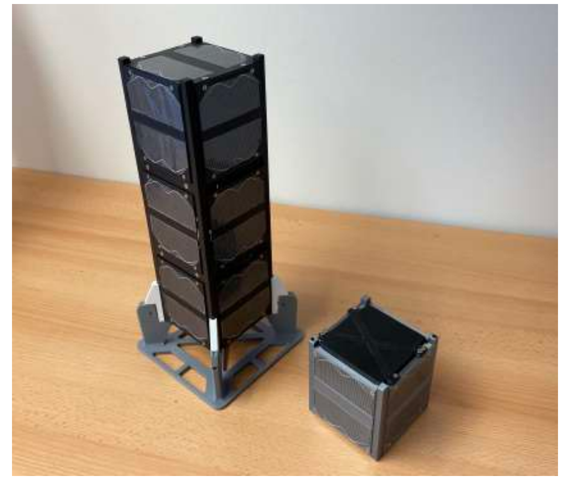
CAMELOT

Cubesats Applied for MEasuring and Localising Transients



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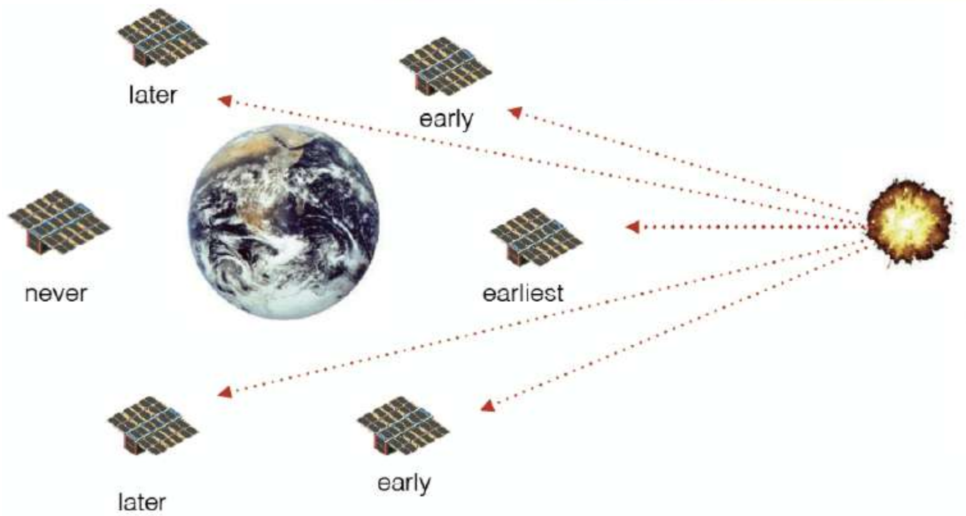
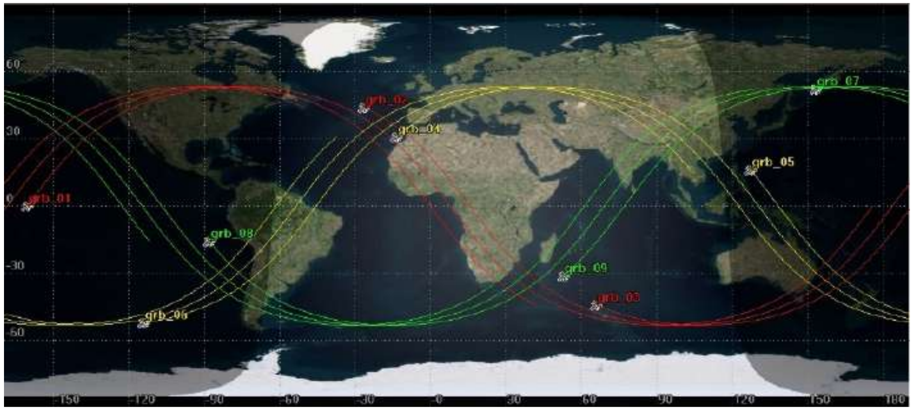
CAMELOT: Cubesats Applied for MEasuring and LOcalising Transients



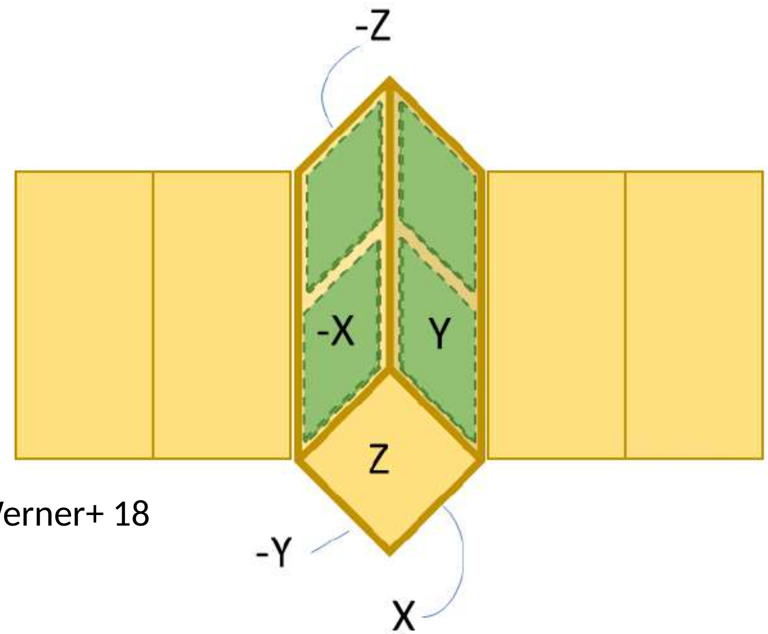


Satellite platform	3U CubeSat
Target orbit	9 satellites constellation in LEO in three orbital planes
Payload	Four 150x75x5 mm^3 CsI scintillators read out by Multi-Pixel Photon Counters (MPPCs)
Goal	Degree-scale timing-based localisation with a similar sensitivity to the Fermi-GBM detector

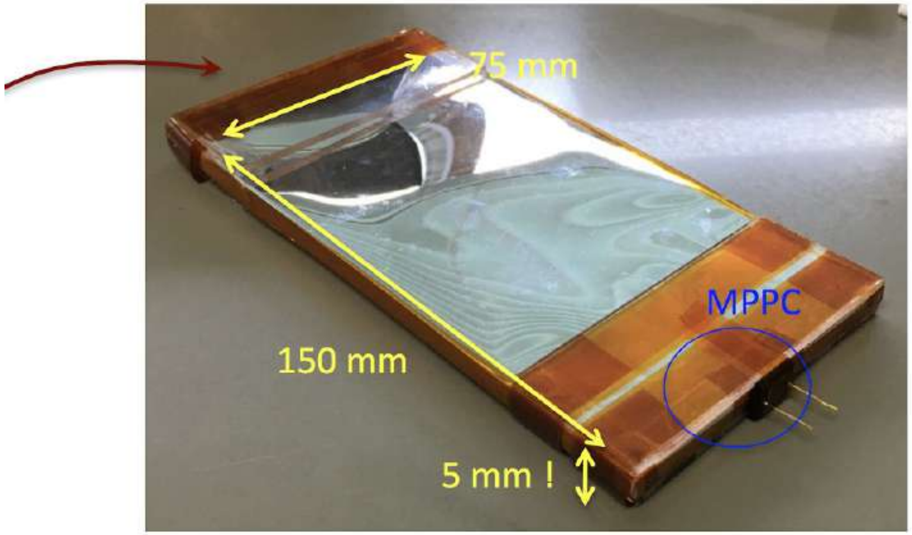
MISSION CONCEPT

- Equipped with GPS receiver for precise time synchronisation
- Inter-satellite (Iridium NEXT) communication equipment for rapid data download
- All sky coverage with a large effective area

CAMELOT: DETECTOR DESIGN



Werner+ 18



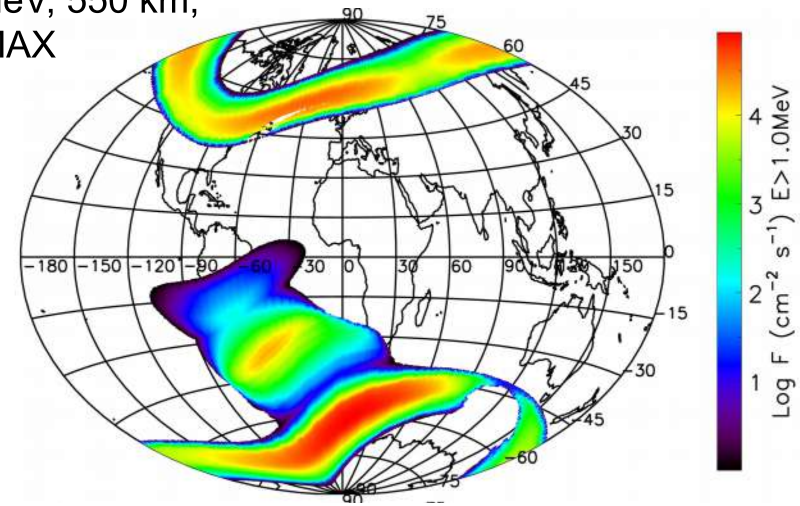
- To maximize the effective area, the detectors based on CsI scintillators and Multi-Pixel Photon Counters (MPPC) will occupy two lateral extensions
(8.3 cm x 15 cm x 0.9 cm x 4)

- The large and thin detectors with small readout area are challenging

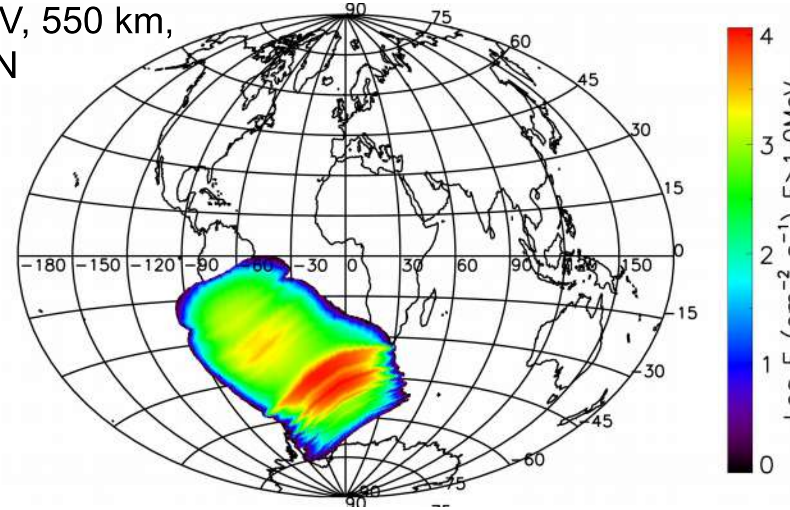
- The read out of the CsI detectors with MPPC has been evaluated in the lab. The system provides a large light yield, compact readout area and relatively low operational voltage.

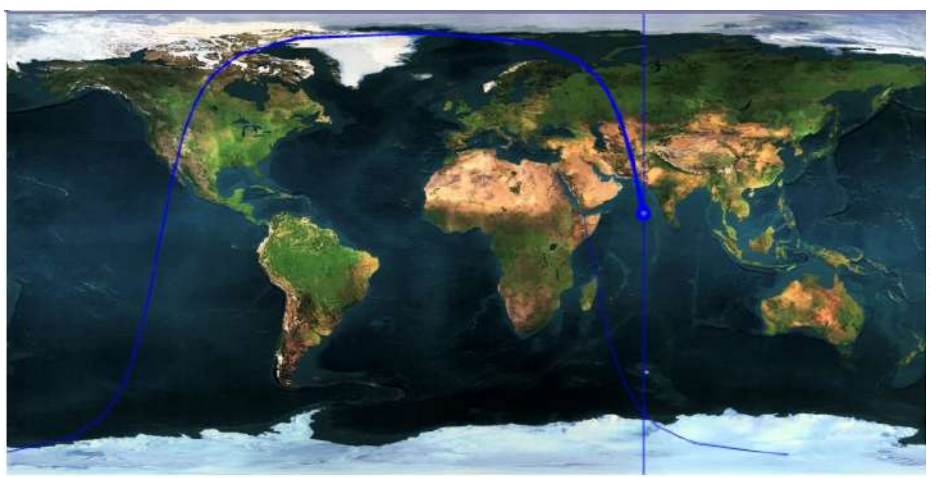
DUTY CYCLE FOR A GRB INSTRUMENT: LARGELY AFFECTED BY TRAPPED CHARGED PARTICLES

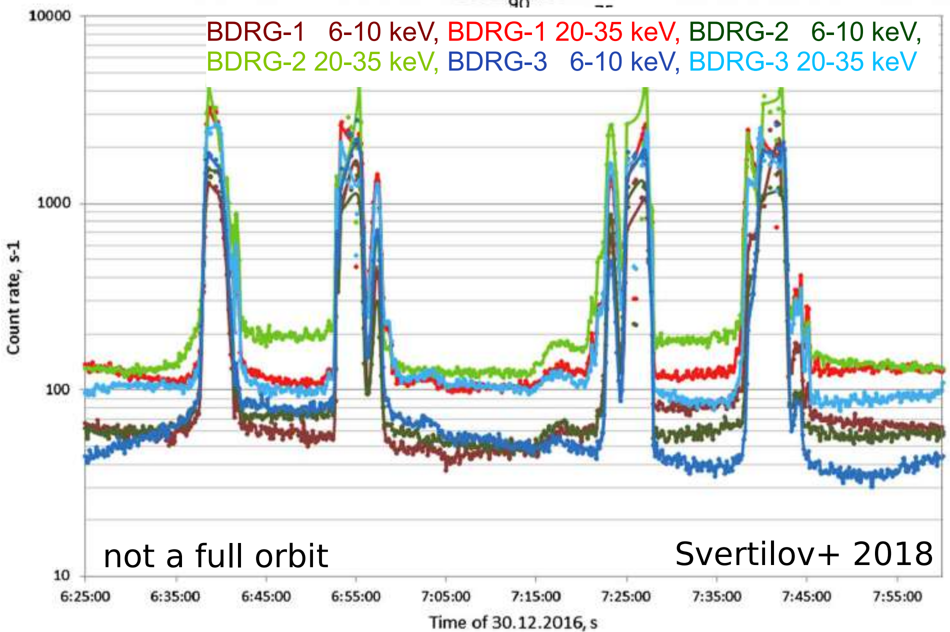
Trapped electrons,
E>1 MeV, 550 km,
AE8 MAX



Trapped protons,
E>1 MeV, 550 km,
AP8 MIN



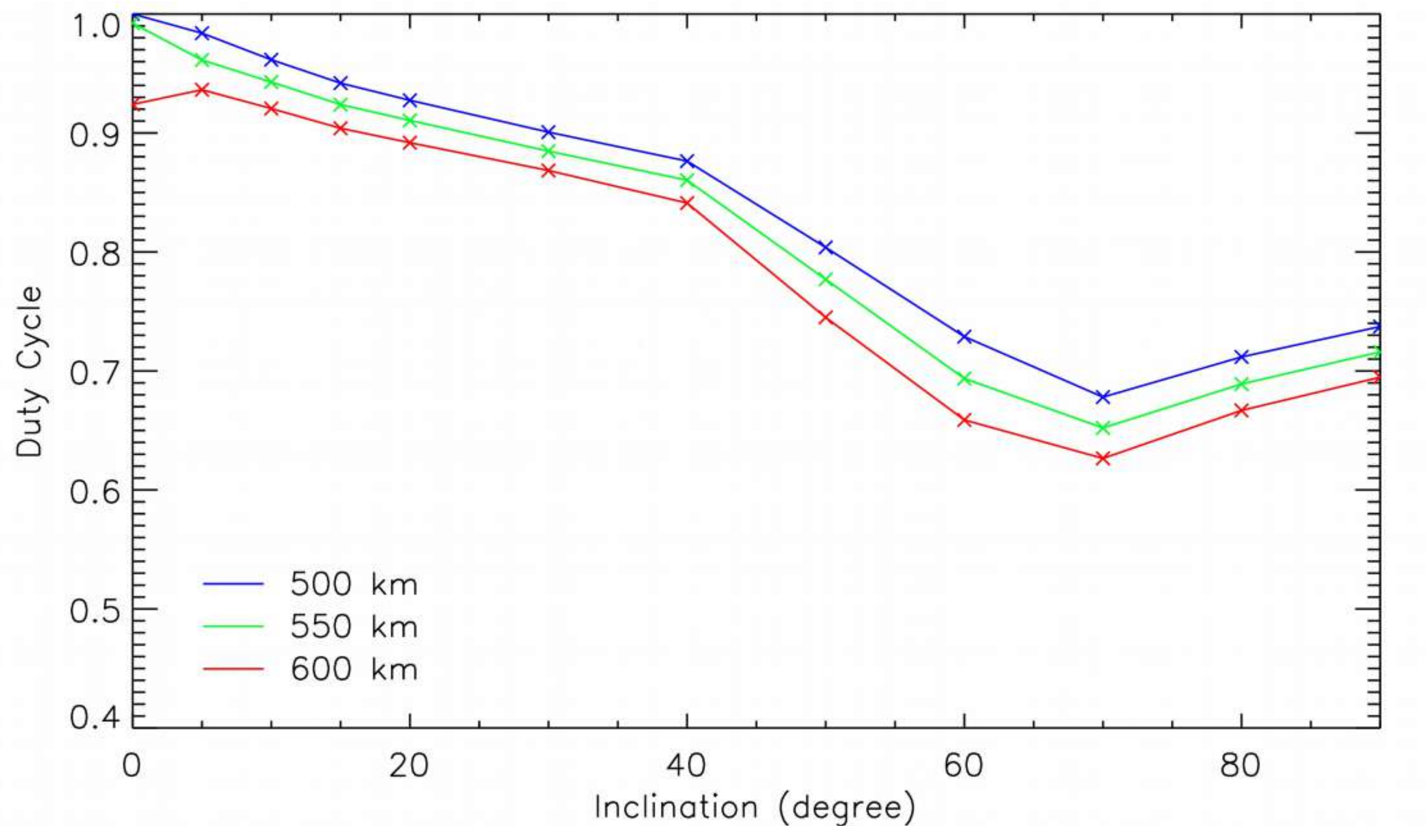




Svertilov+ 2018

DUTY CYCLE FOR A GRB INSTRUMENT: LARGELY AFFECTED BY TRAPPED CHARGED PARTICLES

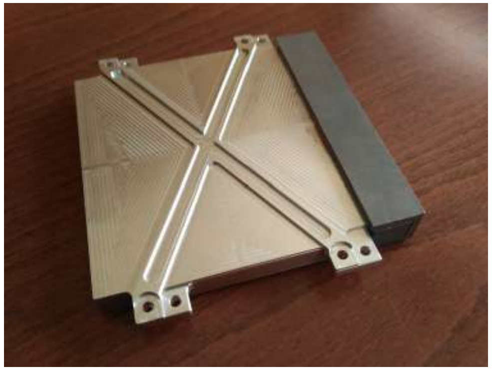
- Fraction of time when integral particle density of electrons AE8 MAX (E_{e-}> 0.57 MeV) + protons AP8 MIN (E_{p+}> 13 MeV) is < 10 $s^{-1}cm^{-2}$
- Best for low inclination ≲ 30°
- Drops to ~70% for polar orbits
- But can be even lower due to rapid background fluctuations in polar regions --> false triggers

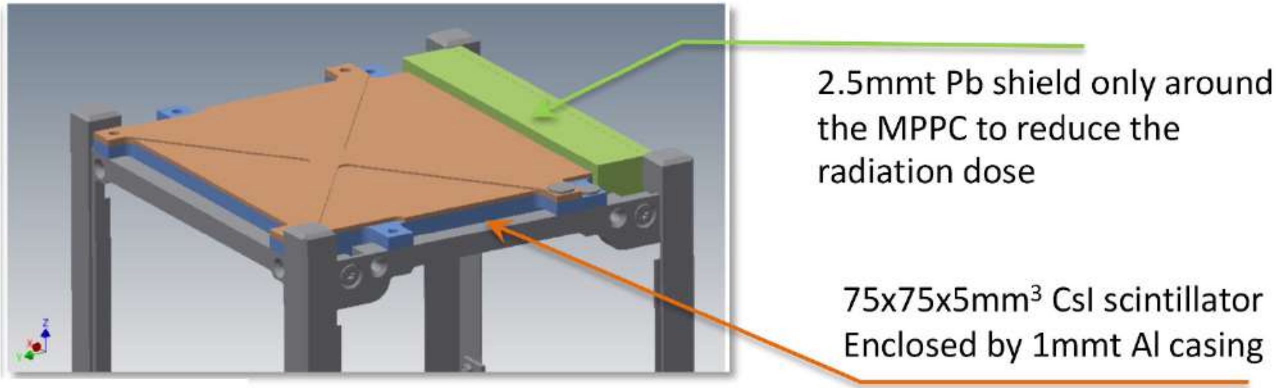


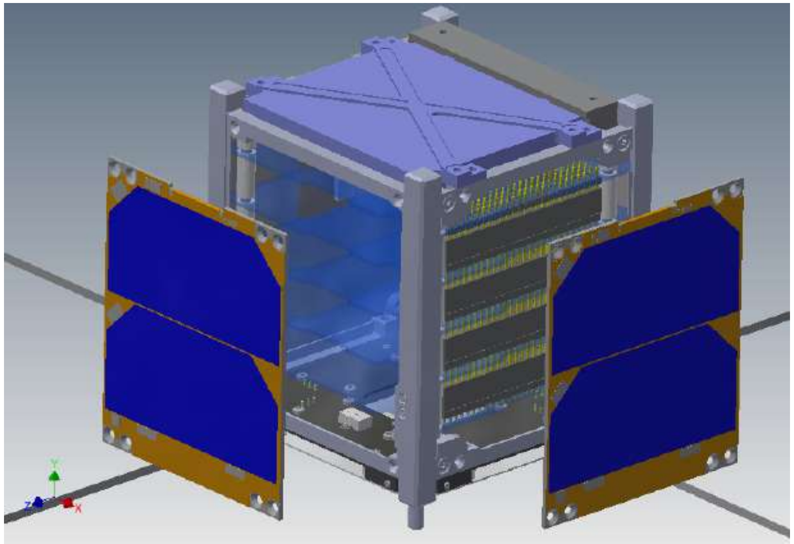
WHERE DO WE STAND?

- We performed a feasibility study and developed the detector concept.
- We developed a GRB detector for CubeSats, which we intended to test step-by-step, on a high-altitude balloon, then 1U and 3U Cubesats. However, we had to proceed directly to an in orbit **demonstration mission** on a 3U CubeSat
- An orbital demonstration mission with two smaller sized detectors as a secondary payload on a 3U CubeSat - ***VZLUSAT-2*** - will be launched NET mid January next year
- An orbital demonstration mission with a smaller sized detector on a 1U CubeSat - ***grbAlpha*** - will be launched NET March next year

GRBALPHA:
THE FIRST DEMO FLIGHT



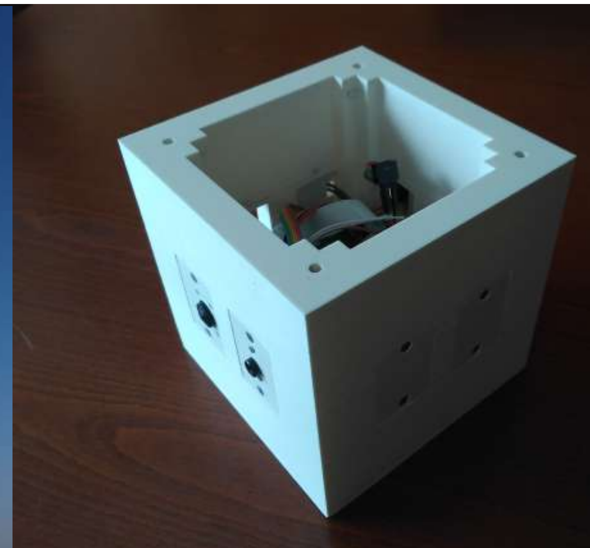


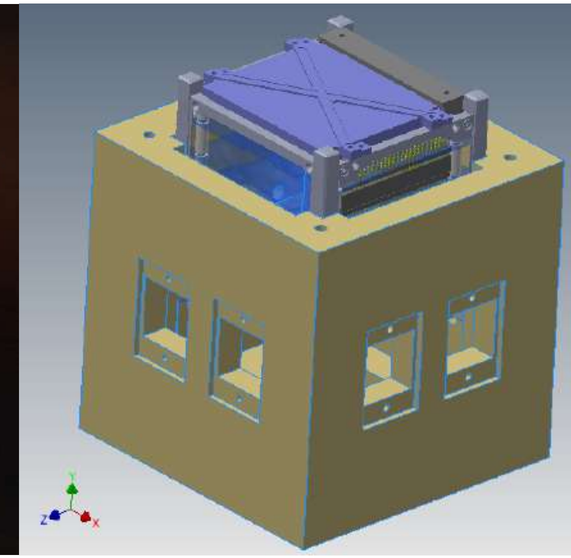


- Small size of detector (75x75x5mm^3) for 1-U platform but the same basic concept to the CAMELOT
- The same concept of support structure, particle shields and electronics will be tested
- To be launched in 2021

With the help of Spacemanic and NEEDRONIX

GRBALPHA: BALLOON FLIGHT





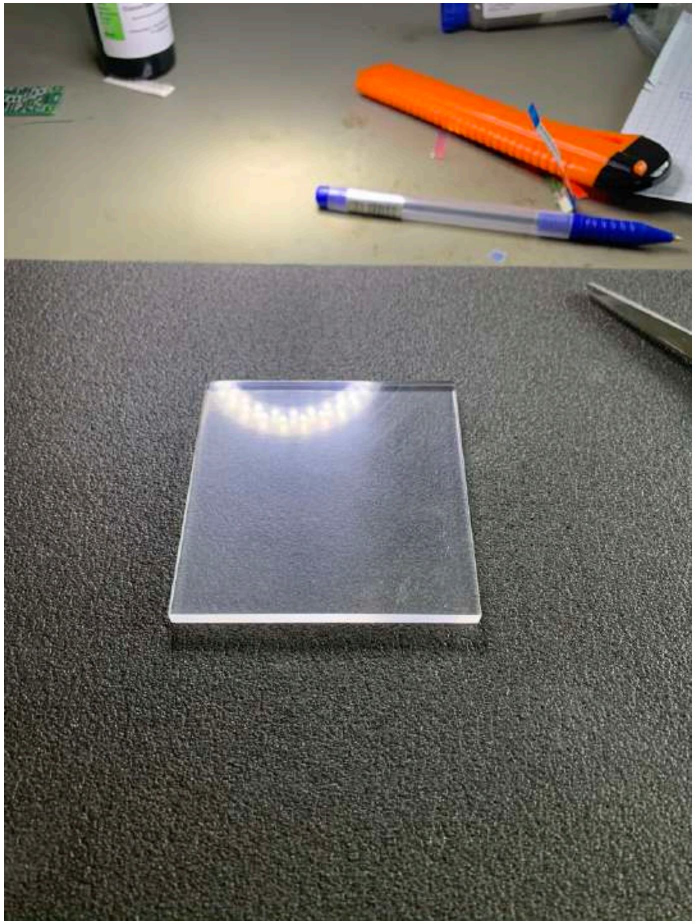
- Up to 30-38 km
- 6-7 hours of flight
- Relatively easy to launch
- 3D printed gondola: thermal isolation
- Spin-off: new IR sensor based attitude determination

VZLUSAT-2: OUR DEMO FLIGHT

Here are our detectors

- VZLUSAT-2 is a technology mission with an earth observing camera as a primary payload
- Two detectors ($75x75x5mm^3$) as a secondary payload
- The detector concept, the MPPCs, the support structure, and electronics will be tested
- The software, data handling and processing will be tested

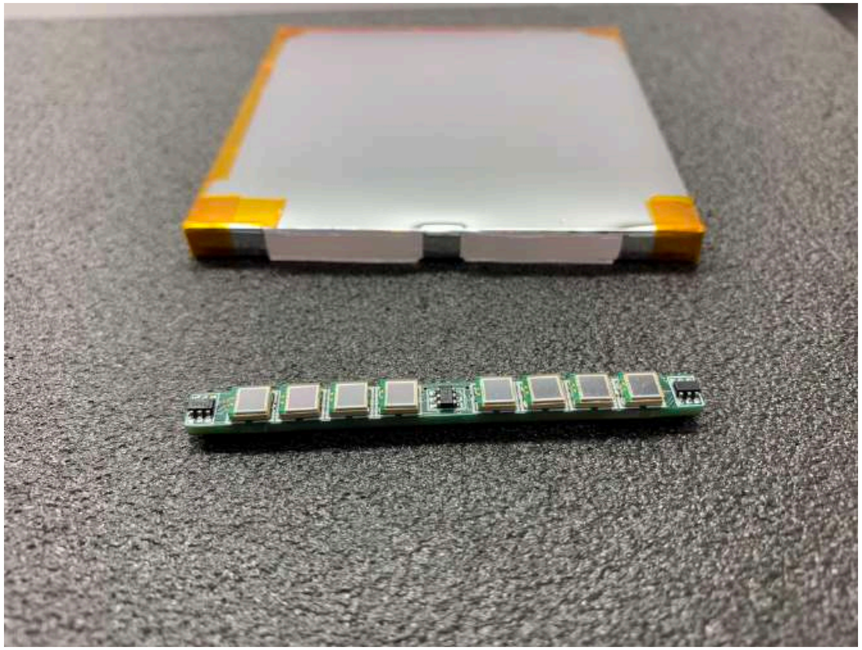
VZLUSAT-2: OUR DETECTOR



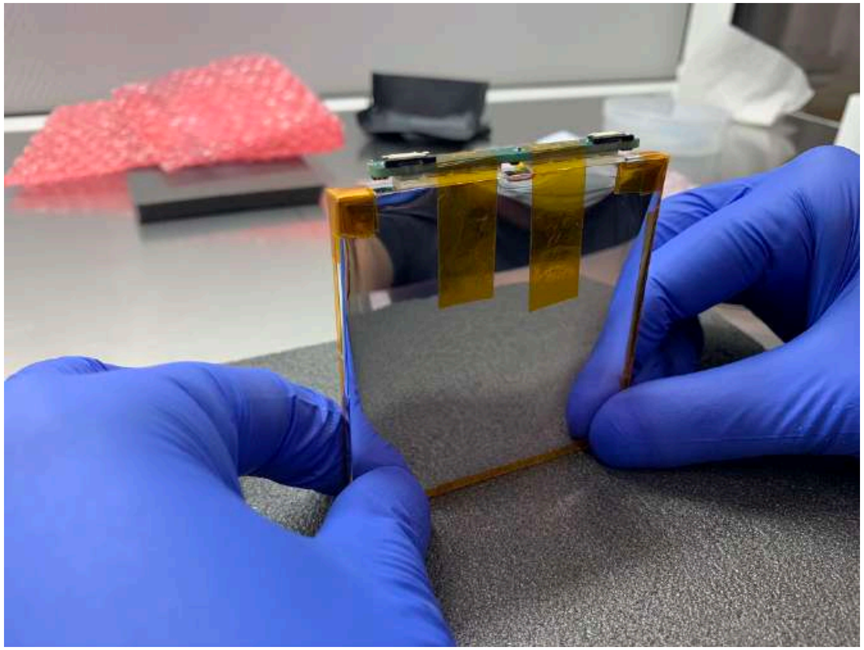
CsI (Tl) scintillator
75 x 75 x 5 mm

Wrapped in ESR

VZLUSAT-2: OUR DETECTOR



2 channels of 4 MPPCs
(S13360-3050 PE)



Attached using optical rubber (Optical glue DOWSIL 93-500 for GRBAlpha)

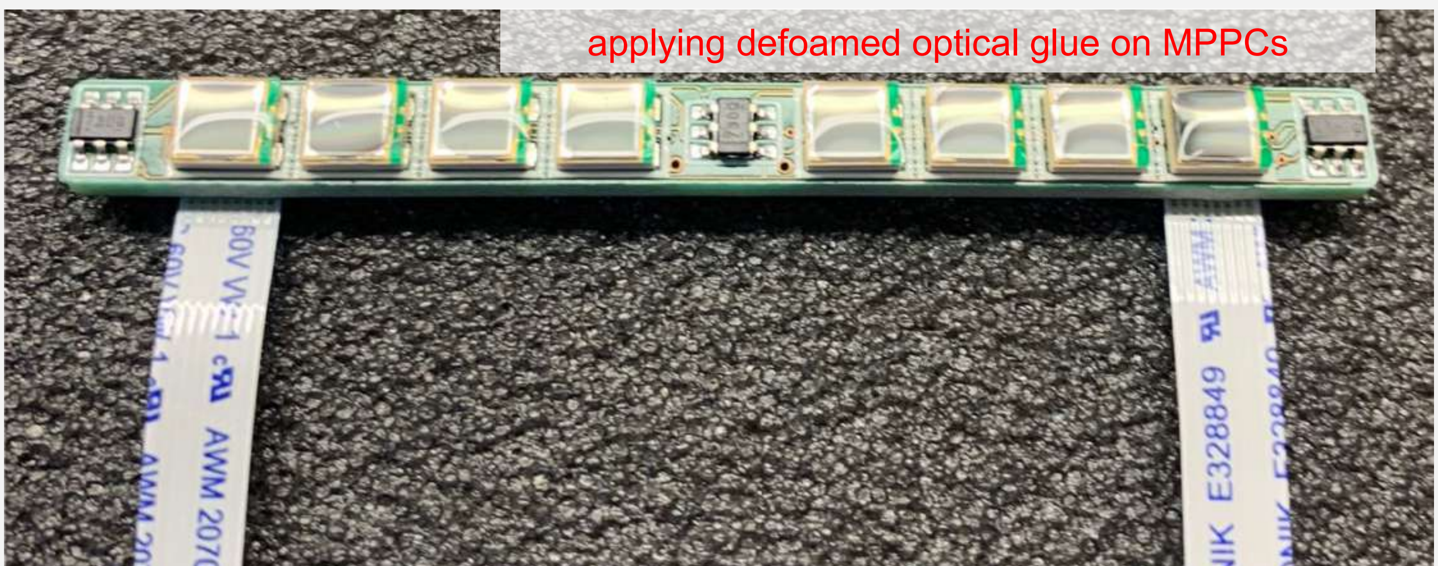
Defoaming and applying optical glue

- We used a vacuum chamber to defoam the optical glue DOWSIL93-500 before using it with the primer PR-1200 to glue MPPC board and CsI

prepare vacuum chamber

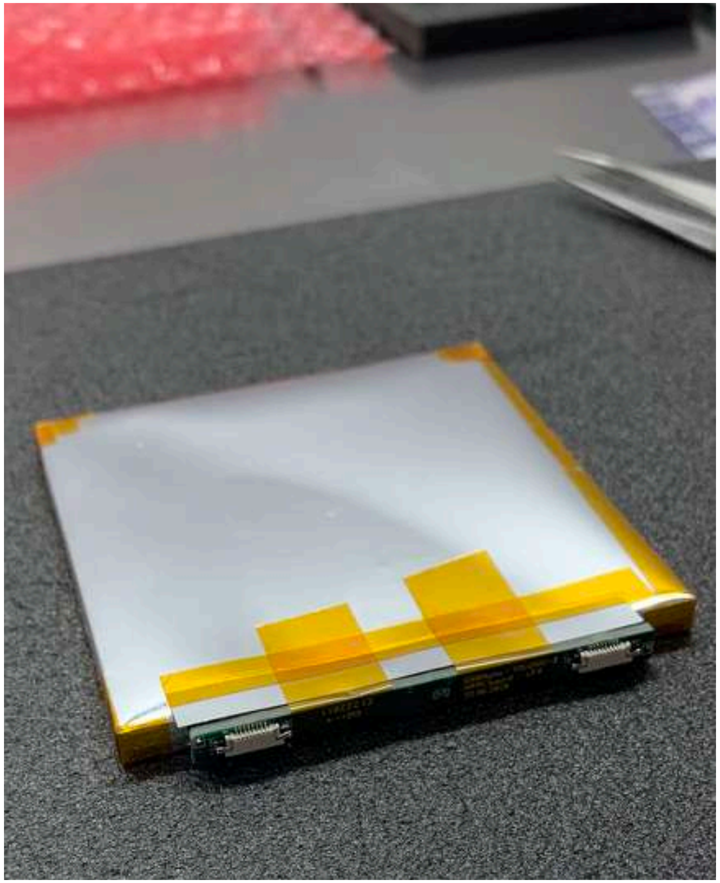
carefully watching what happens with optical glue

lots of bubbles appeared

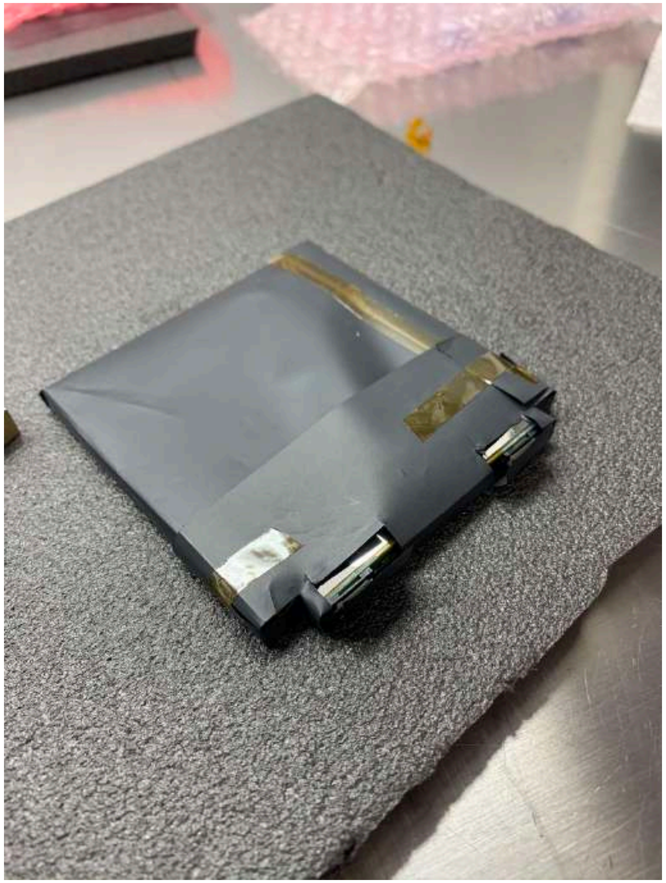


applying defoamed optical glue on MPPCs

VZLUSAT-2: OUR DETECTOR

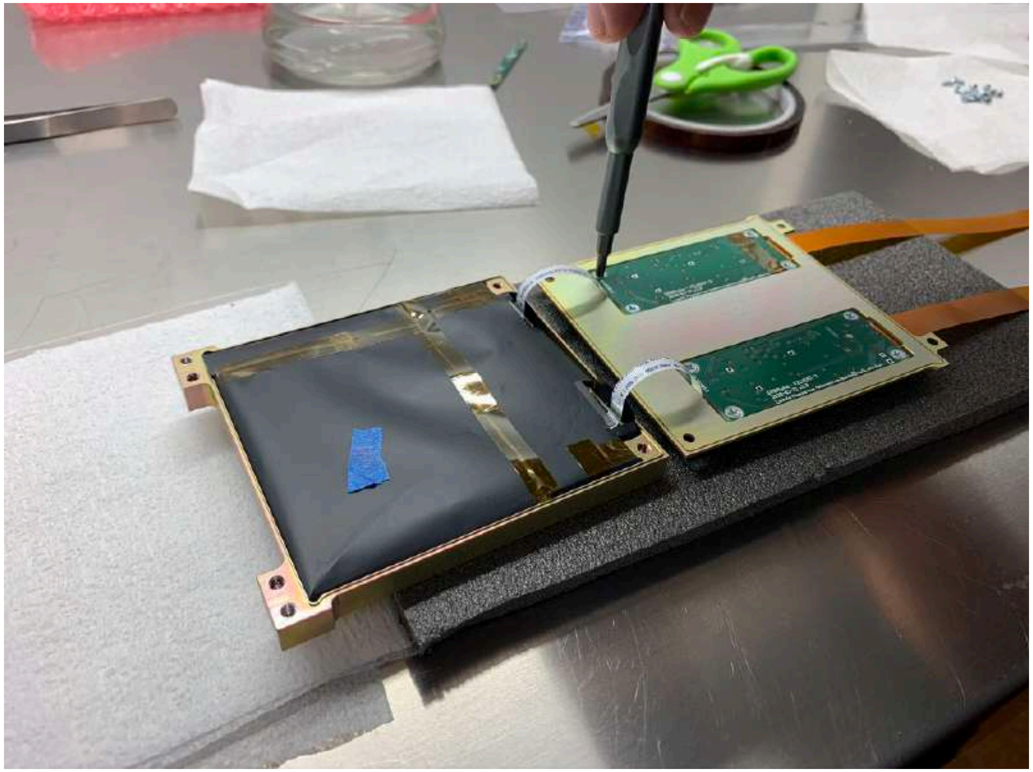


ESR wrapped scintillator with
The attached MPPC board

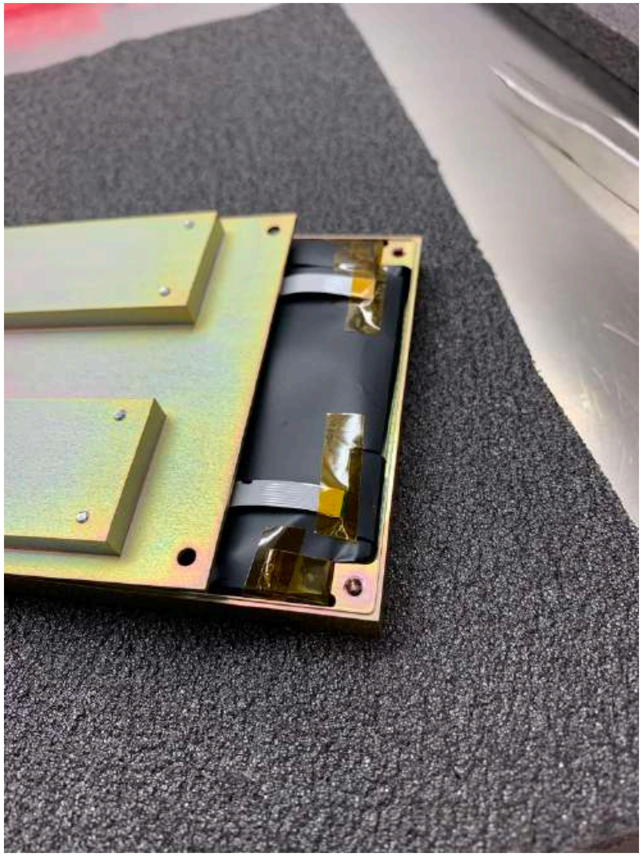


The detector is wrapped in a tedlar
sheet (DuPont TCC15BL3)

VZLUSAT-2: OUR DETECTOR



Placed into a 1 mm thick Al casing together with two analogue boards

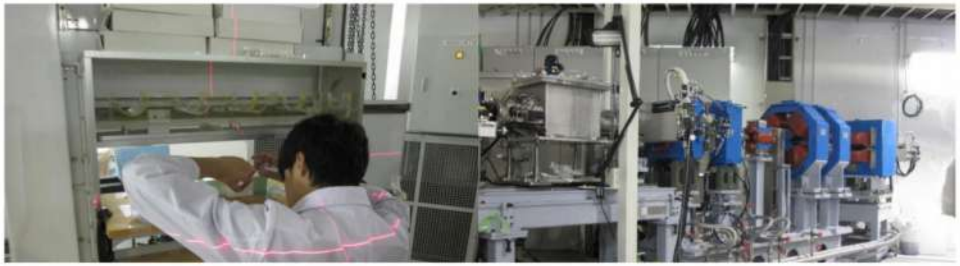


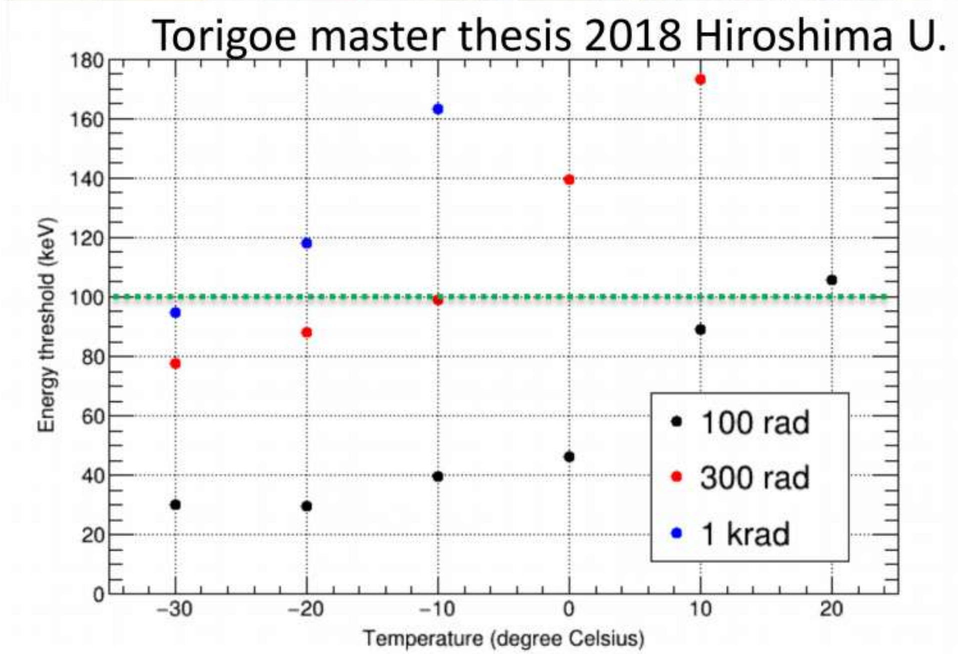
Additional wrapping around the MPPC board

OUR DETECTOR:
PROTECTION OF MPPC BY LEAD SHIELD

- 2mm thick lead shield to protect MPPCs from protons (PbSb4)

- Beam test performed by Kento Torigoe, Masanori Ohno, Hiromitsu Takahashi et al. (Hiroshima U.) at Wakasa-wan accelerator center in Japan

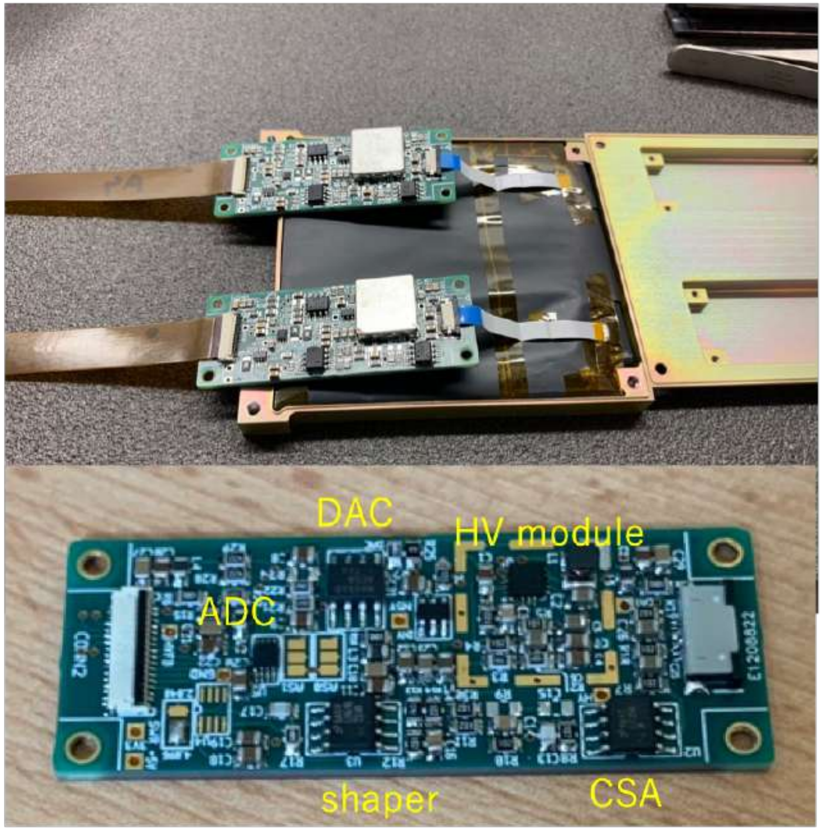




- Serious radiation damage for MPPC:
  > 100 keV threshold in 1-year operation
  Temp./dose control are important !

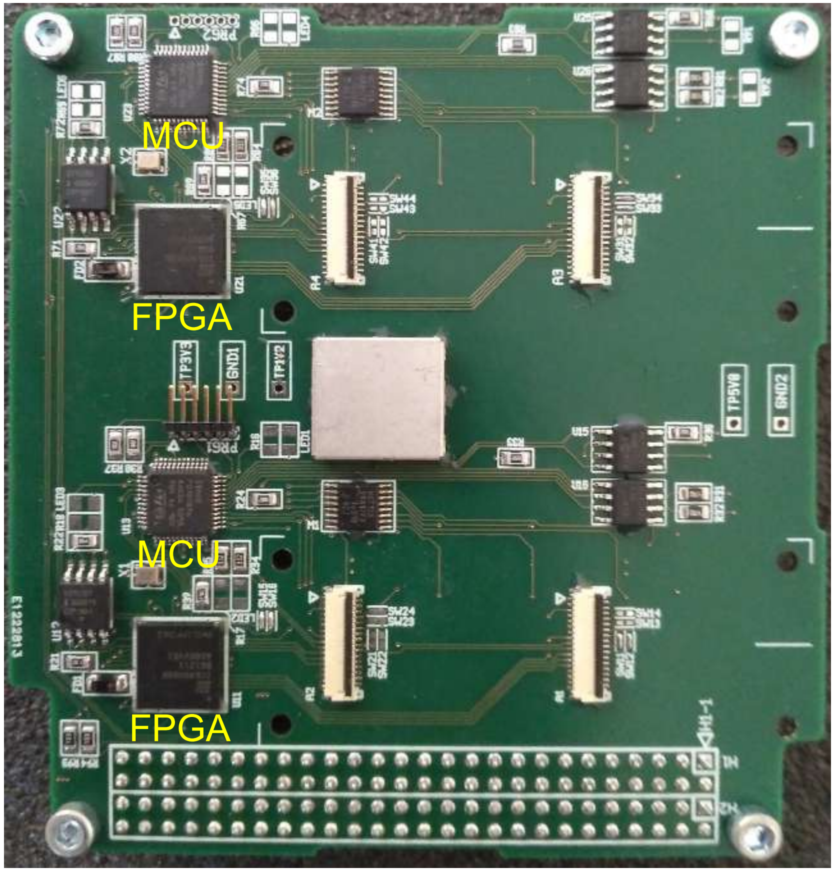
VZLUSAT-2: ELECTRONICS

Compact analog electronics



- A simple CSA (LF356)+ shaping amplifier (LM6142)
- 12-bit sampling ADC (LTC2315-12)
- HV supply module (LT3482) controlled by DAC

Digital board



- FPGA - iCE40HX8K-BG121
- MCU - STM32F072CBT7 ARM Cortex-M0

THE ADVENTURES OF DETECTOR DELIVERY

Arrived in Prague

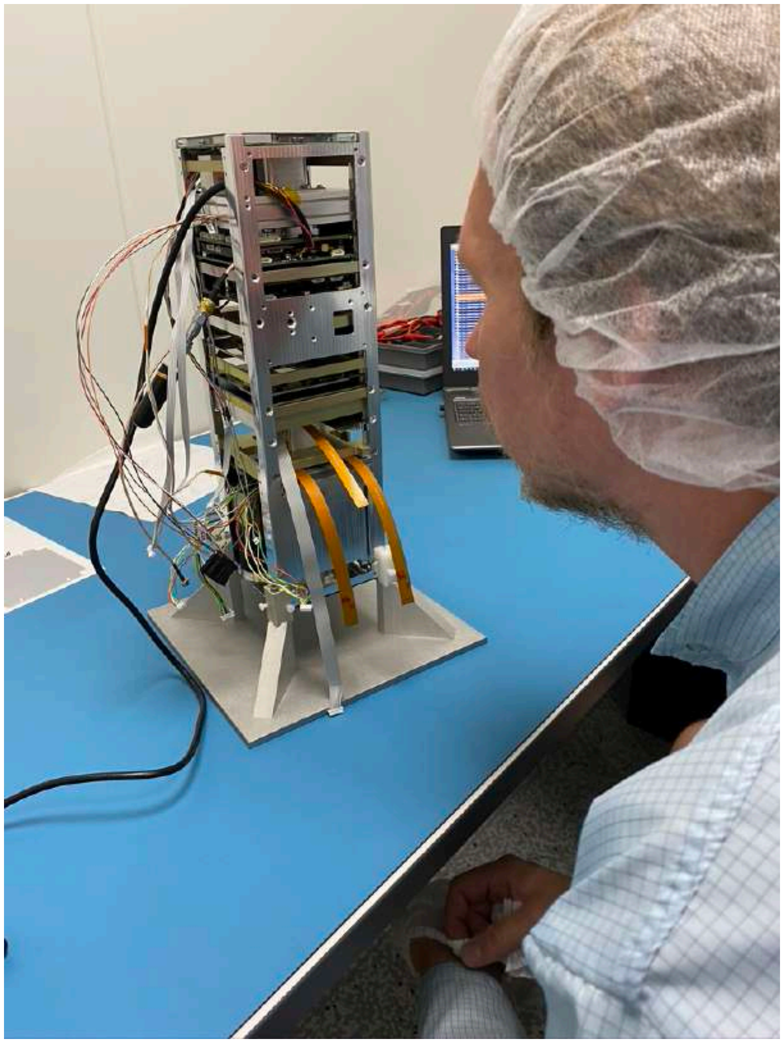
VZLUSAT-2: OUR DETECTOR

Weight: 2 x 280 + 50 g

Power: 0.7 W

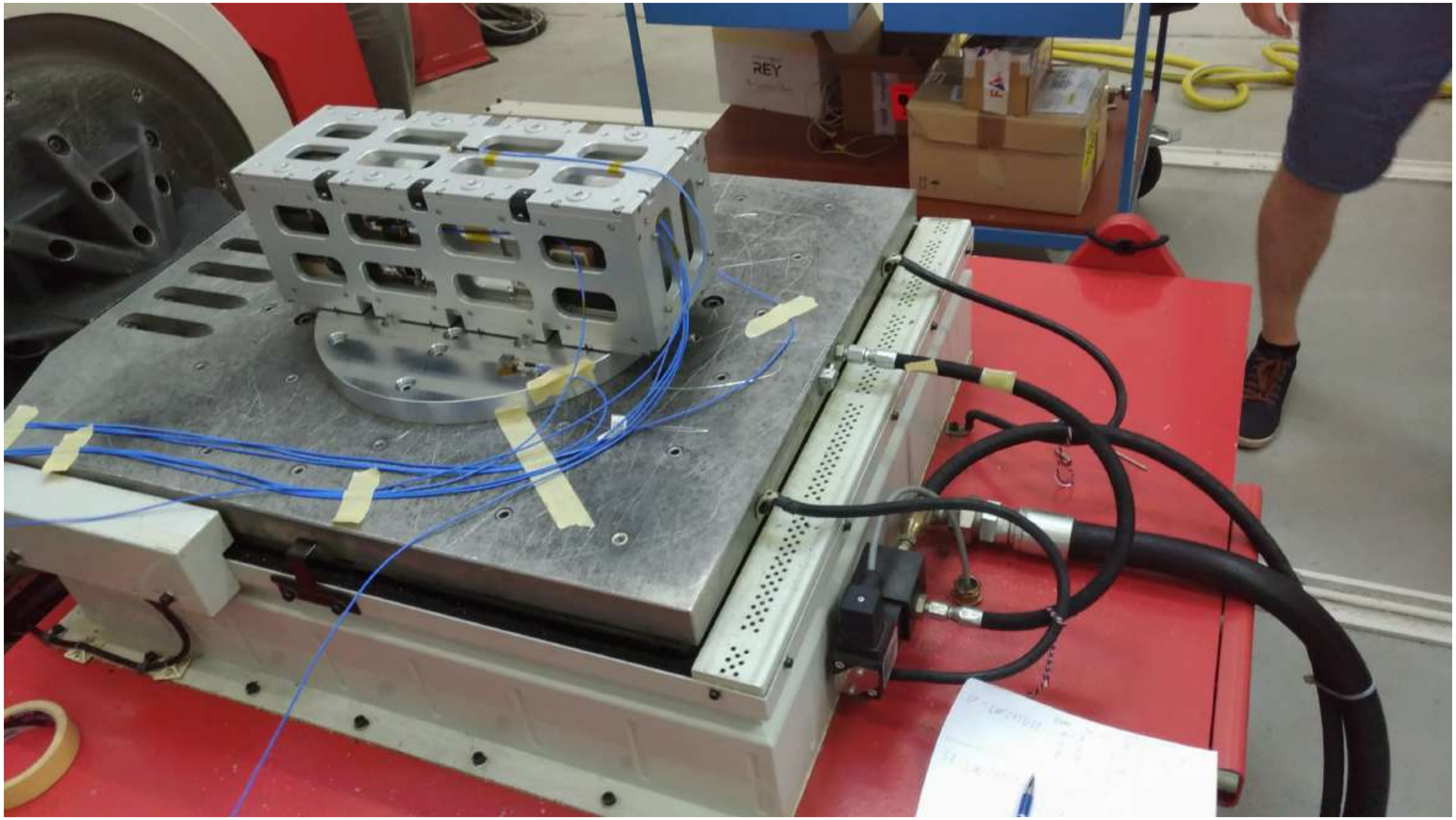
VZLUSAT-2: OUR DEMO FLIGHT

Tested that it operates on
the satellite bus



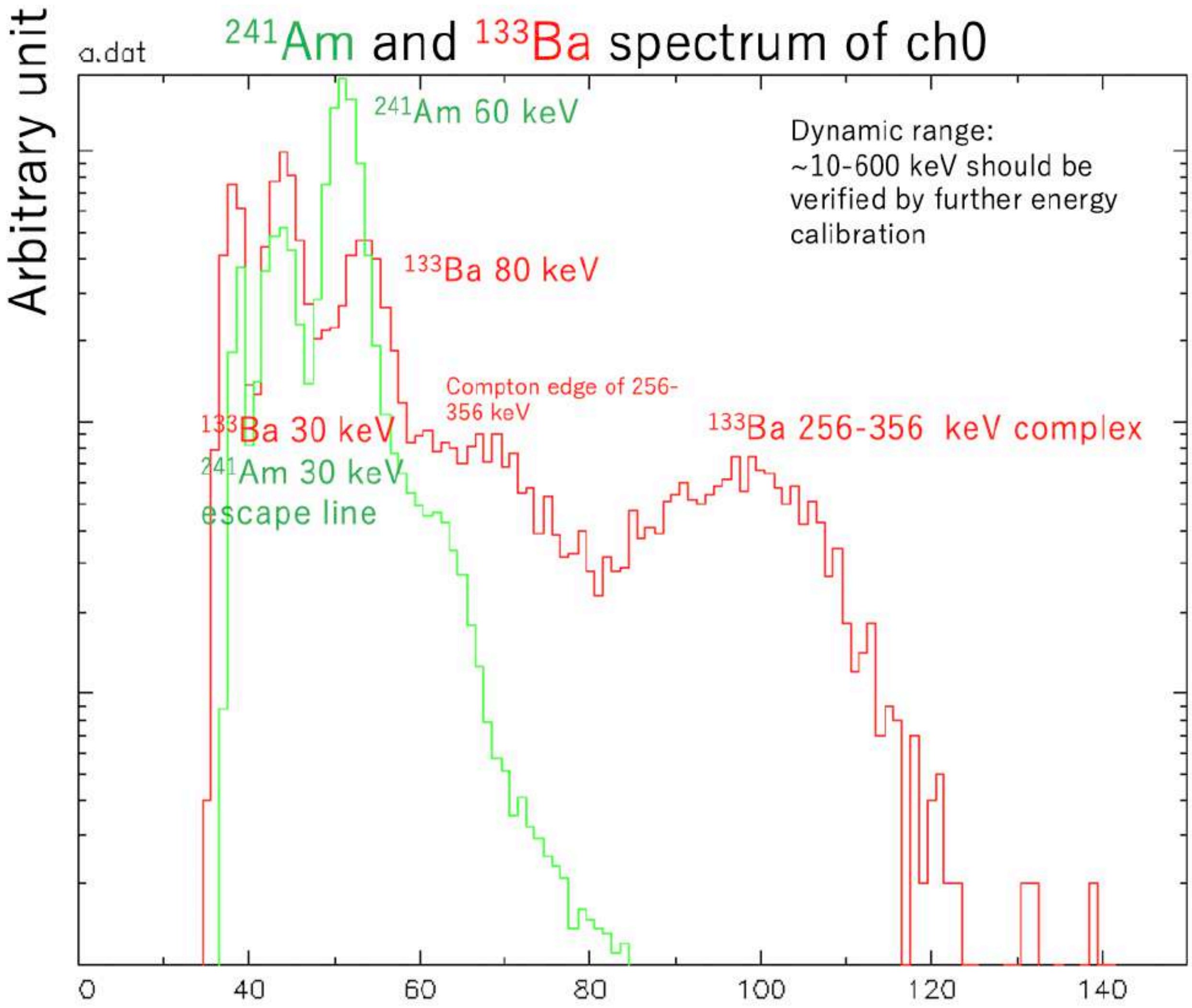
Integrated into the EM of the satellite

ENVIRONMENTAL TESTS IN VZLU CZECH AEROSPACE RESEARCH ORGANISATION



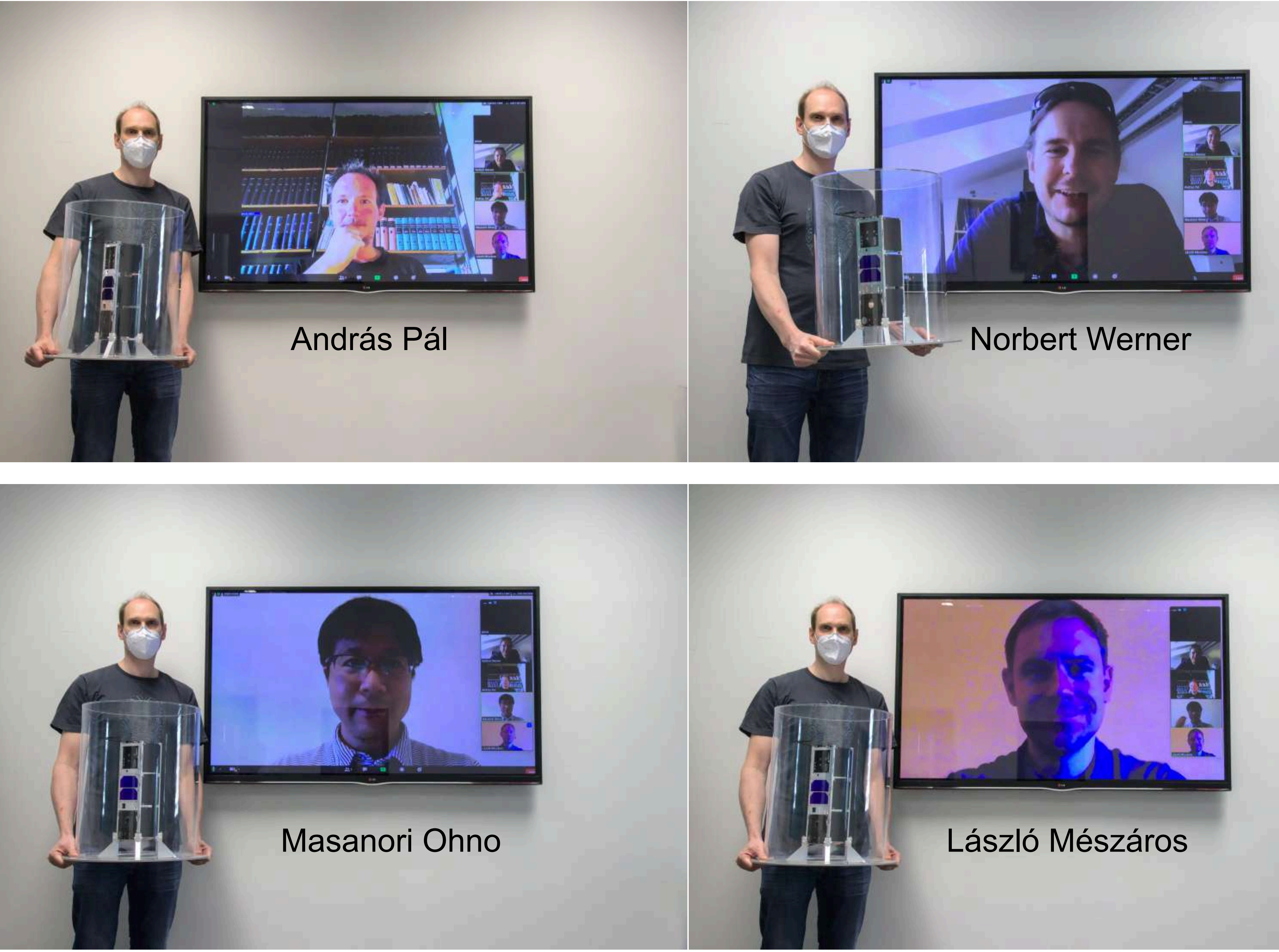
Vibration tests, shock tests, and thermo-vacuum tests

SPECTRUM

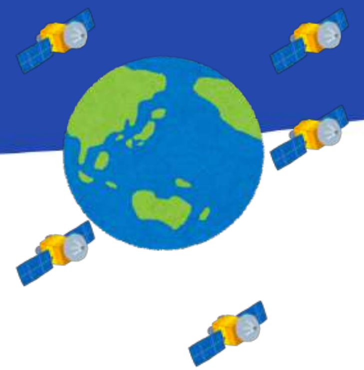


Arbitrary unit
a.dat
241Am and 133Ba spectrum of ch0
241Am 60 keV
Dynamic range:
~10-600 keV should be
verified by further energy
calibration
133Ba 80 keV
Compton edge of 256-
356 keV
133Ba 30 keV
241Am 30 keV
escape line
133Ba 256-356 keV complex
0
40
60
80
100
120
140


1


András Pál
Norbert Werner
Masanori Ohno
László Mészáros

FURTHER STEPS

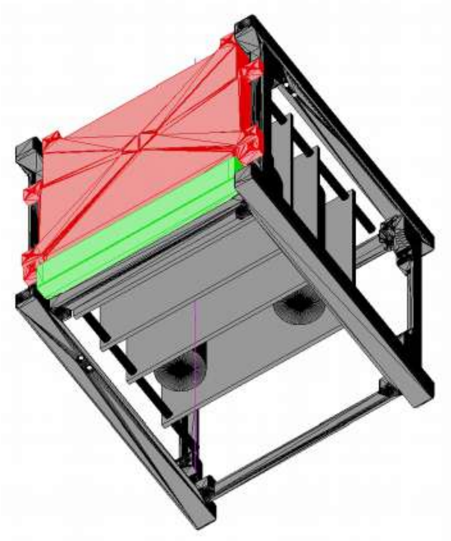


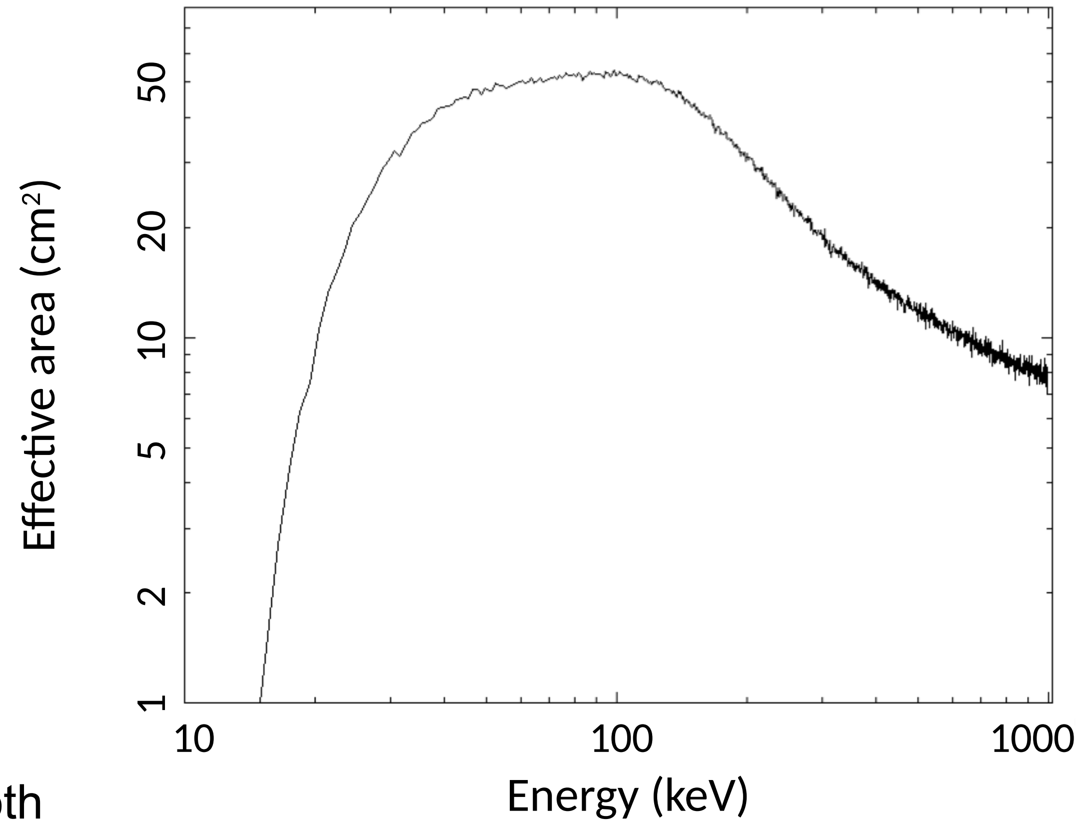
- Finish the integration of GRBAlpha, perform all necessary environment testing (next week) and deliver the satellite to Moscow (by Christmas)
- Finish the onboard scientific software, which will be uploaded after the launch of VZLUSAT-2
- Operate the detectors in orbit
- Build a constellation of GRB detecting nano-satellites with the addition of follow-up observation capability

GRBALPHA:
GRB DETECTION CAPABILITY

Can we detect GRBs using such small detectors?

- We estimate the photon numbers based on the detector response of GRBAlpha and the flux distribution of Fermi-GBM GRBs





- 10-20 % of Fermi-GBM GRBs (both long and short) can be detected by grbAlpha (~10-20 GRBs/year)

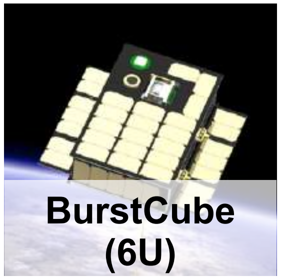
A MOSTLY CZECH CONSTELLATION ?

The transportation ministry in collaboration with ESA issued a call for proposals for a **ambitious technological/scientific mission**

With VZLU Czech Aerospace Research Organisation as prime and Masaryk University as the main scientific partner we are proposing a mission consisting of a fleet of three micro-satellites (50 kg), supplemented by CubeSats

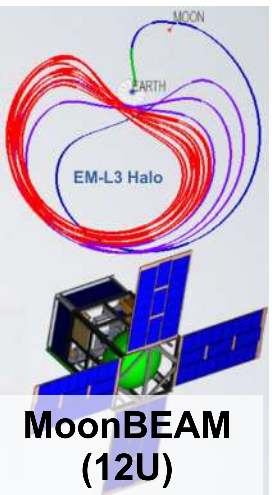
The main goal of the micro-satellites will be to perform rapid (within 30s) followup observations in X-rays (20 cm^2), NUV, and NIR (d=20 cm aperture)

OTHER TEAMS BUILDING GRB NANOSATELLITES



BurstCube
(6U)

- Many other teams are building nanosatellites for GRB detection
- Towards a Network of GRB Detecting Nanosatellites, 2018, Budapest
  https://asd.gsfc.nasa.gov/conferences/grb_nanosats/



MoonBEAM
(12U)

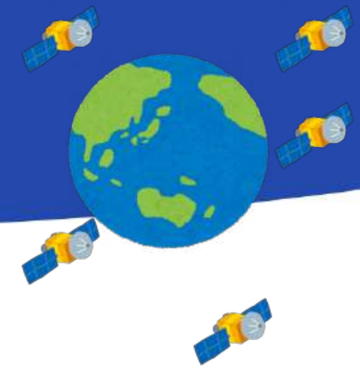
GRID
(6U)

AND
SEVERAL
OTHER
PROJECTS

SkyHopper
(12U)

- GRBNanoSats Wiki (www.grbnanosats.net). Every ~month there is a telecon; presentations of teams' progress, software tools, related experiments etc.
- To join please contact me or write to J. Perkins jeremy.s.perkins@nasa.gov

SUMMARY



- Constellations of CubeSats providing both **all-sky coverage** and **localisation capability** will be highly **complementary to large missions** monitoring the high energy sky
- The orbital demonstration missions of our first two GRB detecting CubeSats are expected to be launched in the next six months
- A close collaboration between GRB detecting CubeSats will leverage the advantages of nano-satellites and different detector concepts - *such close collaboration between missions is key for the success of global networks of GRB detecting nanosatellites*

Werner et al., Proc. of SPIE 10699 (2018) id.106992P
Ohno et al., Proc. of SPIE 10699 (2018) id.1069964
Pál et al. arXiv: 180603685
Torigoe et al. NIMPA 924 (2019) 316
Řípa et al. AN 340 (2019) 666