VZLUSAT-1 and space environment

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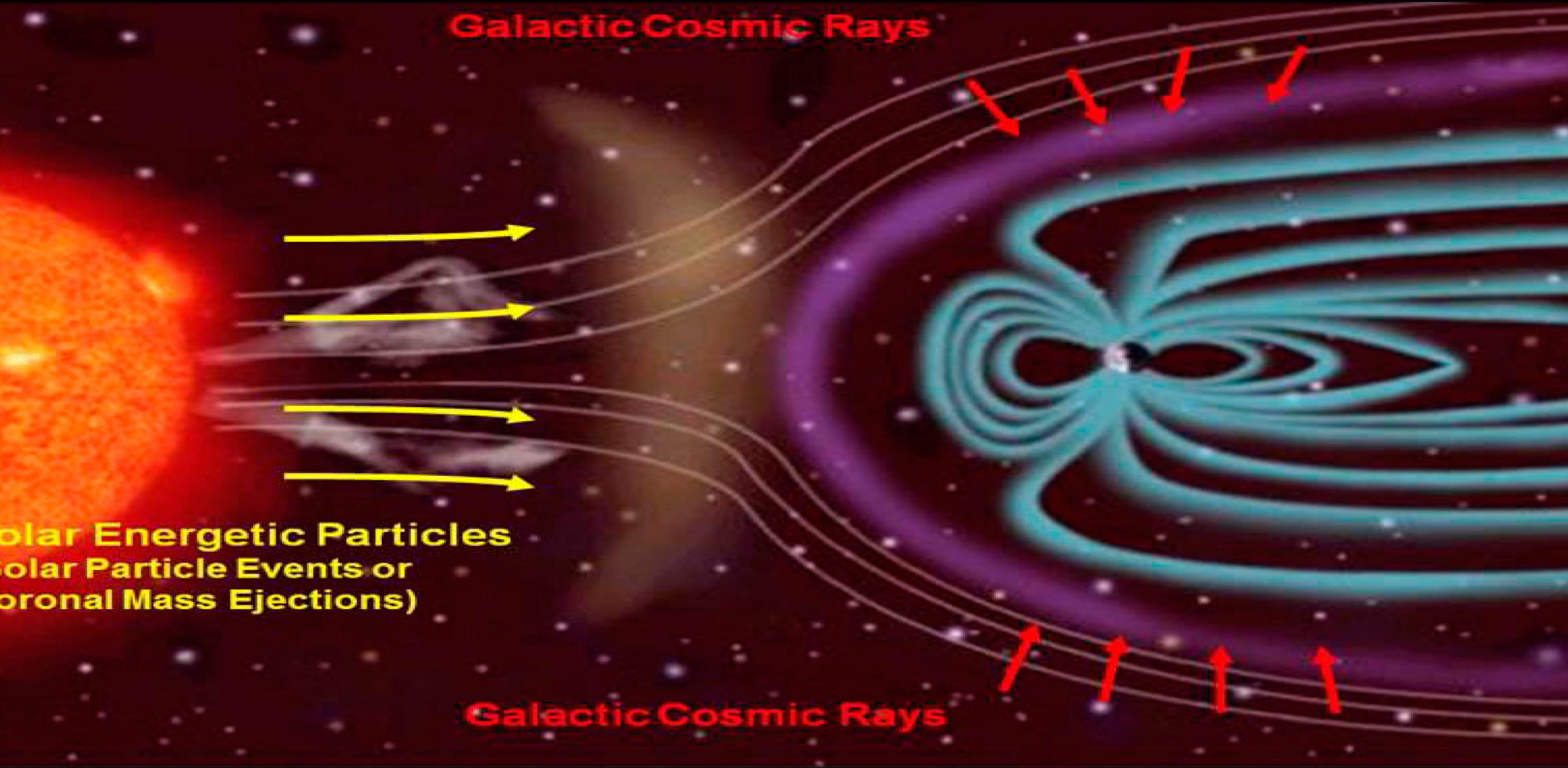
VZLU

5M

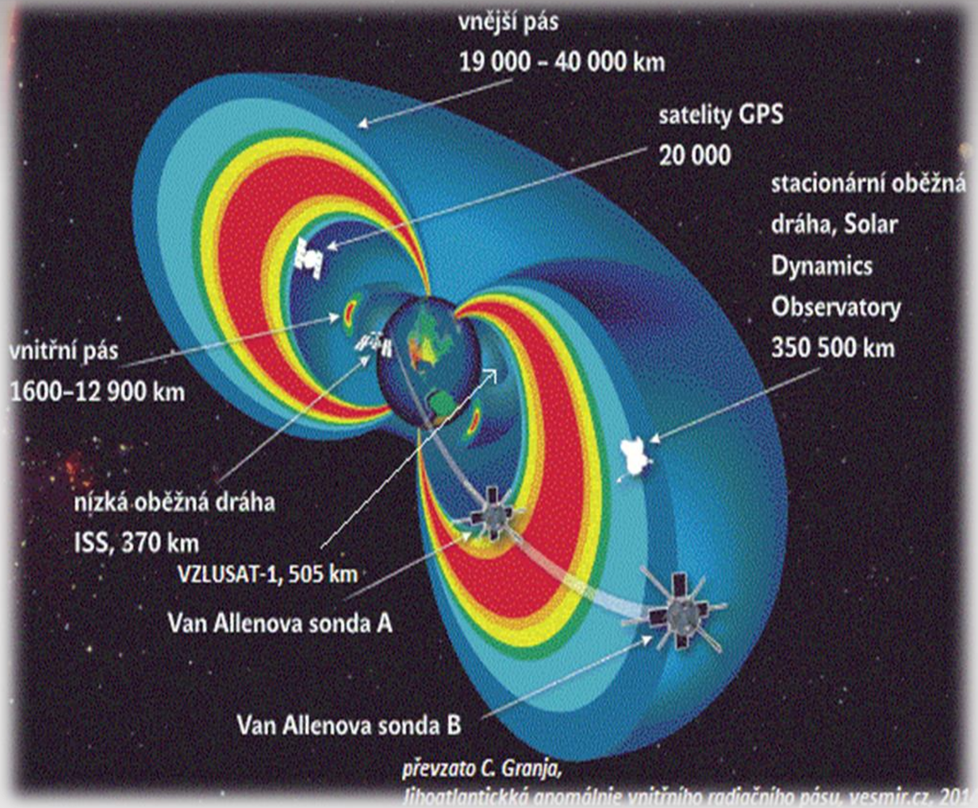
THIN FILM
TECHNOLOGICAL
SERVICE

SPACE RADITION



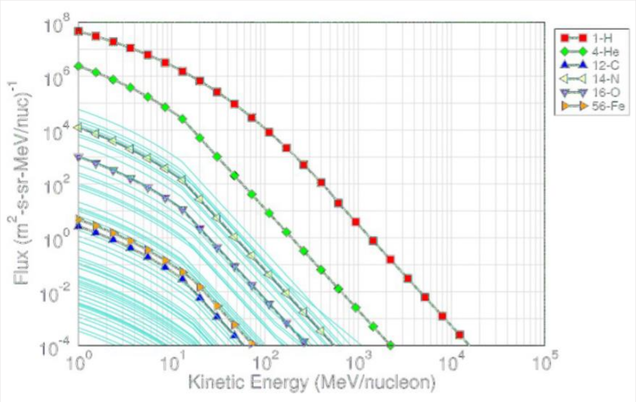
EARTH'S RADIATION BELTS

- Energetic particles (p^+, e^-) trapped by the magnetic field of the Earth
- Inner radiation belt (1600 - 13000 km):
  - protons 10-100 MeV, elektrons up to 1 MeV)
- Outer radiation belt (19000 - 40000 km):
  - elektrons 0,1-10 MeV
  - Very dynamic, strongly influenced by the Solar wind
- VZLUSAT-1 (SSO, altitude 505 km)
  - Under the inner radiation best
  - Flies through the belts in the region of Southatlantic anomaly and in polar region



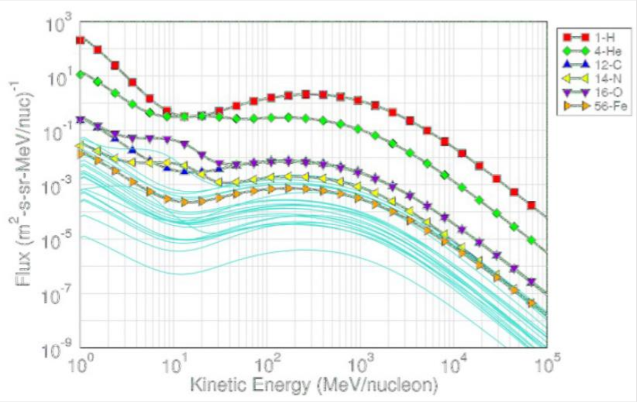
SOLAR WIND, FLARES AND CMEs

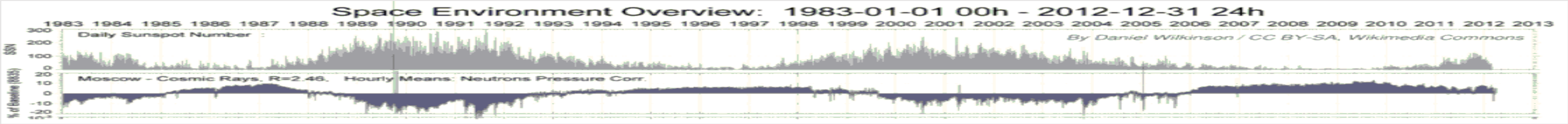
- Solar wind: continuous supply of e^-, p^+, He^{2+}
- Solar flares and CMEs (Coronal mass ejections)
  - X-rays and UV radiation, e^-, p^+, ions
  - Četnost závisí na slunečním cyklu



GALACTIC COSMIC RAYS

- Radiation originating outside of Solar system
- Low fluxes, high energies, broad particle spectrum



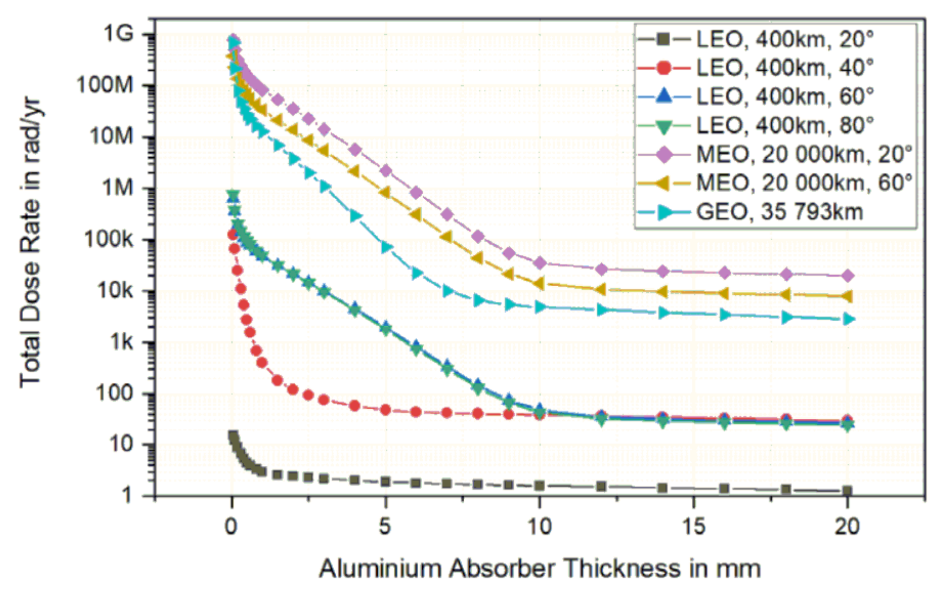


Mutual dependency – the lower the Solar activity, the higher GCR level and vice versa

RISKS OF RADIATION

- Human crews – deadly dose approx. 500 rad
- Risks to electronics
  - Critical dose (absorbed energy per mass) for COTS approx. 10 krad
  - Dangerous Single Event Effects (SEE) – individual hits by energetic particles (both reversible and irreversible damage)
  - The higher the integration of electronic devices, the more vulnerable to radiation damage they are (primarily by SEE)
- Materials (primarily polymeric materials and glass) can be sensitive to radiation too – changes of mechanical properties, changes of colour etc.

Comparison of radiation levels at different orbits

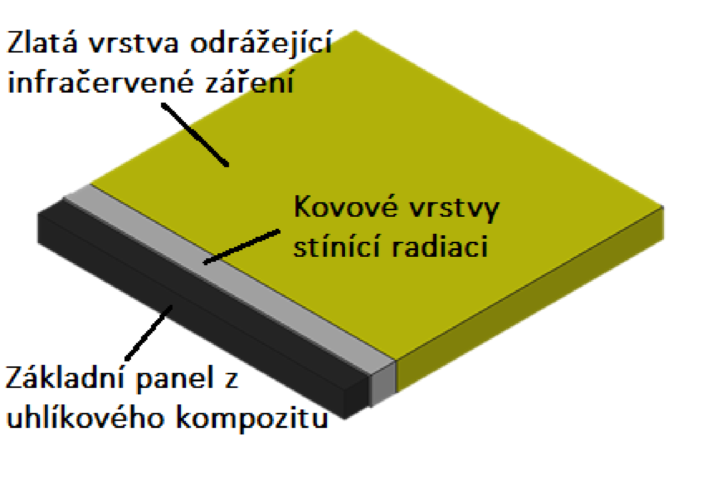


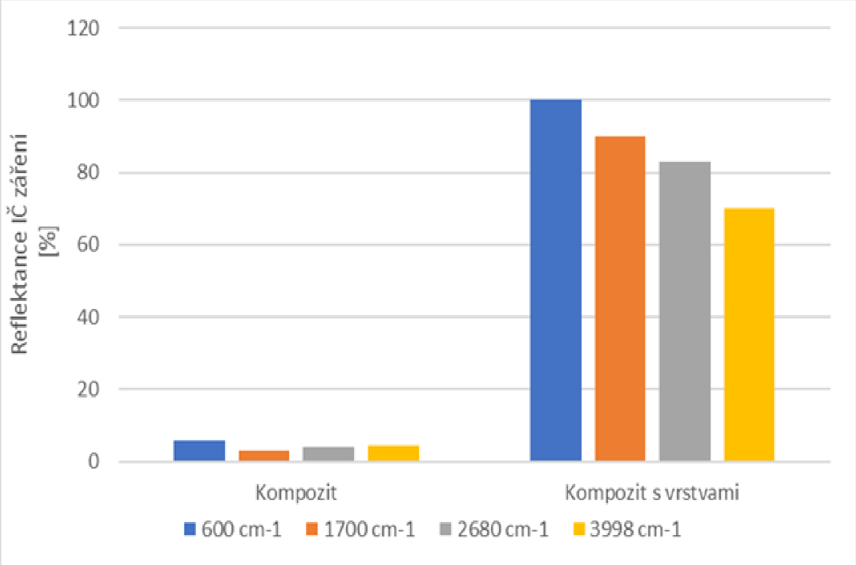
Převzato z Ch.Tscherne, Space Radiation Environment, RADHARD 2018

SHIELDING – COMPOSITE PANELS

- Structural panels of VZLUSAT-1 are based on carbon fibre reinforced polymer composite (CFRP) (producer 5M)
  - Lighter material with better mechanical properties, but worse radiation shielding capabilities than traditionaly used Al alloys
- Radiation hardened composite shielding (RHCH) = composite with metallic coatings
  - Maximalized shielding capabilities and light weight
  - Better thermal and mechanical properties

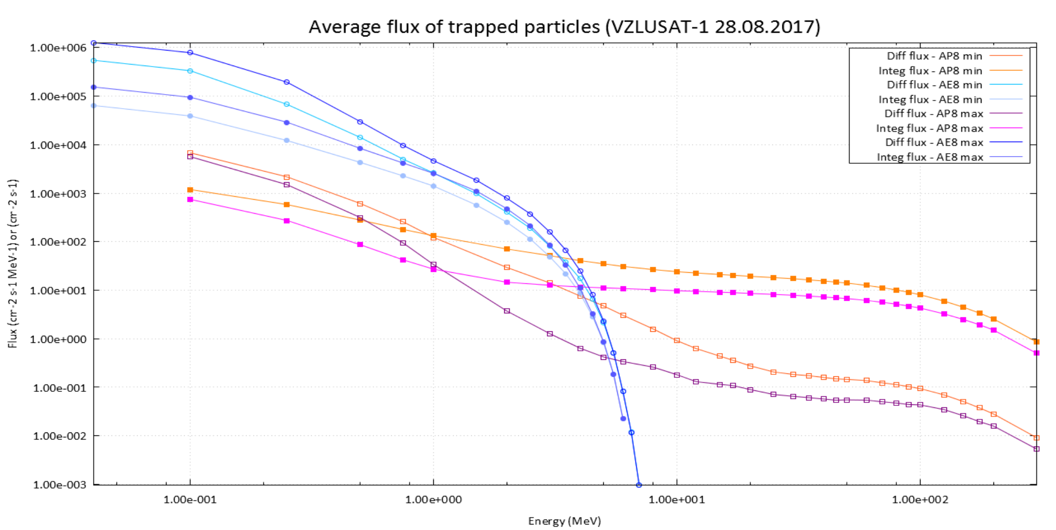
- *Coatigns designed by computer simulation of shielding capabilities*
- *Improvement of thermal and mechanical properties verified experimentally*

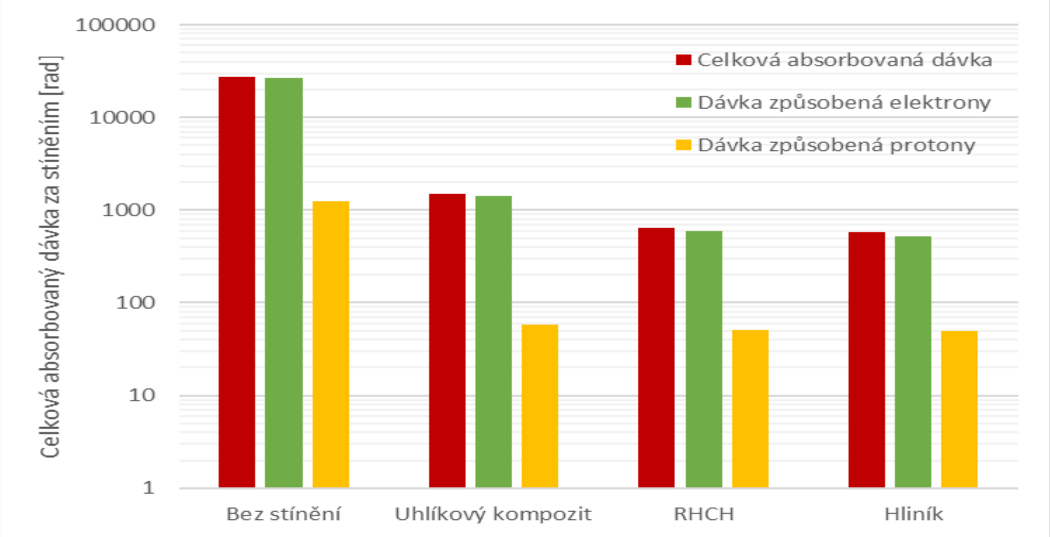




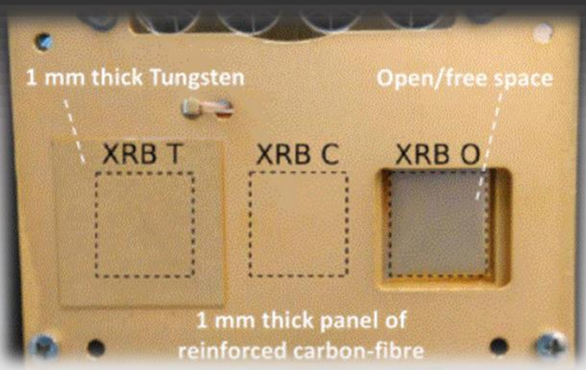
SIMULATION OF THE ENVIRONMENT AT VZLUSAT-1 ORBIT AND OF THE SHIELDING CAPABILITIES

- Spectrum of radiation generated in OMERE software
- Transport of the radiation through matter simulated in MULASSIS tool
- Total ionizing dose (TID) absorbed in Si detector behind the shielding was evaluated
- All materials with the same surface density cause significant decrease of TID (from 27 krad to units of krad per year)
- RHCH – better shielding capabilites than CFRPstejné hmotnosti jako hliníkový panel stejné stínicí schopnosti

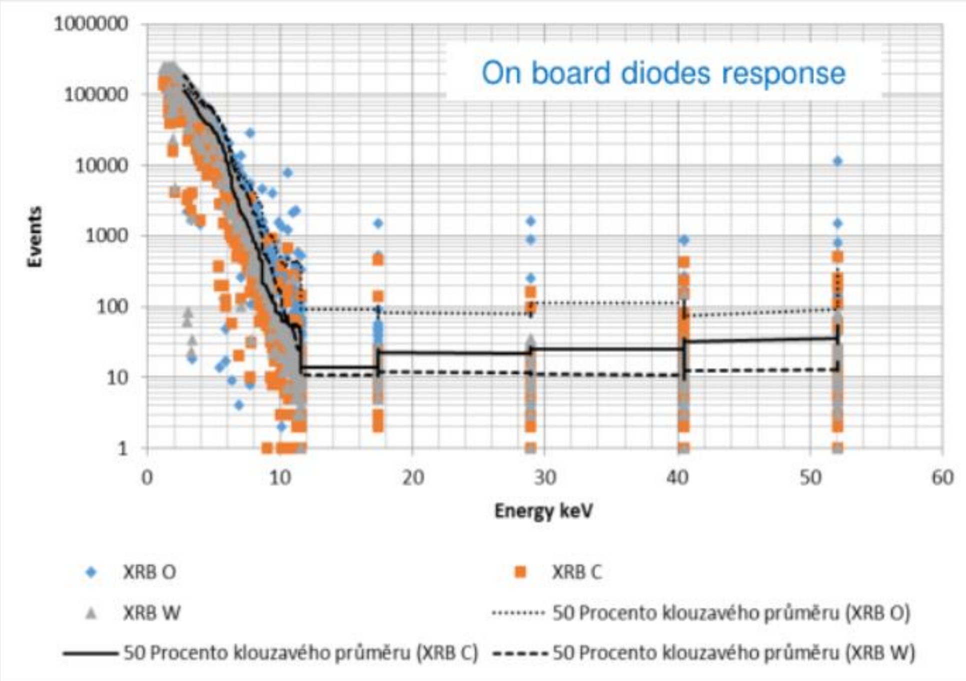




MEASUREMENT OF SHIELDING CAPABILITES OF CFRP AT THE ORBIT

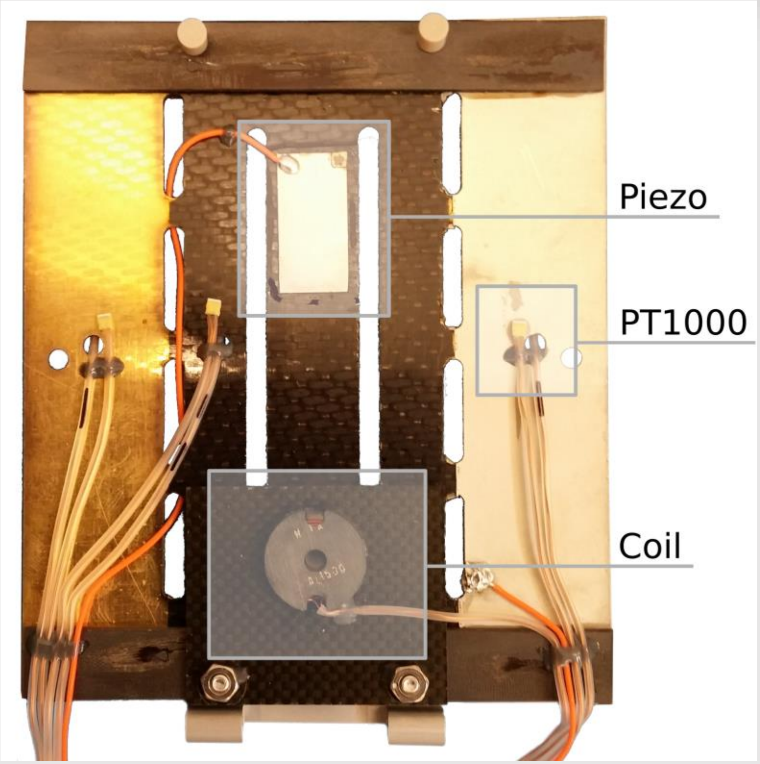


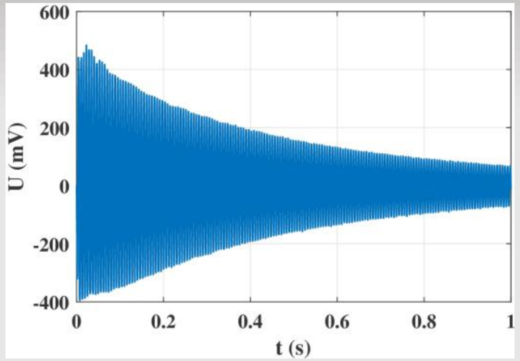
- Experimental verification of shielding capabilities of RHCH by a panel of 3 Si PIN diodes detecting radiation:
  - From the open space
  - Behind RHCH
  - Behind RHCH shielded by 1 mm W

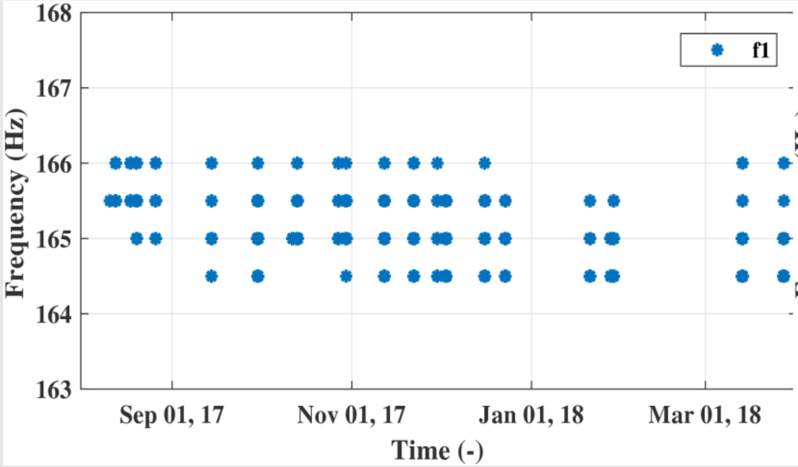


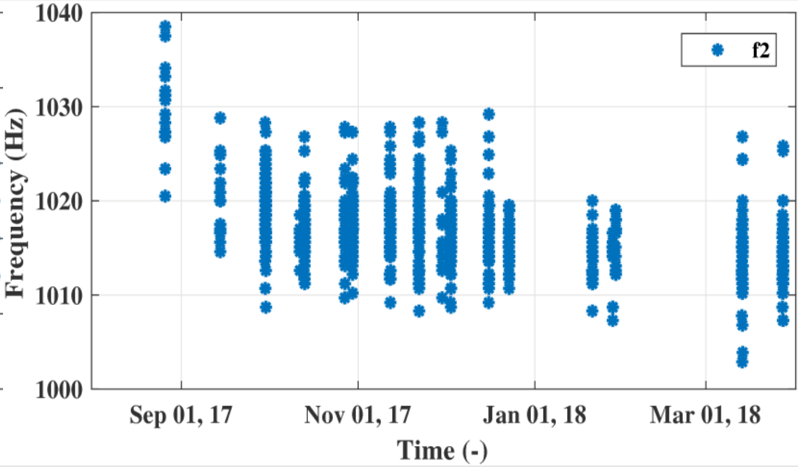
MEASUREMMENT OF MECHANICAL PROPERTIES OF RHCH AT THE ORBIT

- Non-destructive measurement of mechanical properties by vibration spectroscopy (change of the resonant frequency is monitored)







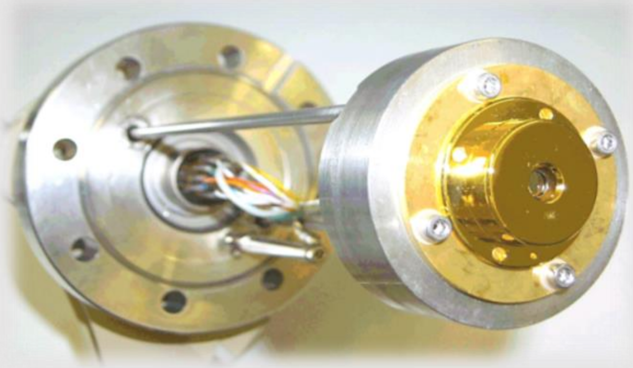


OUTGASSING IN SPACE

- Hidden danger in space – high vakuum (10^{-6} až 10^{-9} torr at LEO)
- Many materials (mainly organic – polymers) significantly outgasses, degrade and the vapour from them can damage other parts of the spacecraft
- Even materials relatively stable in vacuum can contain pockets of volatile substances, that can burst in space vakuum and cause problems
- For sensitive instruments even natural adsorption layer that every surface has because of Earth‘s atmosphere can be harmful
- Outgassed matter – water vapour, siloxanes, hydrocarbons…

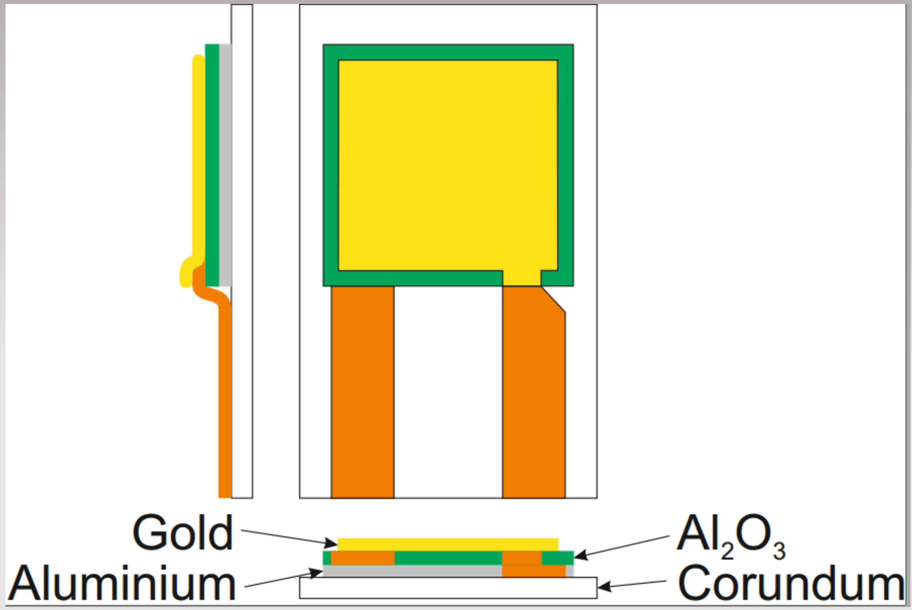
WATER VAPOUR

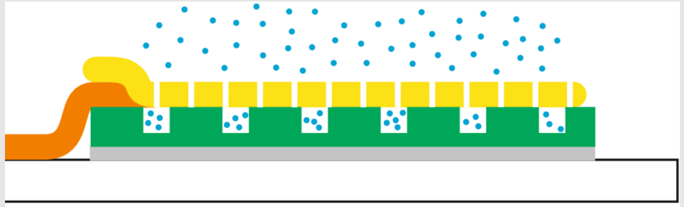
- The major part of outgassed matter for majority of materials
- The biggest danger for cooled surfaces (eg. CCD detectors) – condensation, frozing
- Examples of problems caused by water vapour condansation:
  - CASSINI – condensation at CCD – several time out of service
  - STARDUST – contamination of optics,
  - GAIA – worsening of sensitivity of the optics
- Current measurement – quartz microbalances – necessary to cool under the dew point (as low as -120 °C in space)



THIN FILM MOISTURE SENSORS HAL2

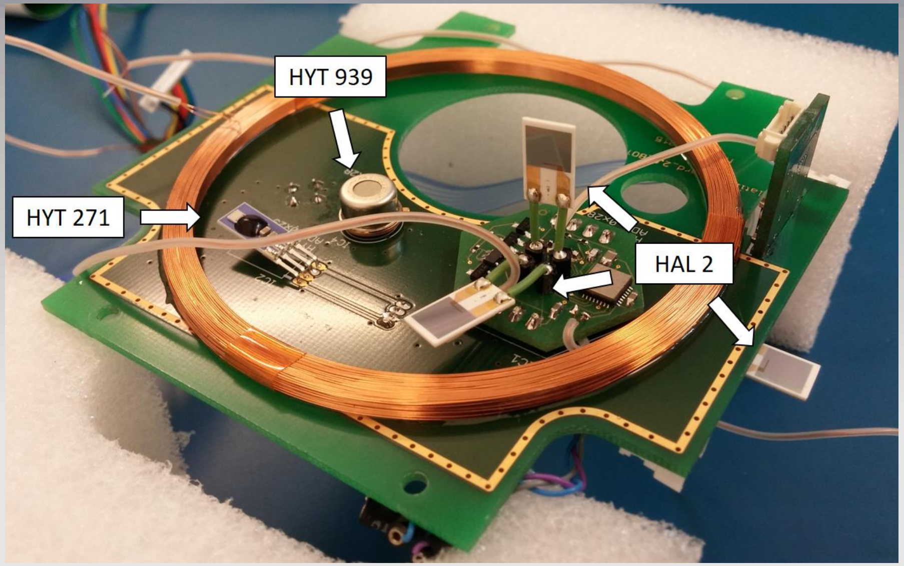
- Ones of the most sensitive sensors in the world
- Trace moisture detection down to DP -100 °C (approx. 10 water molecules ppb)
- Sensitive layer – porous layer based on Al_2O_3 that changes its electrical properties based on the amount of adsorbed water in its structure

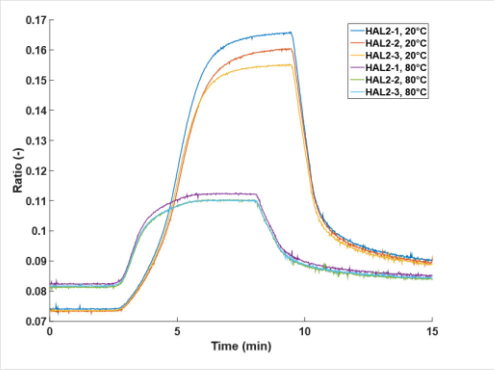




MOISTURE SENSORS ON BOARD VZLUSAT-1

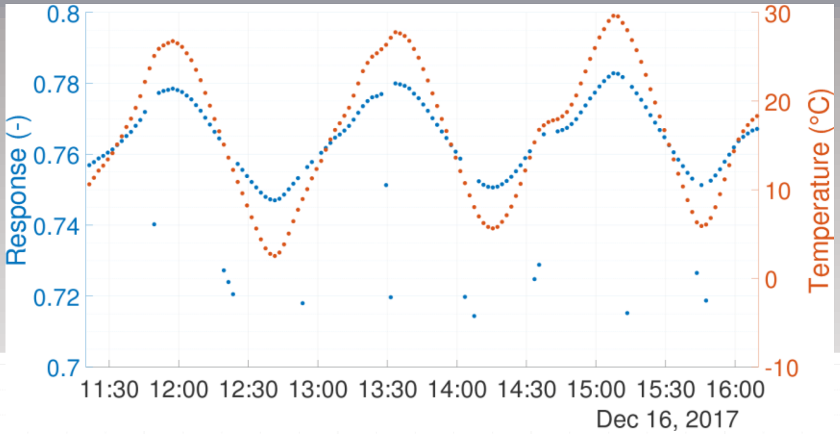
- 2 HAL2 sensors placed inside of the satellite, 1 faces the open space
- Complemented by sensors HYT 271 and HYT 939 from IST AG company
- First use of sensors of this type in space
- Ground tested for detection of water vapour in high vacuum.

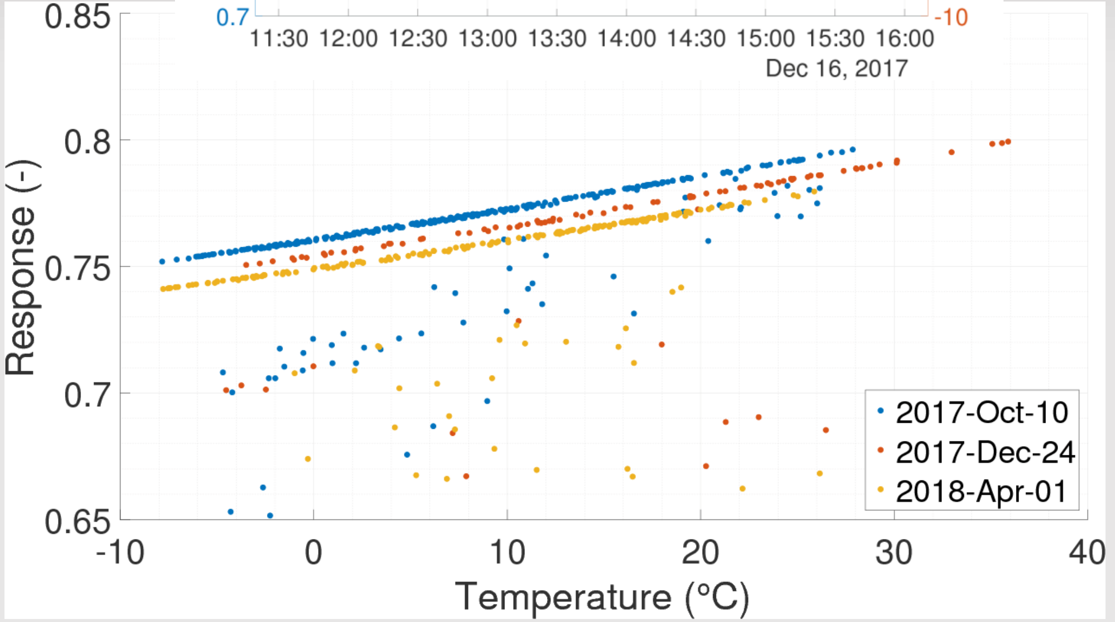




SIGNAL FROM MOISTURE SENSORS FROM SPACE

- The experiment started approx. a month after the launch
- Incidents with significant outgassing have not been detected
- Gradual decrease of signal observed – agrese with a gradual svědčí o postupném zmírňování plynění součástí družice
- The stability of moisture sensors at space LEO condition verified:
  - High vacuum
  - Temperature cycling
  - Radiation





THANK YOU FOR YOUR ATTENTION