On and around the Earth

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Outline

- Where I come from
- The Space Sector
- Space Democracy
- A revolution is in progress
- The detection of Terrestrial Gamma-Ray Flashes with CubeSats

Photo by Enrico Sacchetti

Where I come from (advertisement)

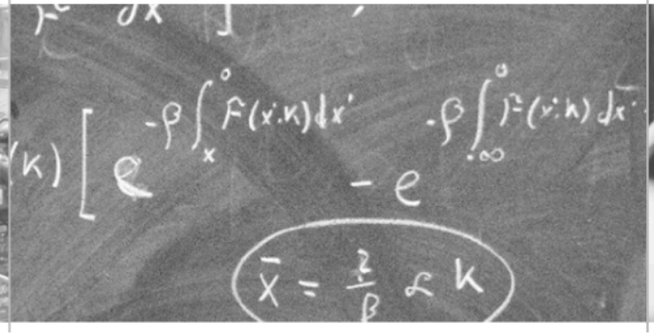
Gran Sasso Science Institute

GRAN SASSO SCIENCE INSTITUTE
SCHOOL OF ADVANCED STUDIES
Scuola Universitaria Superiore

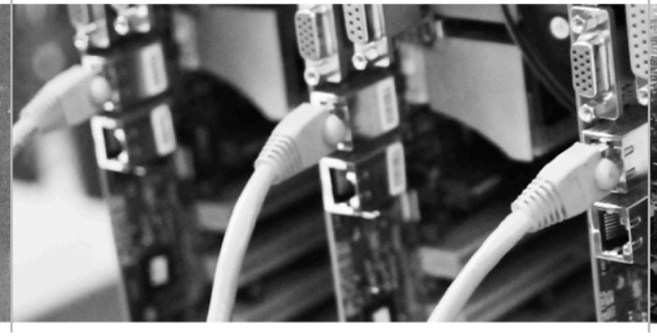
The Gran Sasso Science Institute (GSSI) is an international PhD school and a center for research and higher education in the areas of Physics, Mathematics, Computer Science and Social Sciences.

ASTROPARTICLE

MATHEMATICS

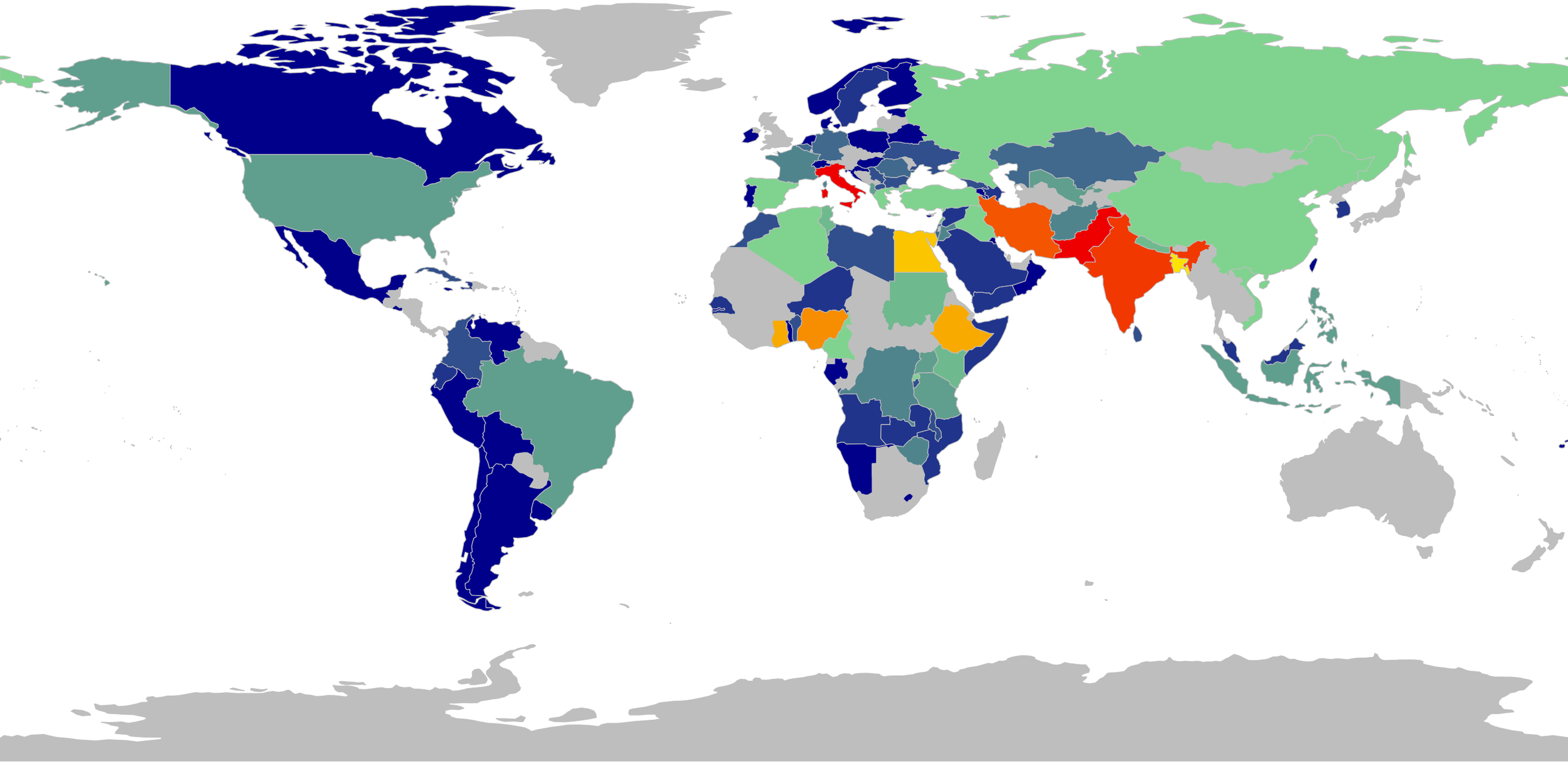


COMPUTER SCIENCE



SOCIAL SCIENCES

Geographical origin of applicants (A.Y. 2022/23)



If you are interested to apply: https://applications.gssi.it/phd/

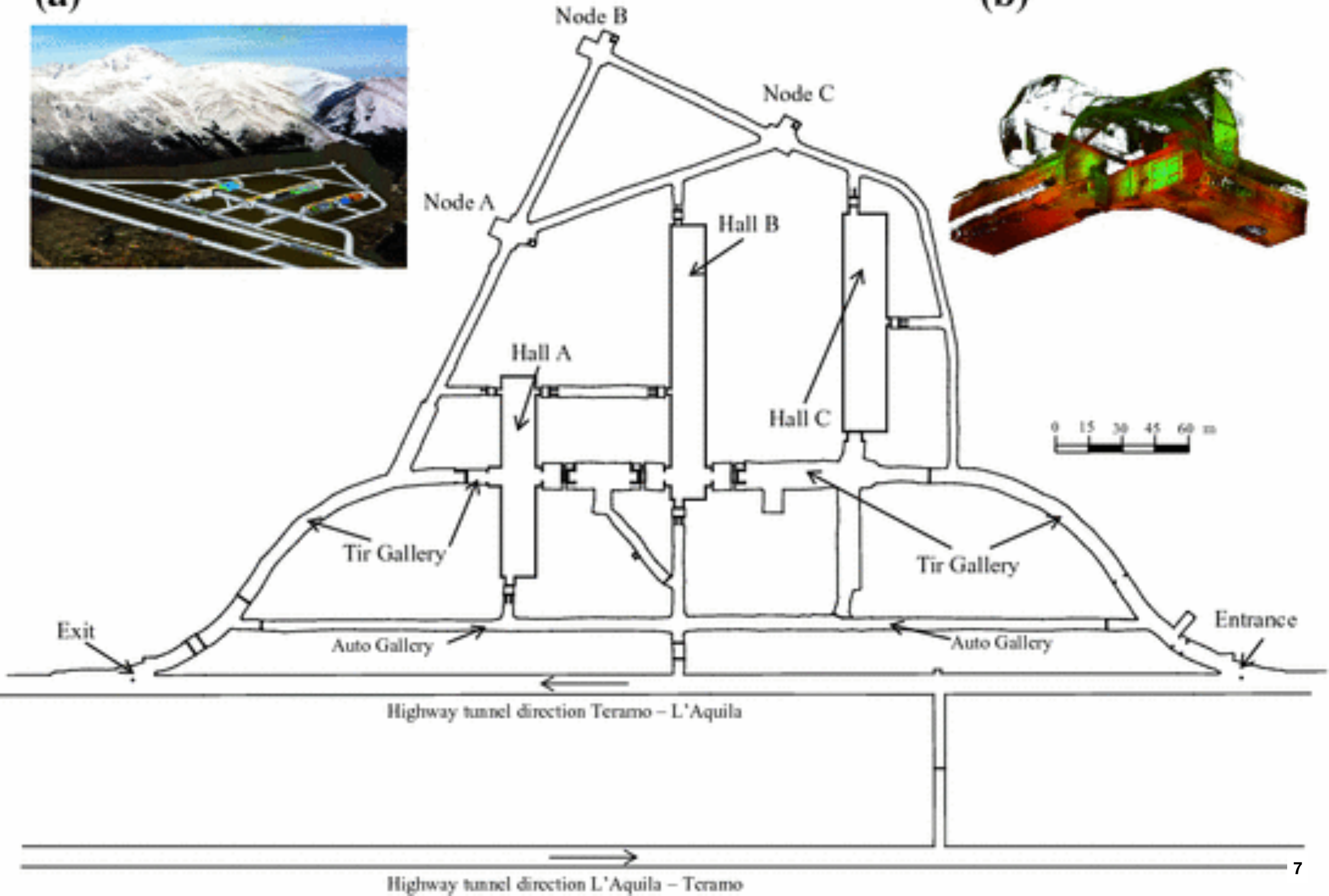
The Gran Sasso National Laboratory: a very special place

Neutrino Physics
Dark Matter Search
Nuclear Astrophysics
. . .
All that is very rare and very hard to discover . . .

The Gran Sasso National Laboratory: a very special place

(a)

(b)

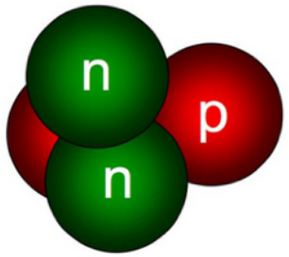


The Gran Sasso National Laboratory: a very special place

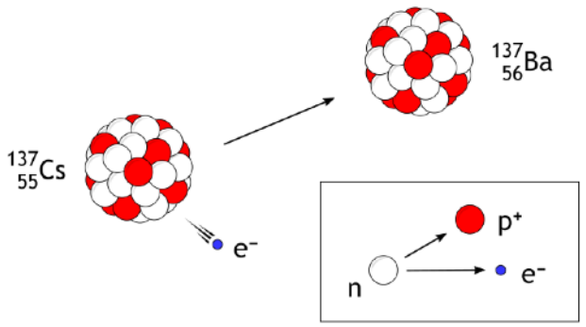
The Gran Sasso National Laboratory: a very special place

Particle radiation

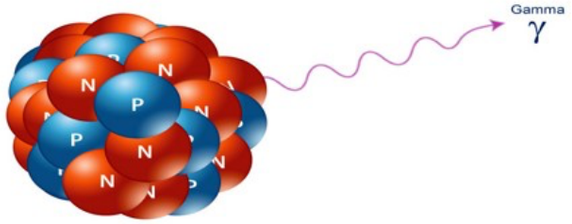
Alfa



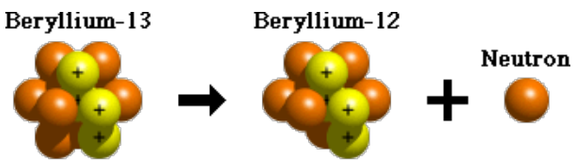
Beta

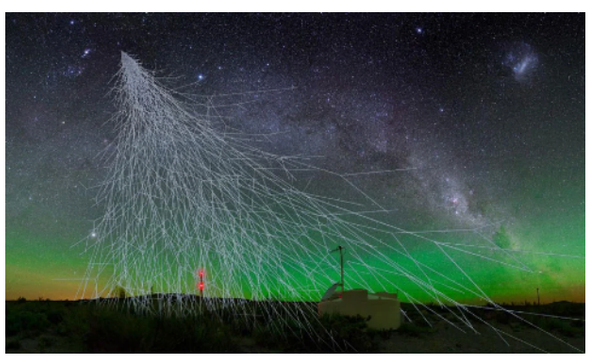


Gamma



Neutron





Muon

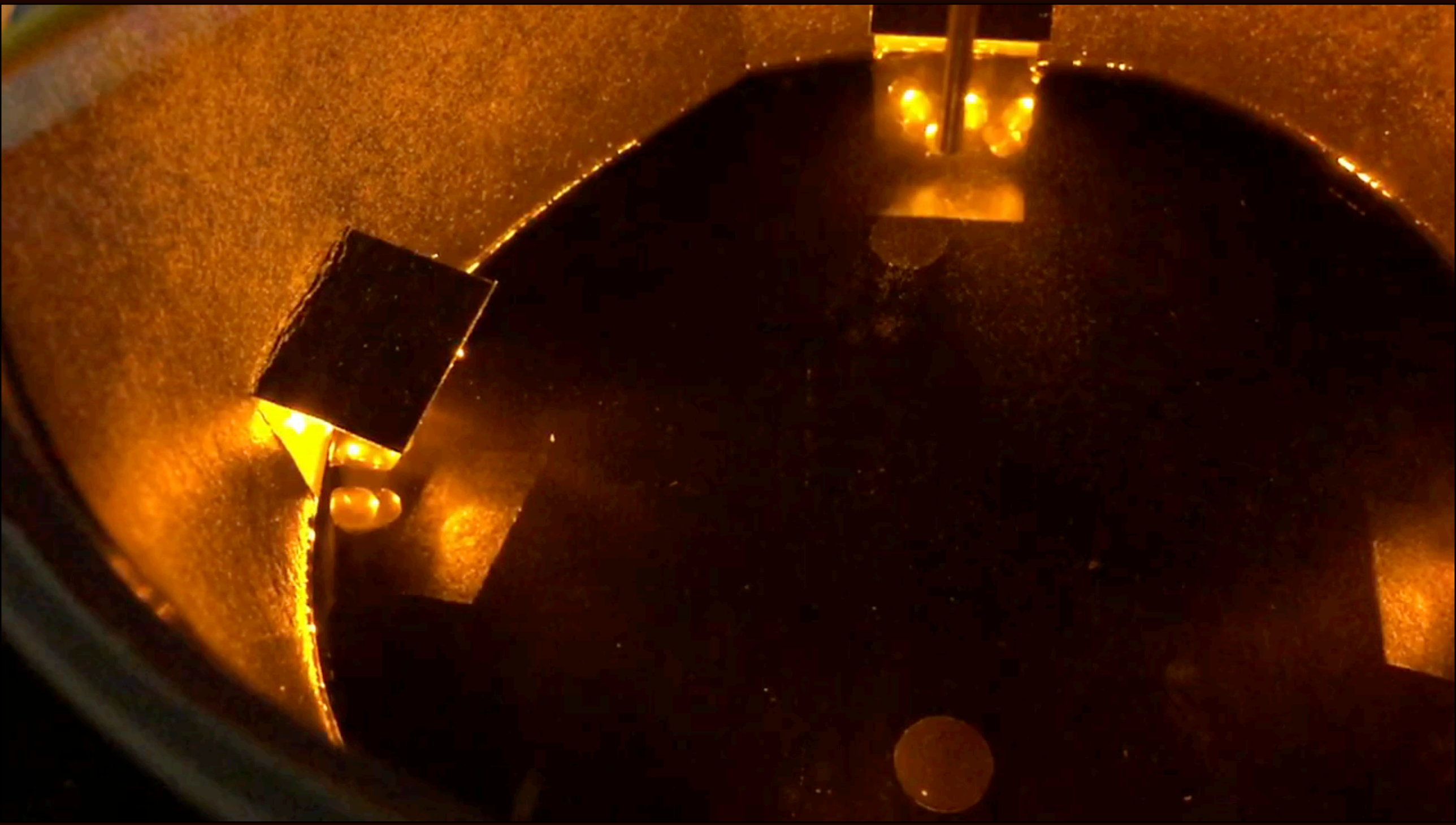
Paper

Aluminum

Lead

Concrete

Detecting and visualising particles



Cosmic Rays

Protons up to Iron nuclei, accelerated by catastrophic astronomical mechanisms

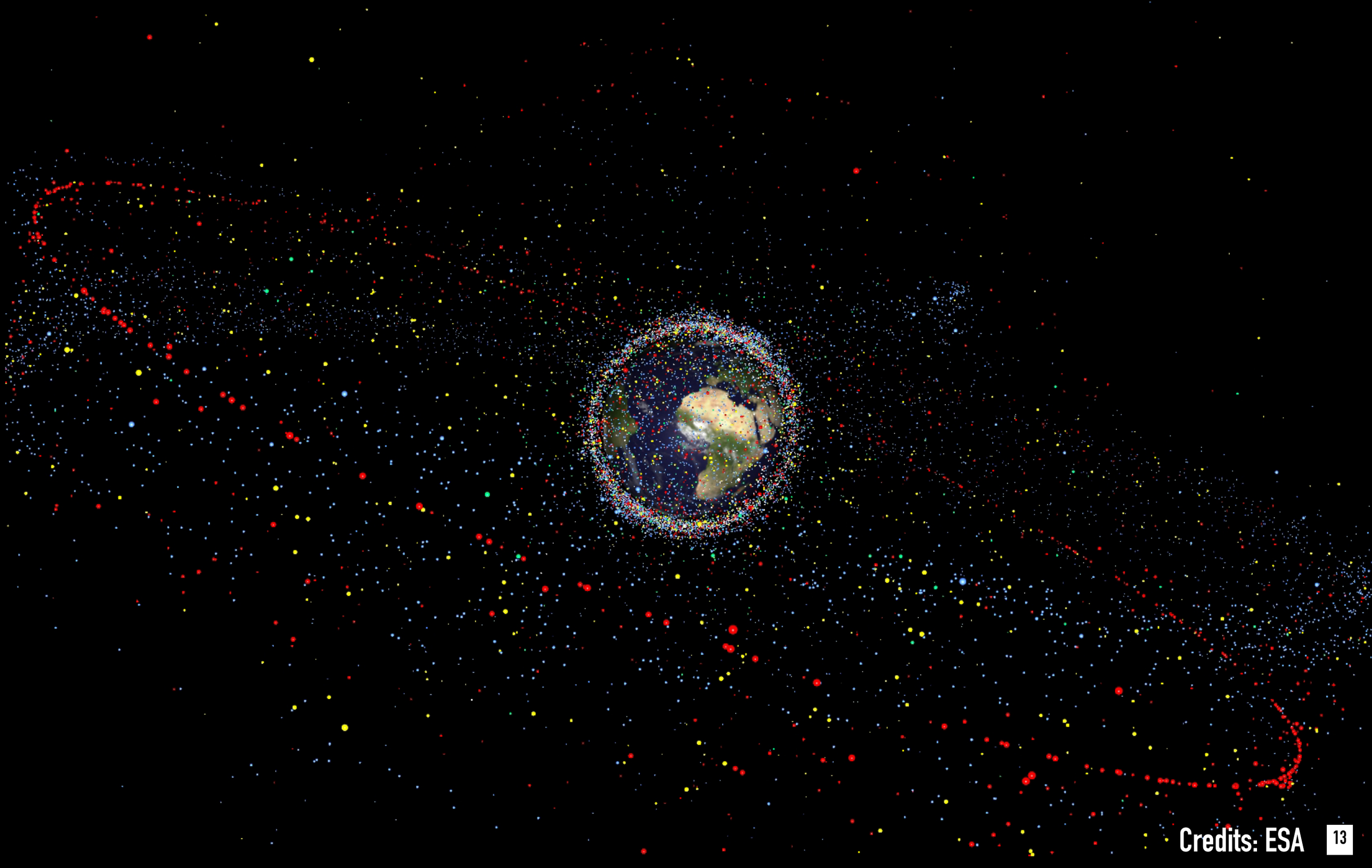
No accelerators can access the entire energy spectrum that we observe in cosmic rays

Primary interactions occur at 10–15 km from ground

100–200 muons per squared meter every second measured at sea level

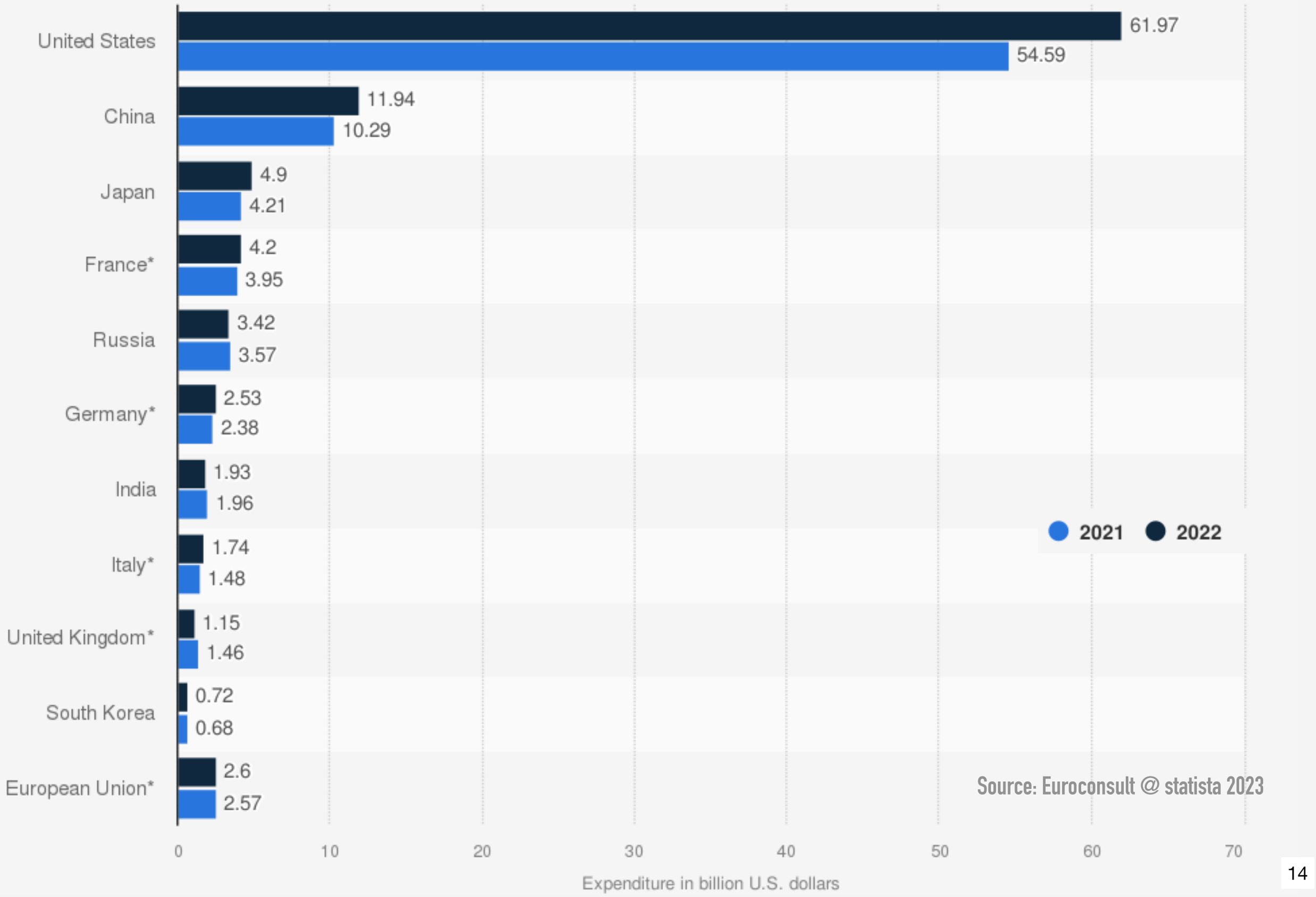
Credits: Cosmus, University of Chicago
Sergio Sciutto

The Space sector



Credits: ESA

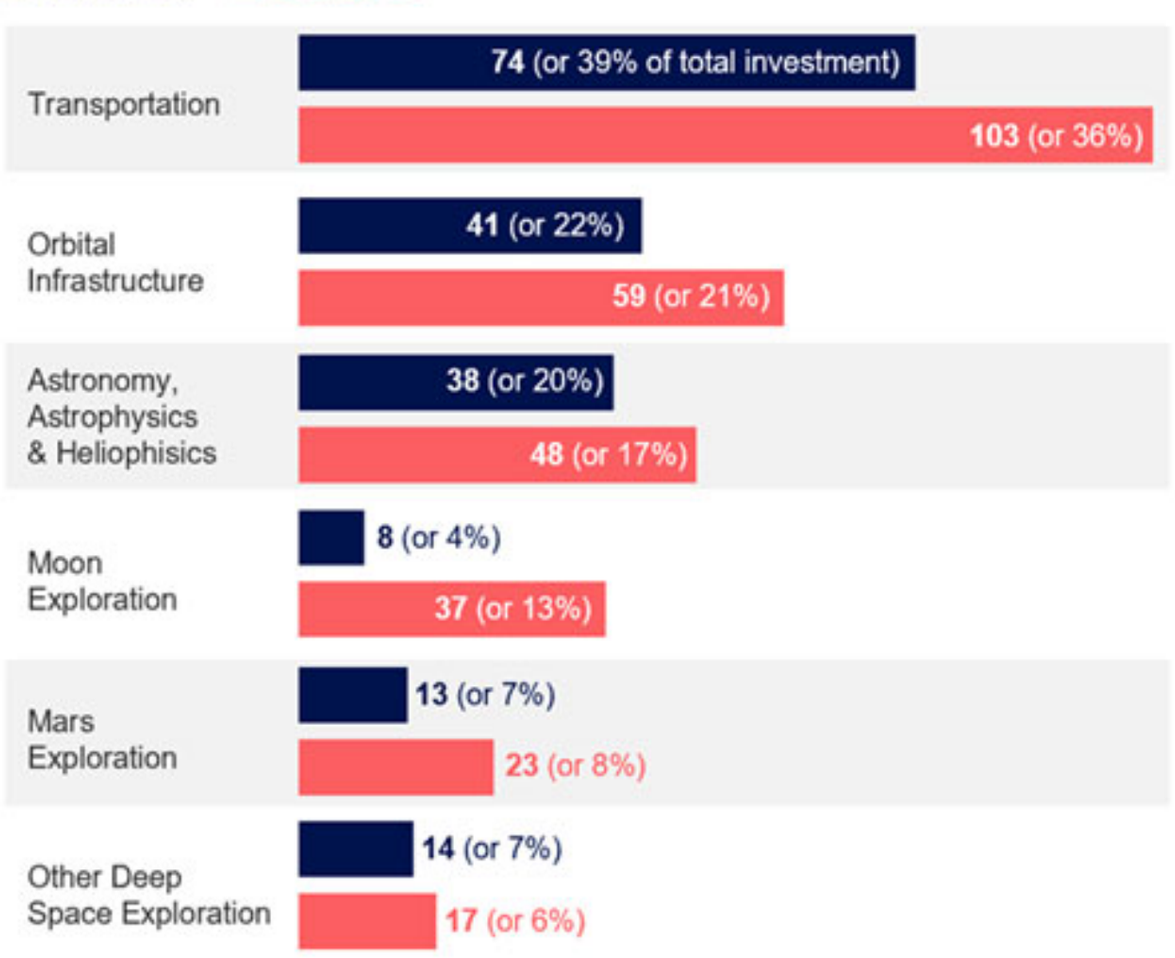
Government expenditure (b$) on space programs



Space Exploration outlook

Investments in Space Exploration by application, 2022

In billion USD

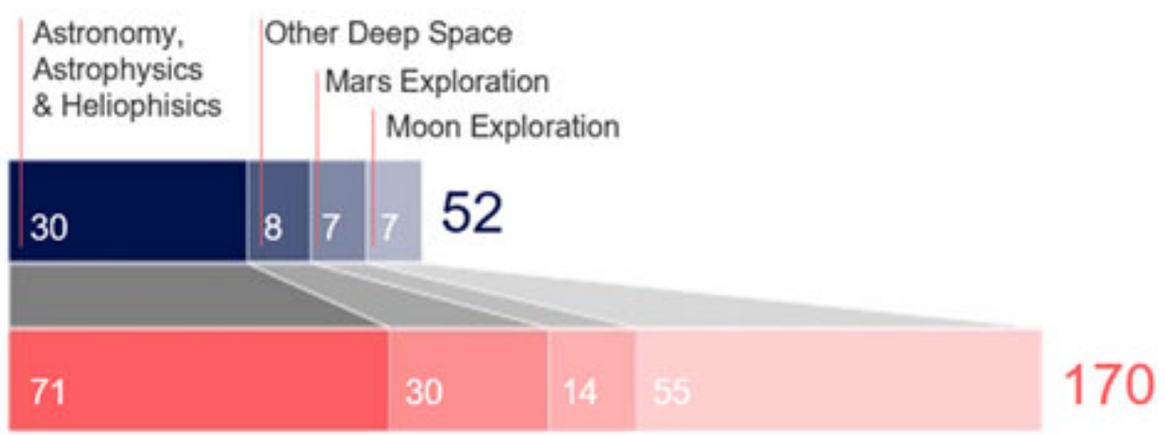


Top 5 investors

In % of total government funding in Space Exploration, 2022

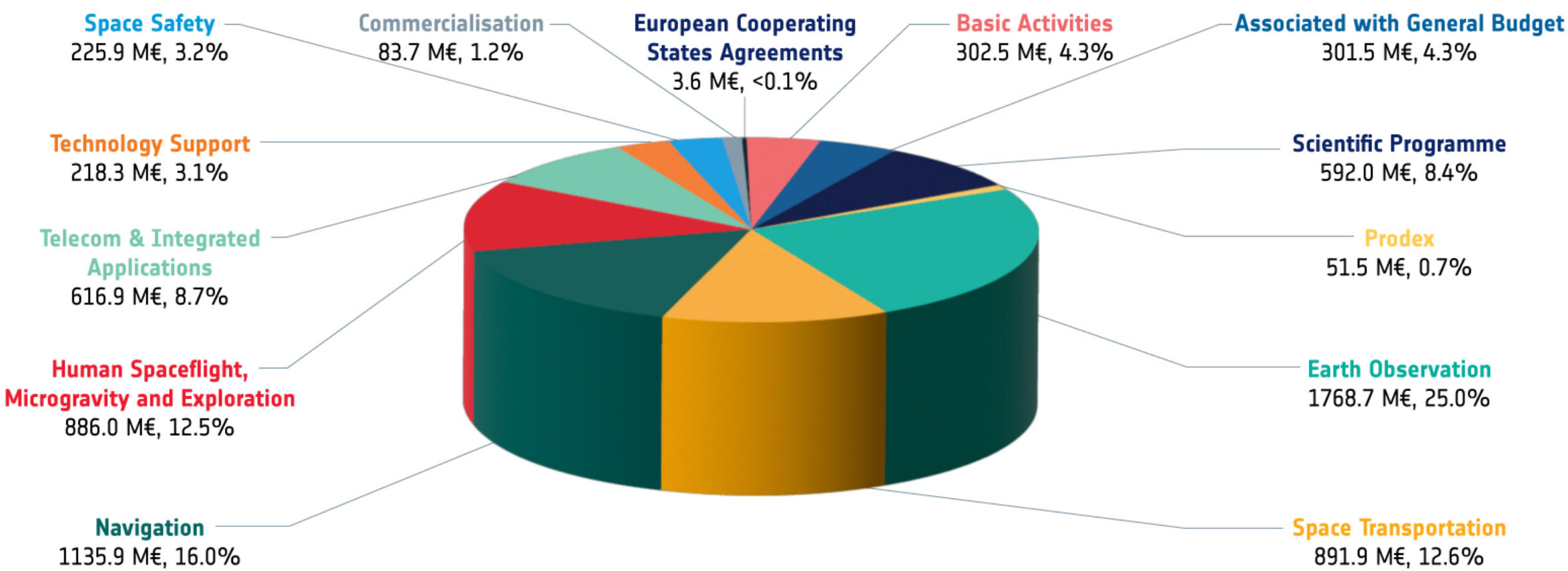
Missions launched and to be launched (>50 kg)

Number of missions



Source: Prospects for Space Exploration, Euroconsult, 2022

European Space Agency 2023 budget (7079 M€)

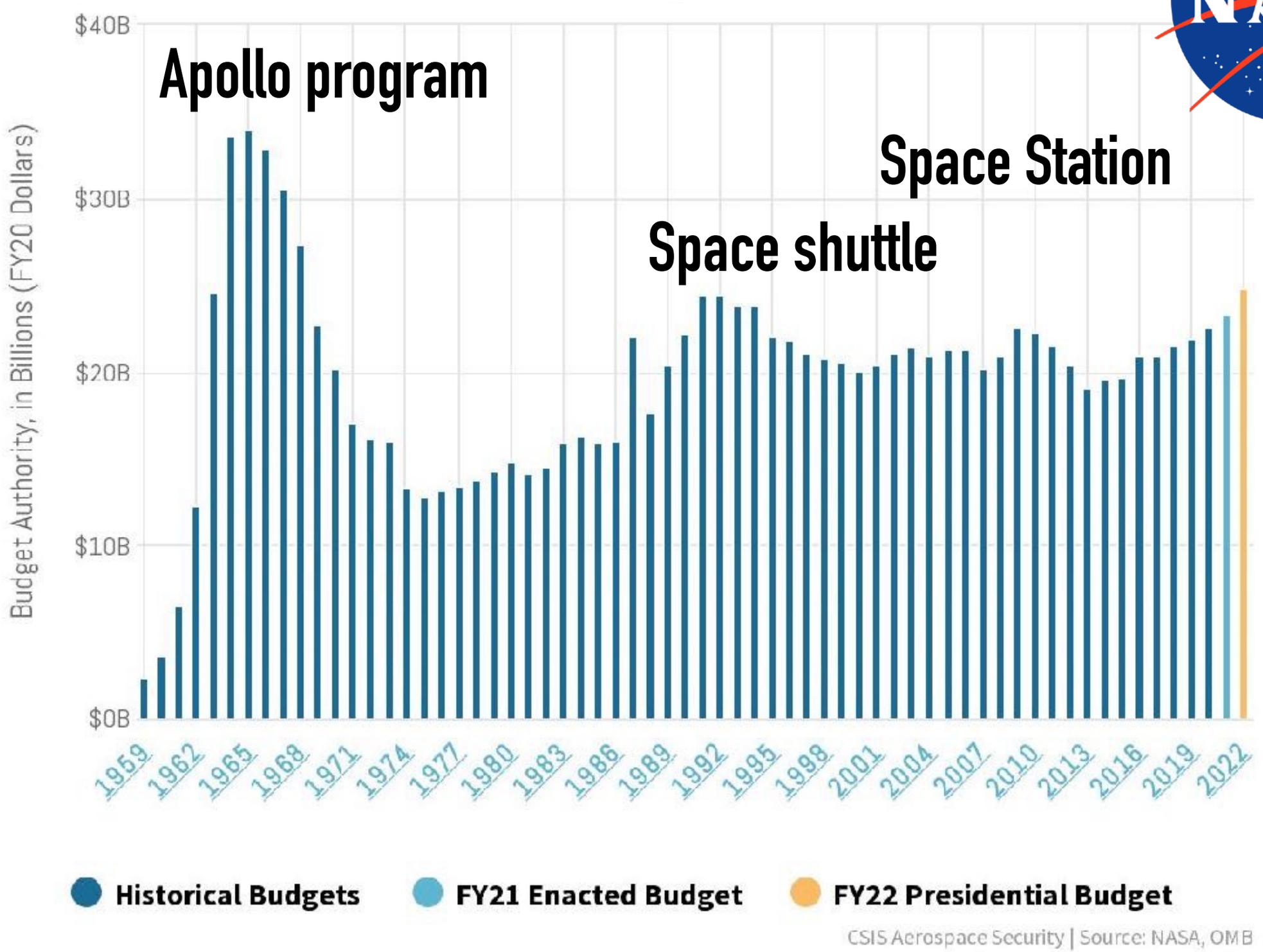


*Includes activities implemented for other institutional partners

esa

2023 CERN budget is 1387 M€

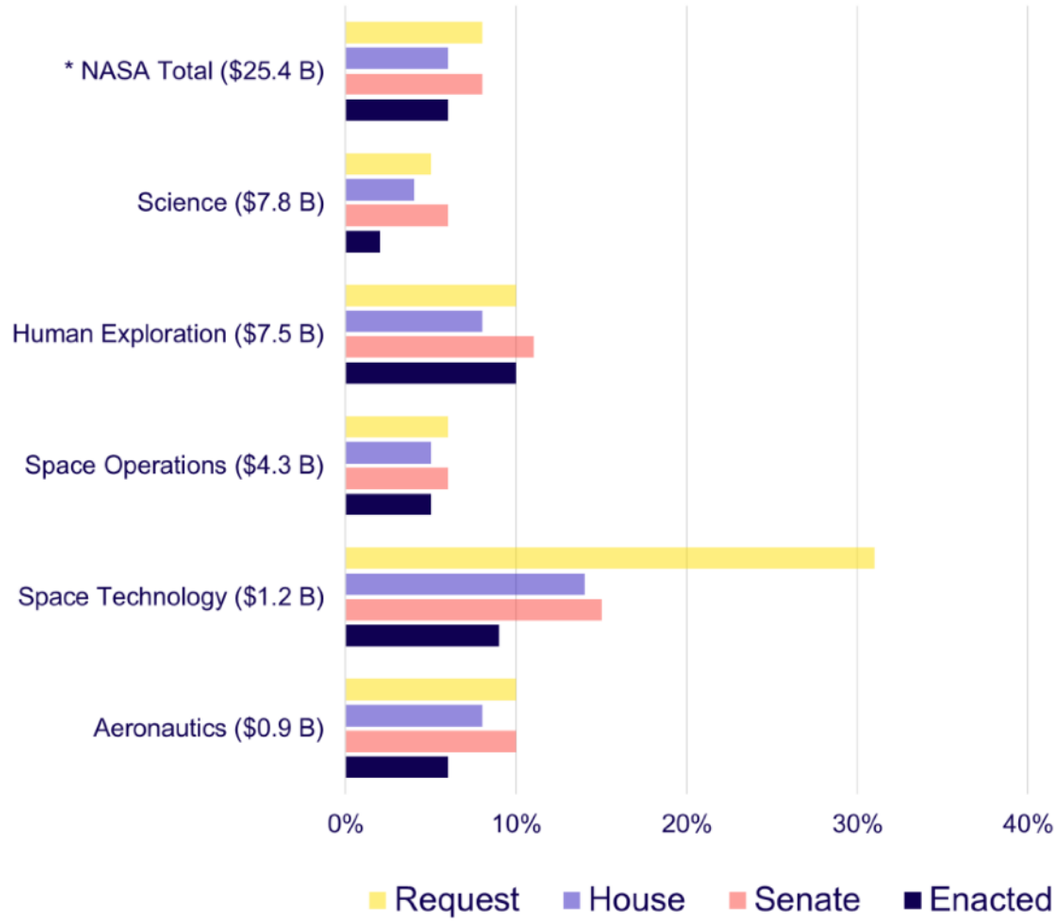
National Aeronautics and Space Administration



NASA FY23 Budget Outcomes

FY23 Appropriations: NASA

% change from FY22 enacted
$ in () are FY23 amounts

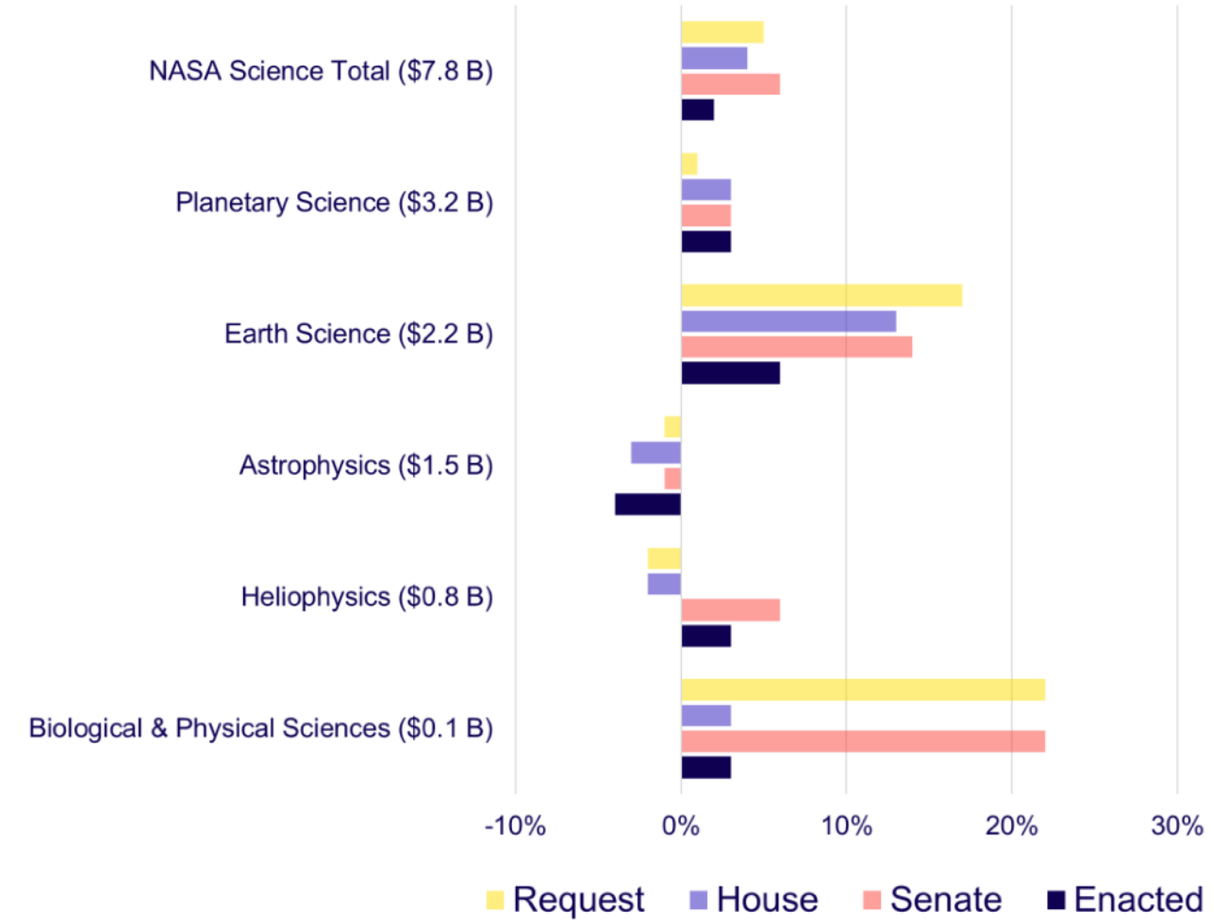


AIP

* Enacted amount includes $367 million in supplementary funding

FY23 Appropriations: NASA Science

% change from FY22 enacted
$ in () are FY23 amounts



AIP

UNITED NATIONS OFFICE
FOR OUTER SPACE AFFAIRS

ACCESS TO SPACE FOR ALL

A joint initiative to offer access to space research facilities, infrastructure and information, and to promote international cooperation in the peaceful uses of outer space.

https://www.unoosa.org/documents/pdf/Access2Space4All/AccSpace4All_Brochure_final.pdf

SDG 4 "Quality Education": Access to Space for All provides educational resources supporting the hands-on component.

SDG 8 "Decent Work and Economic Growth": Access to Space for All builds capacity for individuals to access jobs in the space industry.

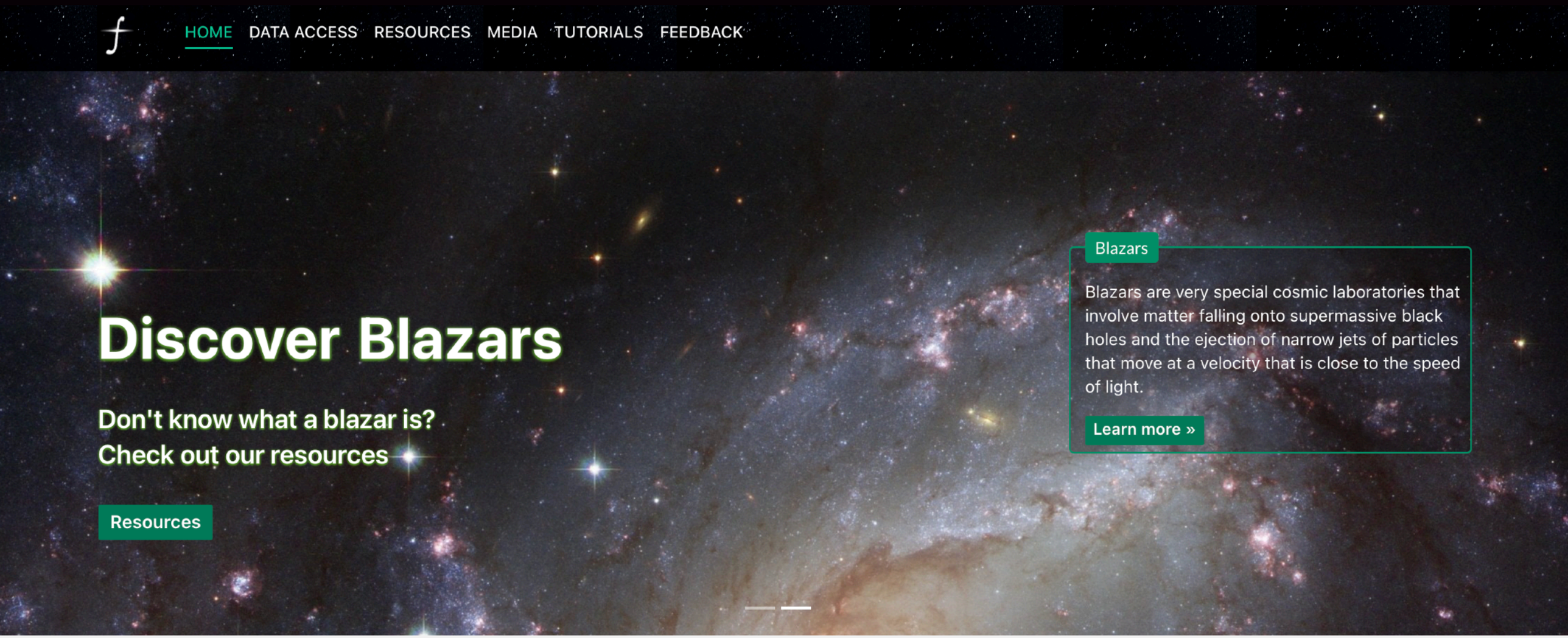
SDG 9 "Industry, Innovation and Infrastructure": Thanks to some of the hands-on opportunities of Access to Space for All, institutions create facilities that remain available once the opportunity has been completed.

Space democracy

Credits: Google Earth

Data Usability

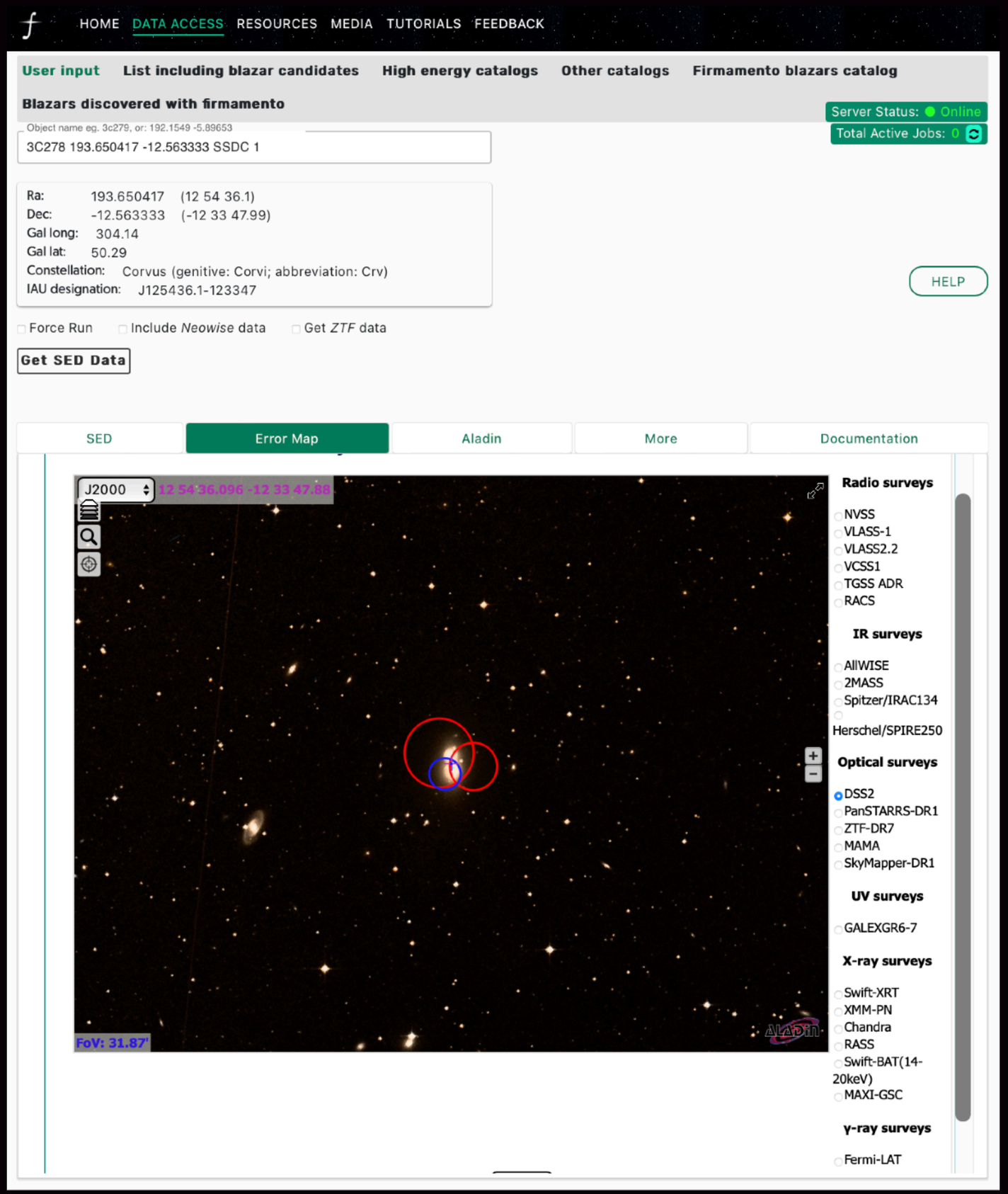
The Firmamento Project



Blazars are fascinating astrophysical sources that are playing an increasingly important role in modern astrophysics. Because of their extreme properties, such as the ability to emit highly variable radiation over a wide range of wavelengths, from radio waves to gamma-rays, blazars are believed to be powered by a relativistic jet of matter that is emitted from the vicinity of a supermassive black hole and points in the direction of the Earth. Blazars are also strongly suspected to emit neutrinos and cosmic rays, making them important targets for multi-messenger observations that can provide a more complete picture of the Universe.

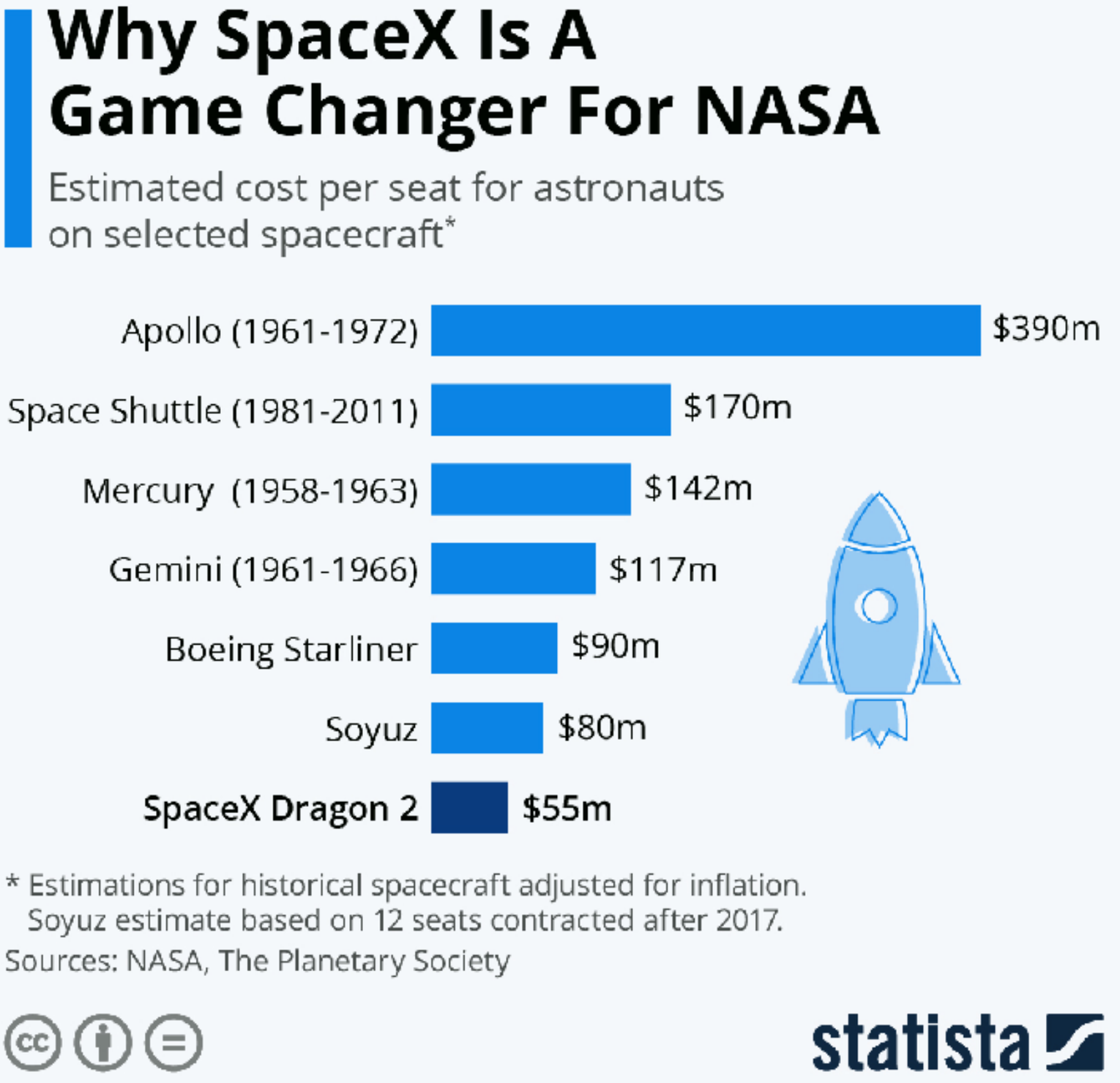
https://firmamento.hosting.nyu.edu/home

The Firmamento Project

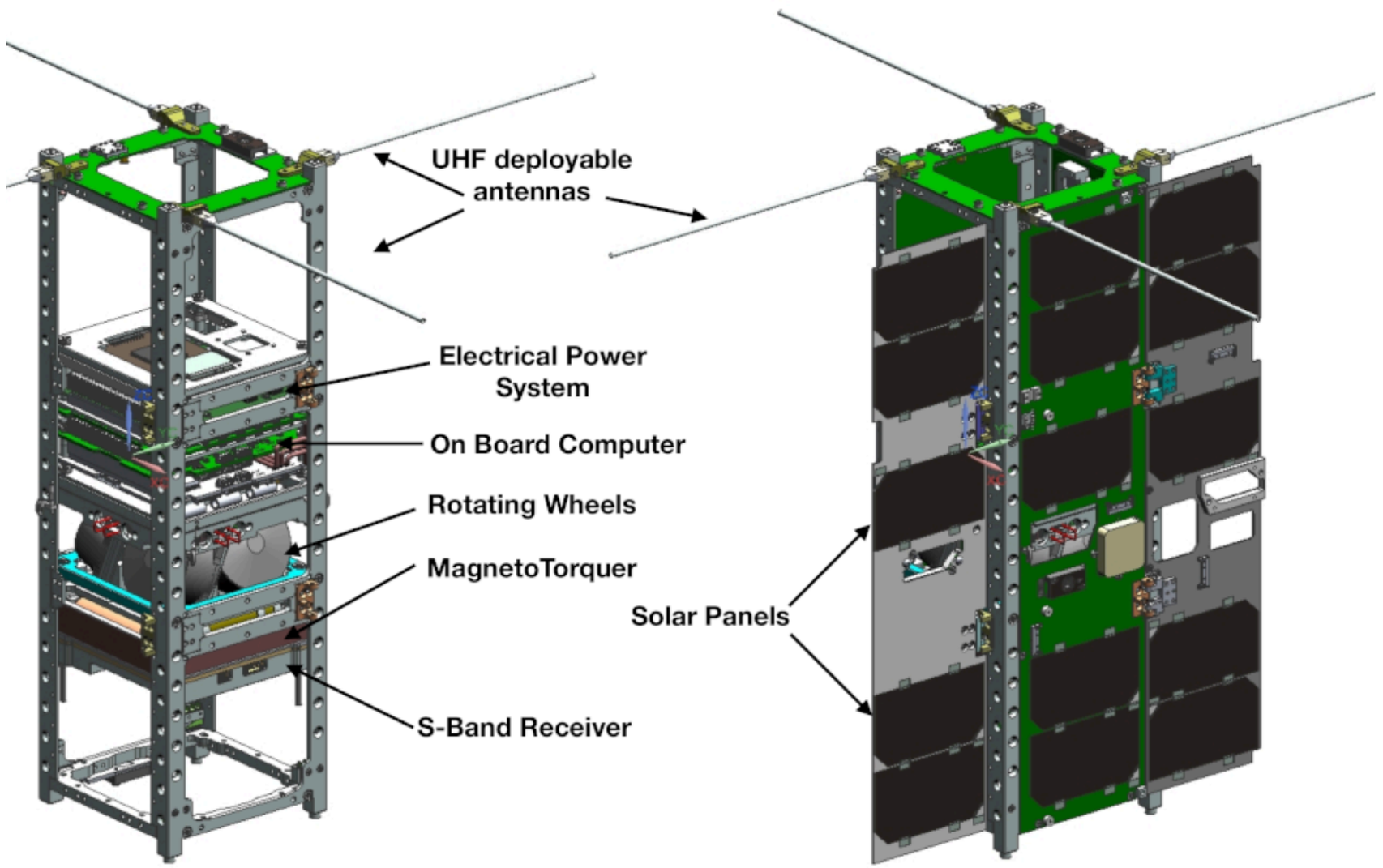


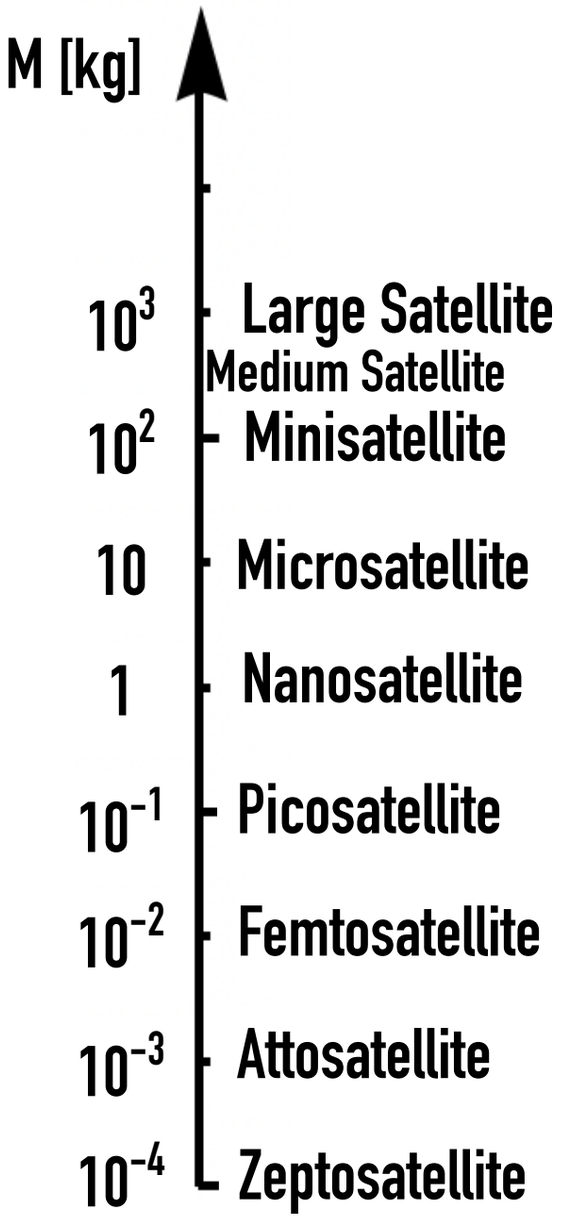
Re-thinking mission concept

The private sector joins the effort



From Multi-Million to (way) less than 1-Million space missions: The CubeSat Standard





- Modular satellite built up from 10 cm x 10 cm x 11.35 cm units (1U);
- Relatively low cost to build and launch (typically << $1M);
- Strict size and weight limits (<1.5 kg/U), and very limited power budget (a few W per U)
- Little-to-no propulsion systems.

Qarman (3U)
studying atmosphere re-entry

PRETTY (3U)
demonstrating GNSS reflectometry

M-ARGO (12U)
demonstrating asteroid rendezvous and identifying in-situ resources

SIMBA (3U)
monitoring climate variables

RACE (2x6U)
demonstrating rendezvous and docking

GOMX-4b (6U)
demonstrating constellation technologies

CUBESPEC (6U)
stellar spectroscopy from space

GOMX-5 (12U)
demonstrating next generation constellation technologies

HERA CUBESATS (2x6U)
observing asteroid deflection assessment (GSTP/S2P)

GOMX-3 (3U)
demonstrating new platform technologies

RadCube (3U)
measuring space radiation and magnetic field

LUMIO & VMMO (2x12U)
measuring lunar surface impact hazards & in-situ resources

PICASSO (3U)
studying the atmosphere

Sunstorm (2U)
measuring X-Ray fluxes

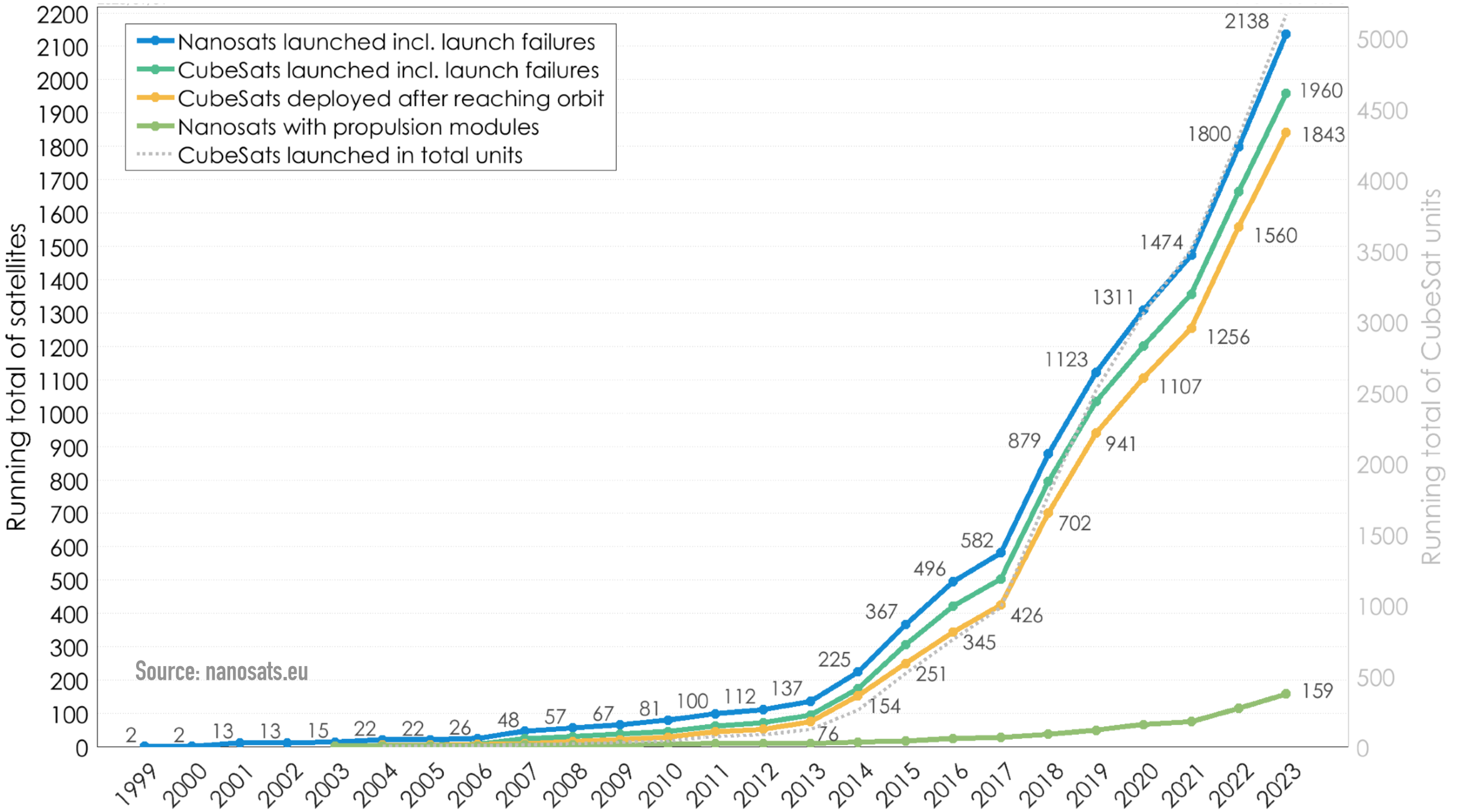
www.esa.int

→ ESA'S TECHNOLOGY CUBESAT FLEET

Funded in GSTP Fly

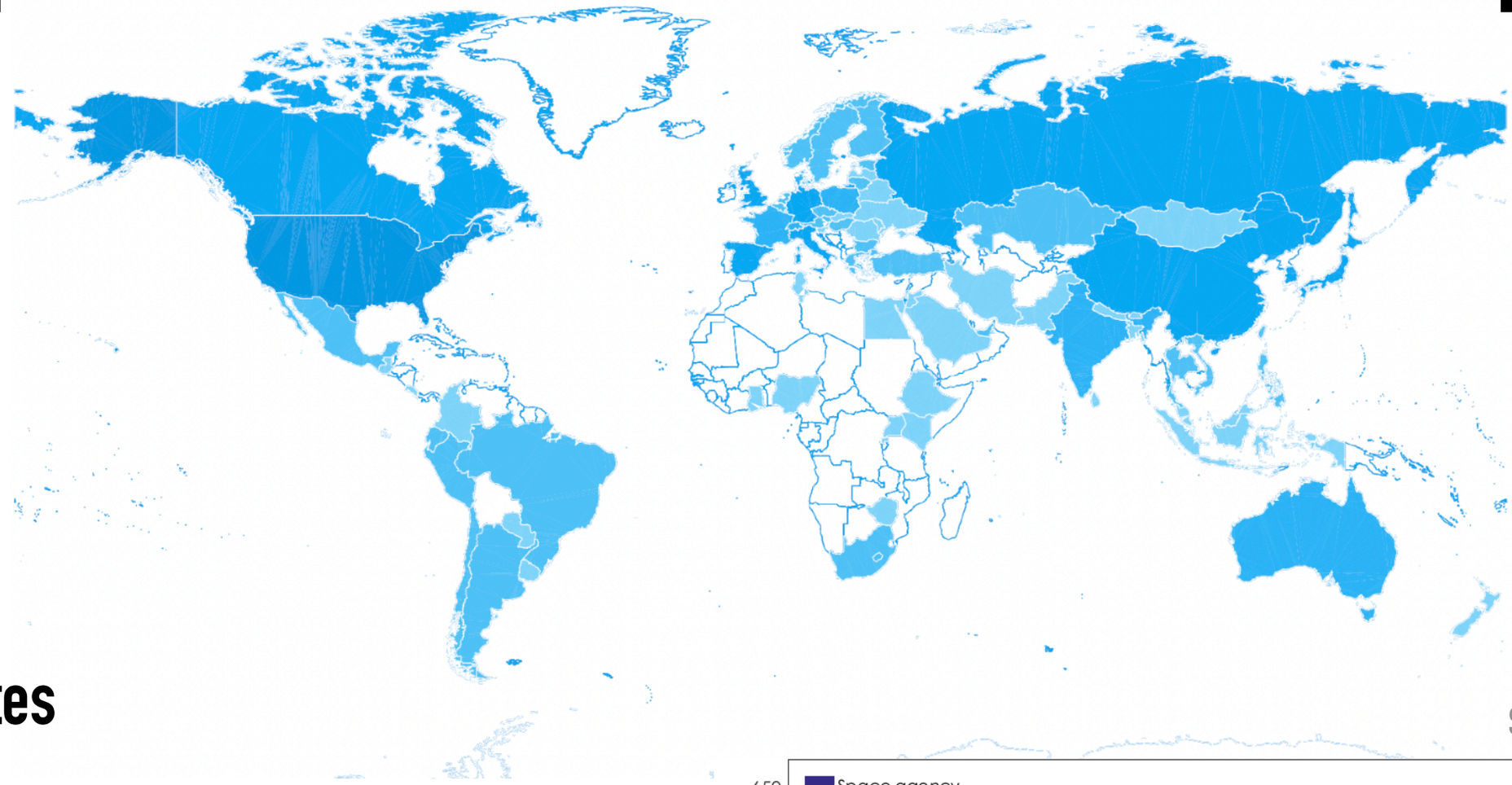
European Space Agency

Launched nanosatellites* versus year

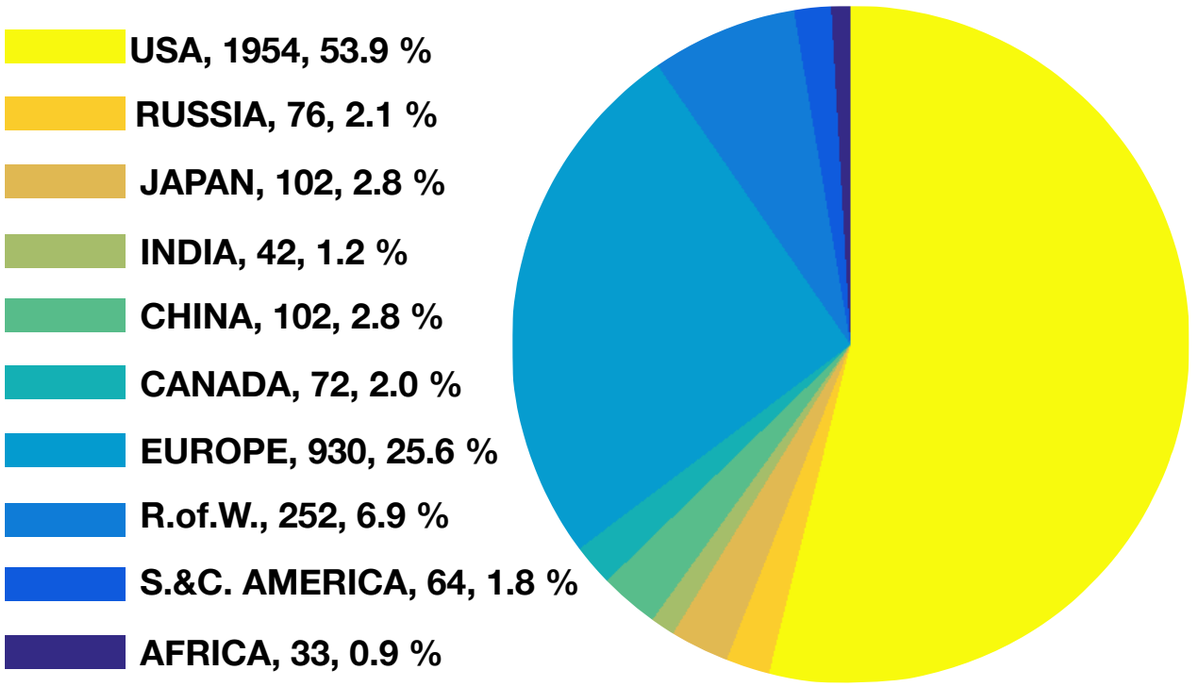


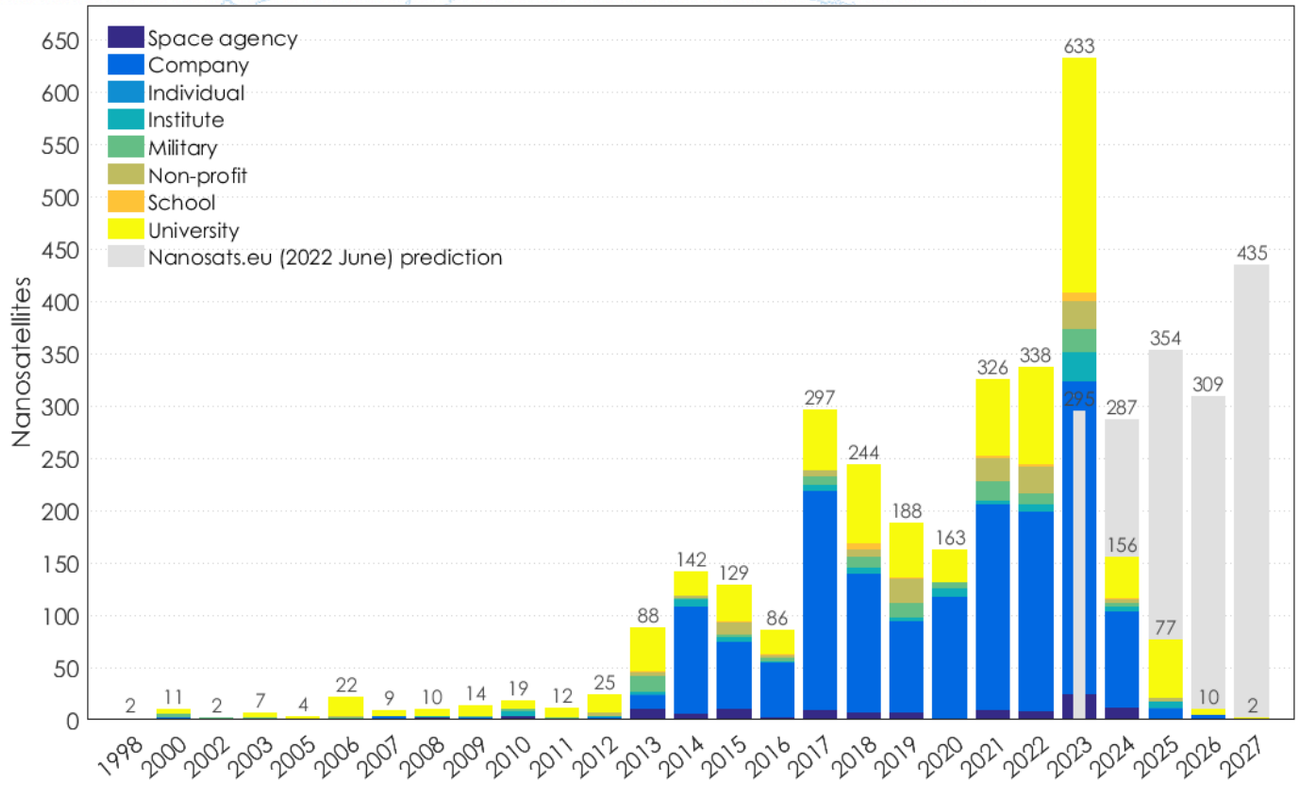
*** the category includes smaller than CubeSat platforms**

The path towards a more democratic use of Space



Launched nanosatellites



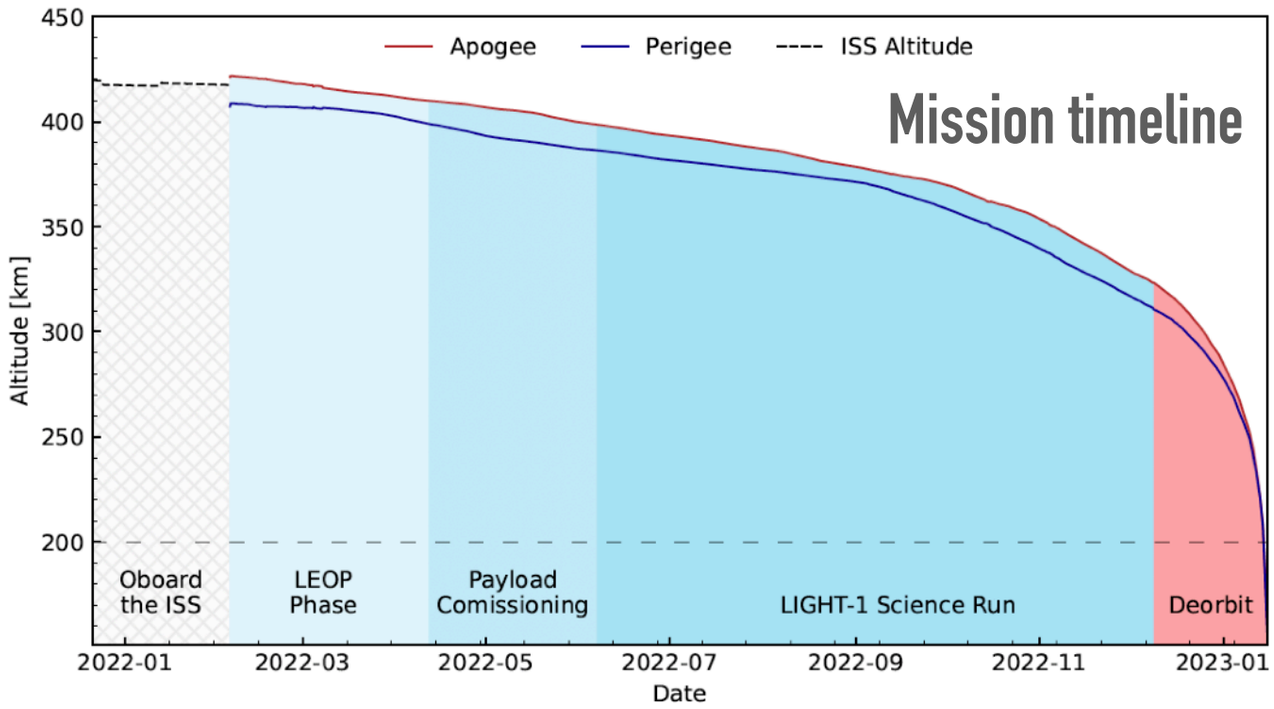


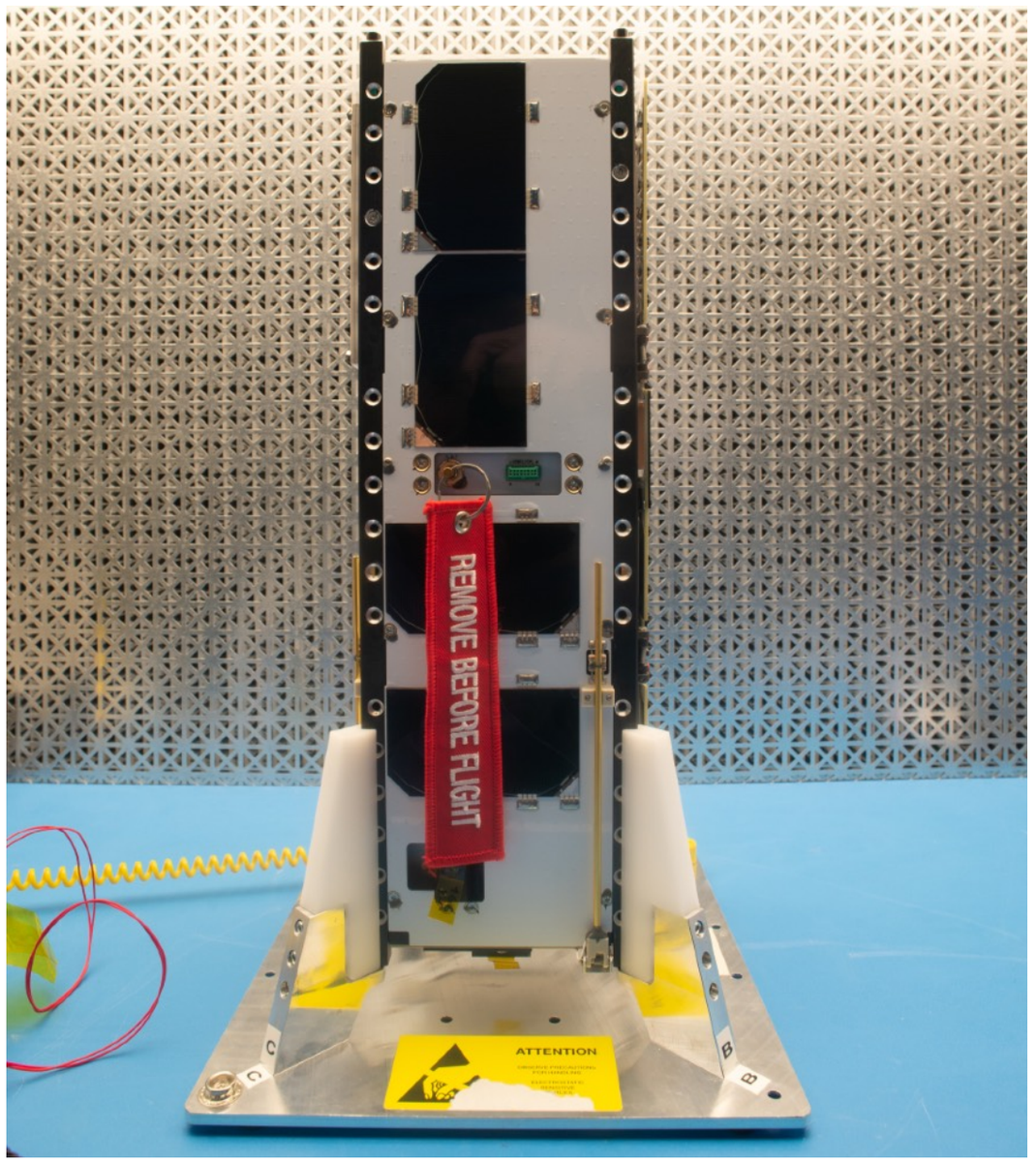
Source: nanosats.eu

The Scientific Payload of LIGHT-1: A 3U CubeSat Mission for the detection of Terrestrial Gamma-Ray Flashes

الحمولة العلمية لضوء - ١ : قمر صناعي مصغر من ثلاث مكعبات مخصص لكشف ومضات جاما الأرضية

- To survive the extreme stress of a SpaceX Falcon9/Dragon launch
- To be on time (from PDR to IN-ORBIT operations < 3 y. + COVID19)
- To measure the particle rate at LEO (ISS orbit, 51.6^{o})
- To study TGFs at sub-microsecond timescale
- To measure the activity in the South Atlantic Anomaly region
- To space-qualify the technology and prove the detection concept





جامعة نيويورك أبوظبي
NYU ABU DHABI
جامعة خليفة
Khalifa University
NSSA
الهيئة الوطنية لعلوم الفضاء
National Space Science Agency
وكالة الإمارات للفضاء
UAE SPACE AGENCY
United Arab Emirates
JAXA

Discovering TGFs

1969 - 1972
Vela 5A/B and 6A/B
Detection of 16 GRBs

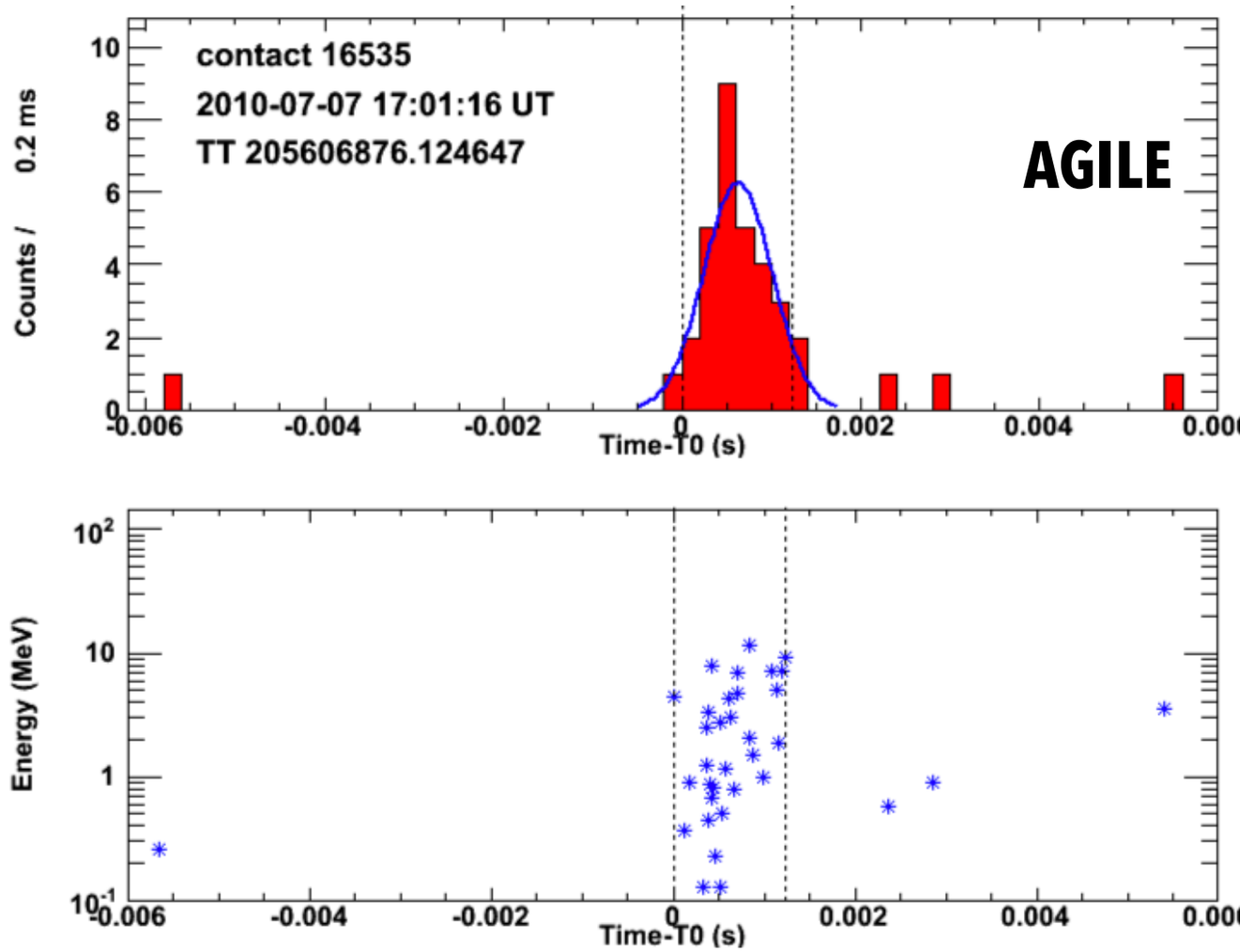
1991 - 2000
BATSE-CGRO
Detection of 2704 GRBs + a handful of high energetic short burst from ground (TGFs ?)

2007 - present
AGILE
Detection of TGFs

2008 - present
FERMI
Detection of TGFs

2018 - present
ASIM
Optimised to detect TGFs

2020 - 2020
TARANIS
VEGA 17 launch failure



The Science of a TERRESTRIAL GAMMA RAY FLASH

Varying Energy from 10 keV up to several tens of MeV

Fast events (hundreds of μs)

Little is known about the structure of TGFs

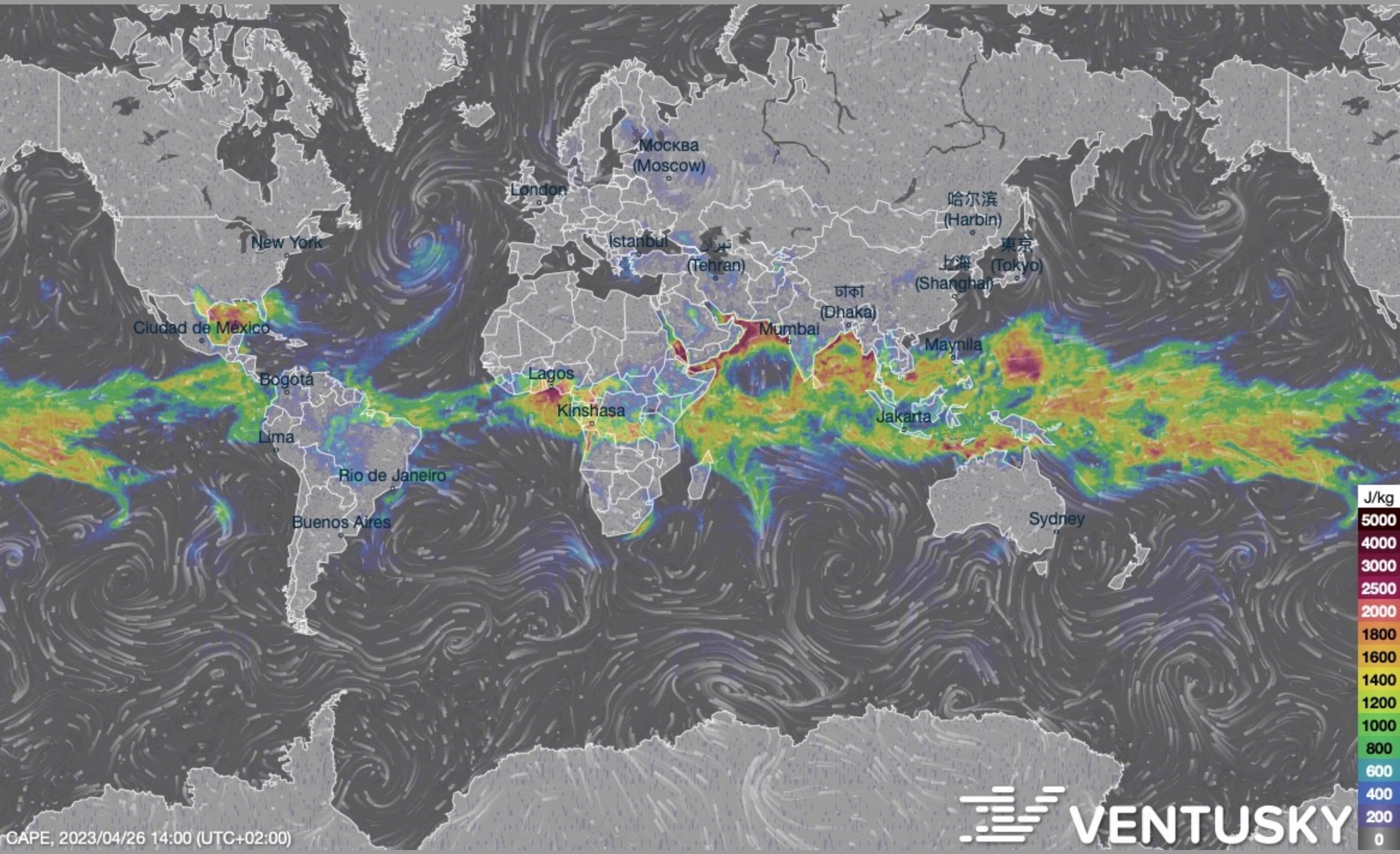
Fast electrons → lose energy in form of gamma rays in the atmosphere

World's most powerful natural particle accelerators

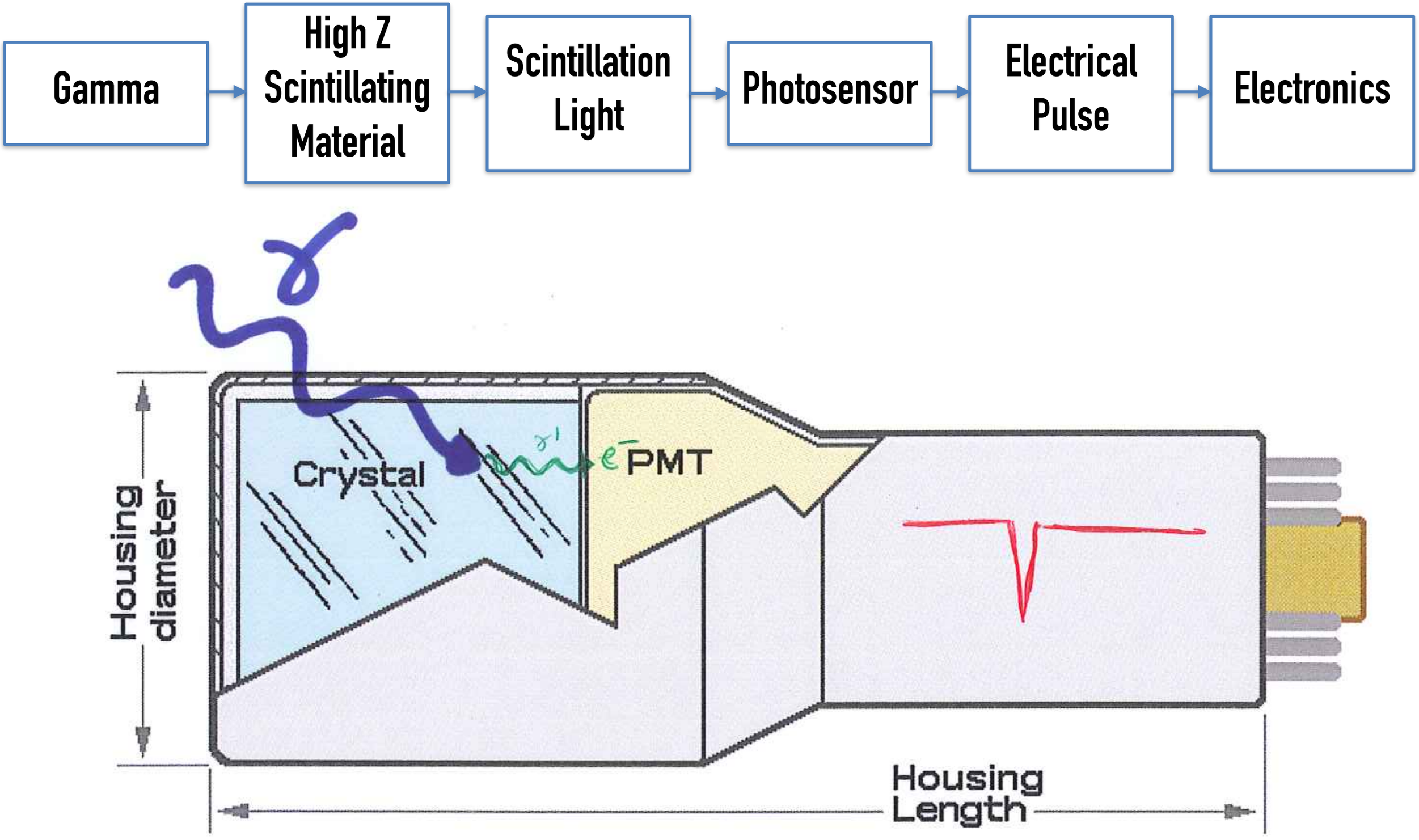
Terrestrial Gamma-Ray Flashes (TGF): an introduction

Credit: NASA

Daily Thunderstorm Distribution



How to detect gamma-rays



LIGHT-1 Payload: Design Characteristics

Parameter	Value
Detection Energy Range	~ 20 keV – 3 MeV
Time resolution	~ 100 ns
Absolute Timing	< 4 µs
Spectral Resolution	15% @ 20 keV, < 5%@ 511 keV
Effective Area	40 cm^2 @ 50 keV, 20 cm^2@ 511 keV
PMT Payload Size (Fits in 1U)	74 x 74 x 86 mm
SiPM Payload Size (Fits in 0.75U)	74 x 74 x 68 mm
PMT Payload Weight	1,085 g
SiPM Payload Weight	966 g
Power Consumption	< 5.9 W average
Data Budget	50 MB/day
Operational Temperature Range	Between –30° C to 55° C
Survival Temperature range	Between –40° C to 60° C

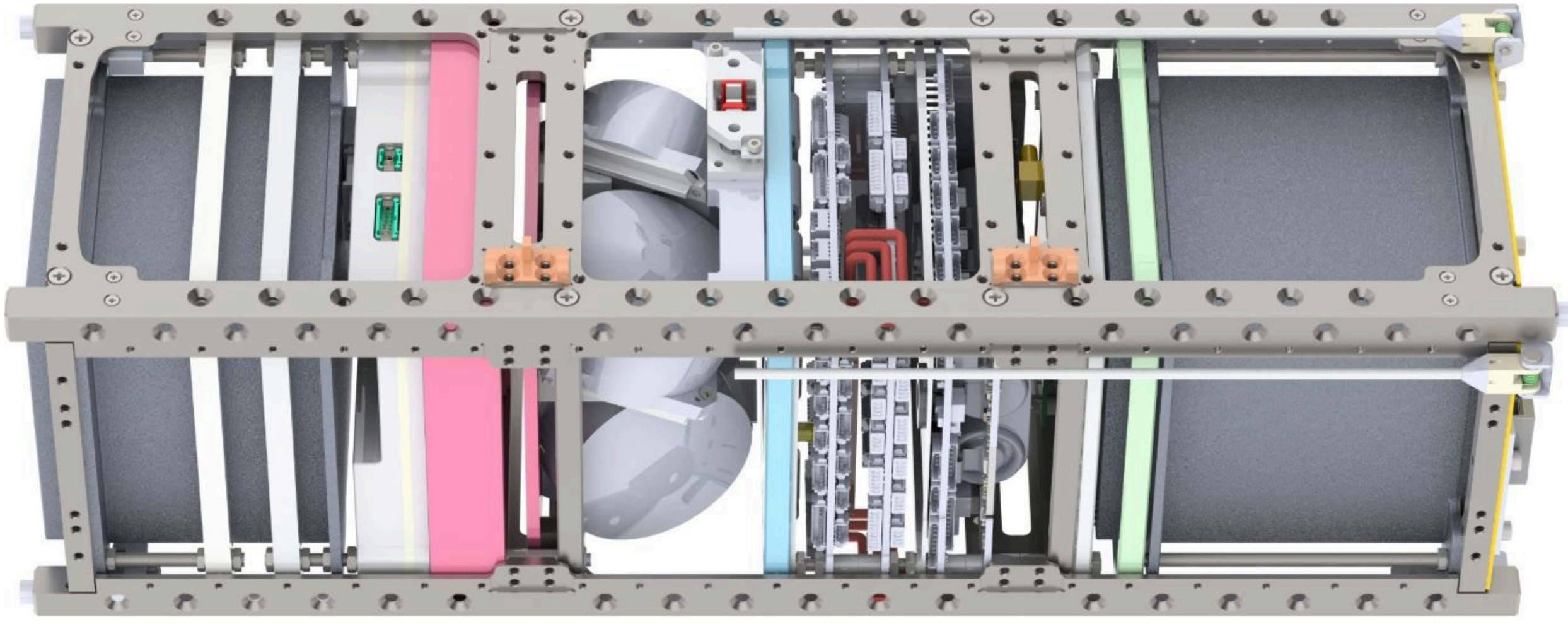
LIGHT-1 Satellite

SiPM/MPPC payload

Magneto Torquer

On Board Computer

PMT payload



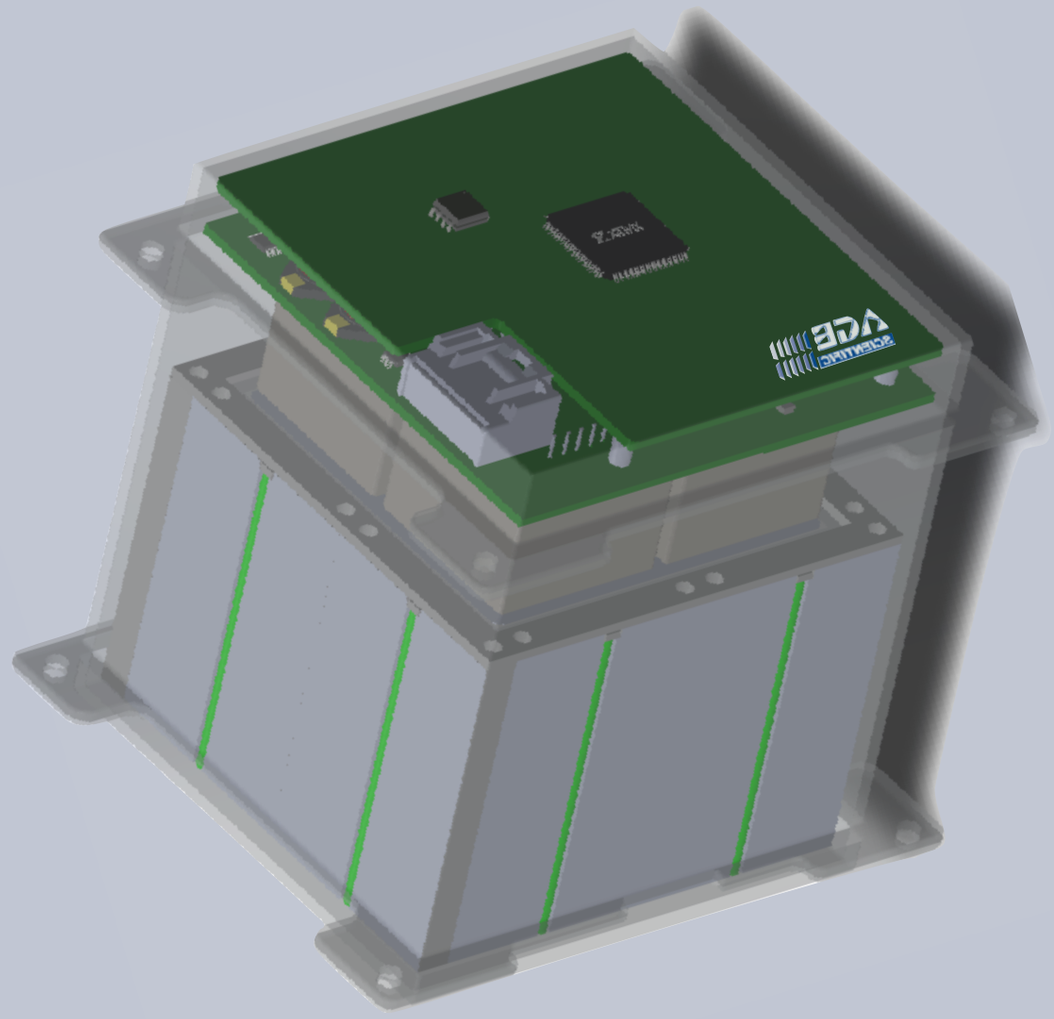
S-Band Receiver

Rotating wheels

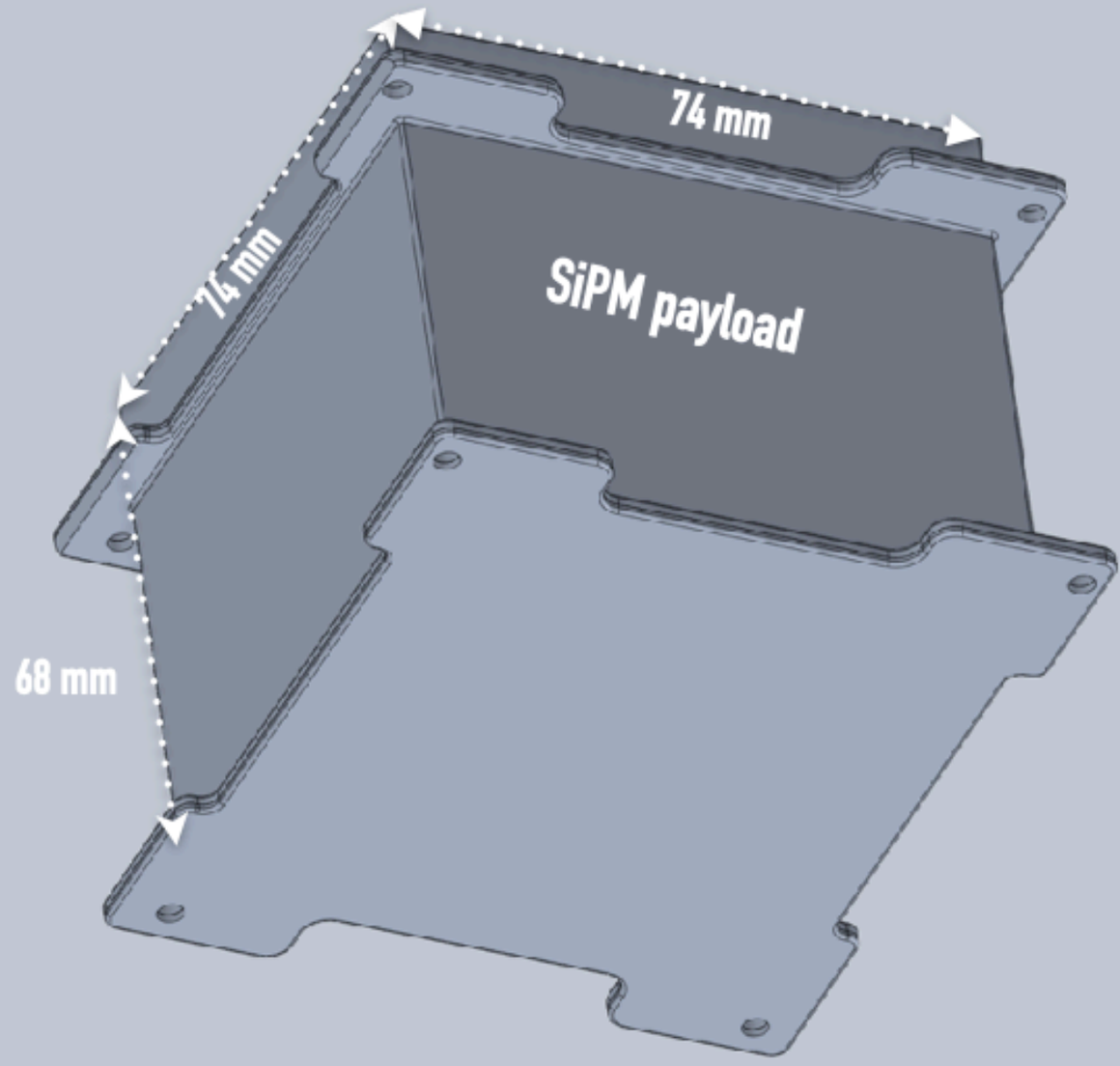
Electrical Power System

UHF deployable antenna

3D model of the LIGHT-1 payload

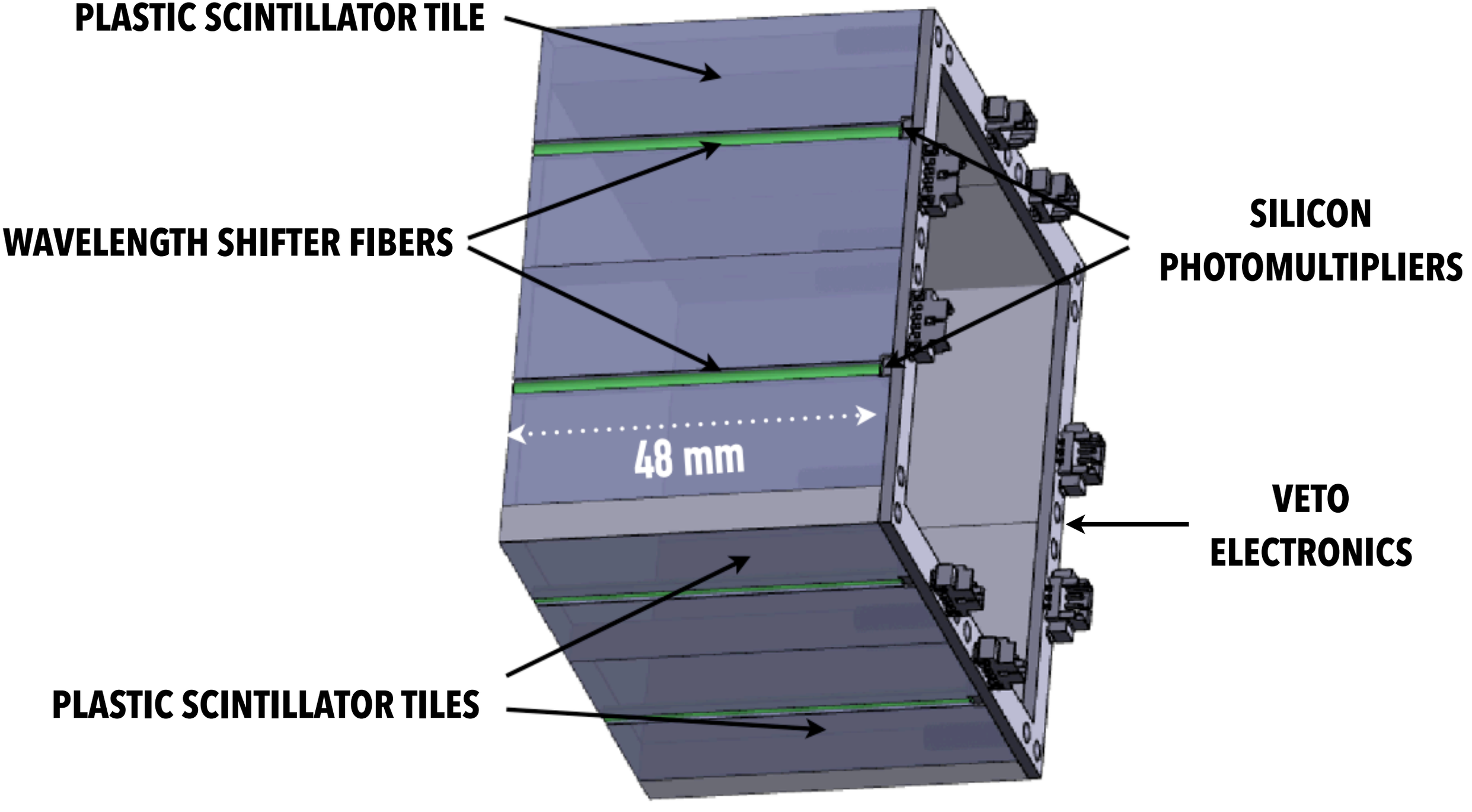


M = 1,185 g

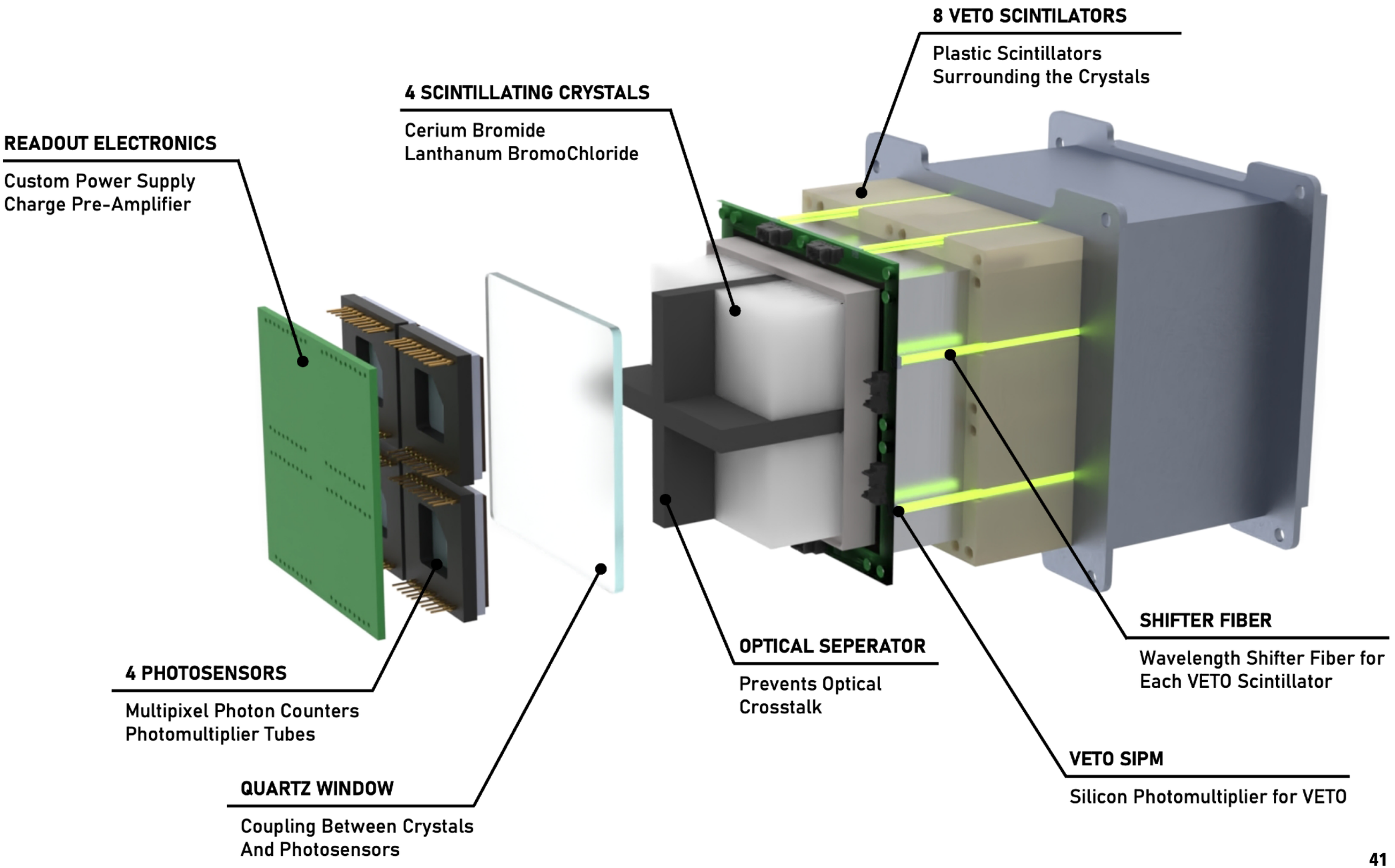


M = 966 g

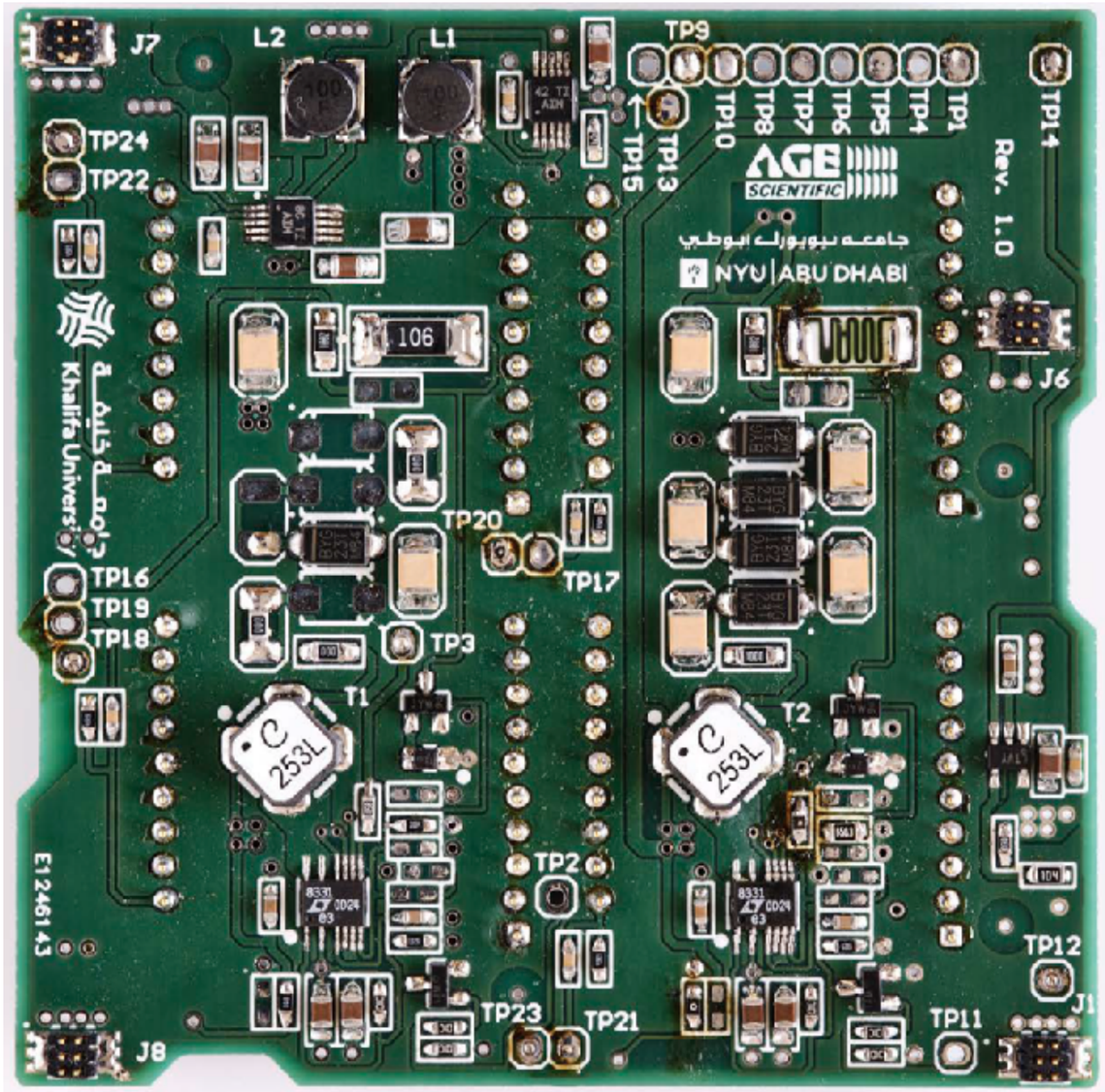
The LIGHT-1 VETO to reject charged particle induced events

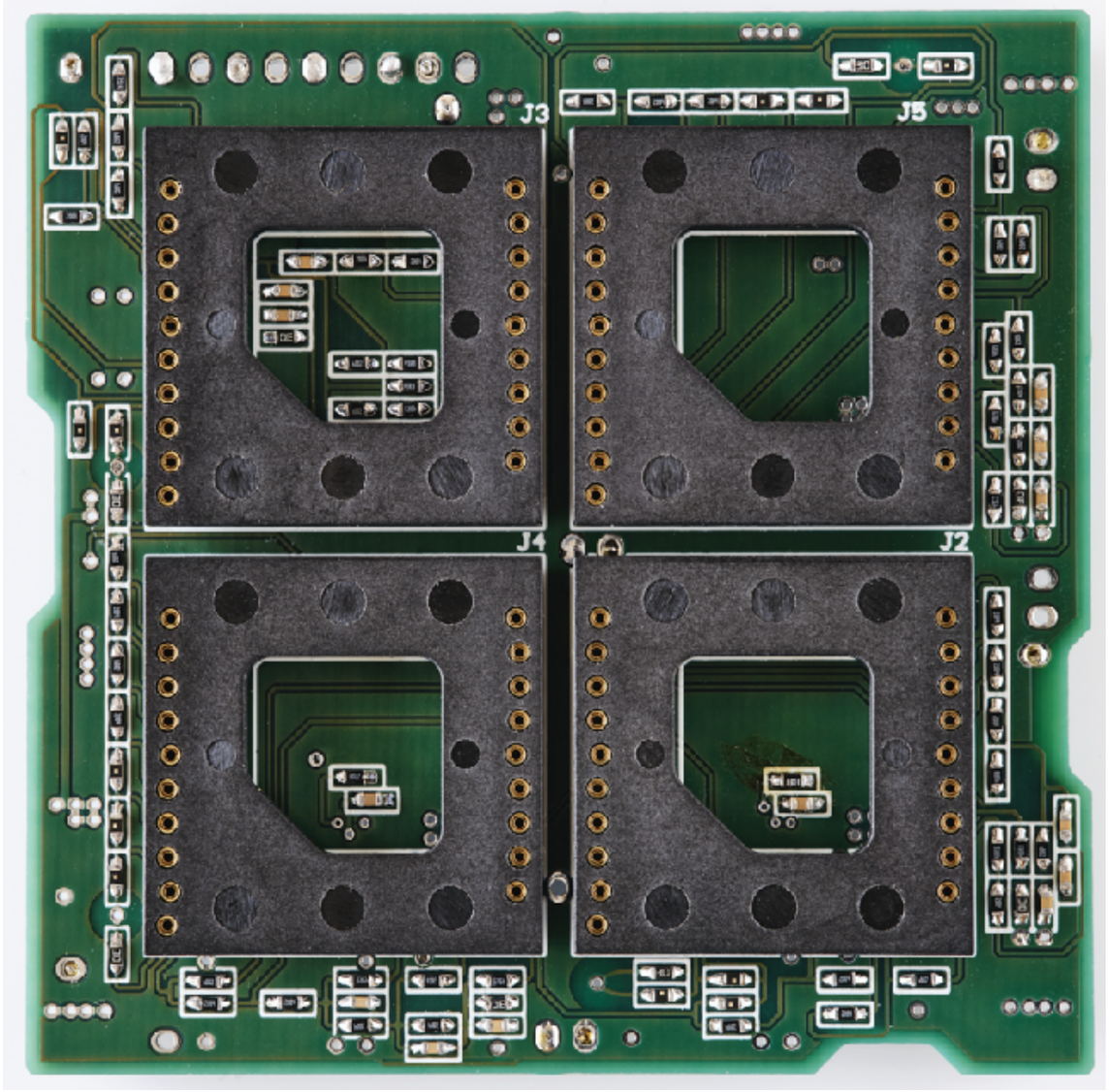


The LIGHT-1 payload concept



Proximity Electronics (Power Supply)

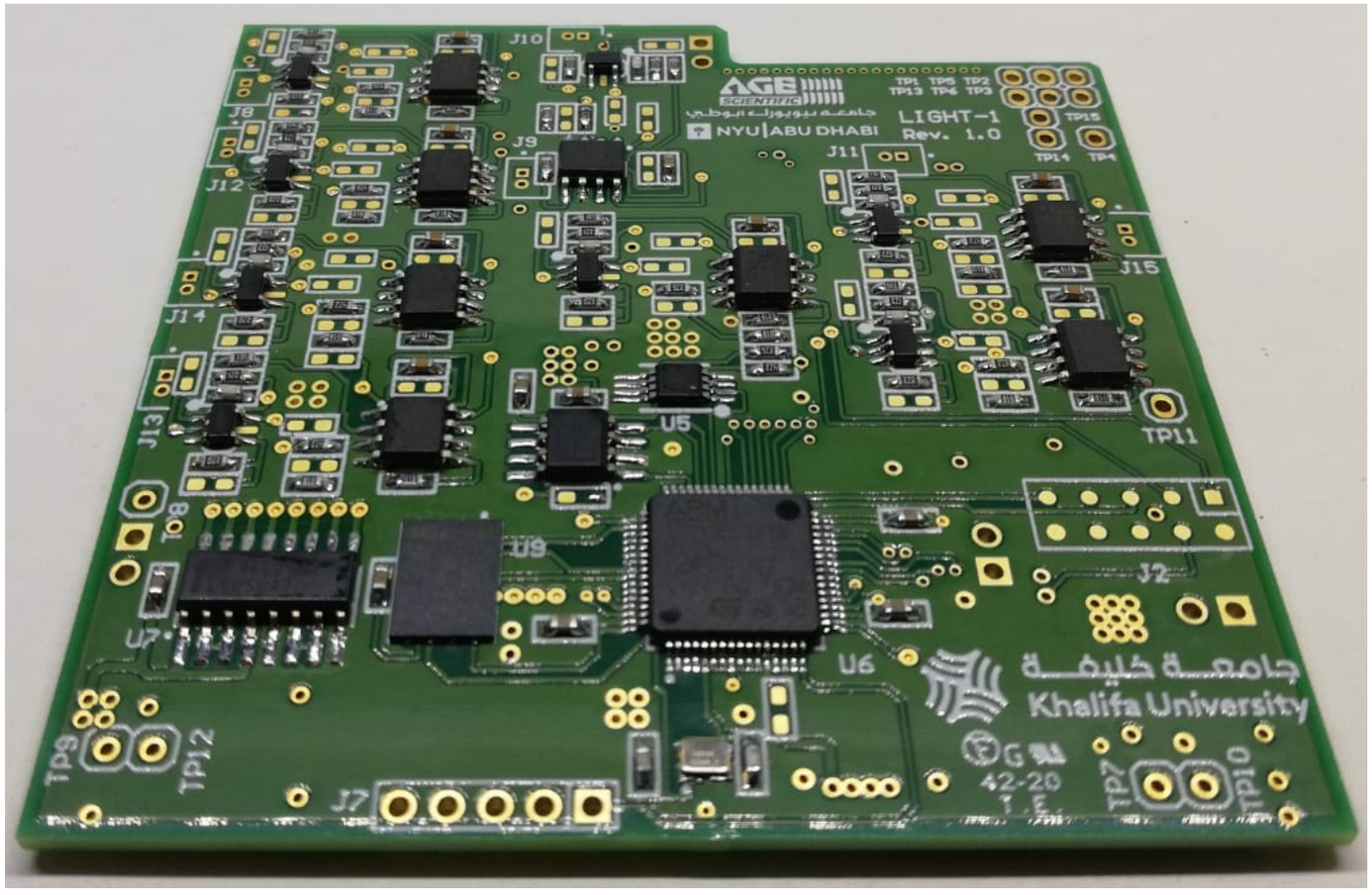


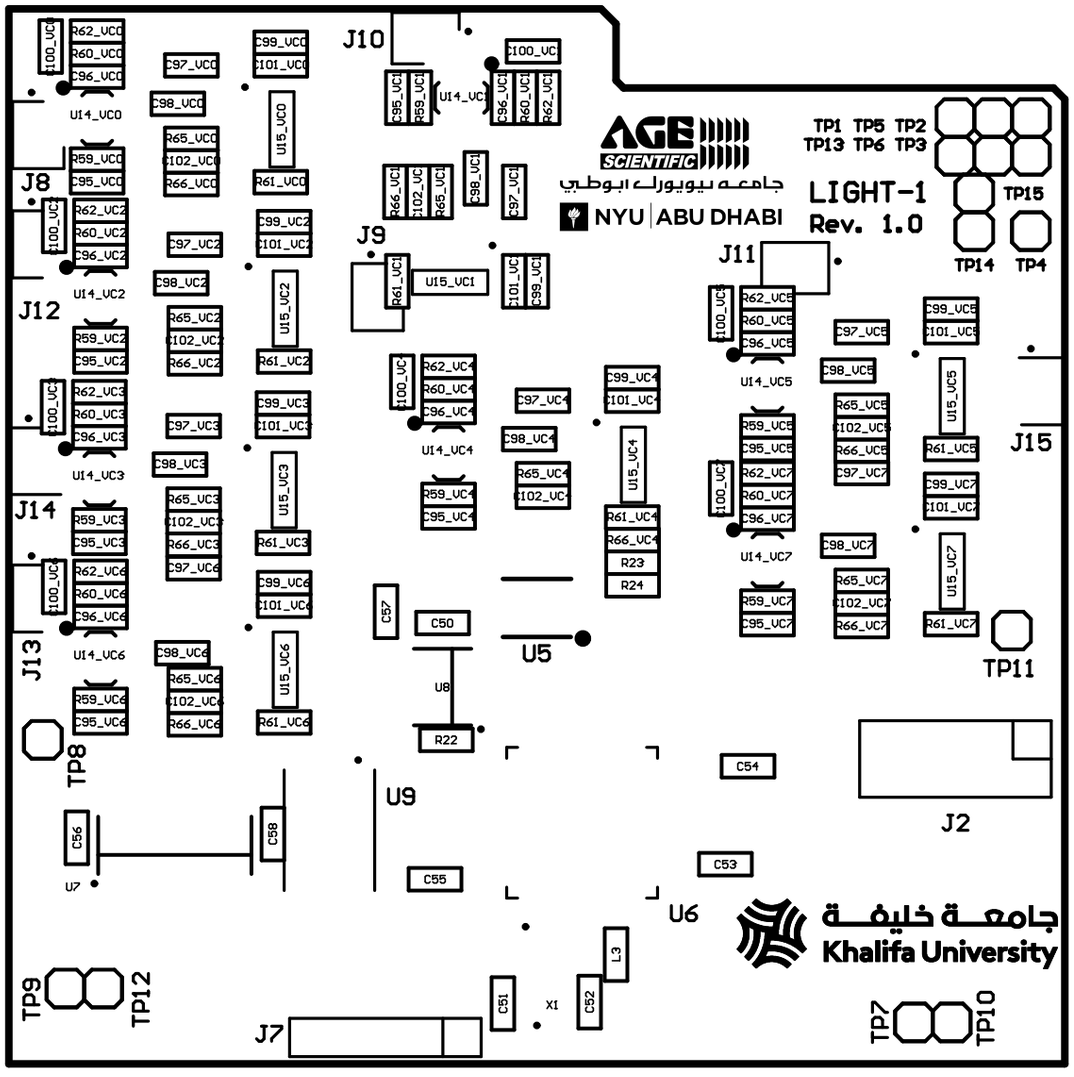


Main Characteristics:

- Operation and Readout of 4 photosensors (each) + VETO SiPMs (8)
- Based on C.O.T.S. (Components off-the-shelf);
- Detector Voltage Biasing (PMT/SiPM and VETO). PMT: -600 V to -750 V; SiPM: 25 V to 62 V; VETO: 25 V to 38 V;
- Voltage Inputs: +3.3 V, -3.3 V, +5 V;
- Weight: 27 g (SiPM) – 35 g (PMT)

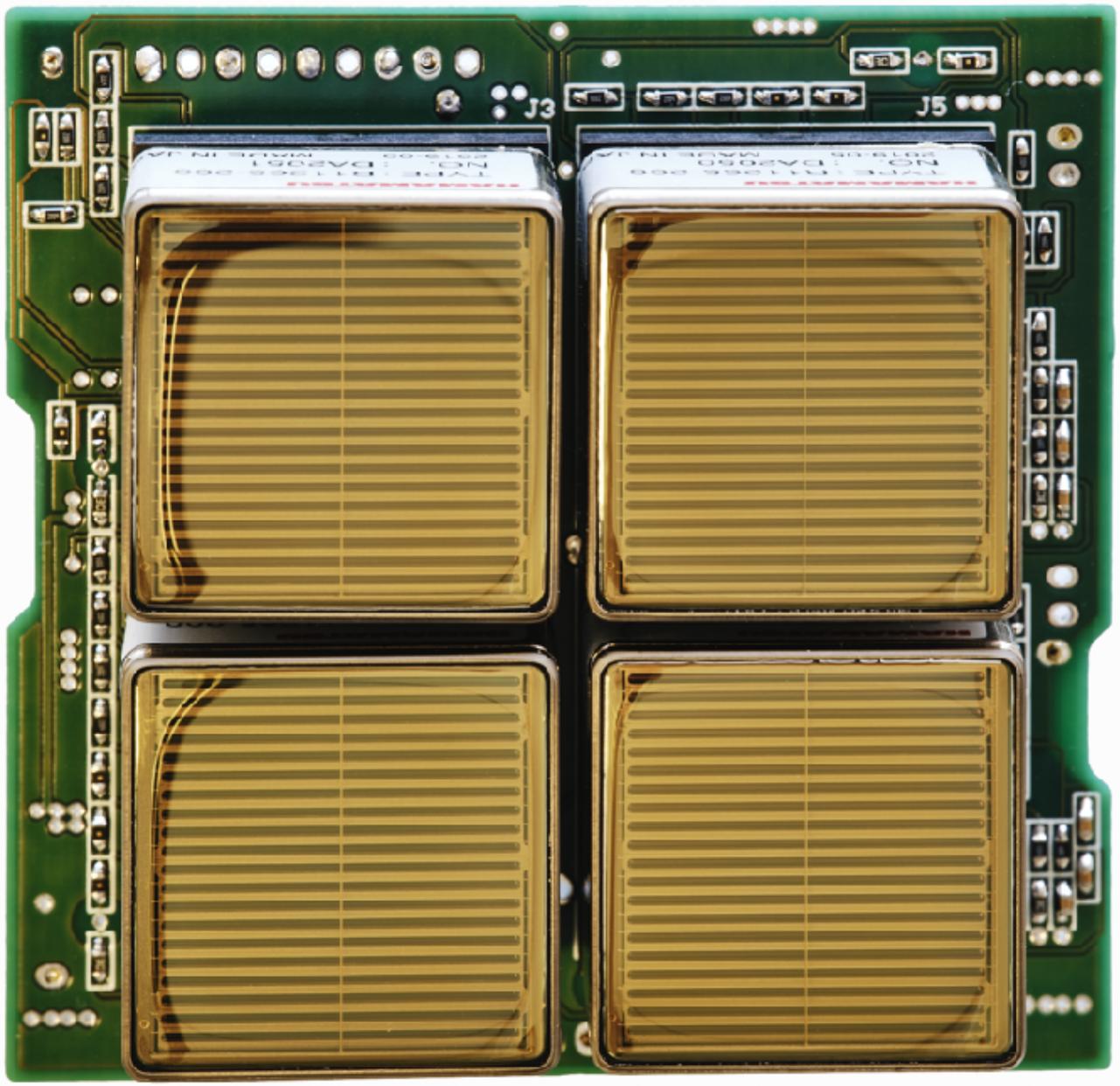
Proximity Electronics (CTRL & FE board)



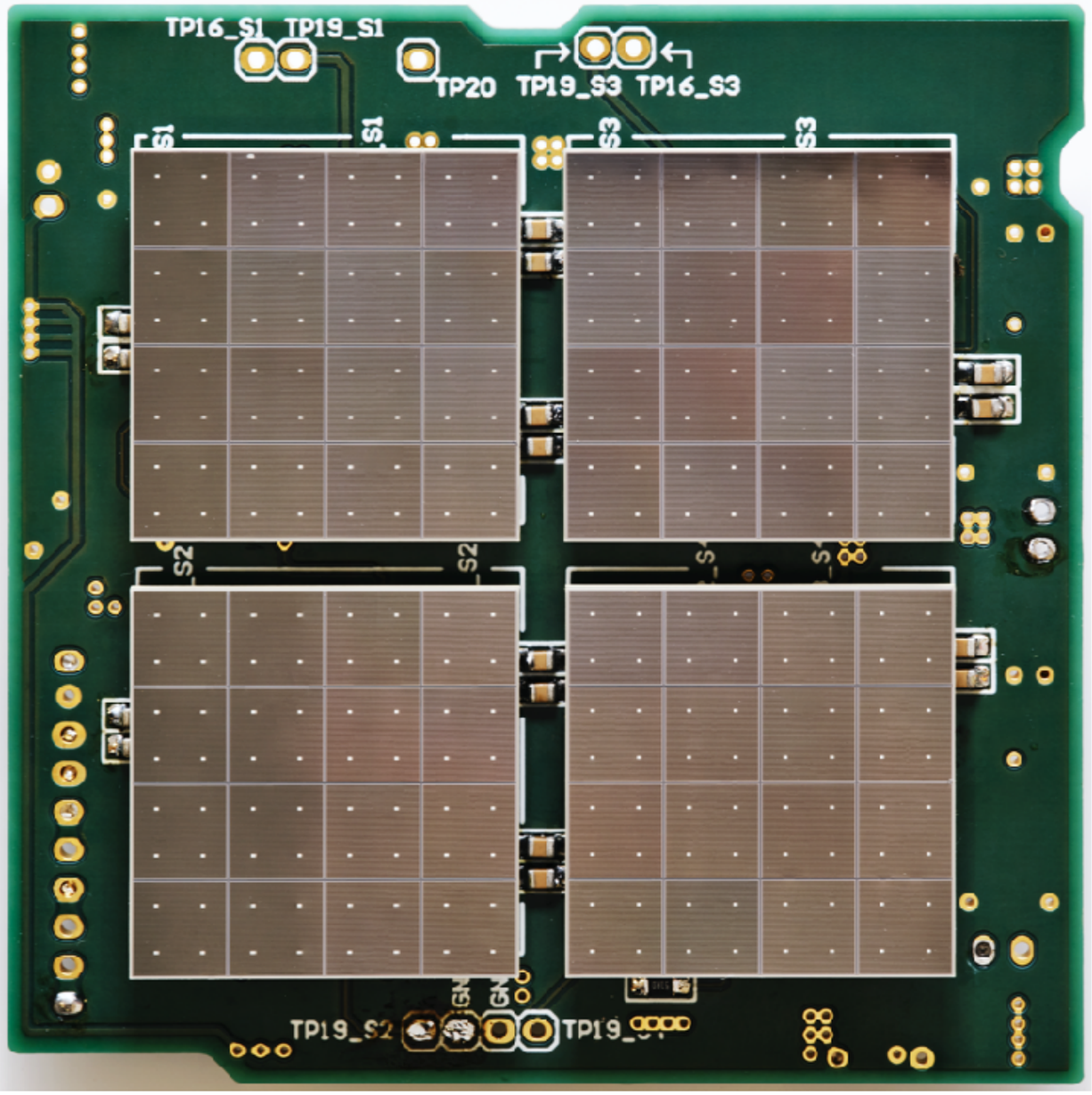


- Payload operations;
- Signal conditioning;
- Signal Charge extraction (ADC+FPGA);
- CubeSat Software Protocol (CSP) compliant ;
- Event builder;
- Time stamping;
- Preprocessing and data priority assignment;
- Temperature monitoring;
- Voltage Input: +3.3 V;
- Weight: 27 g.

The photosensor Arrays

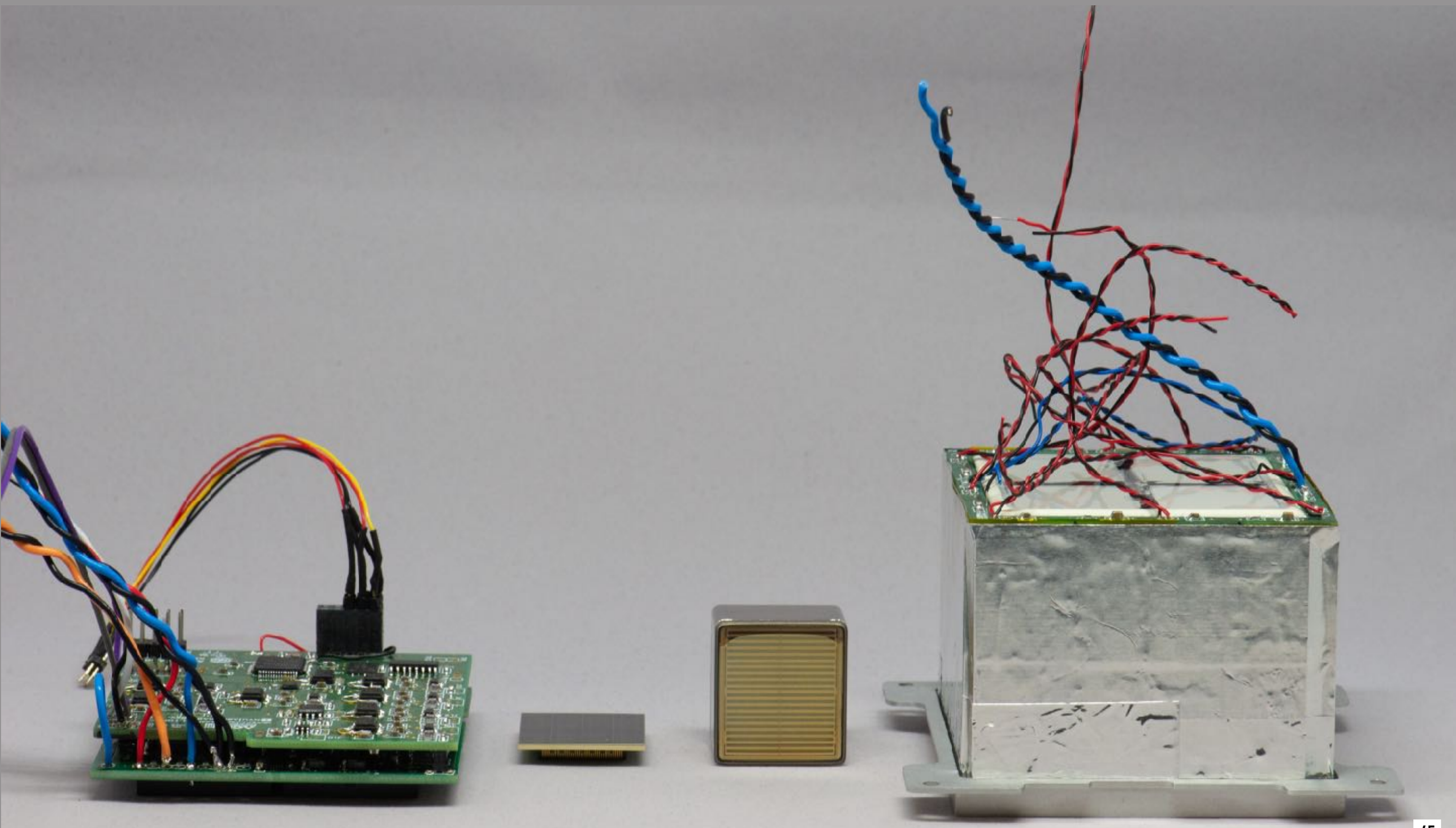


PMT Array

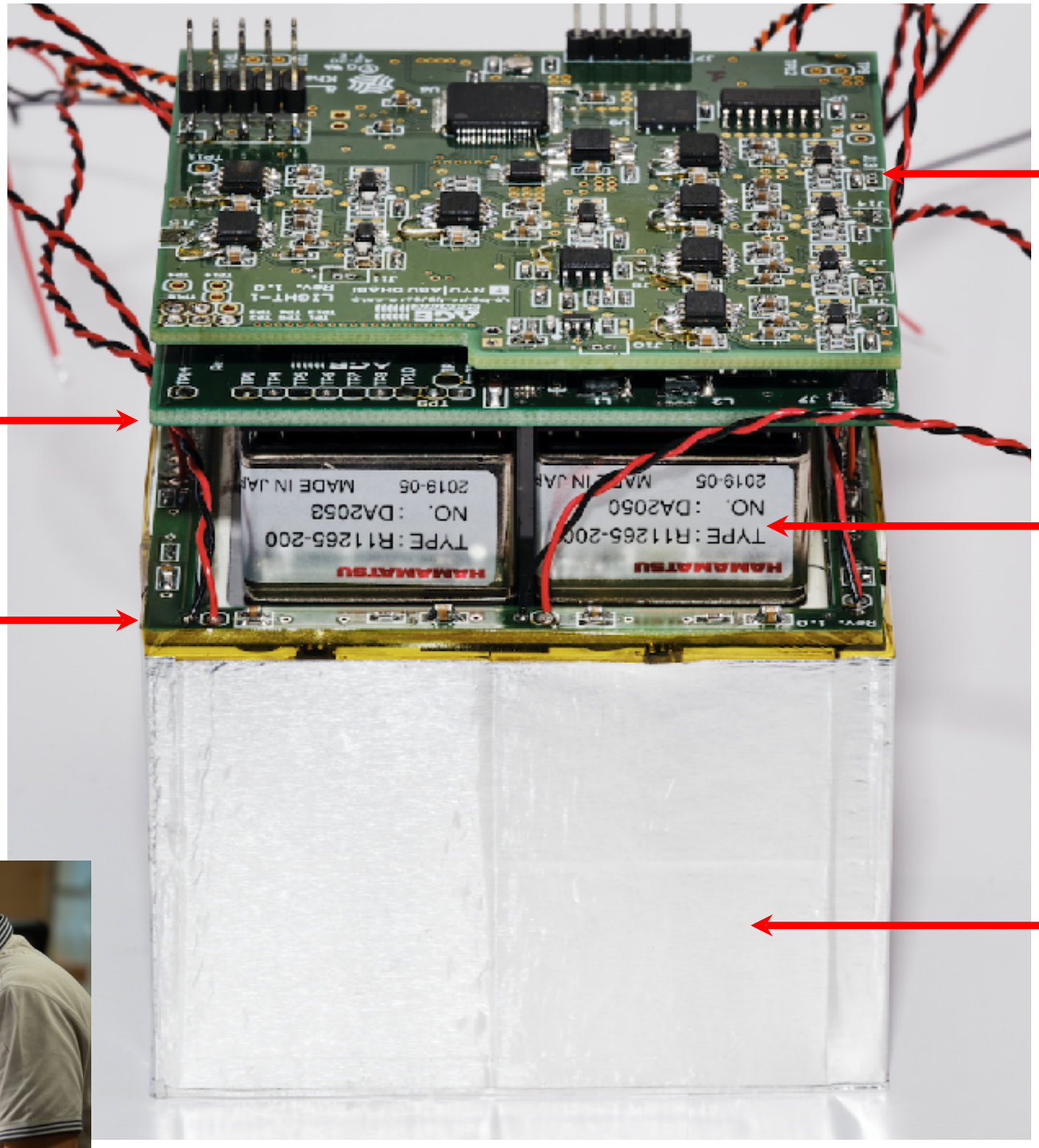


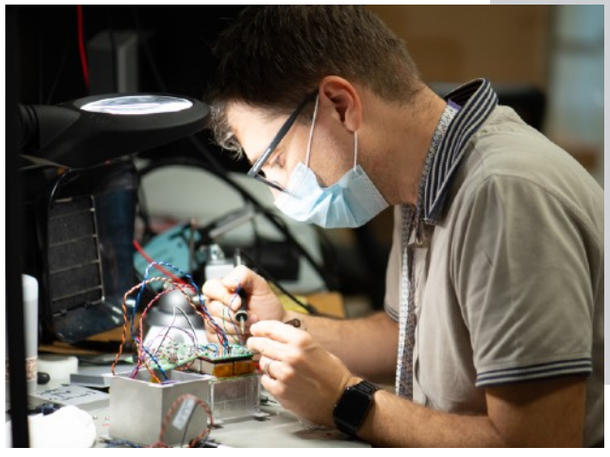
MPPC/SiPM Array

LIGHT-1 Instrument: the key components

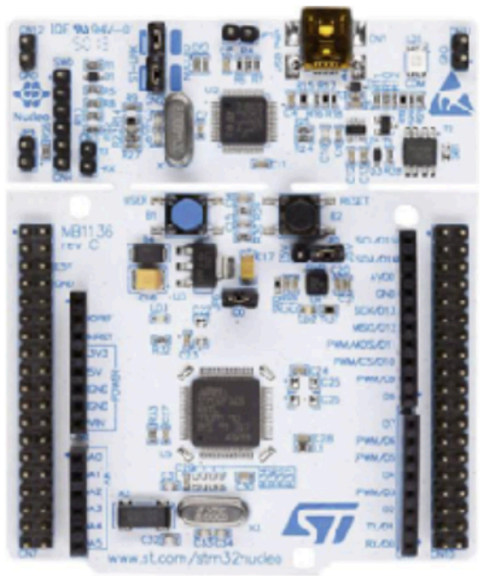


The PMT payload (Inner View)





Pre-Flight Setup: LIGHT-1 final touches

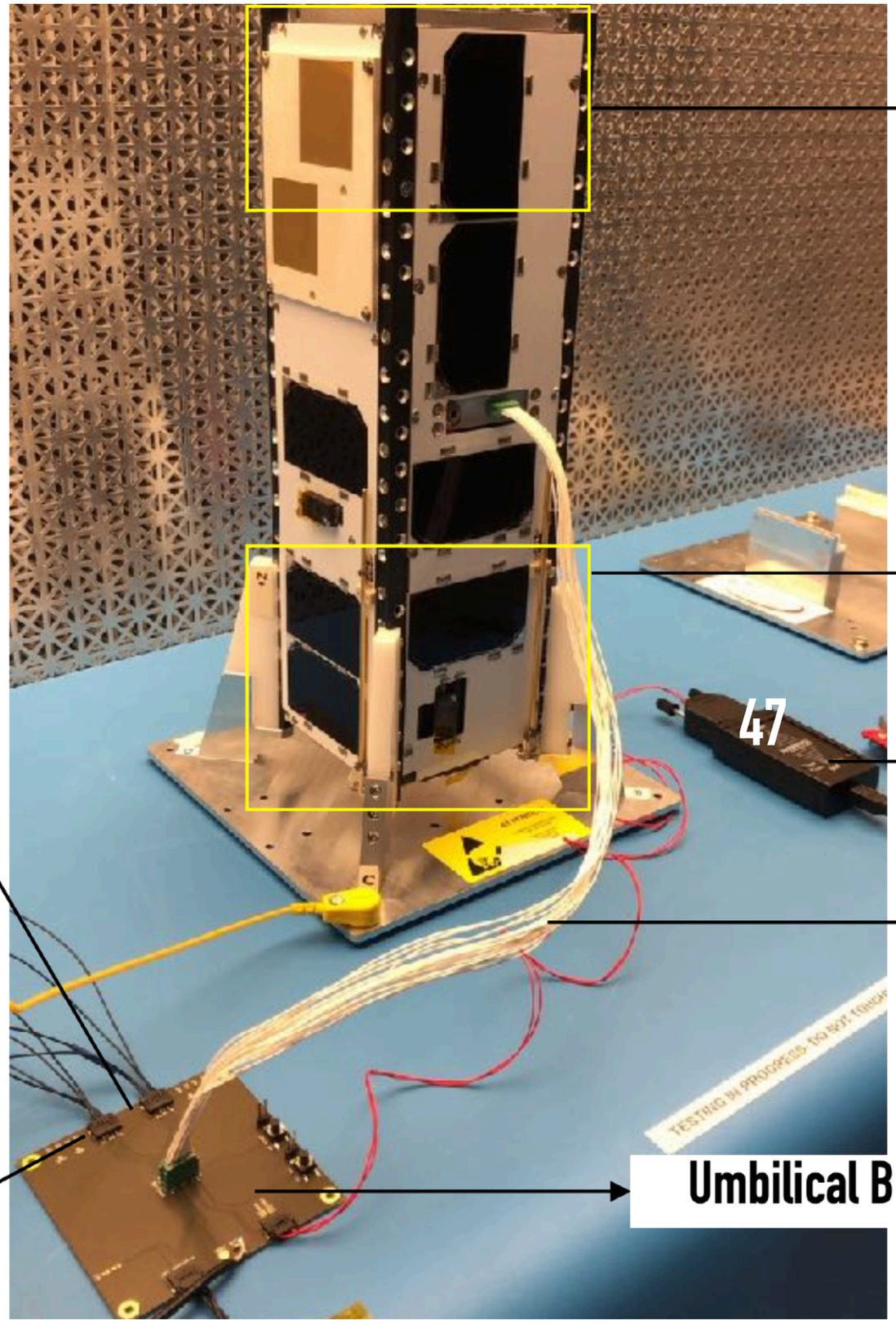


NUCLEO BOARD SiPM

To connect to SiPM Payload

NUCLEO BOARD PMT

To connect to PMT Payload



SiPM Payload (~0.7 U)

PMT Payload (1 U)

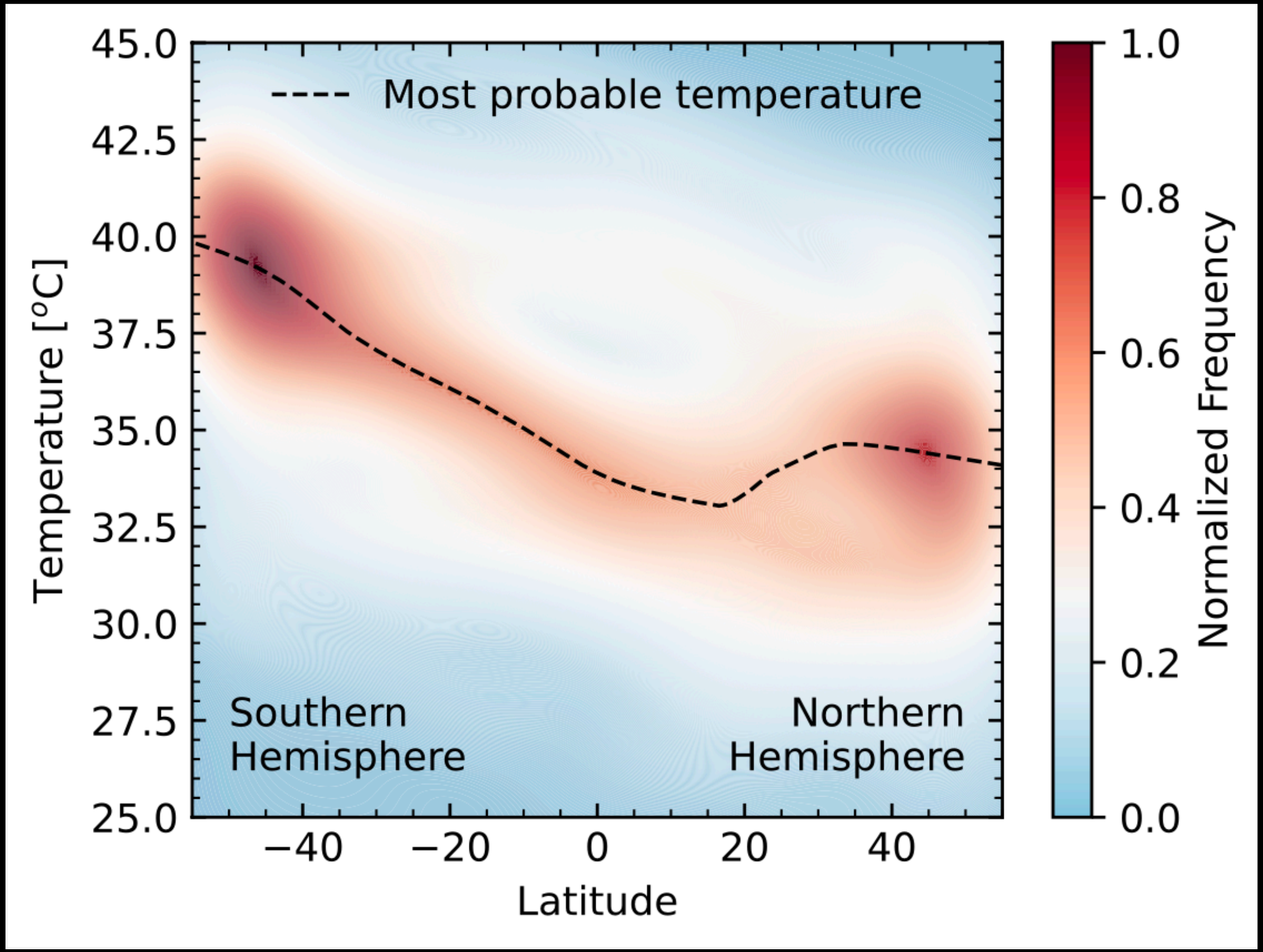
CANBUS Adapter

Umbilical CORD

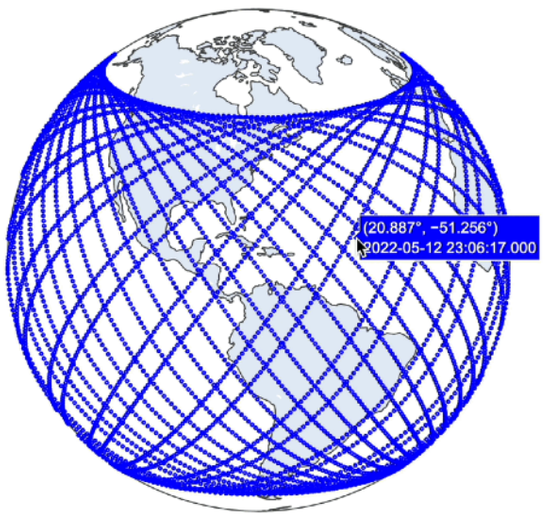
Umbilical BOARD

Highlights from LIGHT-1: Experiencing the thrilling of a launch

Highlights from LIGHT-1 (work in progress)



LIGHT-1 path VS thunderstorm location



3 typical orbits (90' each) – Tracking based of TLE technique, Lightnings (x,y,z,t) from open data repository

In conclusion

- The Space Sector is continuously expanding, even though it is still matter of fews
- The UN is fostering the Access to Space for All initiative to get to Space Democracy
- A revolution is in progress: data usability and reshaping mission concepts
- The use of CubeSats for the detection of of prompt emission of gamma-rays from Earth/Space is being explored and a handful of missions have been already deployed

Credits: NASA