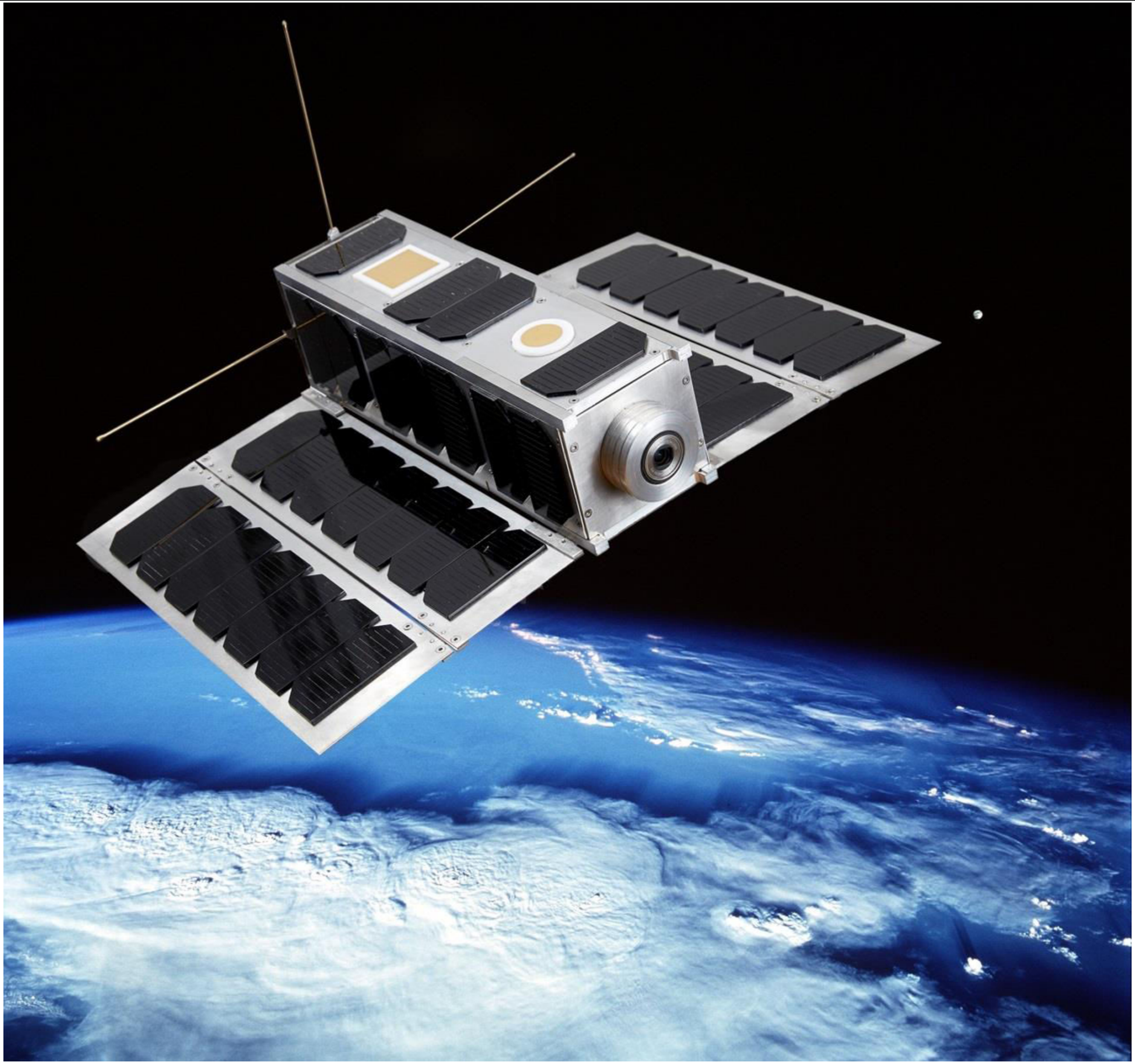


gravity mode pulsation resolved -> stellar interial modelling

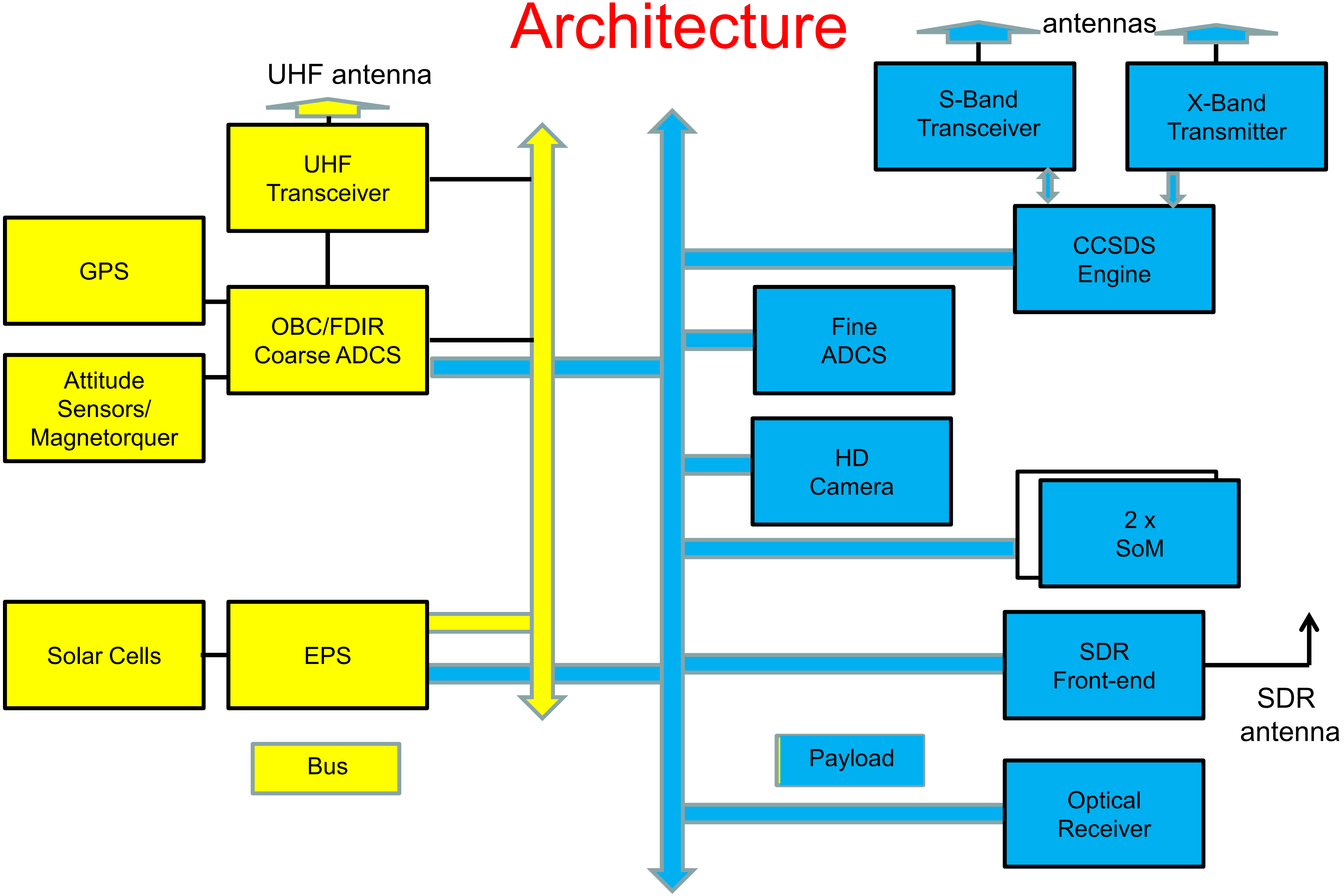
ASTEROSEISMOLOGY

OPS-SAT

- First ESA-owned CubeSat, initiated by ESOC
- Goal: in-orbit demonstration of new technology and novel operational concepts
  - New ground software: MO services
  - CCSDS-compatible S-band communications
  - High-speed downlink in X-band (up to 50 Mbit/s)
  - Fine-ADCS
  - Camera experiments
  - Radio signal monitoring with software defined radio
  - Optical communiations payload

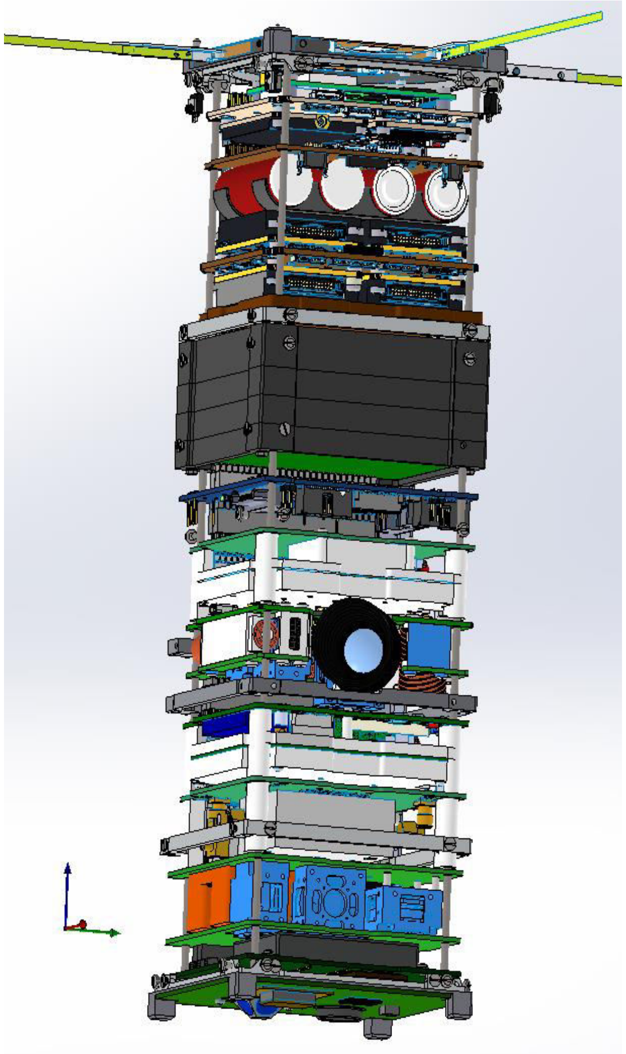


Architecture



OPS-SAT

- 3U CubeSat
- Mass: ~ 5 kg

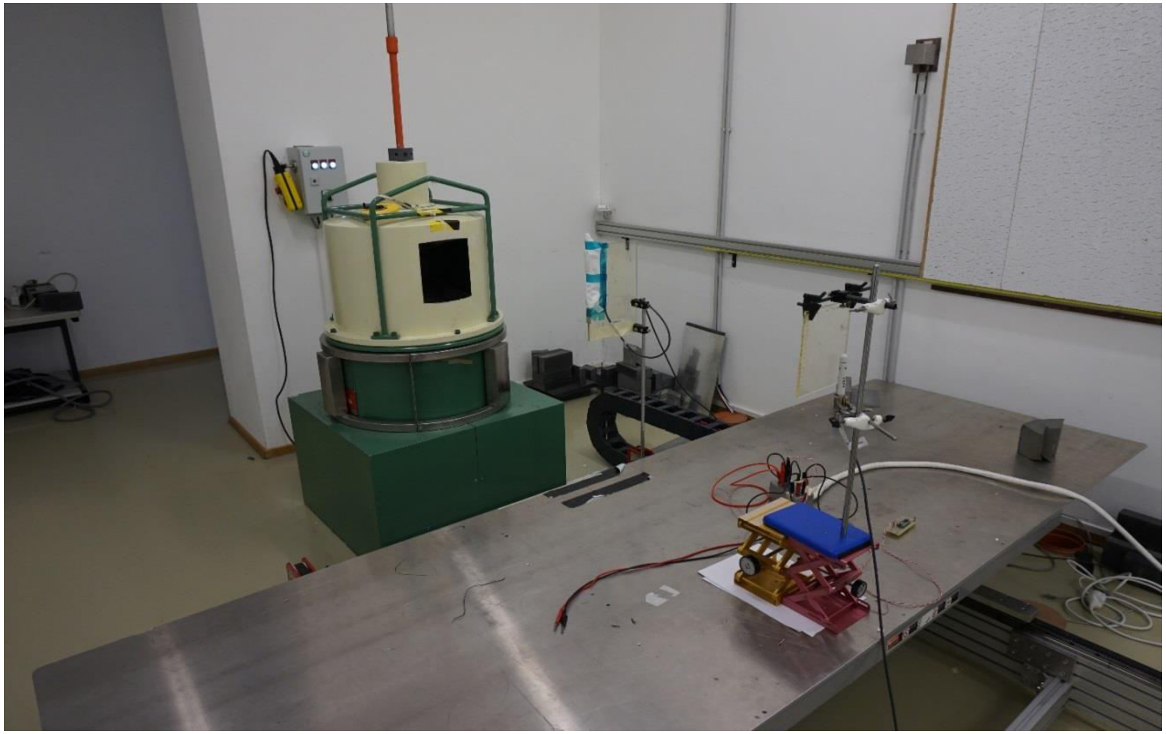


OPS-SAT

- Carries powerful system-on-chip-module processor
  - dual ARM-9 processor core with 800 MHz clock and reconfigurable field-programmable arrays
- Processor board developed by TU Graz
- Complete flight software can be change
  speed uplink)

Radiation Tests

- Critical components radiation tested at ESTEC
- 20 krad



S-Band Transceiver

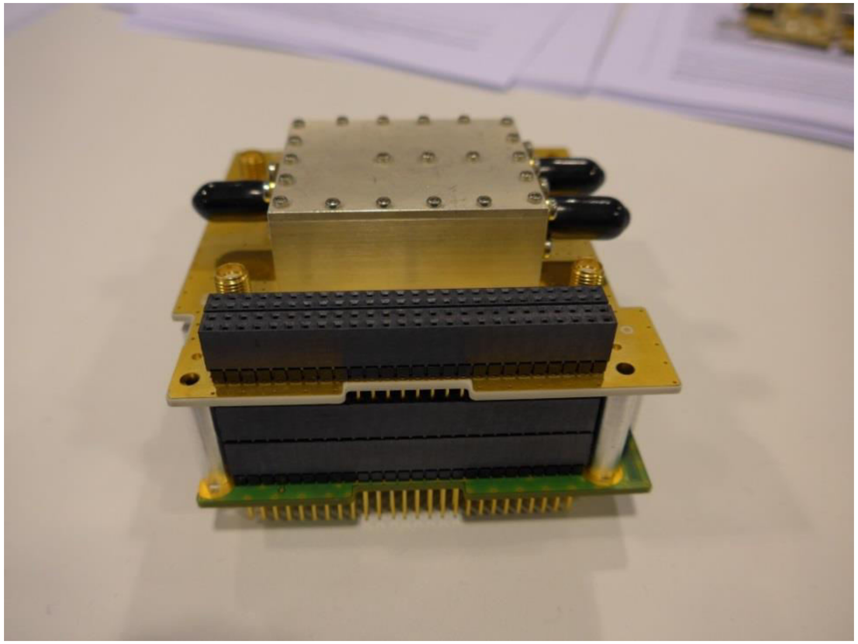
- Regulated telemetry spectrum
- Uplink Datenrate: 256 kbit/s
- Downlink Datenrate: 1 Mbit/s

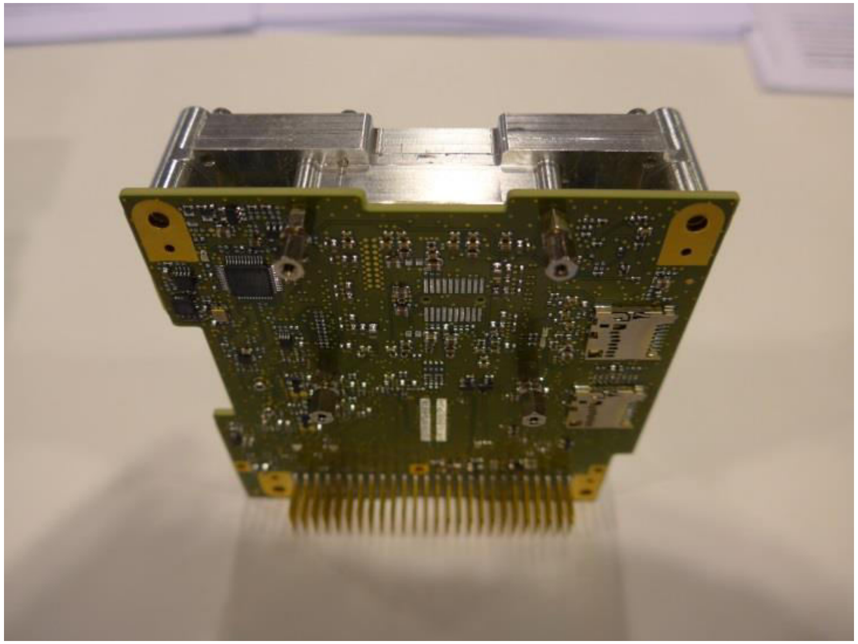
X-Band Transmitter

Frequency: ~ 8 GHz

Data rate: up to 50 Mbit/s

High science data throughput





Source: Syrlinks

OPS-SAT Comms System

- Fully compatible with CCSDS standard
- Ground infrastructure of ESA (ESTRACK)
- OPS-SAT operated as any other ESA mission
- Highest uplink data rate ever (256 kbit/s)
- New protocols tested (MO services)

CCSDS Engine

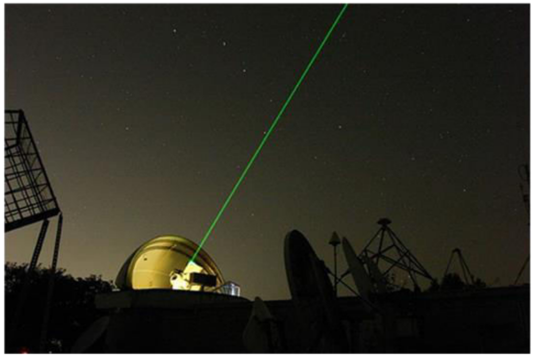
- CCSDS Engine ensures compatibility with ESA Ground Segment, both in S- and X-Band
- Developed by SRC Warsaw in cooperation with CREOTECH

Software-defined Radio Unit

- RF front-end interfacing with processing platform
- Frequency range: 300 MHz – 3.8 or 6 GHz
- RX / TX capabilities
- Can be used as universal transceiver, adaptation to higher bands (Ku, Ka)

Source: MEW Aerospace

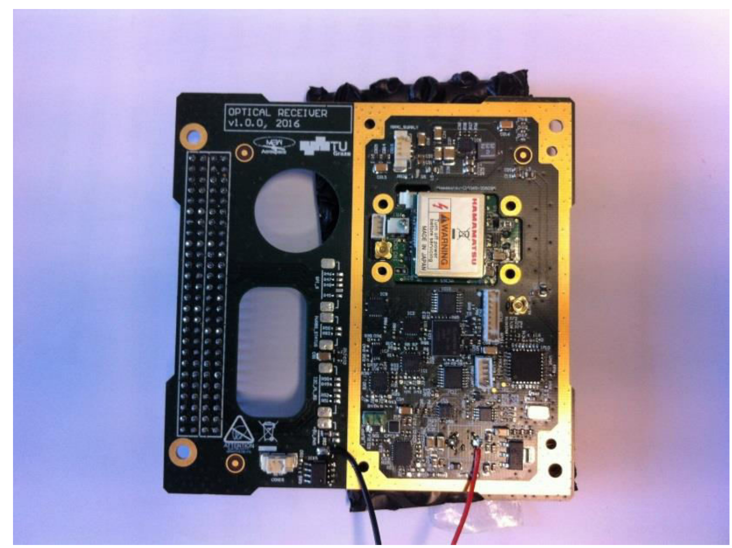
Optical Receiver



400 mJ pulse energy
10 ps pulse duration

Equivalent to 40 MW per pulse

Development by
MEW Aerospace



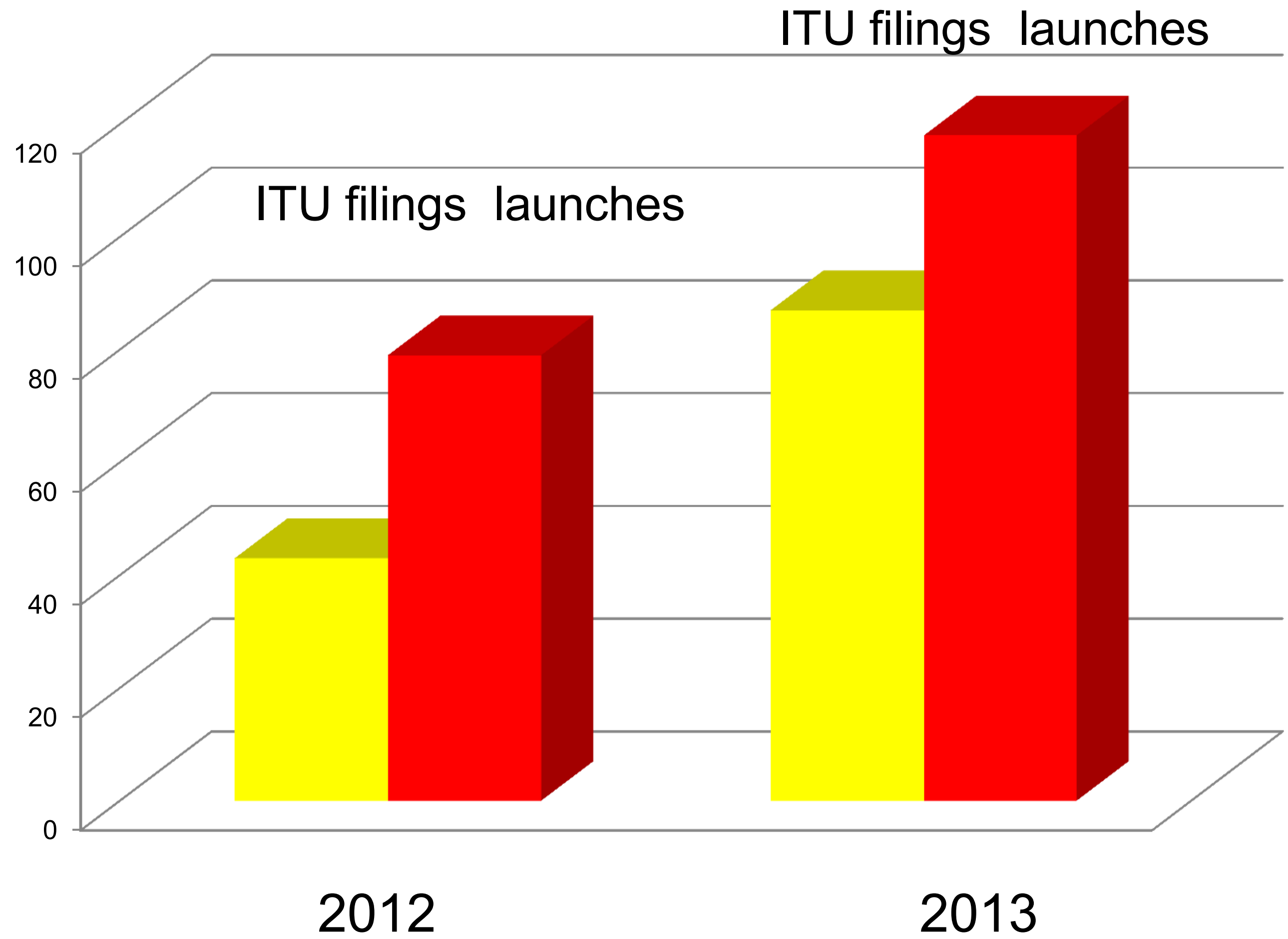
Optical uplink from Lustbühel Observatory / Graz

Application: uplink of cryptographic key

Frequency Coordination

- International and national regulations require proper frequency coordination with ITU
- Satellite owner/operator has to notify both IARU and ITU, even if only amateur satellite service frequencies are used
- Frequency coordination process is simplified for satellites using only amateur radio bands, as they are already pre-coordinated
- Traditional VHF/UHF amateur radio bands are crowded
- UHF amateur band is not exclusive

Frequency Coordination



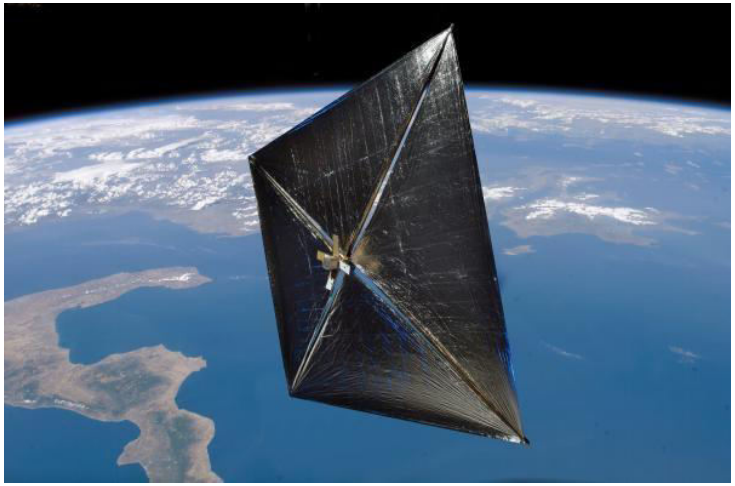
Source: ITU

Frequency Coordination

- Lack of coordination is breach of law
- Risk of interference
- BRITE experiences significant interference in Europe from powerful terrestrial radio sources
- For next mission use of coordinated band is recommended

Space Debris

- Increasing number of nansosatellites imposes a space debris risk
- LEO orbit crowded
- Orbit to comply with < 25 year orbital life-time
- or: active de-orbiting mechanisms
  - Deployable sails/structures
  - Drag mechanisms
  - Propulsion (e.g. micro arc-jets)



Source: sciencedaily.com

Summary

- Nanosatellites and CubeSats have matured from pure educational projects to in-orbit demonstrators
- Proof that demanding scientific and technological missions can be carried out with small satellites at low cost and within short timescales
- Industry and Space agencies are increasingly using nanosatellite technology
- Commercial services are already in place using constellations
- Reliability increased: professional implementation
- Tailored PA/QA standards introduced

Summary (2)

- Next astronomy mission can make use of recent developments in processors and communication subsystems

- Coordinated frequency bands should be used instead of traditional amateur radio bands to avoid interference and to provide higher data throughput

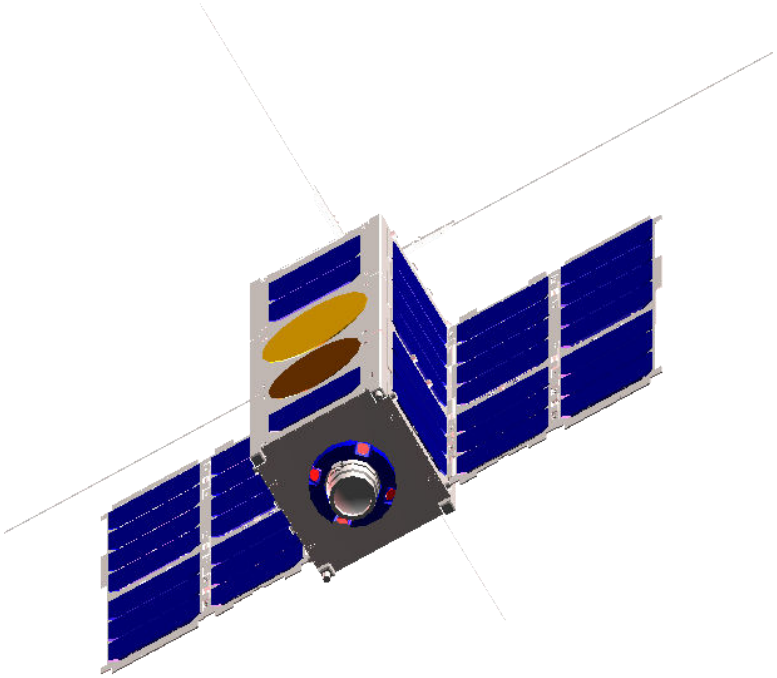
Summary (3)

- Large number of spacecraft require strict adherence to existing rules and procedures to avoid harmful interference and space-debris problems
  - Authorisation
  - Registration
  - Frequency coordination
  - Compliance with „Code of conduct“

Acknowledgements

- BRITE-Austria and UniBRITE operations is supported by the Austrian Aeronautics and Space Agency (FFG) within the Austrian Space Applications Program

- OPS-SAT is funded via ESA‘s GSTP Program



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near CNES, Toulouse, F

Central Case Project (CCP)

The CCP sponsor for SpaceTech 2016 is ESA
The topic proposed by the ESA DG is Moon Village
The participants have to create a viable business case on the Moon

They have chosen to explore in lunar robotic services

Facts and Further Information

Duration of the programme:	3 semesters (18 months)
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Website: SpaceTech.tugraz.at

Programme Direction and Contact

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SpaceTech Alumni Association

The Alumni Association is a very active network of dedicated Space professionals. Main contact is:

Alumni Association Chair:
Noah Saks (ST13)
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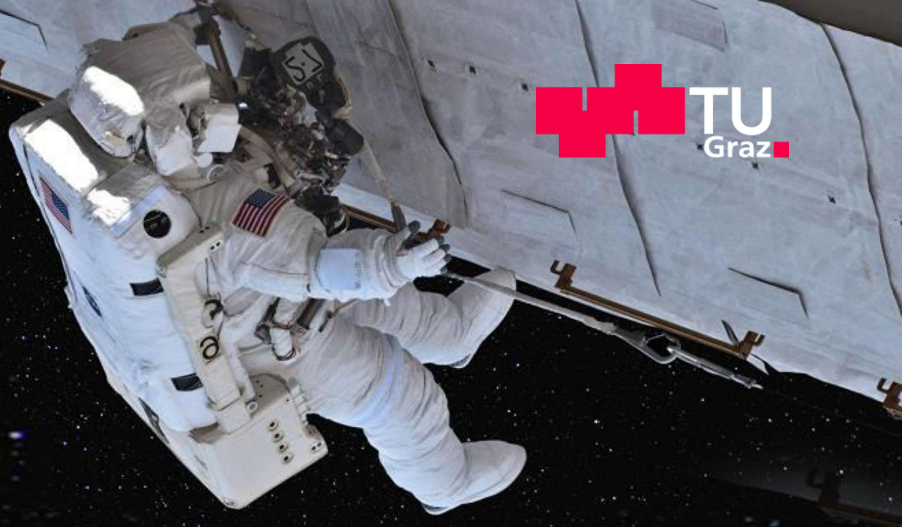
Symposium

At the end of each SpaceTech Master the Alumni Association organizes a Symposium at ESA ESTEC, the Netherlands. The 2017 topic is:

„New Space: Changing the Space Business Landscape"

Career example

James M. Free: participated SpaceTech in 2003-2004 (ST6)
2013 Director of NASA Glenn Research Center (GRC)
2016 Dep. Ass. Administrator for Human Exploration & Operations



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