

# 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

جامعة نيويورك أبوظبي  
NYU | ABU DHABI



جامعة خليفة  
Khalifa University

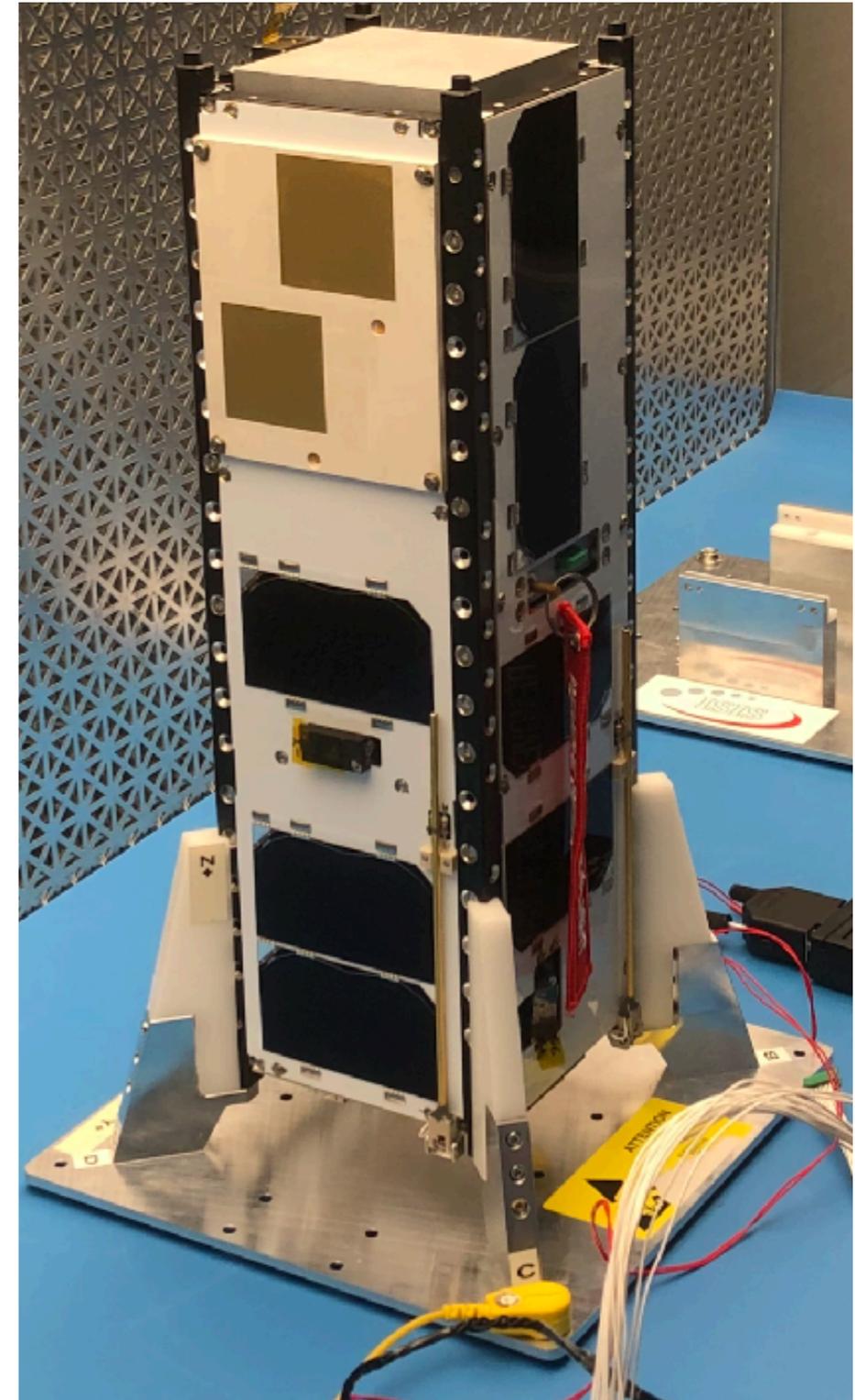
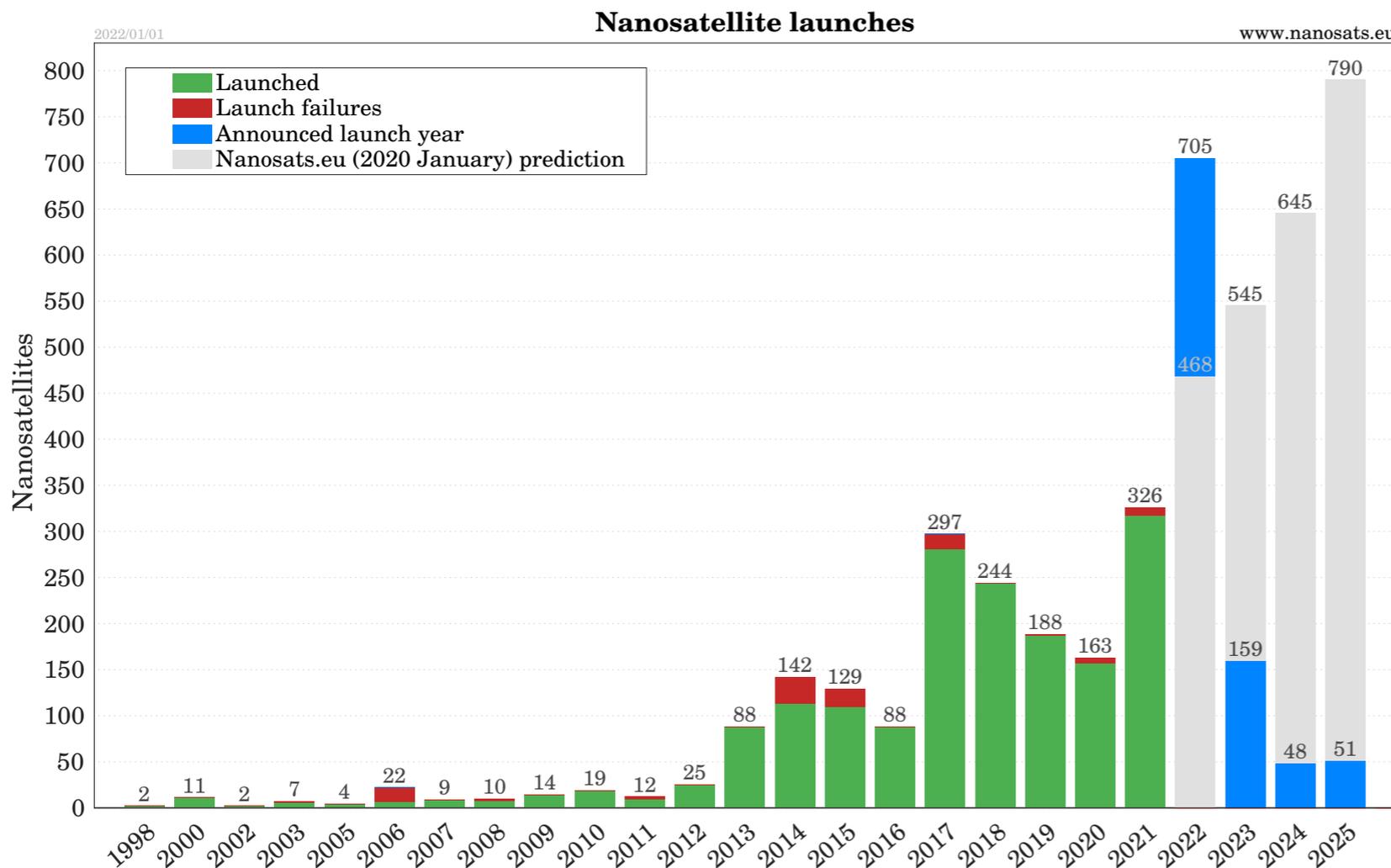
وكالة الإمارات للفضاء  
UAE SPACE AGENCY

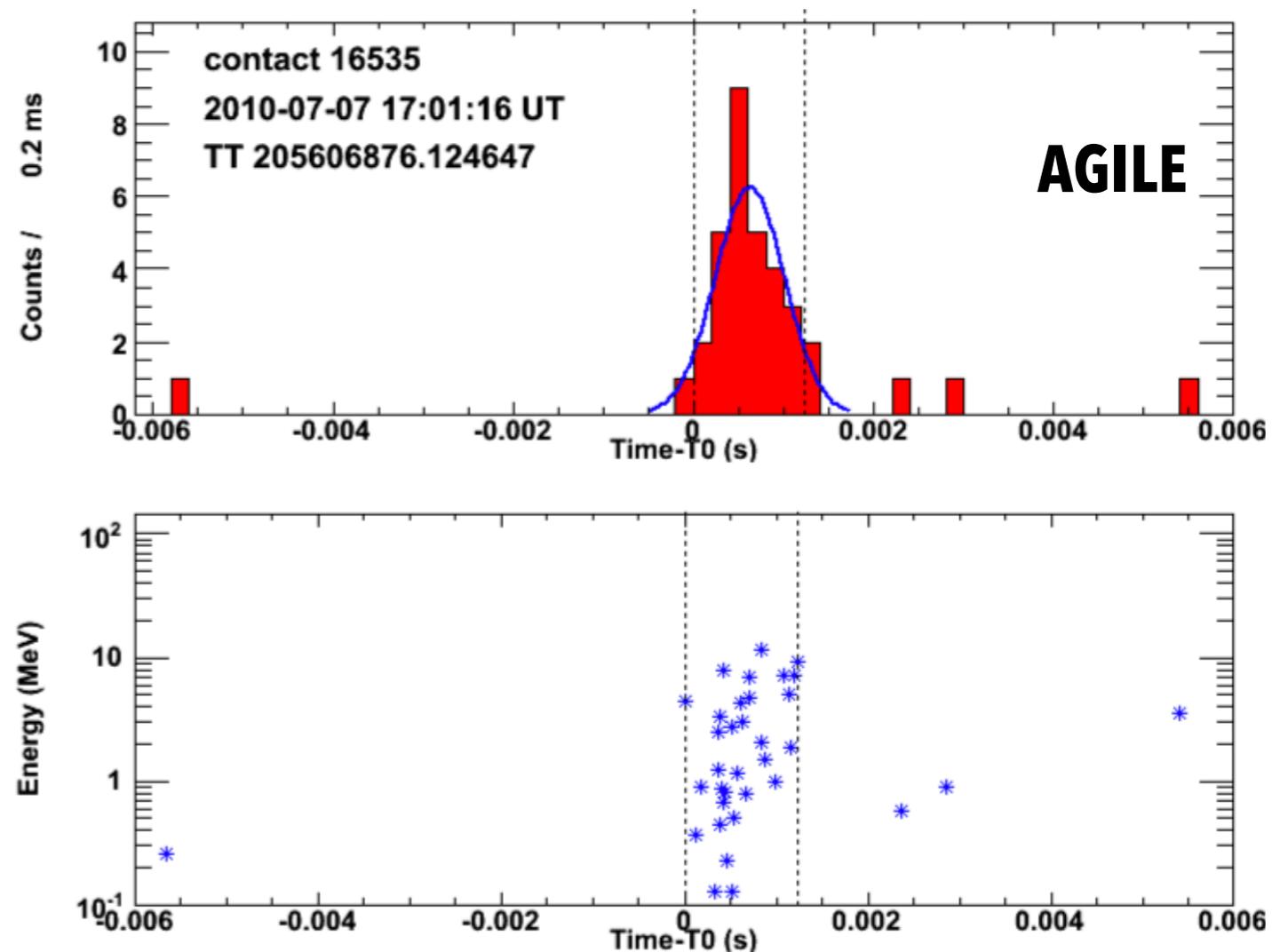
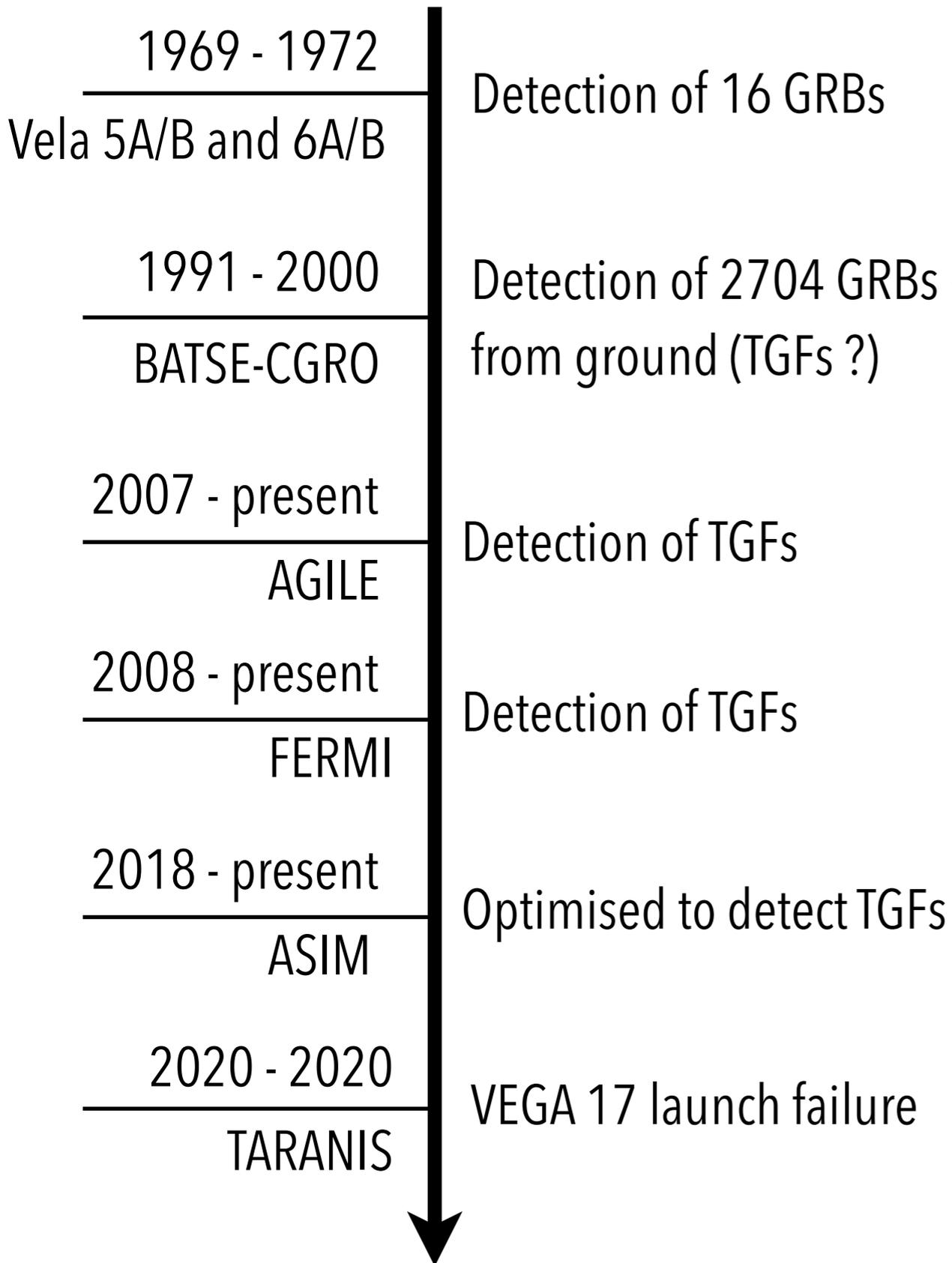


NSSA  
الهيئة الوطنية لعلوم الفضاء  
National Space Science Agency



- Terrestrial Gamma-Ray flashes (TGF) in a nutshell
- The CubeSat standard as a new paradigm to access Space
- The LIGHT-1 Mission
- The Scientific Payload
- First Flight Data and preliminary results

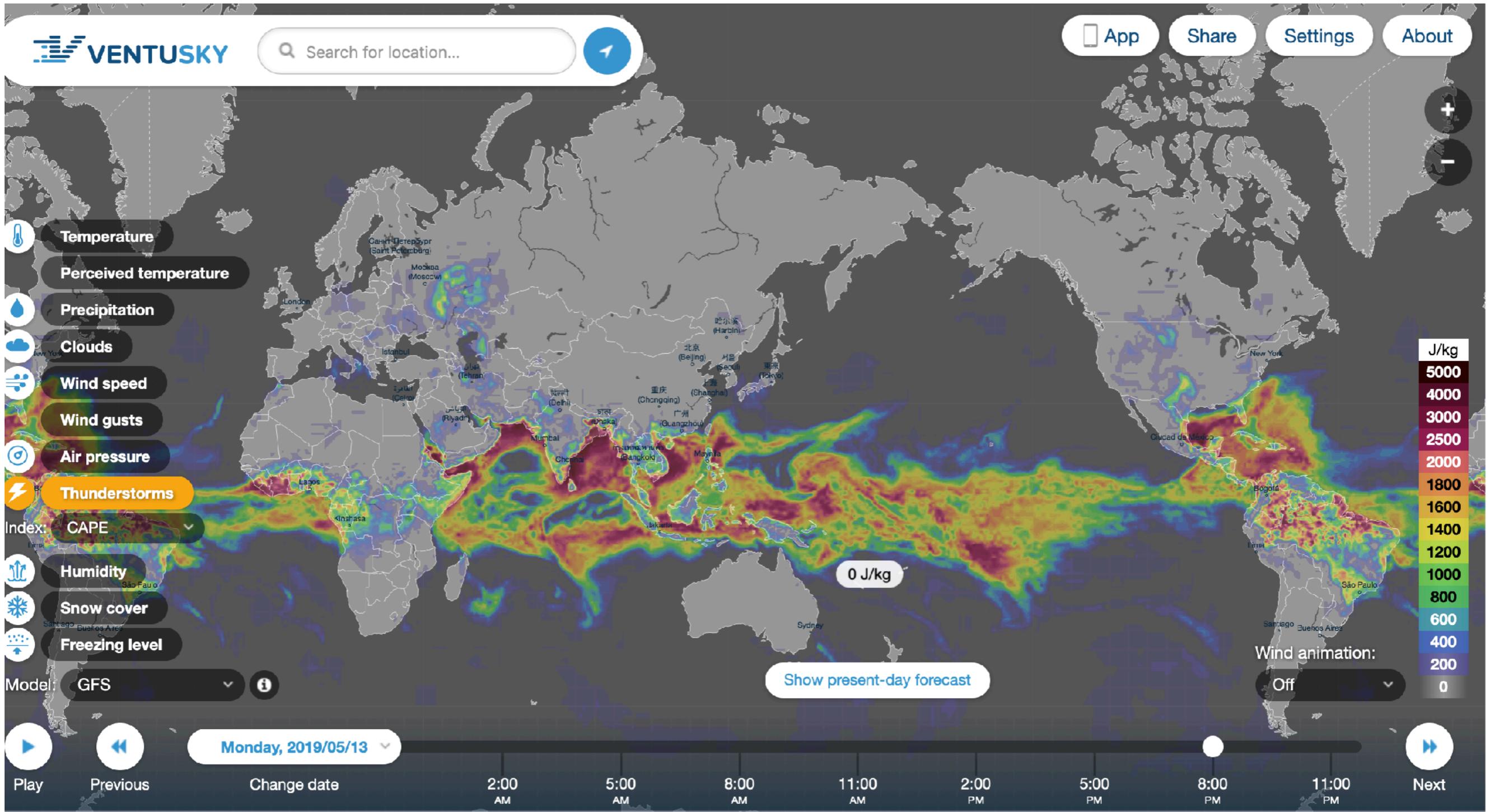




# Terrestrial Gamma-Ray Flashes

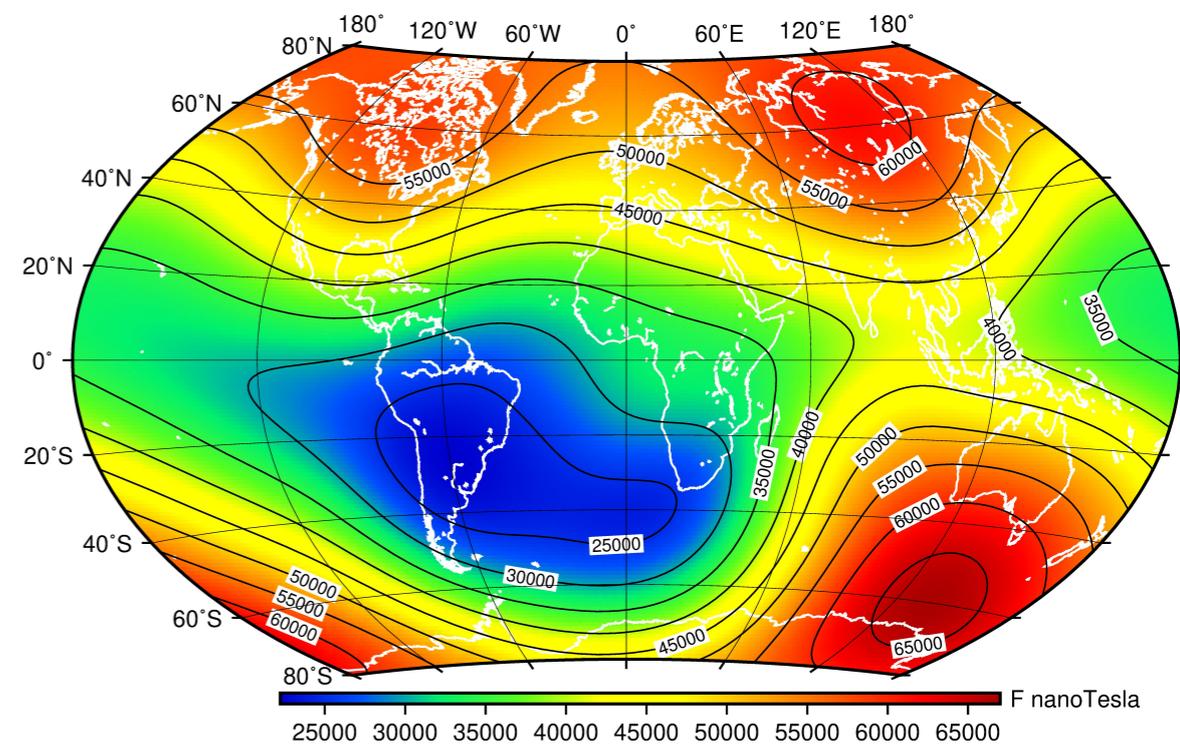
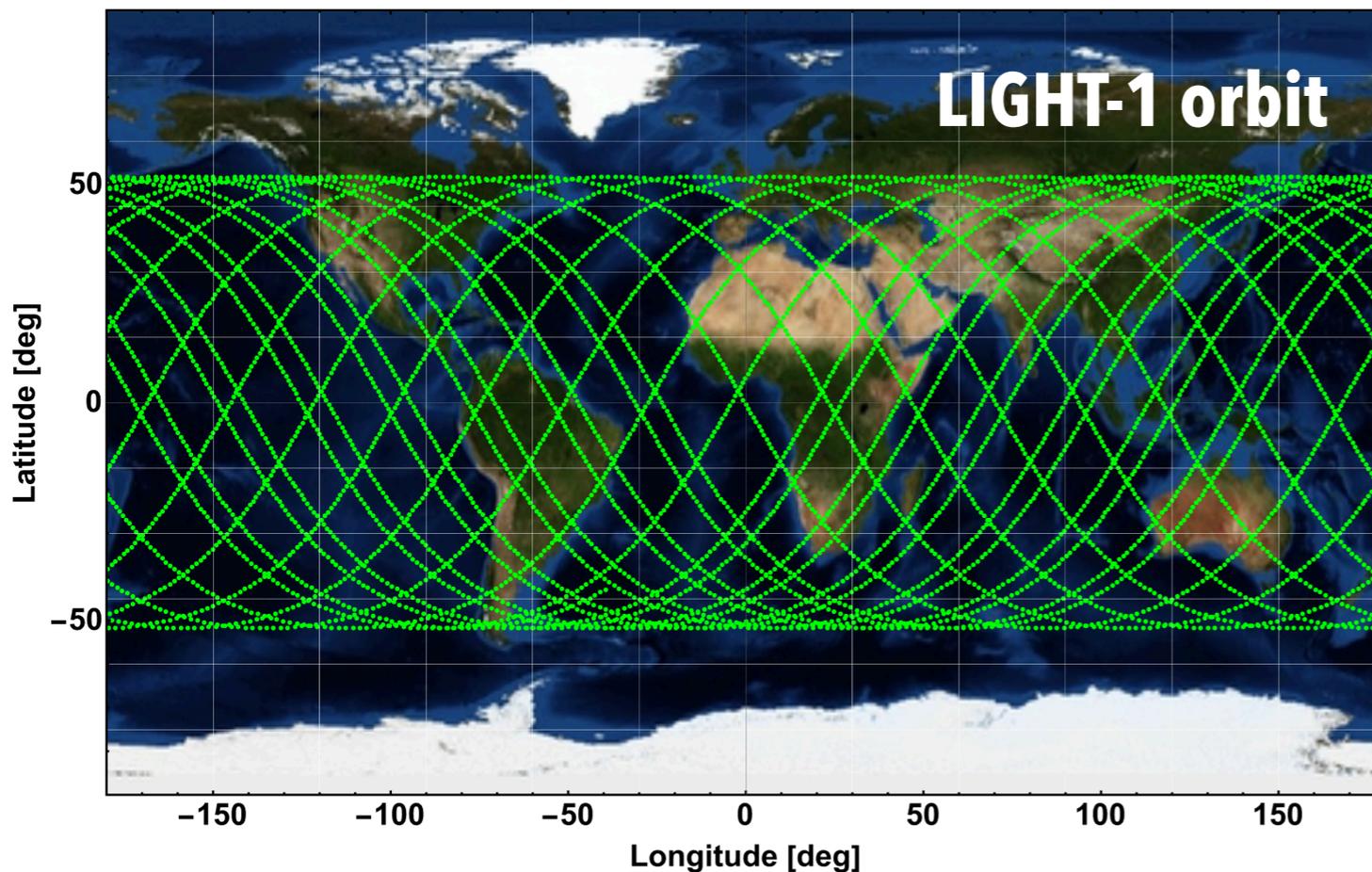
Origin	Atmospheric Process: Lightning, Thunderstorms, Tropical Storms
Primary particle counterpart	Gamma via bremsstrahlung
Secondary particle counterpart	Electron Beams - Neutrons from photoproduction
Other detectable counterparts	Radio emission (sferics)
Energy Range	10 keV up to $\sim 100$ MeV
Event Duration	$\sim$ hundreds of $\mu$ s
Fluence @ 400-500 km	$\sim 1$ gamma/cm <sup>2</sup>
Estimated rate (FERMI)	400k events per year
Originating Altitude	(usually) 9 km to 15 km
Generation Mechanism	Not yet fully understood

# Daily Thunderstorm Distribution

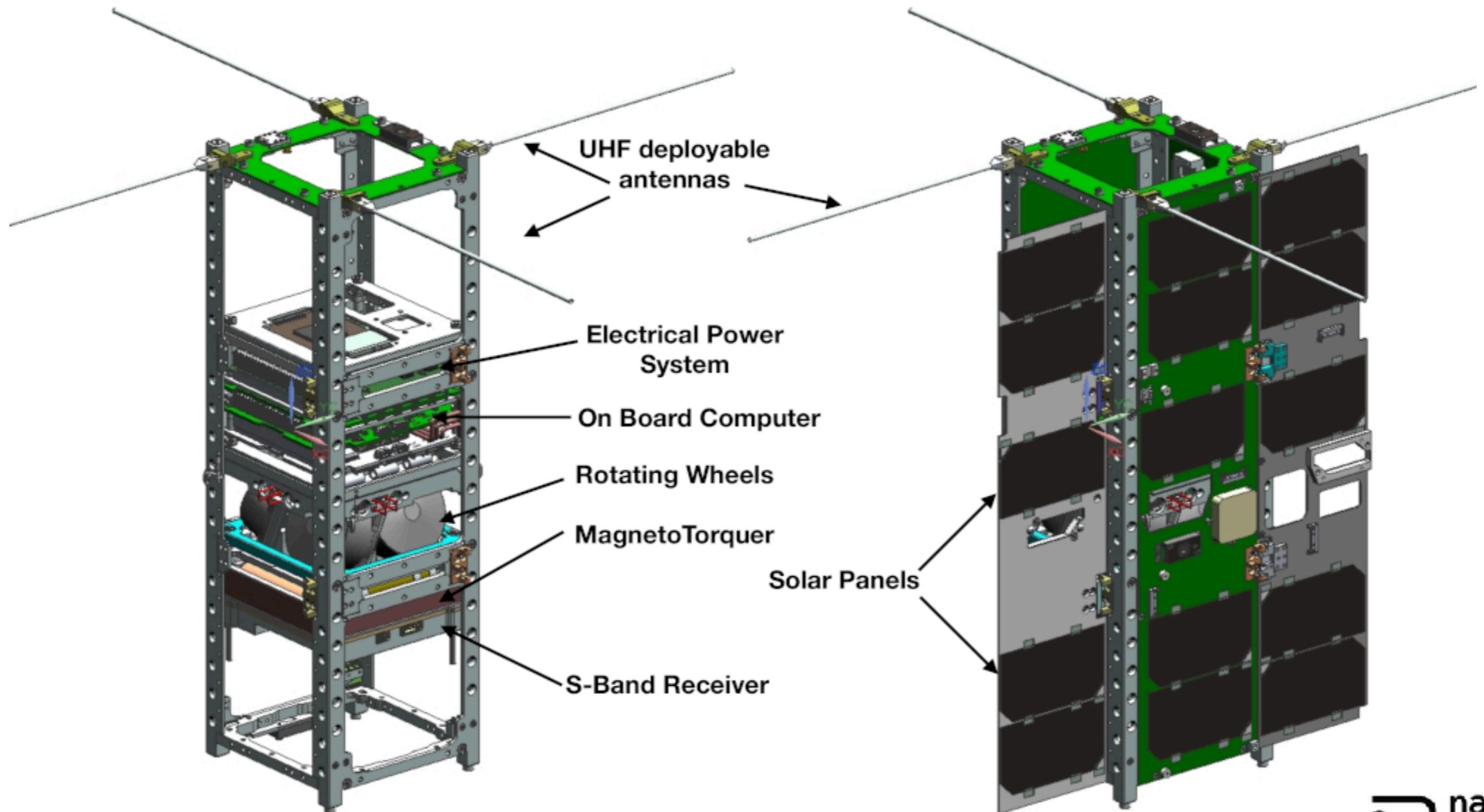


# LIGHT-1 mission requirements

- To survive the extreme stress of a SpaceX Falcon9/Dragon launch;
- To be on time (from PDR to ON-ORBIT operations < 3 y, + COVID19);
- To measure the particle rate (1 sample every 20 s, or every ~ 160 km) at LEO (ISS polar orbit,  $51.6^\circ$ );
- To study TGFs at sub-microsecond timescale;
- To space-qualify the technology and prove the detection concept;
- To measure the activity in the South Atlantic Anomaly region.



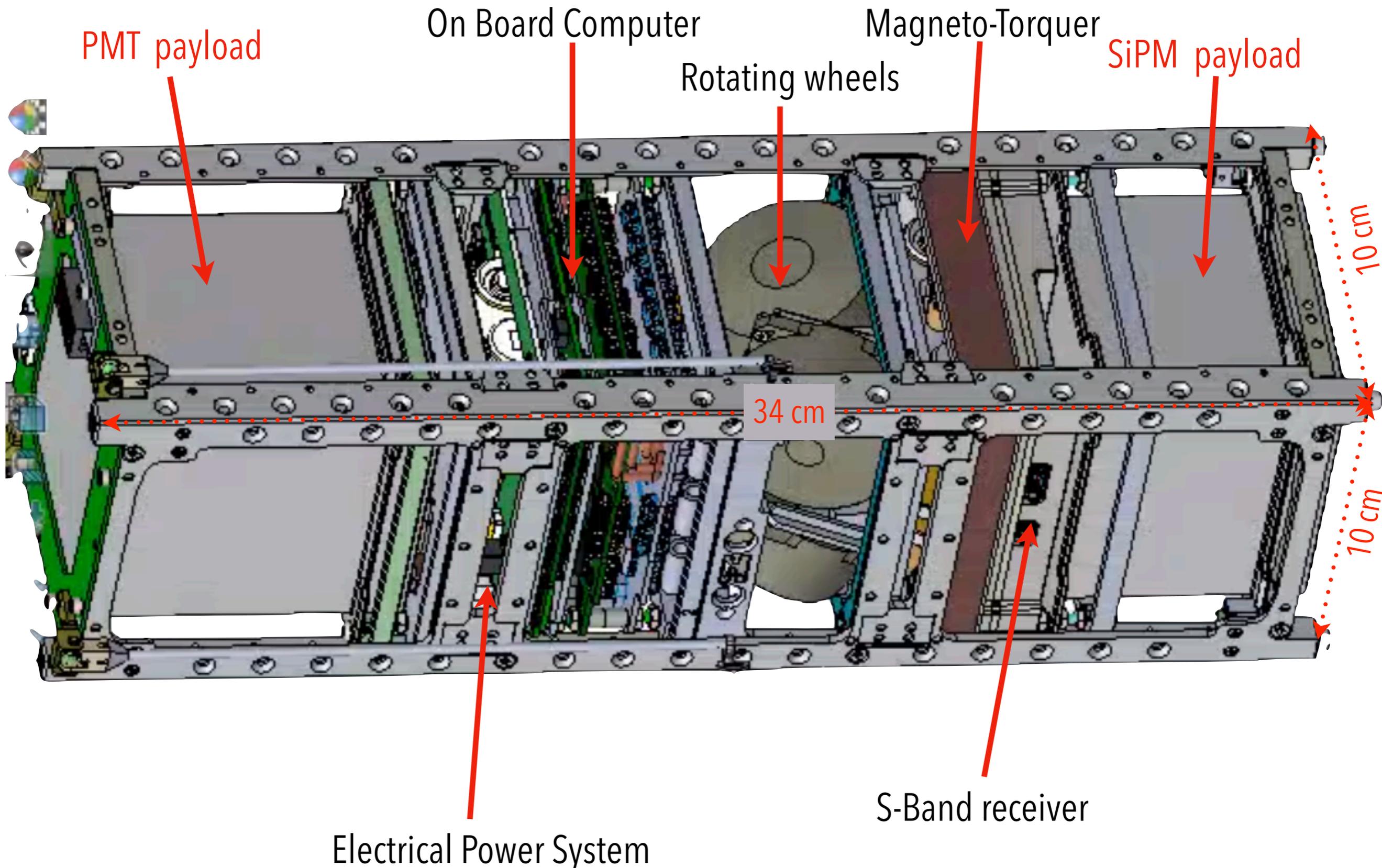
# A ~typical 3U CubeSat



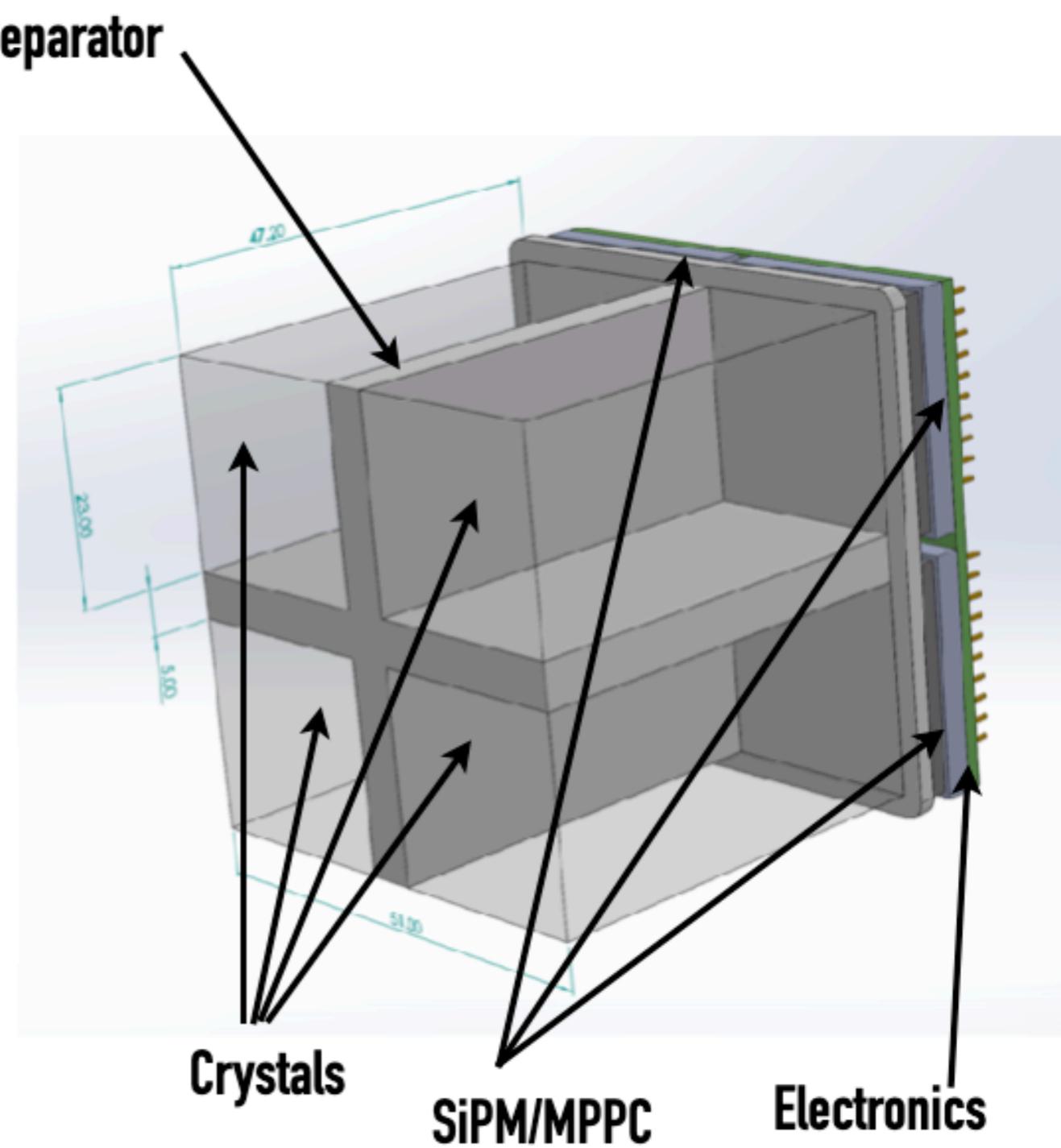
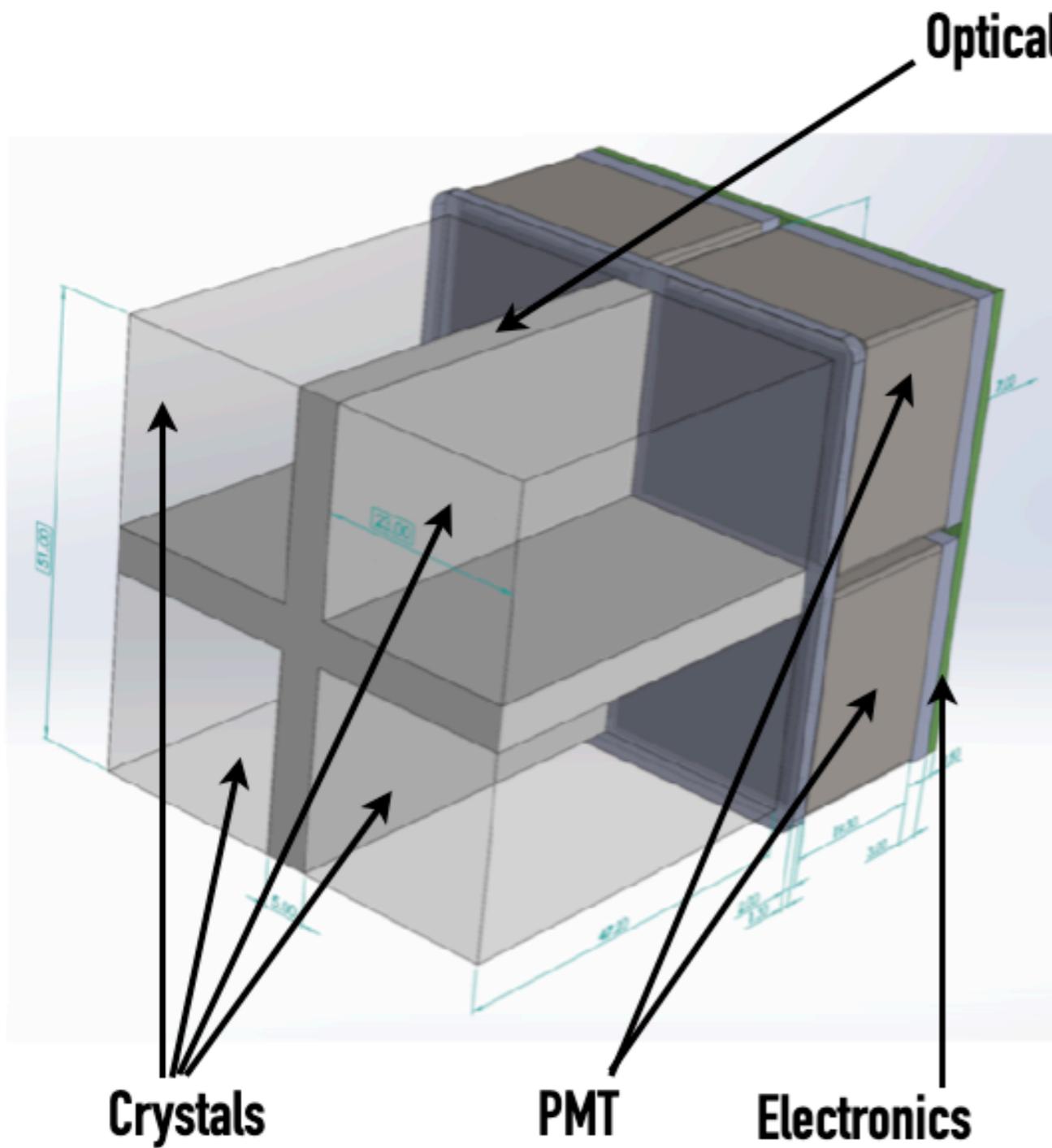
- Modular satellite built up from  $10\text{ cm} \times 10\text{ cm} \times 11.35\text{ cm}$  units (1U);
- Relatively low cost to build and launch (typically  $\ll \$1\text{M}$ );
- Strict size and weight limits ( $< 1.5\text{ kg/U}$ ), and very limited power budget (a few W per U)
- Little-to-no propulsion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

Parameter	Value
Detection Energy Range	~ 20 keV - 3 MeV
Time resolution	~ 100 ns
Absolute Timing	< 4 $\mu$ s
Spectral Resolution	15% @ 20 keV, < 5% @ 511 keV
Effective Area	40 cm <sup>2</sup> @ 50 keV, 20 cm <sup>2</sup> @ 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

# The bus of LIGHT-1 satellite

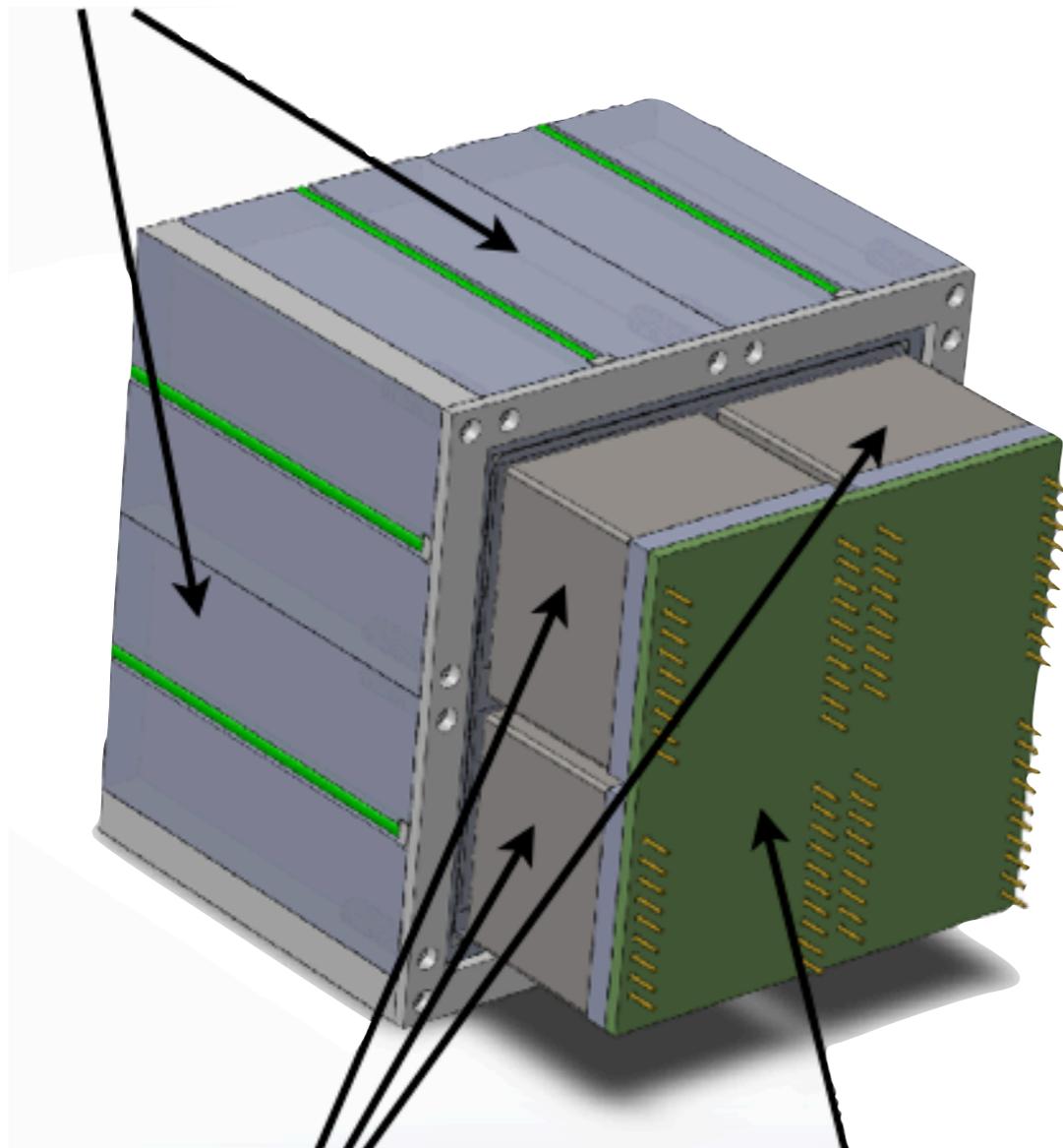


# The LIGHT-1 detection targets



# The LIGHT-1 PMT and SiPM payloads

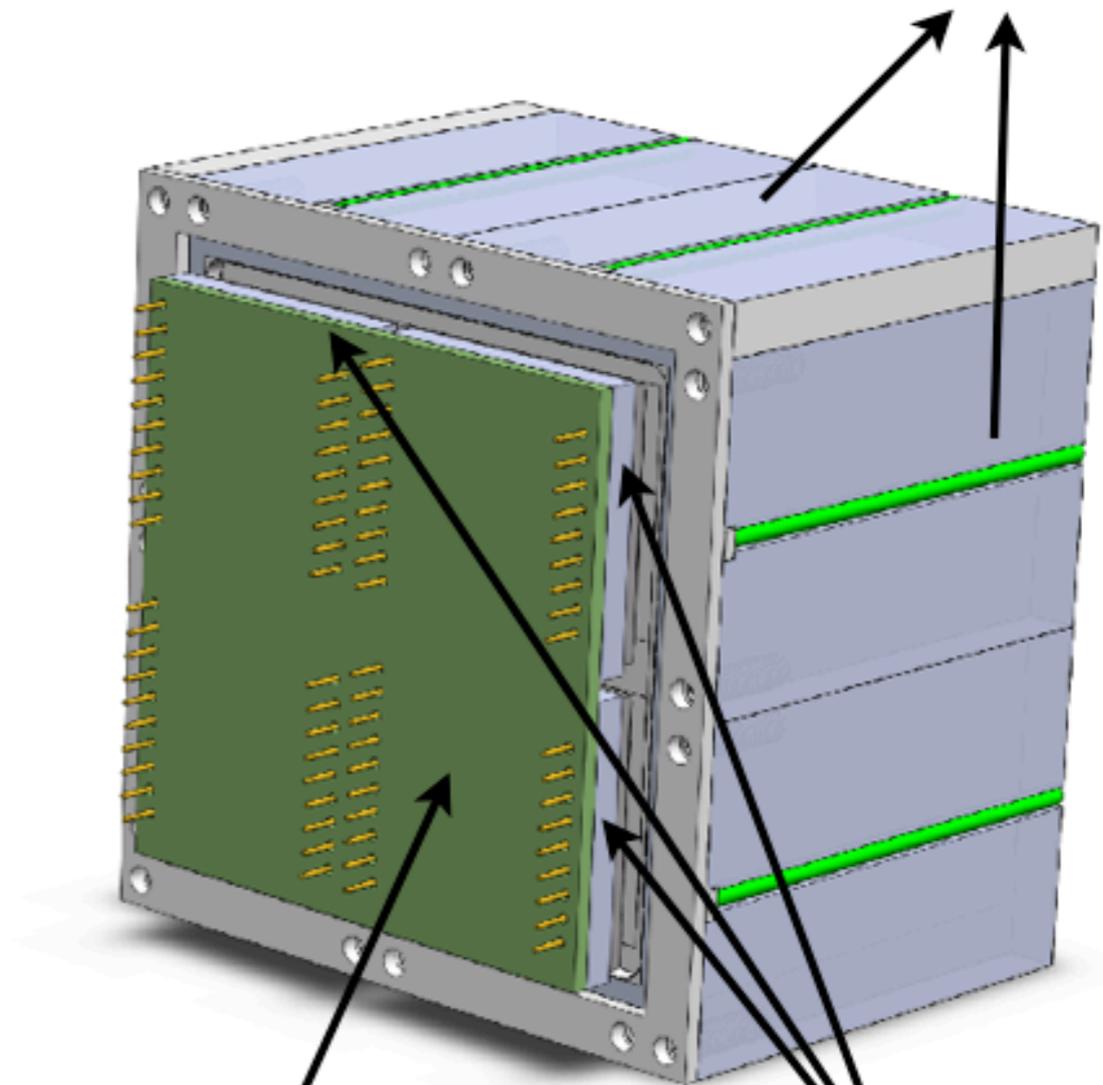
Veto  
System



PMT

Electronics

Veto  
System



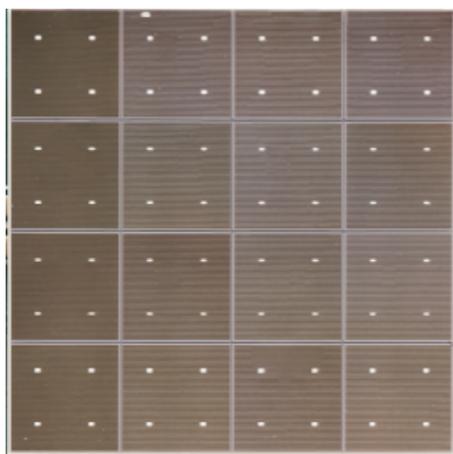
Electronics

SiPM/MPPC

# The Hamamatsu Photosensors

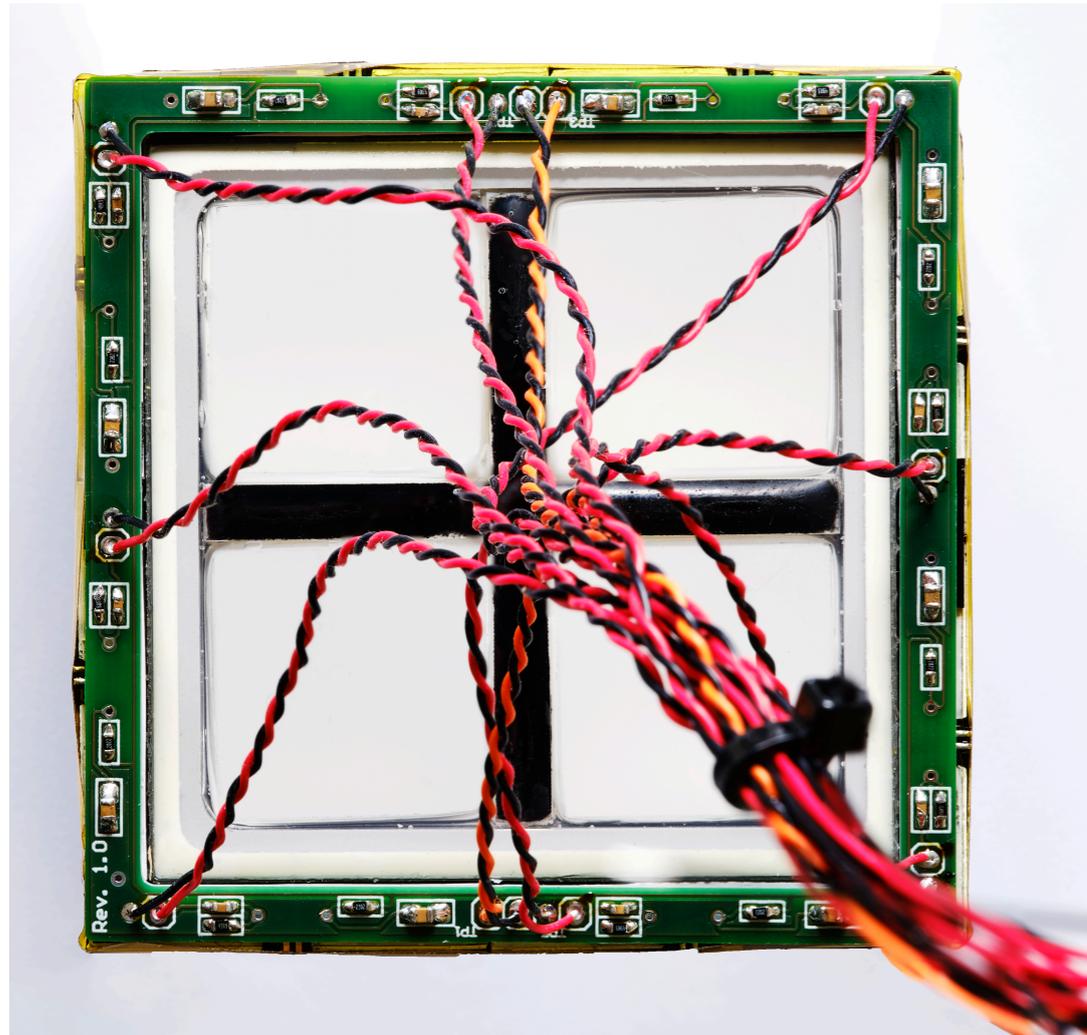


Photomultiplier Tubes  
R11265-200



Multi-Pixel Photon Counters  
S13361-6050AE-04

Characteristics	R11265-200	S13361-6050AE-04
Type of photosensors	PMT	MPPC (aka SiPM)
Dimensions(LXDXH) [mm <sup>3</sup> ]	26X26X19	25X25X1.4
Weight [g]	24	2
Peak Sensitivity [nm]	~ 400	~ 450
Q.E. [%]	43	-
P.D.E. [%]	-	40
Typical Operating Voltage [V]	900	55
Typical Gain at working point	~10 <sup>6</sup>	~10 <sup>6</sup>
Dark Count at working point, room temperature [Hz]	Negligible	> 10 M
Operating Temperature [°C]	-30 to +60	-20 to +60
# of photosensors in LIGHT-1	4	4

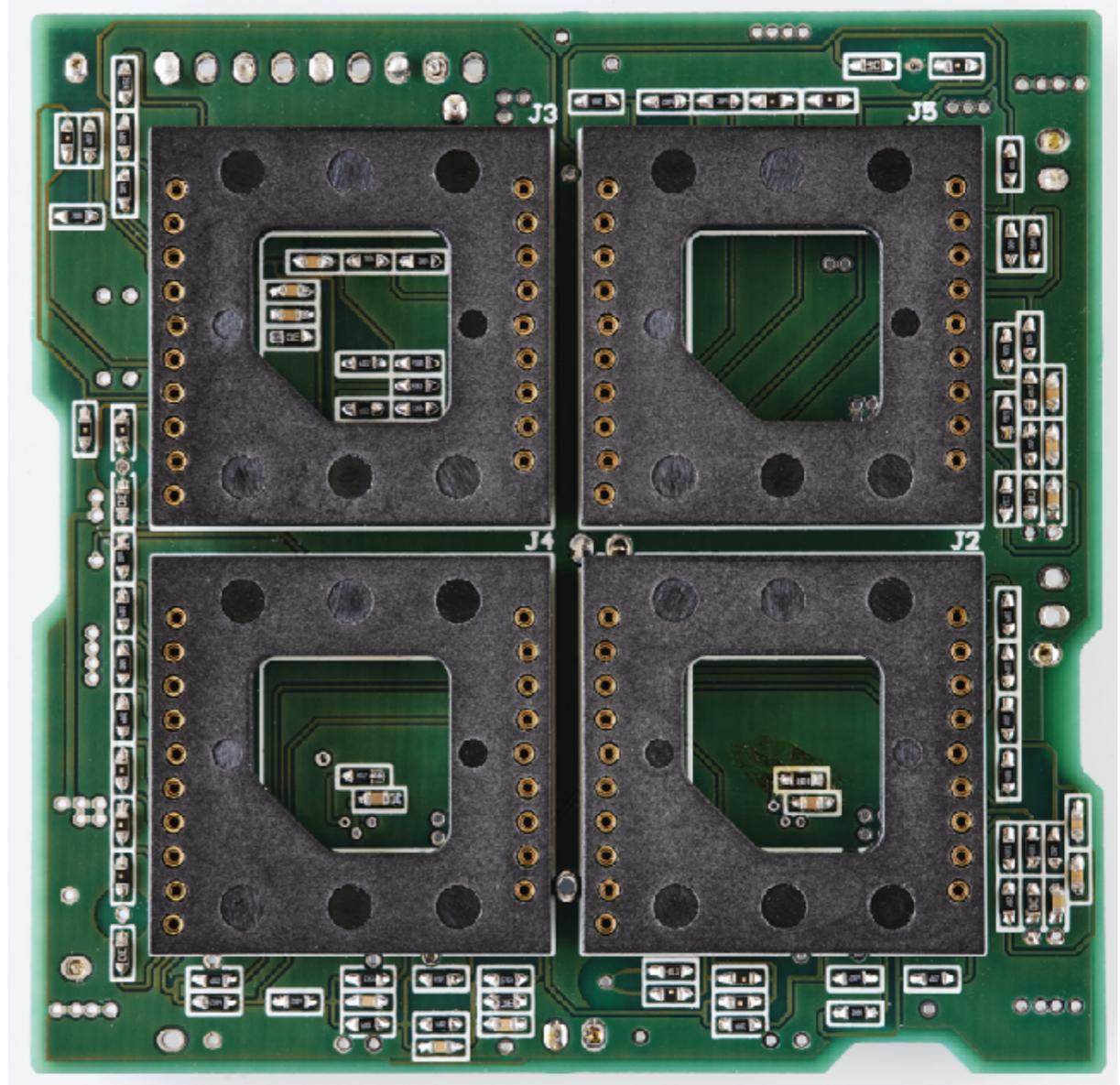
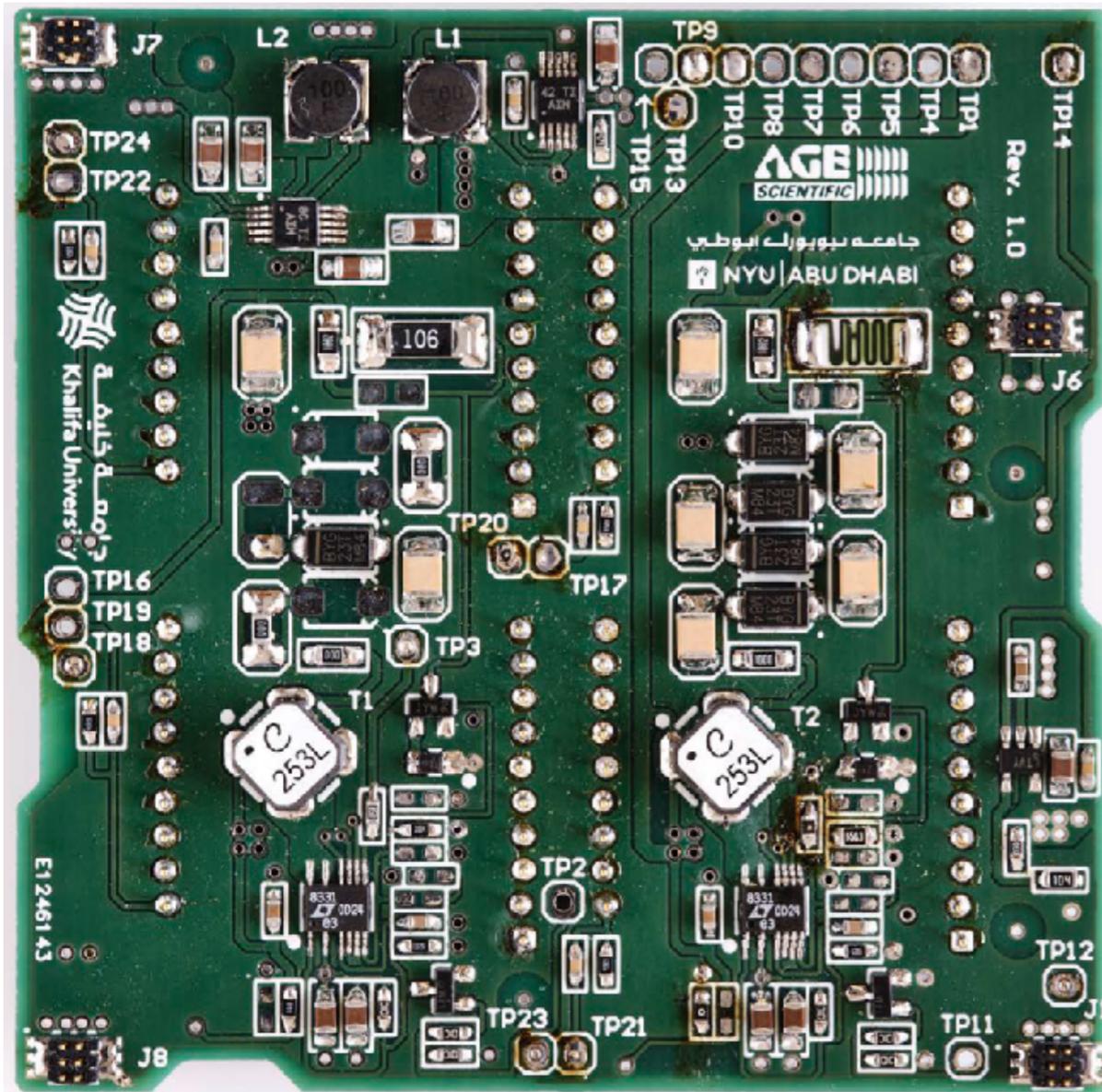


Characteristics	CeBr <sub>3</sub> (LB)	LBC
Density [g/cm <sup>3</sup> ]	5.1	4.9
Hygroscopic	YES	YES
Emission Peak [nm]	~370	~ 380
Typical Resolution @122 keV ( <sup>57</sup> Co) [%]	10	7
Typical Resolution @662 keV ( <sup>137</sup> Cs)	4	3
Typical Decay Time [ns]	~ 20	~ 35
Activity [Bq/cm <sup>3</sup> ]	< 0.01	~ 1

## The LIGHT-1 detection target consists of:

- **6X** (23 mm X 23 mm X 45 mm) Low Background Cerium Bromide (CeBr<sub>3</sub>(LB))
- **2X** (23 mm X 23 mm X 45 mm) Lanthanum Bromo Chlorine (LBC)

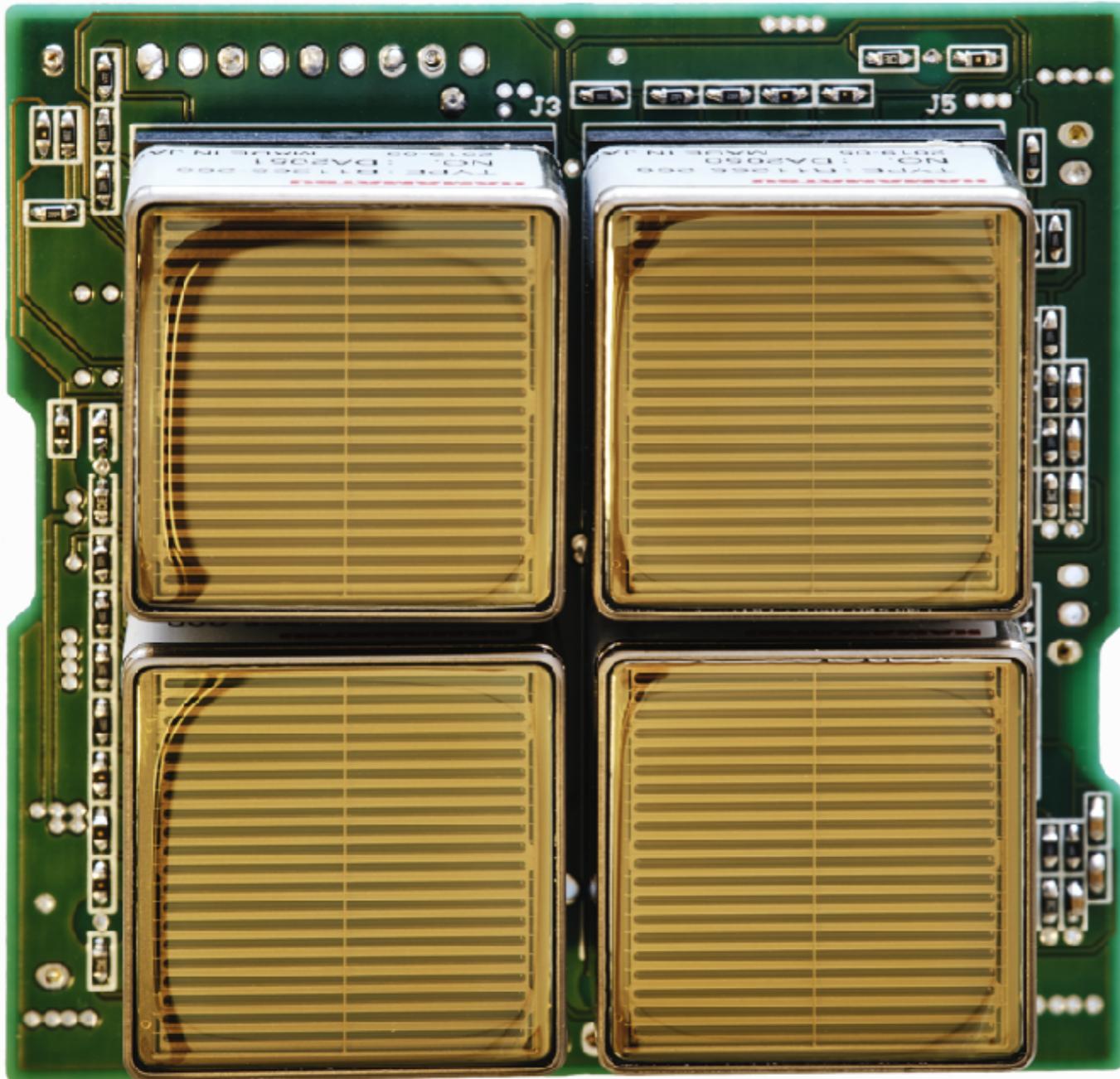
For Basic Unit characterization see here: <https://doi.org/10.1088/1748-0221/14/09/P09017>



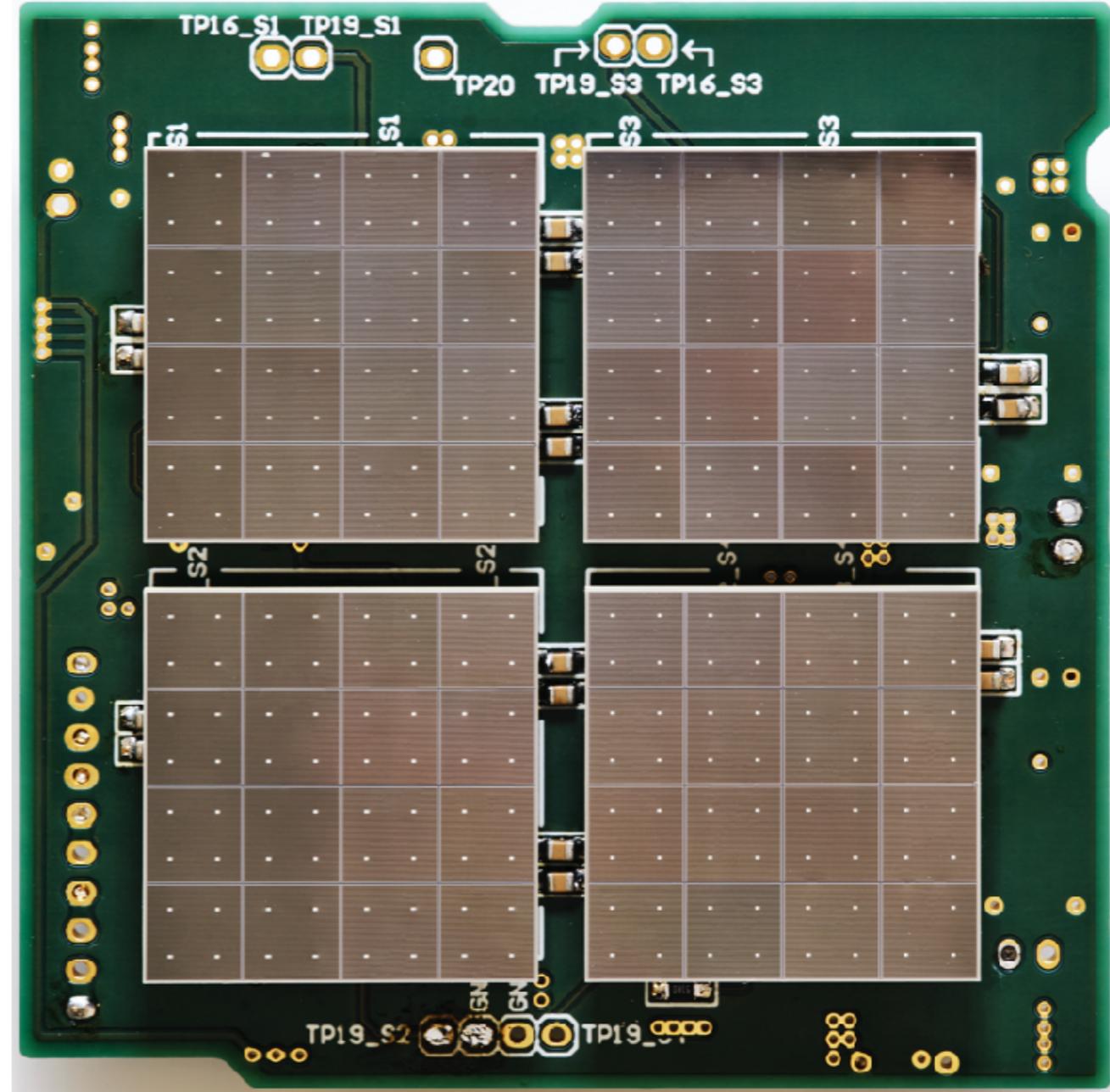
## Main Characteristics:

- 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)

# The photosensor Arrays

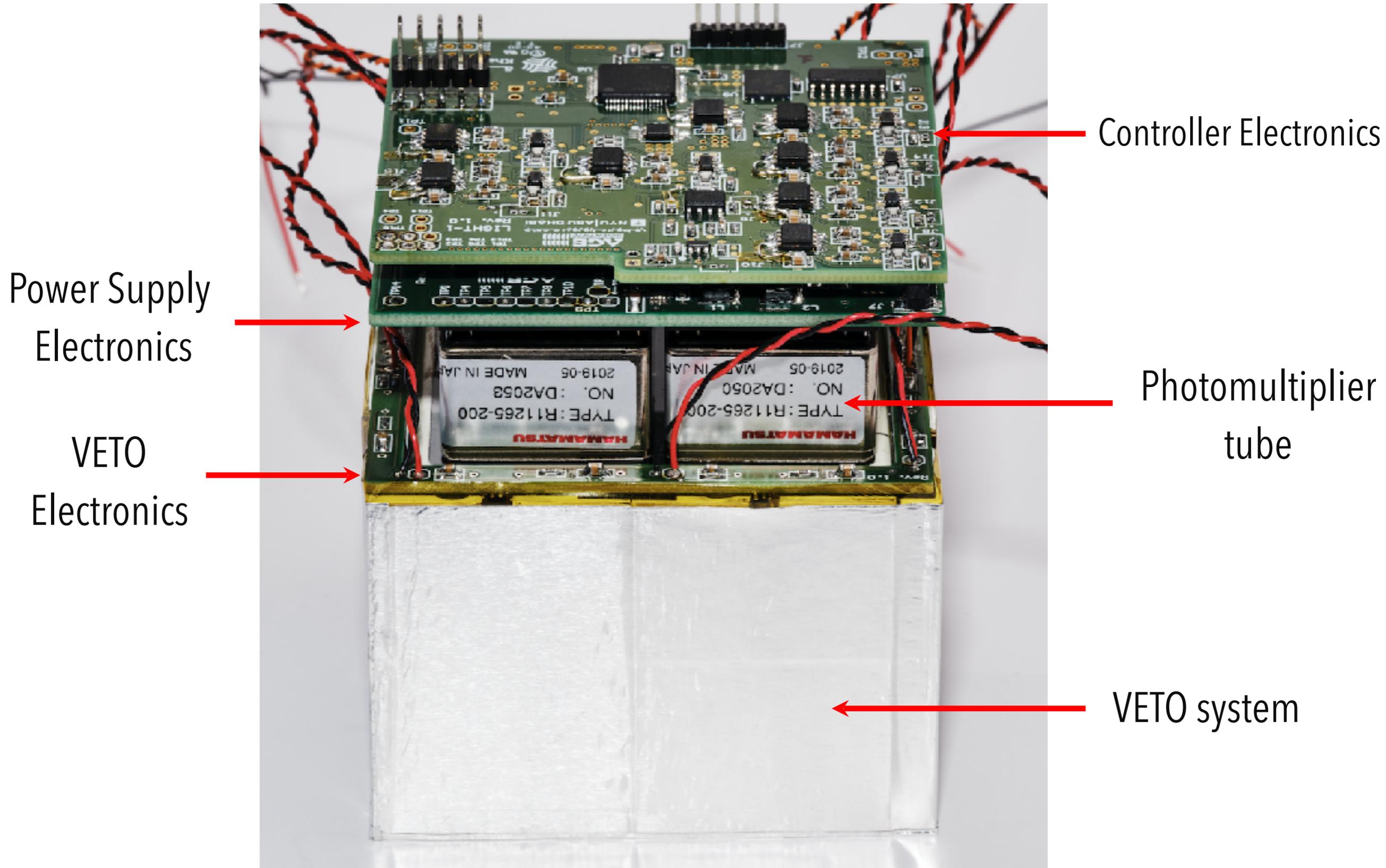


PMT Array



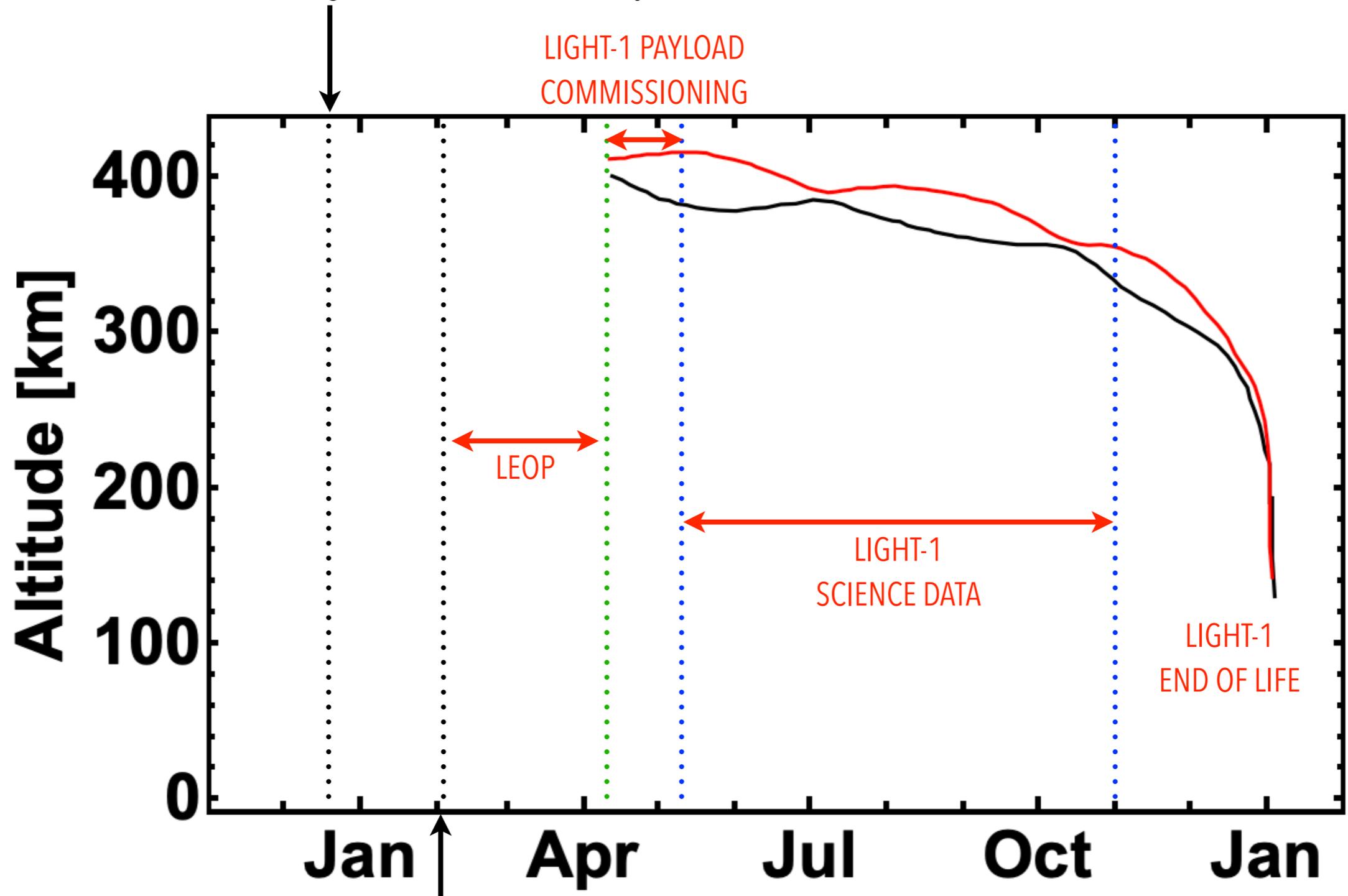
MPPC/SiPM Array

# The PMT payload (Inner View)



# A very intense and (eventually) sad story

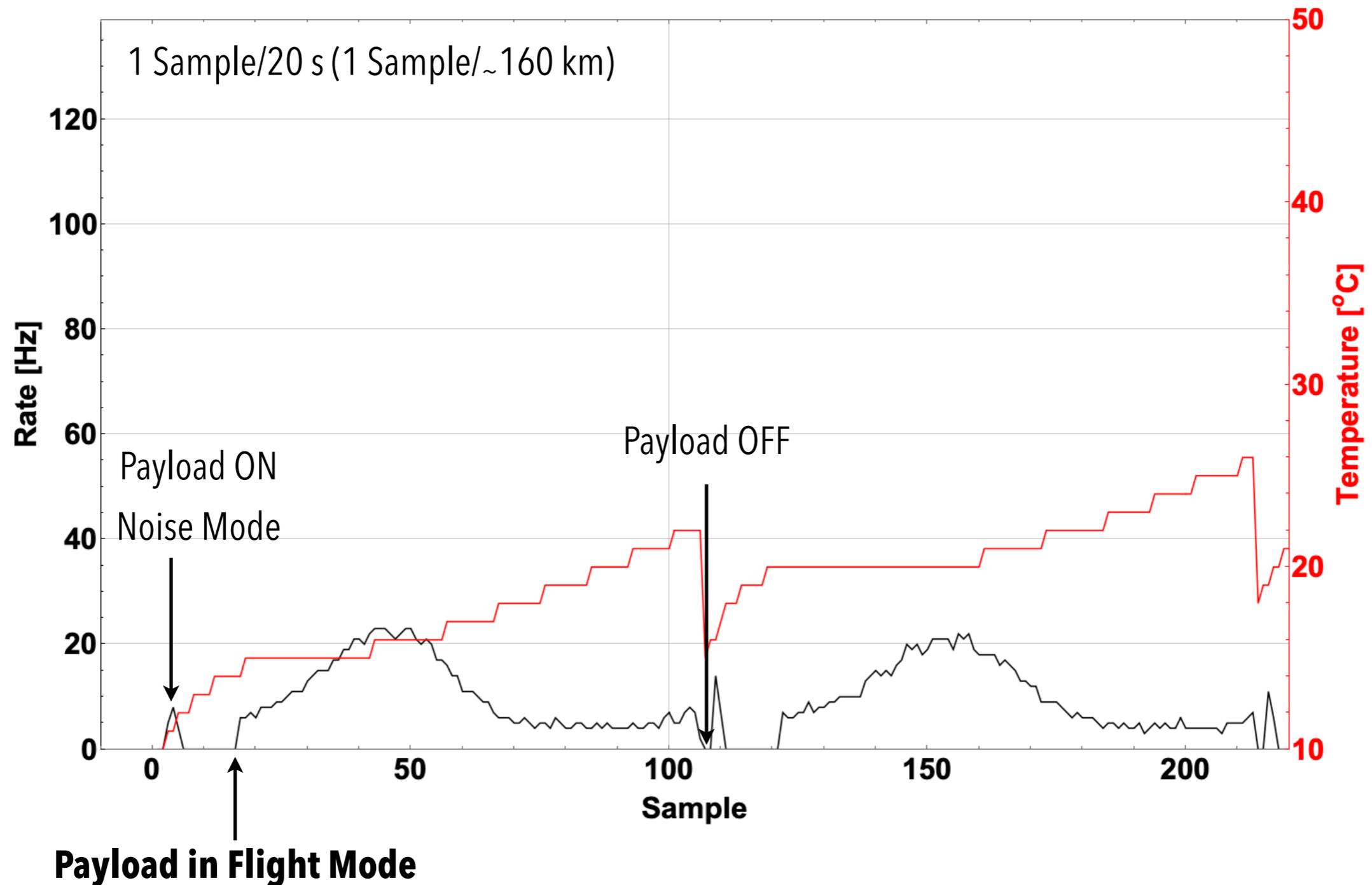
SpaceX Launch from Kennedy Space Center  
on 2021-12-21 (Falcon9/Dragon docked ISS the day after)



Deployment from ISS on 2022-02-03

LEOP = LAUNCH and EARLY ORBIT PHASE

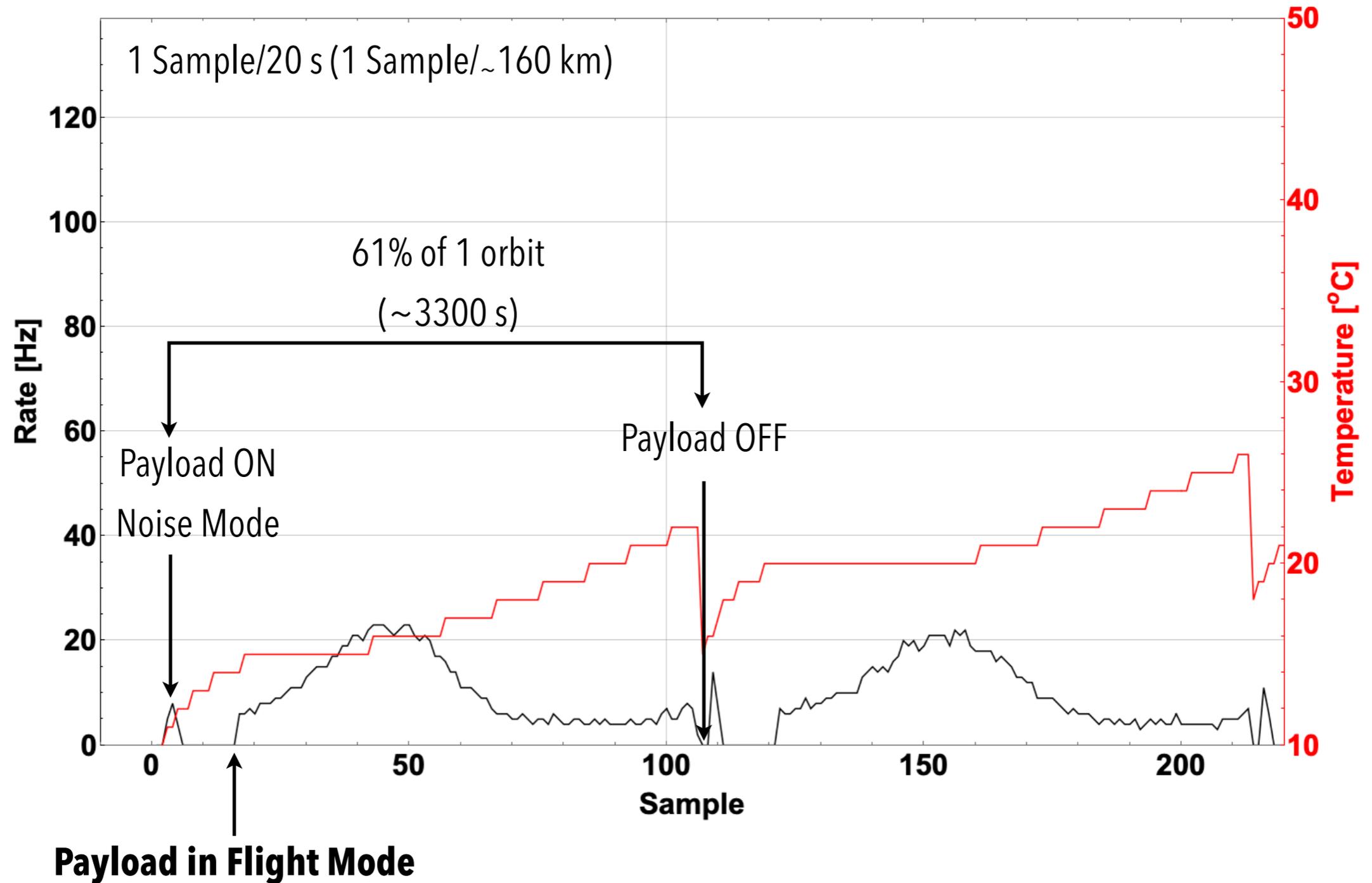
# Measured particle rate (SiPM CH2)



SiPM CH2 detection THR set to 1800 ADC CH / 64k ADC CH

LIGHT-1 Operational DutyCycle (DC): 61%, Effective DC (checks, reboot, SAA): 48%

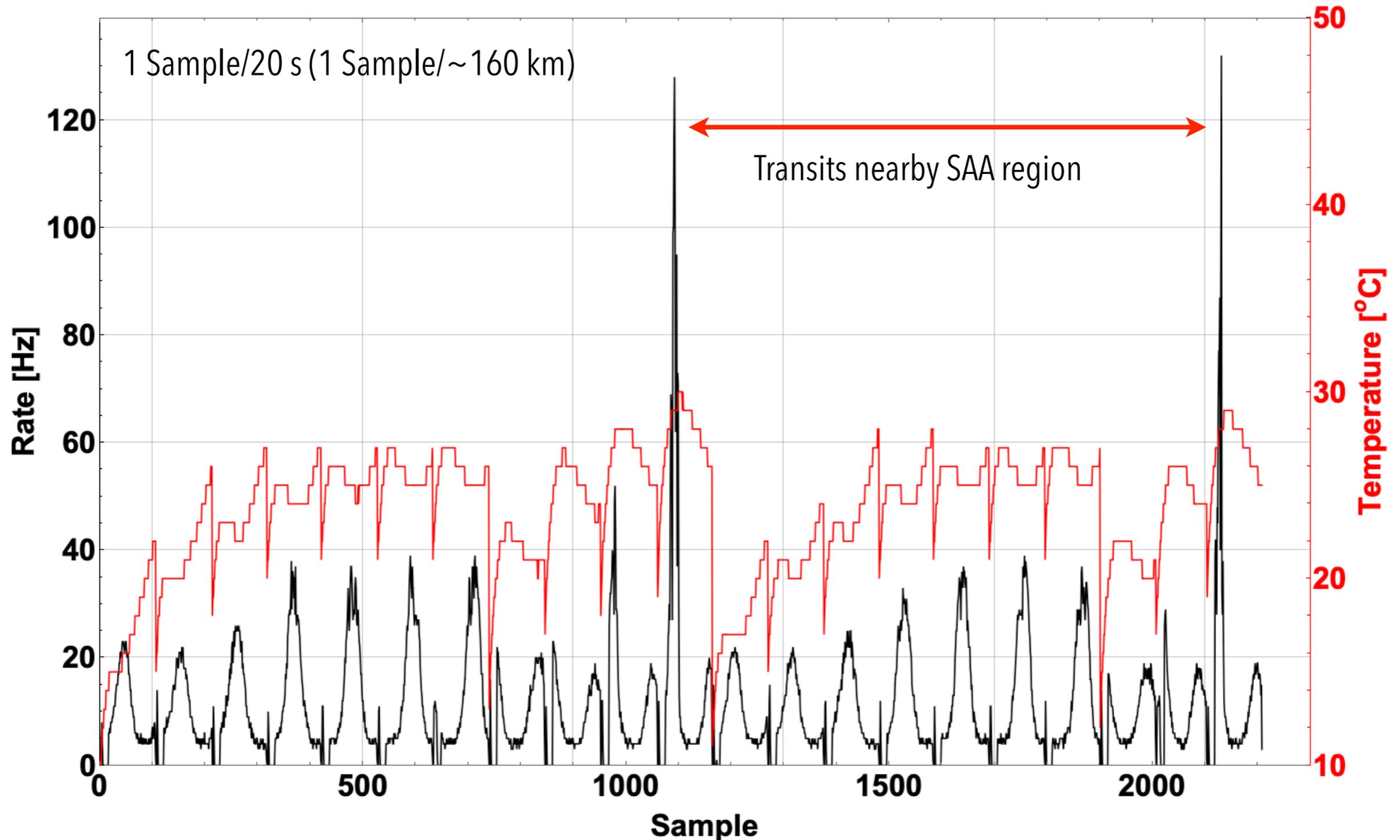
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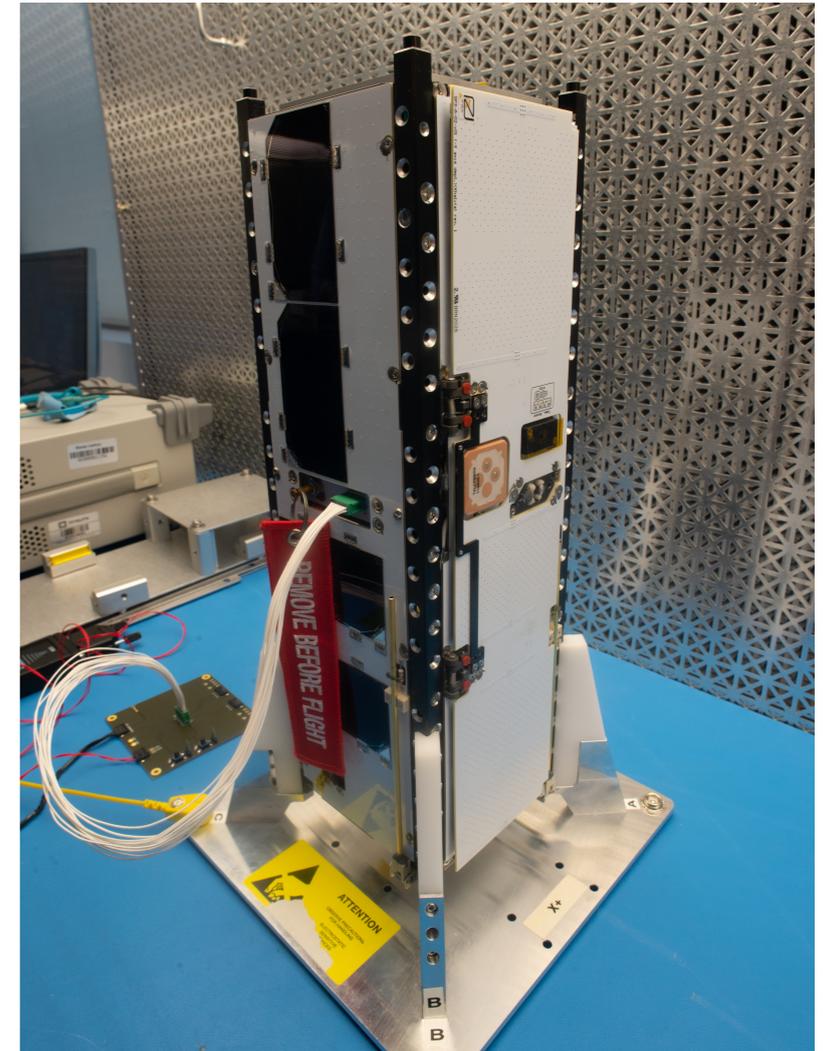


SiPM CH2 detection THR set to 1800 ADC CH / 64k ADC CH

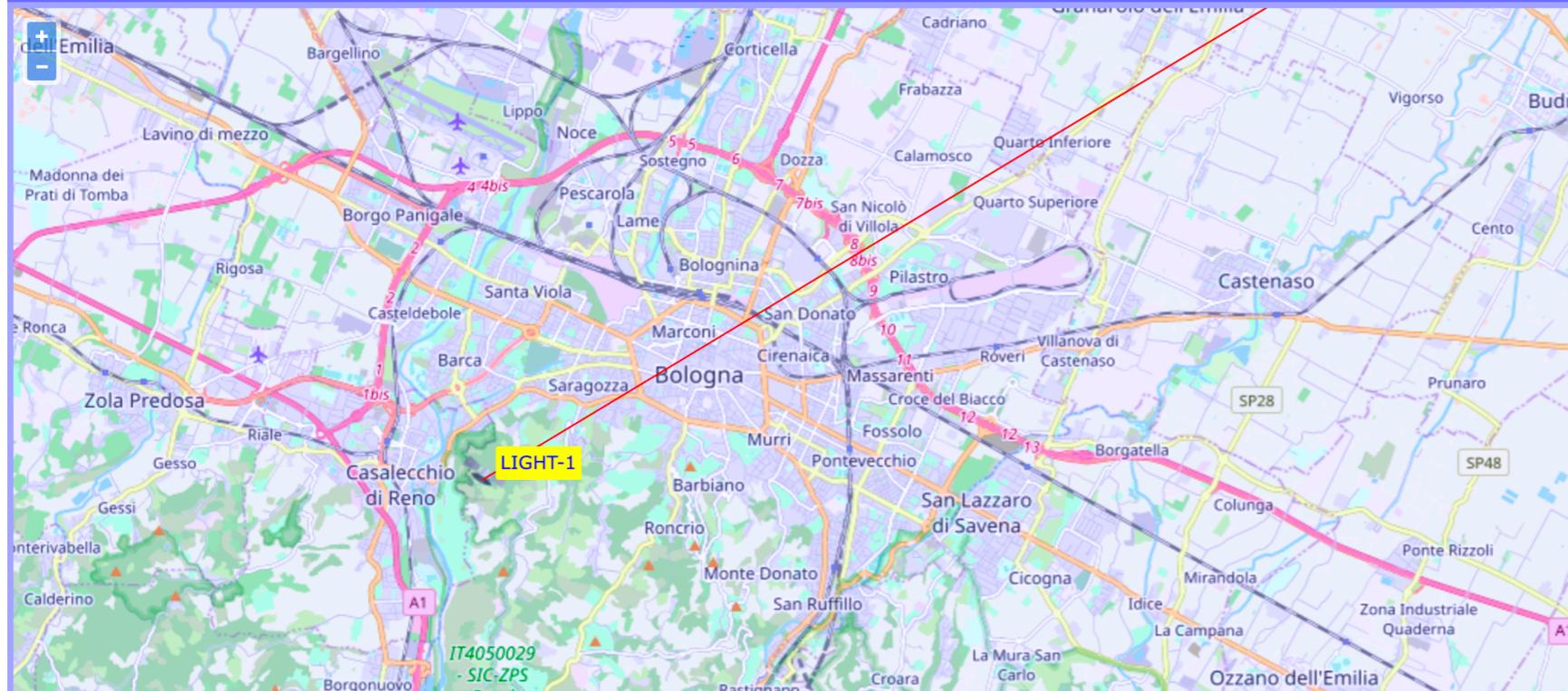
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# Summary and present status

- LIGHT-1 was launched on December 21st, 2021 SpaceX Falcon9/Dragon;
- LIGHT-1 was set into orbit (LEO, from ISS) on February 3rd, 2022;
- LEOP completed, LIGHT-1 payload commissioning completed;
- LIGHT-1 entered in the operating phase on May 10th, 2022;
- It has been a tremendous opportunity to teach students on instrumentation and detector operations;
- working fast toward the identification of TGF candidates.



TIME	Sat, 06/08/2022 12:53:04	Latitude [deg]	44.47	Altitude [km]	380.9	DEC J2000 [d:m:s]	68:06:24	Sun El.[deg]	65.5 (Day)
(UTC)	Sat, 06/08/2022 10:53:04	Longitude [deg]	11.29	Azimuth [deg]	11.3	RA J2000 [h:m:s]	17:53:13	Loaded SAT :	1
Time Off.	+715h 31m 18s (Future)	2459797.95352	JD	Elevation [deg]	-18.9	Magnitude	below horizon	Observer	(registered) 31514



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