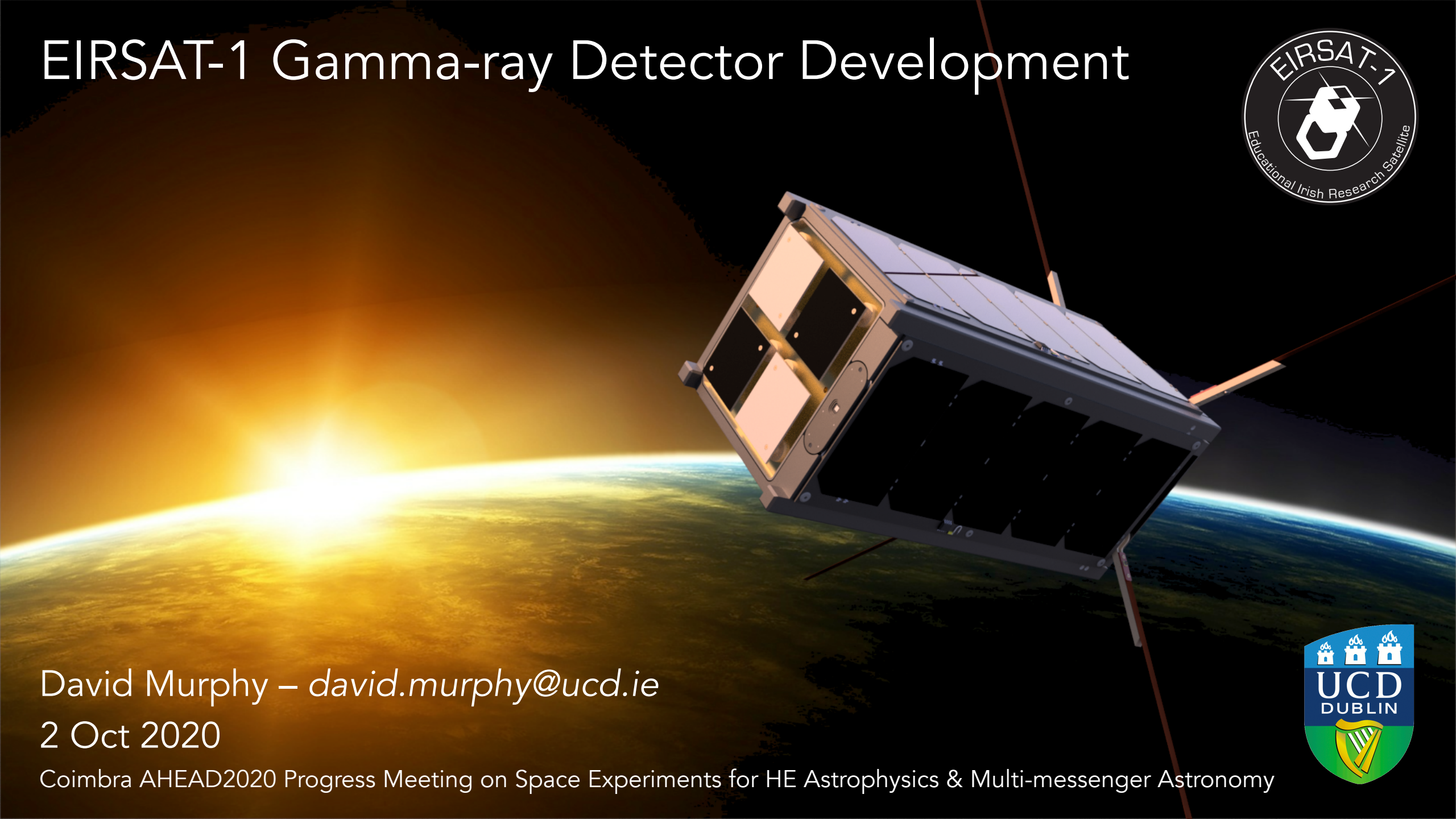
EIRSAT-1 Gamma-ray Detector Development

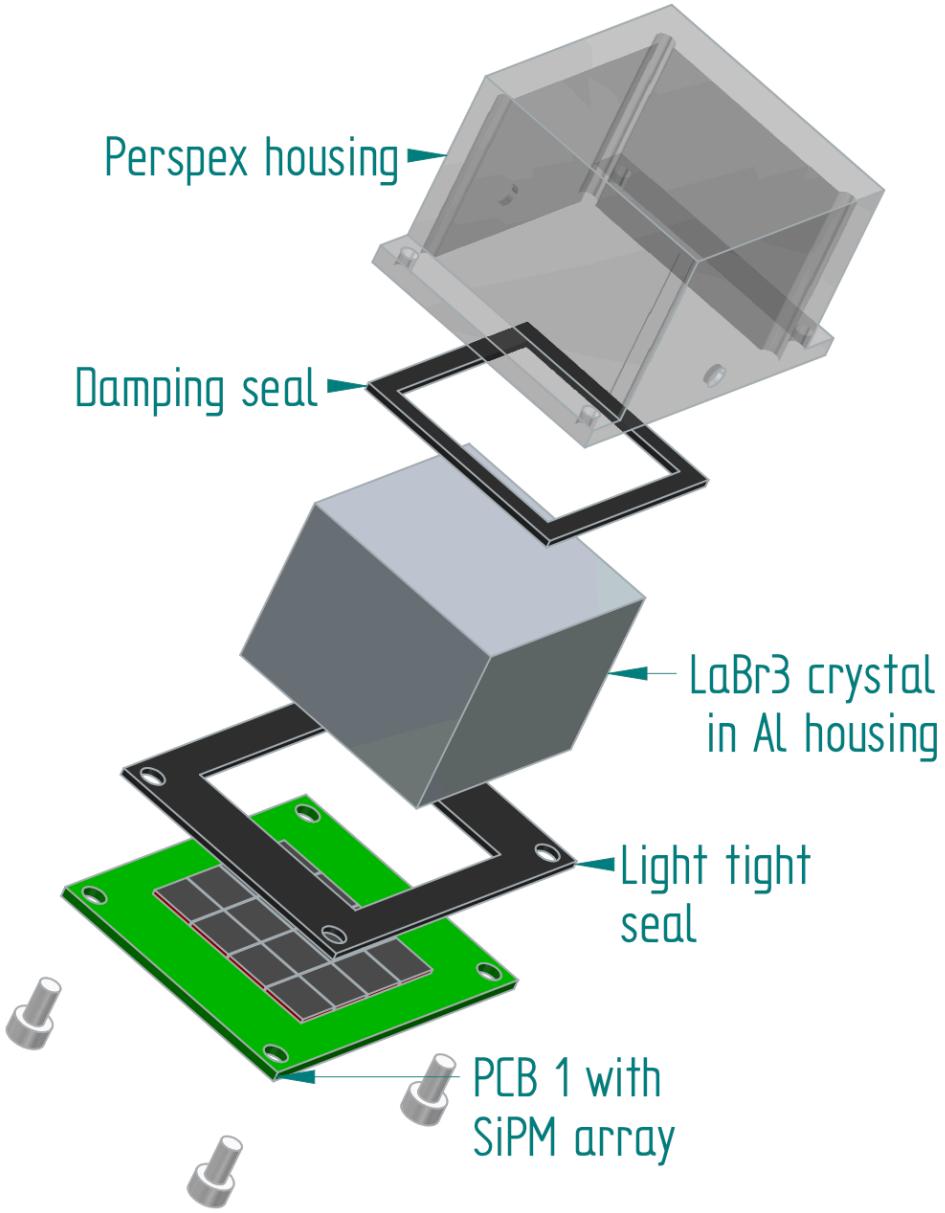


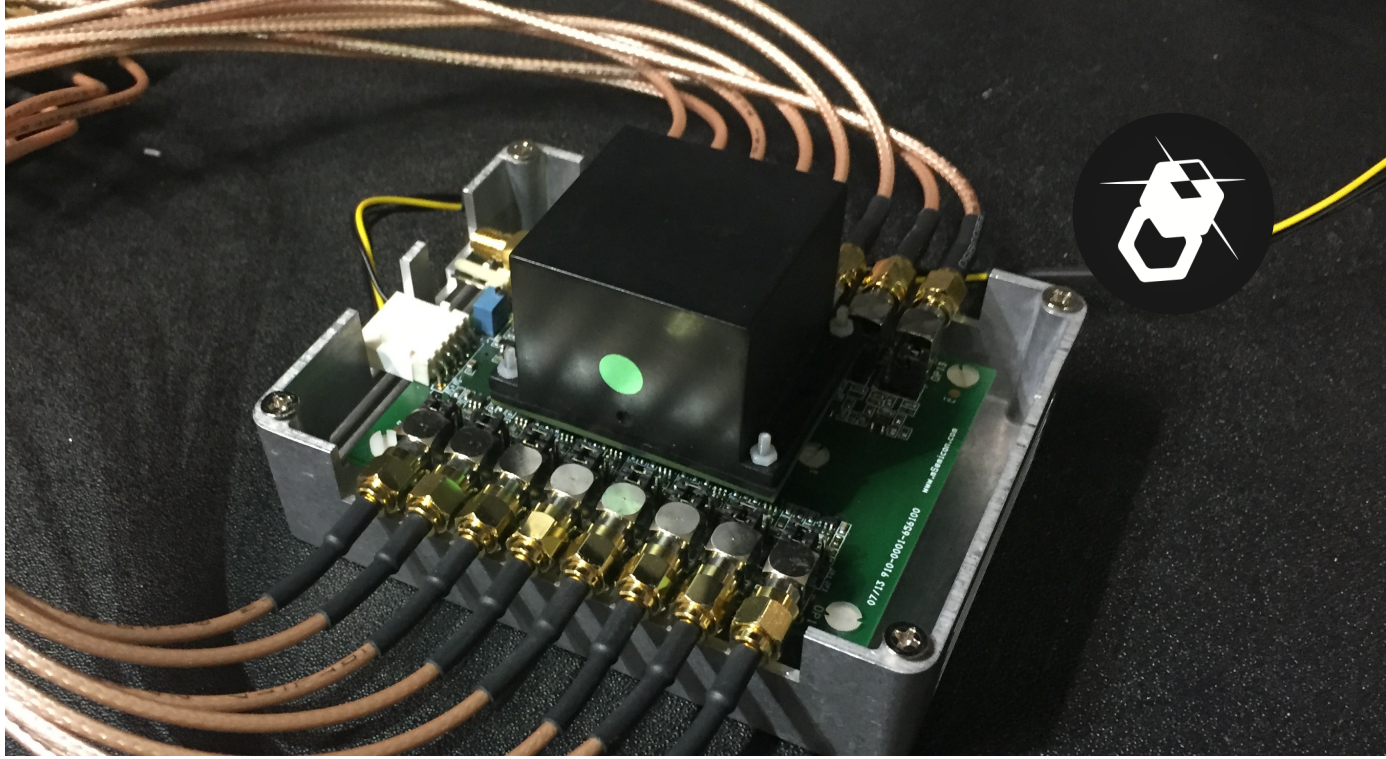
David Murphy – *david.murphy@ucd.ie*

2 Oct 2020

Coimbra AHEAD2020 Progress Meeting on Space Experiments for HE Astrophysics & Multi-messenger Astronomy

GRD





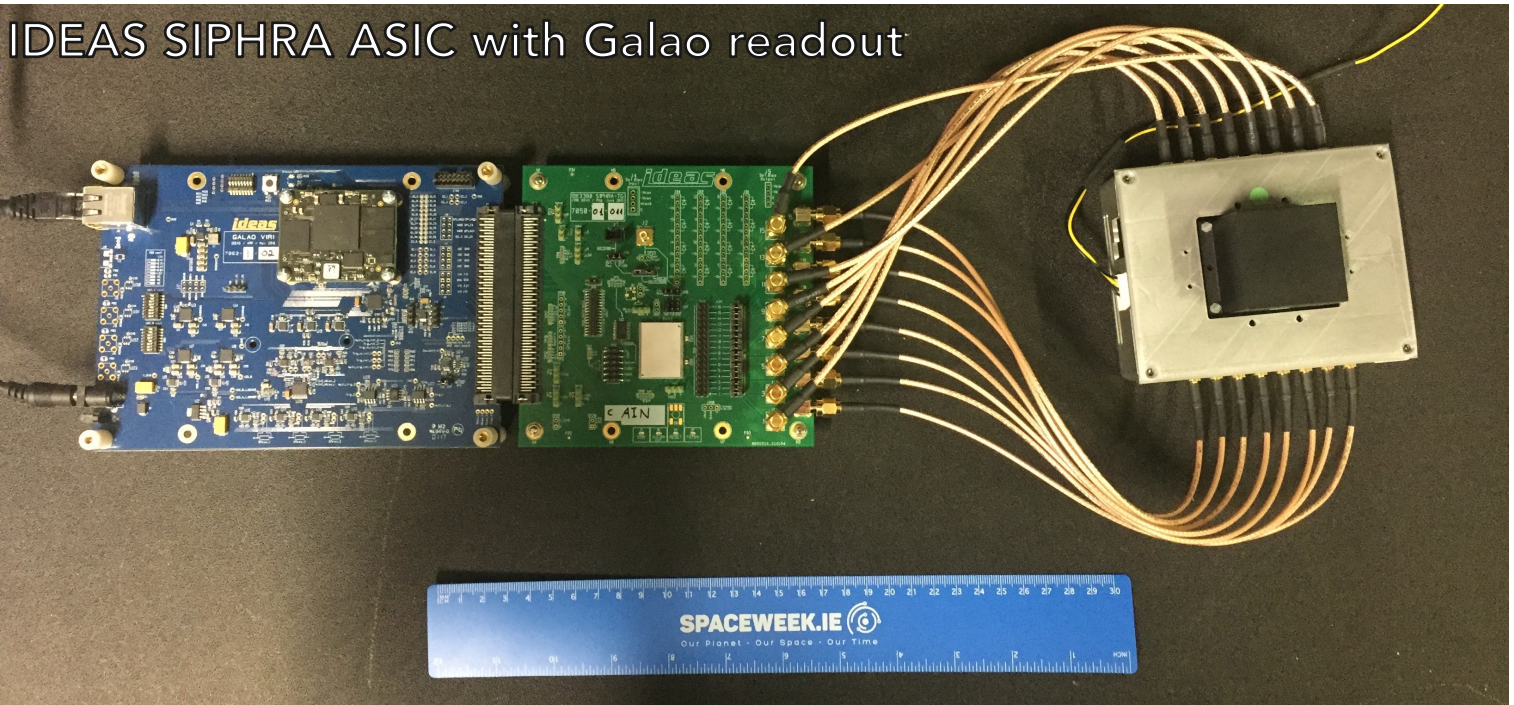
- 4×4 array of Sensl C-series SiPMs
- 28mm × 28mm × 20mm $LaBr_3$:Ce
- Later, 25mm × 25mm × 20mm $CeBr_3$

Ulyanov et al. 2016 – NIM A, Ulyanov et al. 2017 – NIM A

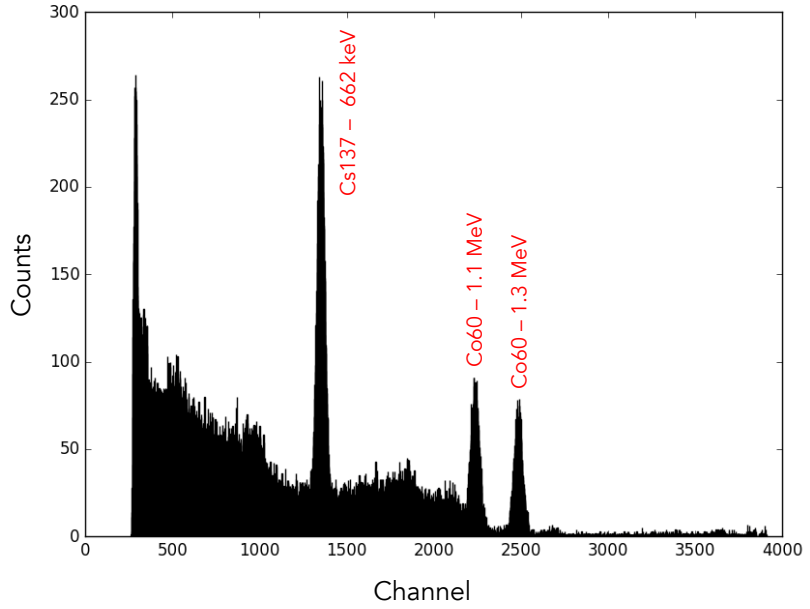
SIPHRA

- Developed by IDEAS
- 16 (+1) channel SiPM readout
- Designed for use in space – latch-up immunity, SEU mitigation, error correction
- Based on requirements of GRD

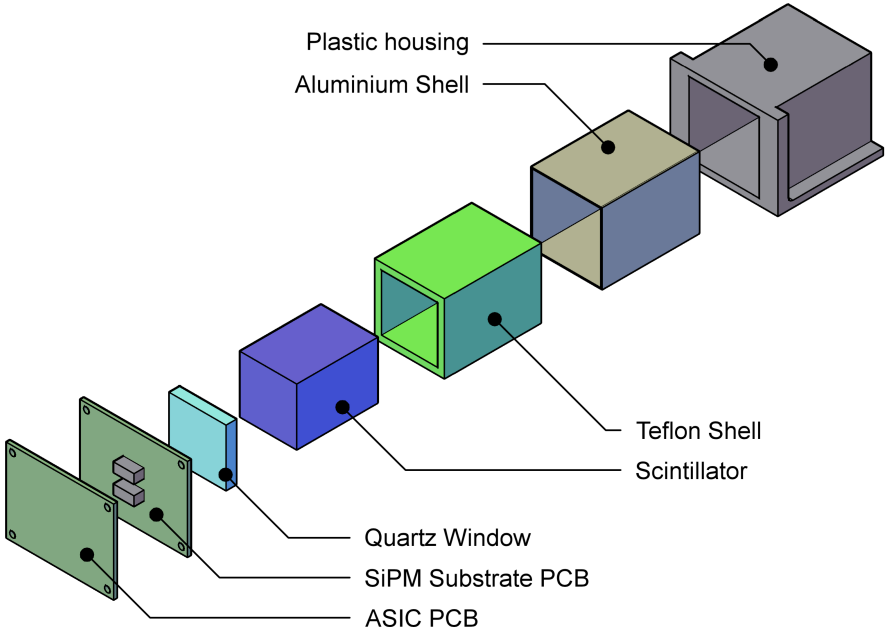
Meier et al. 2016 – AMICSA, Ulyanov et al. 2017 – IEEE

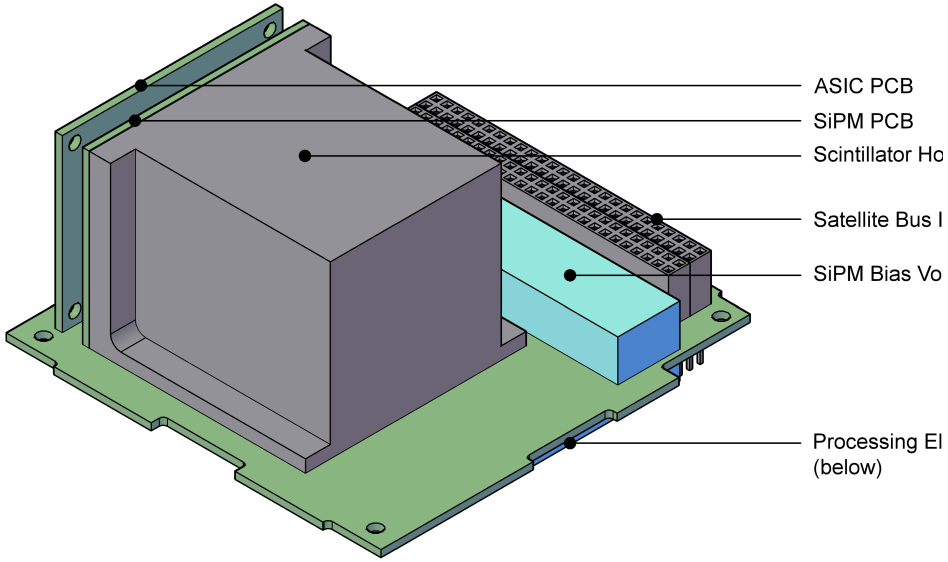


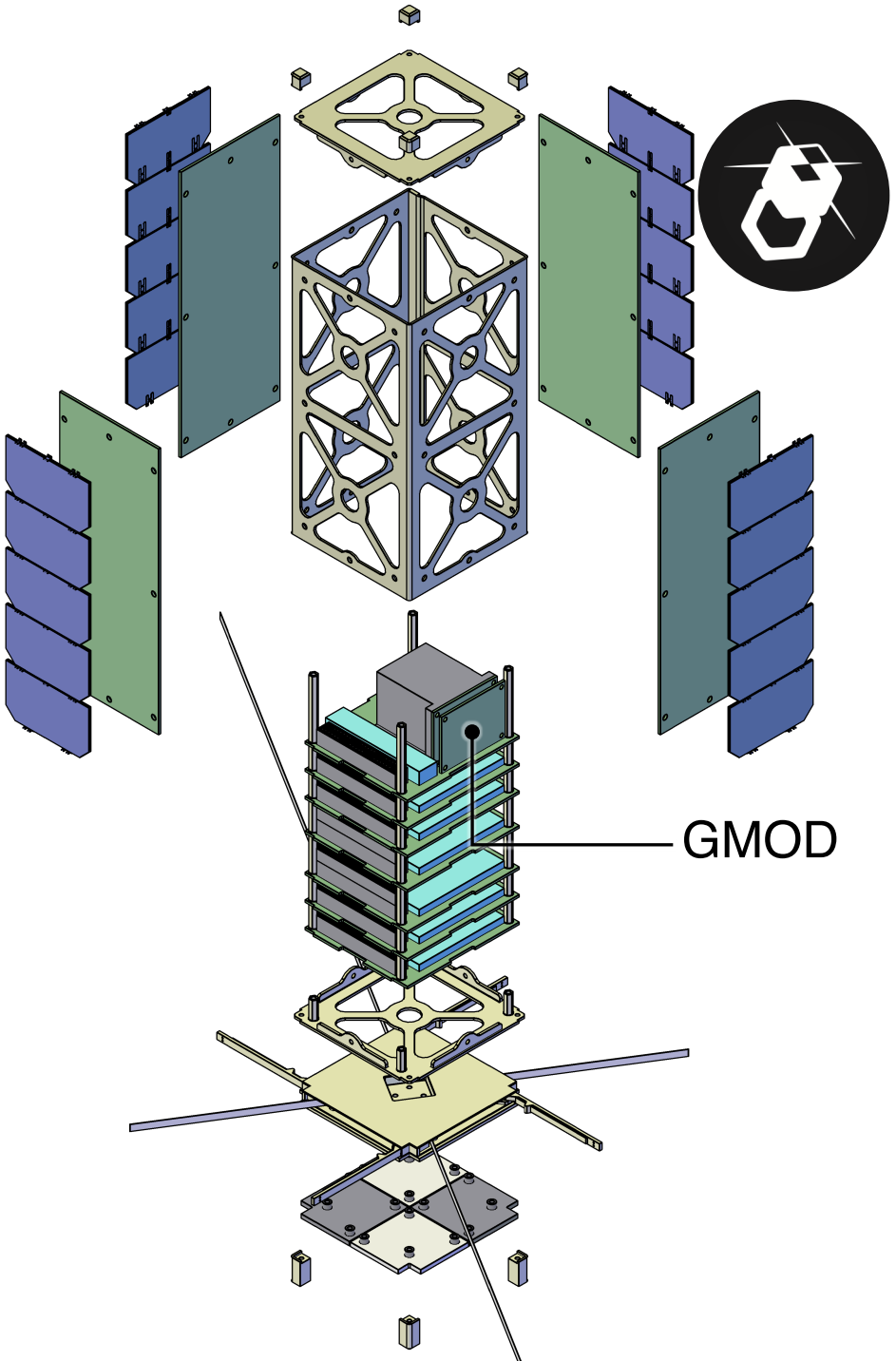
Sample spectra taken with SIPHRA



Early 2017 EIRSAT-1 + GMOD

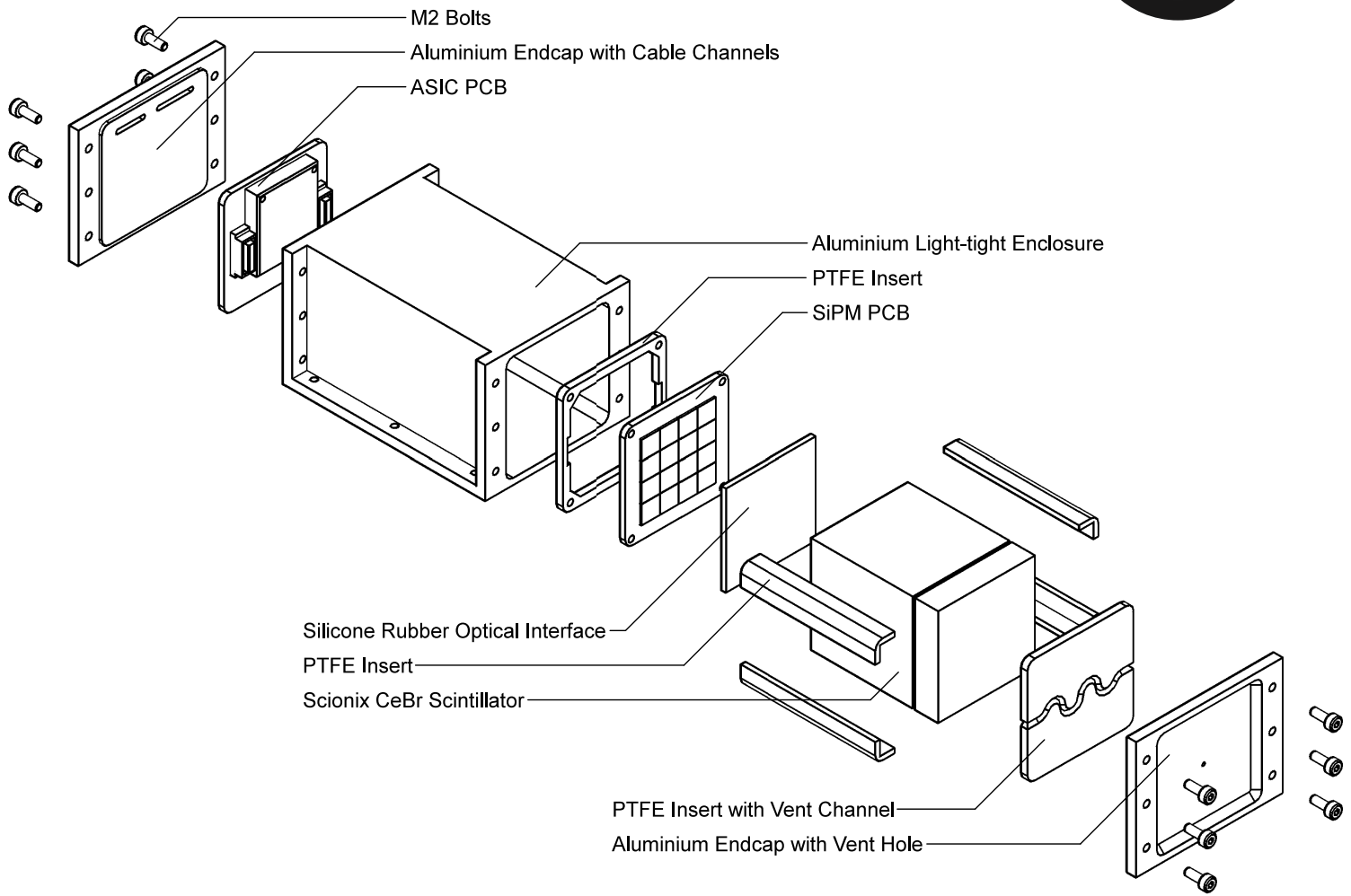






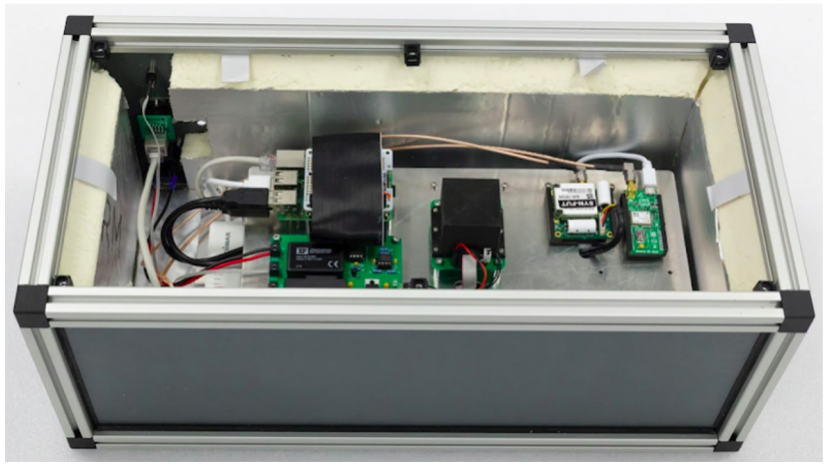
Late 2017 GMOD

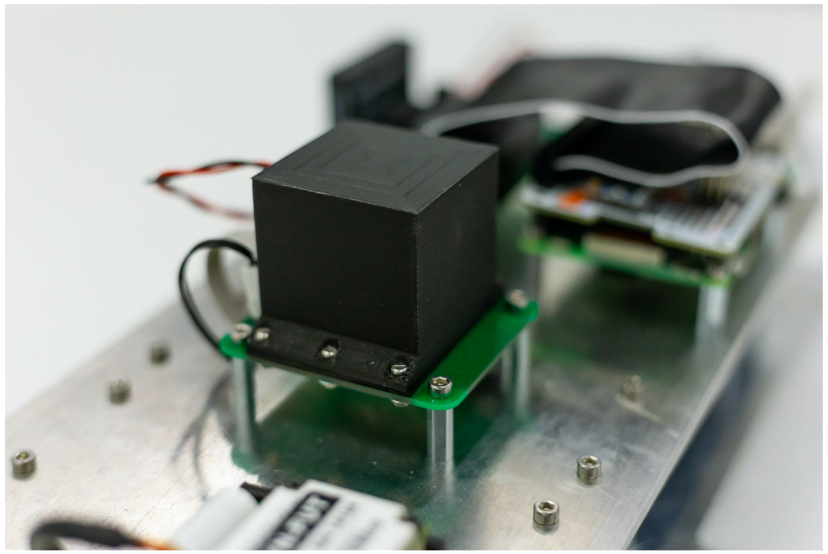
- Based on previous GRD detector built at UCD
- Designed to fit in approx 0.5U of a CubeSat
- Uses several novel technologies:
  - SiPMs by Irish company SensL
  - SIPHRA ASIC by IDEAS
  - Modern, bright scintillator – CeBr3

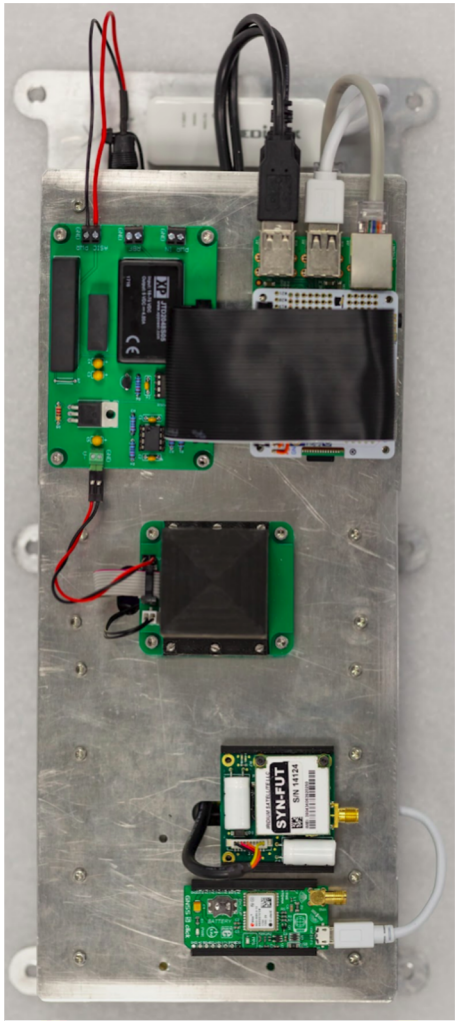


GMoDem
Gamma-ray Module Demonstrator

- Detector
  - CeBr
  - J-series SiPM arrays
  - SIPHRA
  - Galao
- Bias Supply
  - Inhouse design & production
- Readout & Storage
  - Raspberry Pi (via Python)
  - USB Flash Memory
- Telemetry
  - GPS + Altitude
  - Pressure
  - Temp (SiPM, internal, external)
- Structure
  - Aluminium extrusion
  - 600mm × 300mm × 200mm







GMoDem

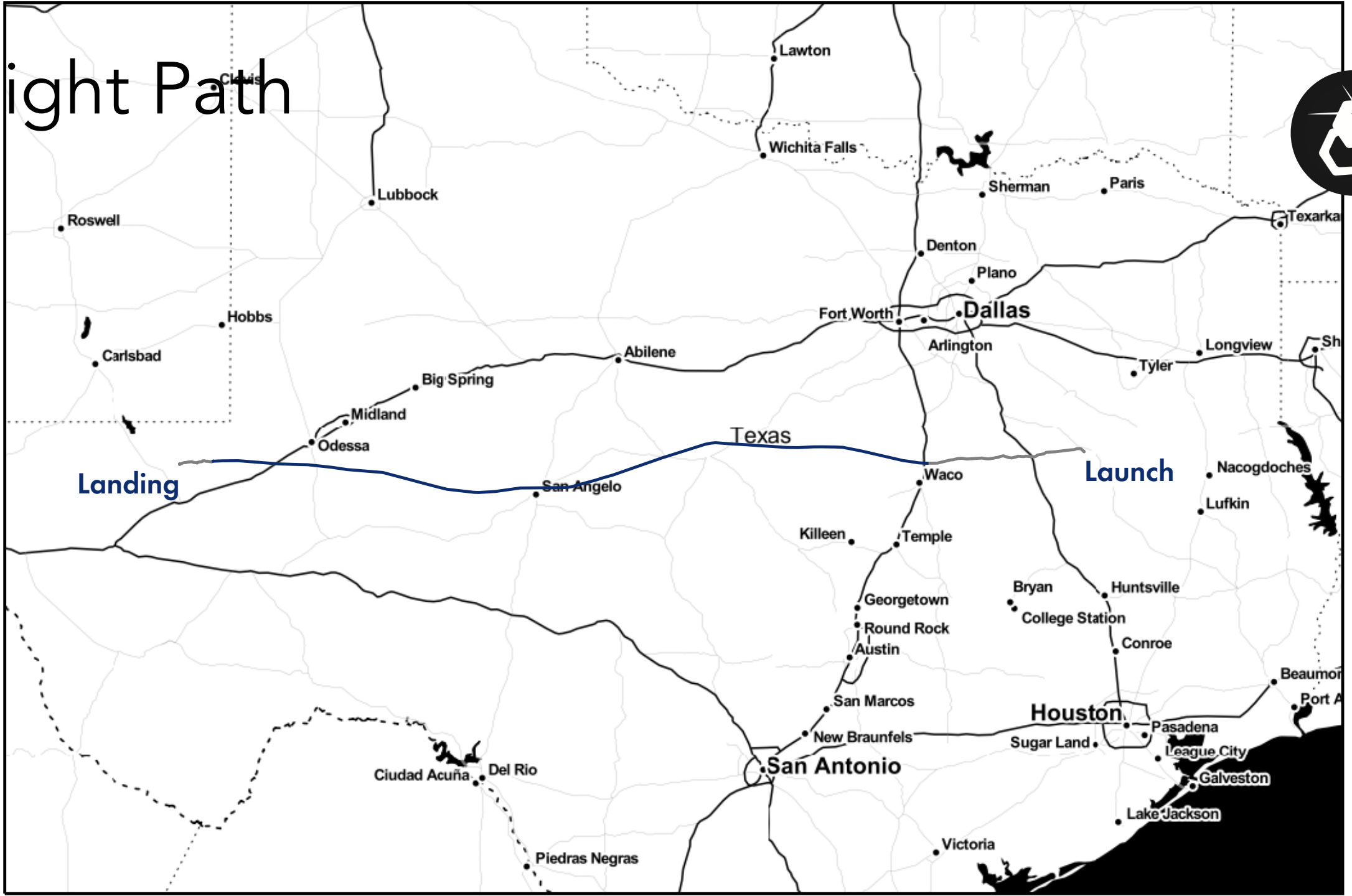




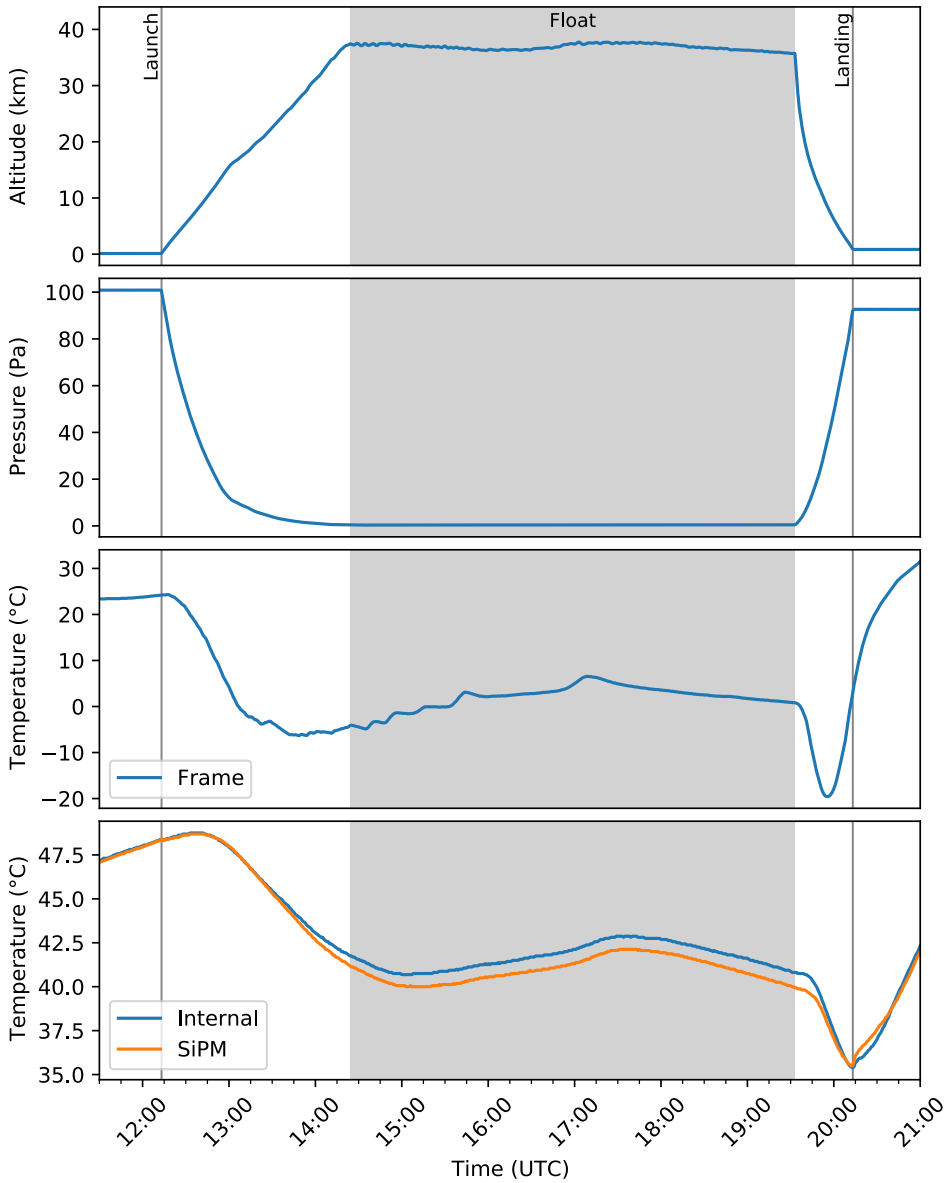


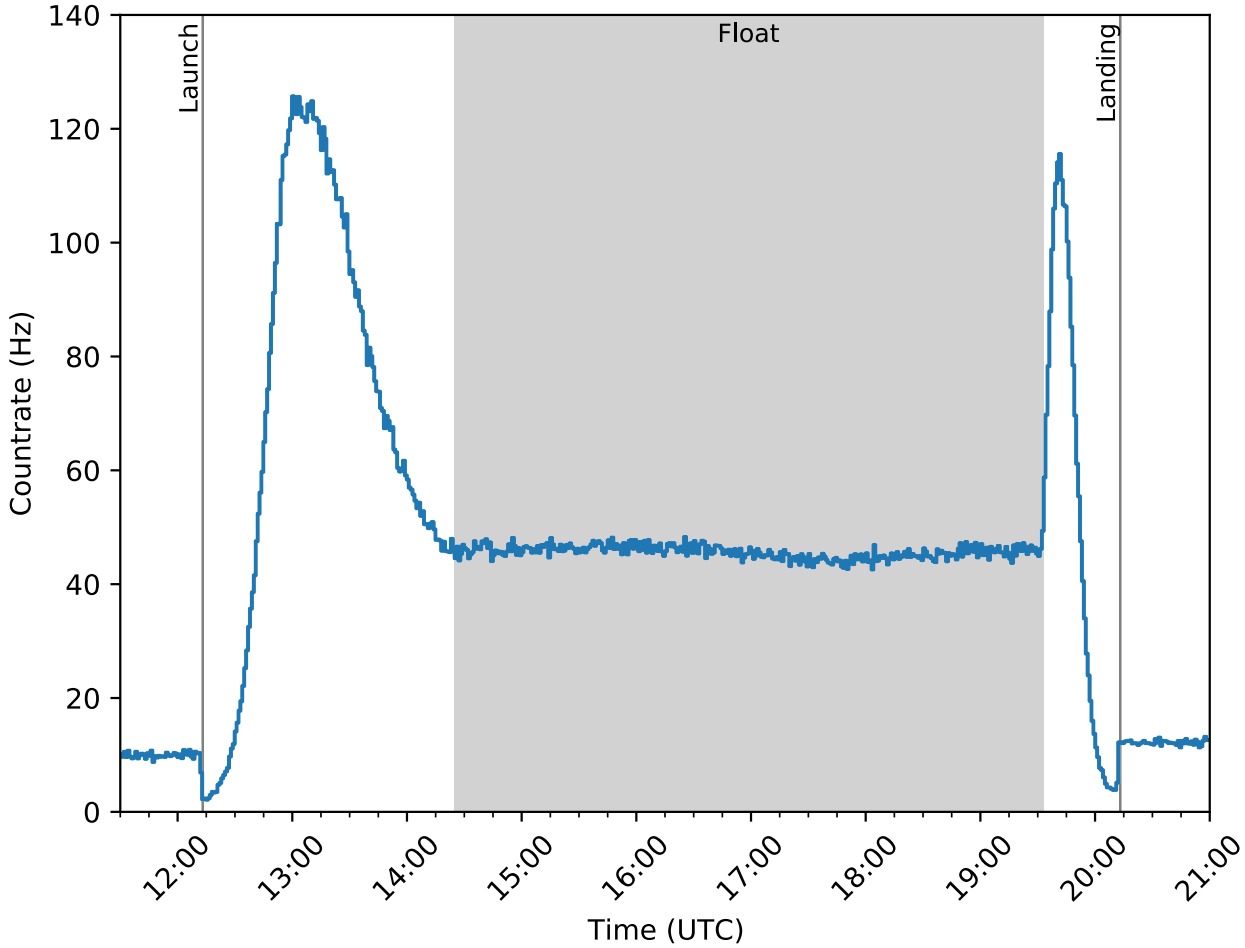
- Launch from NASA Columbia Scientific Balloon Facility
- Float altitude 37.4km for >5 hours

Flight Path


Lawton
Wichita Falls
Lubbock
Roswell
Hobbs
Carlsbad
Abilene
Big Spring
Midland
Odessa
Texas
Landing
San Angelo
Launch
Waco
Fort Worth
Dallas
Arlington
Sherman
Paris
Texarka
Denton
Plano
Tyler
Longview
Nacogdoches
Lufkin
Killeen
Temple
Georgetown
Round Rock
Austin
Bryan
College Station
Huntsville
Conroe
San Marcos
New Braunfels
San Antonio
Houston
Pasadena
Sugar Land
League City
Galveston
Lake Jackson
Beaumont
Port A
Ciudad Acuña
Del Rio
Piedras Negras
Victoria

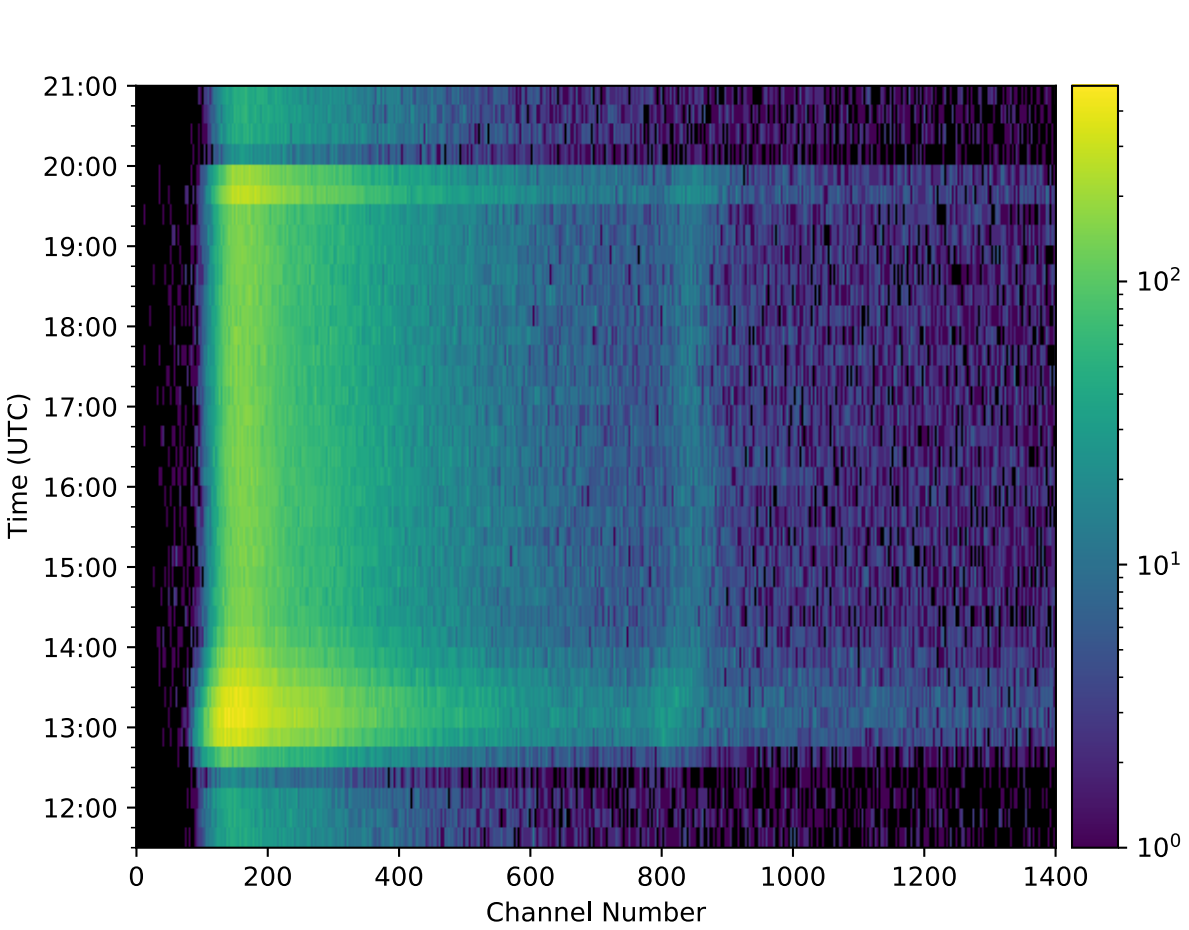
GMoDem - Telemetry

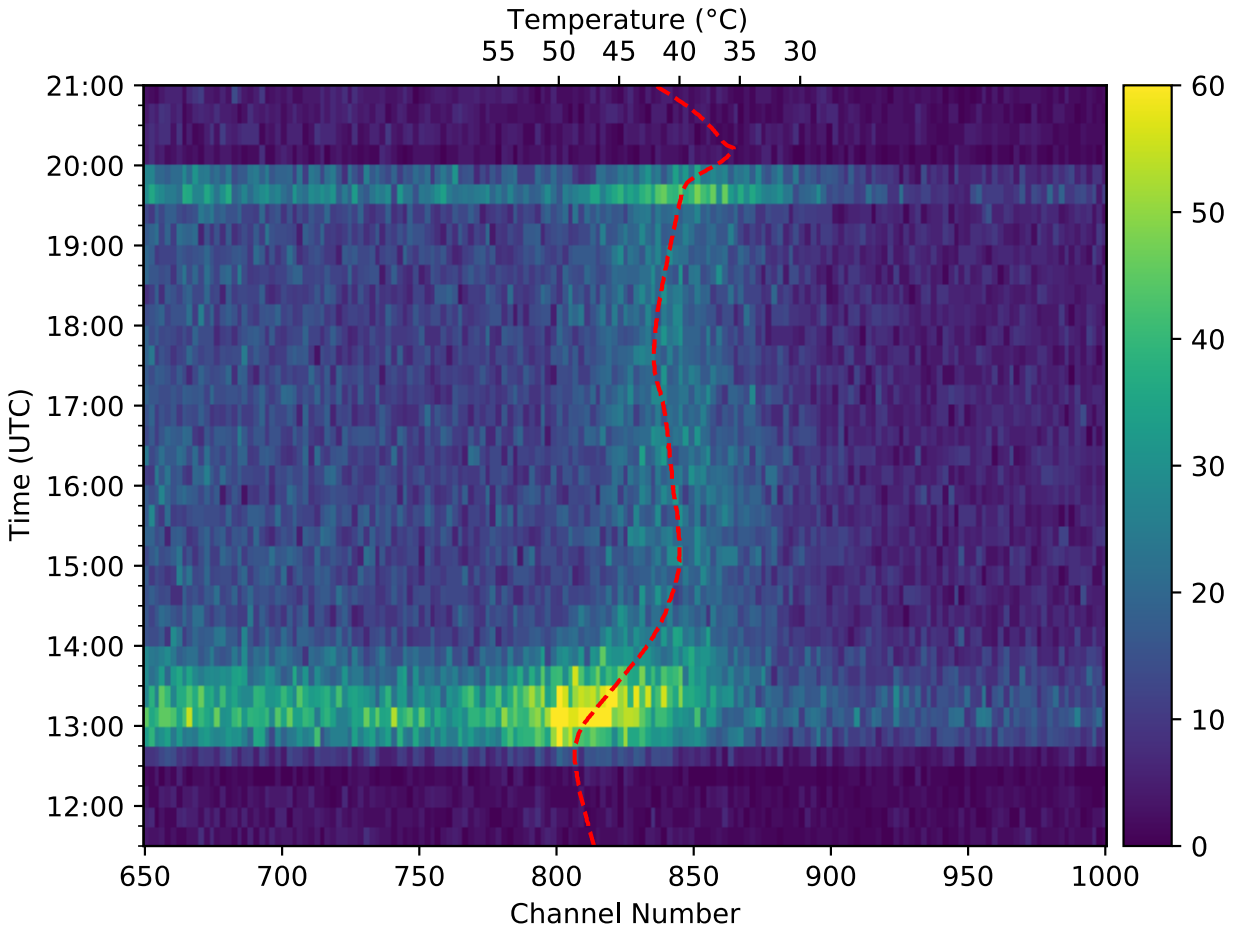




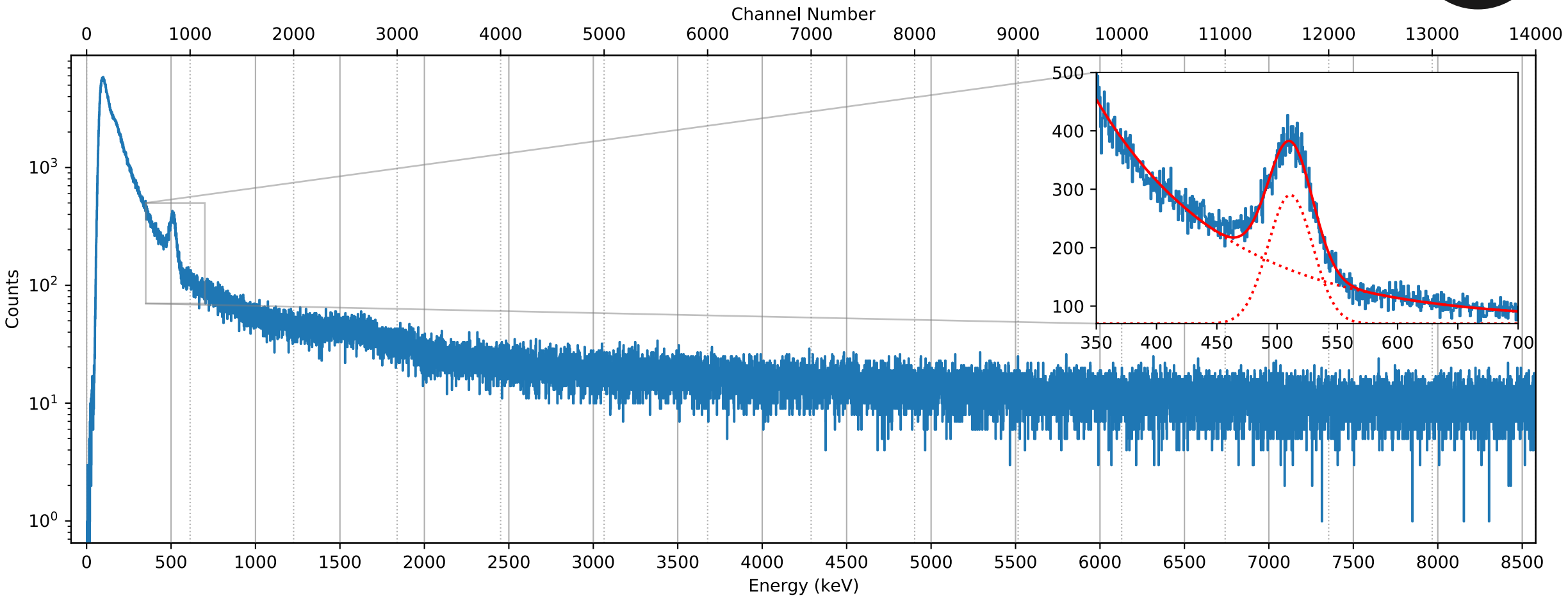
gmodem.spacescience.ie

GMoDem – Time Resolved Spectrum



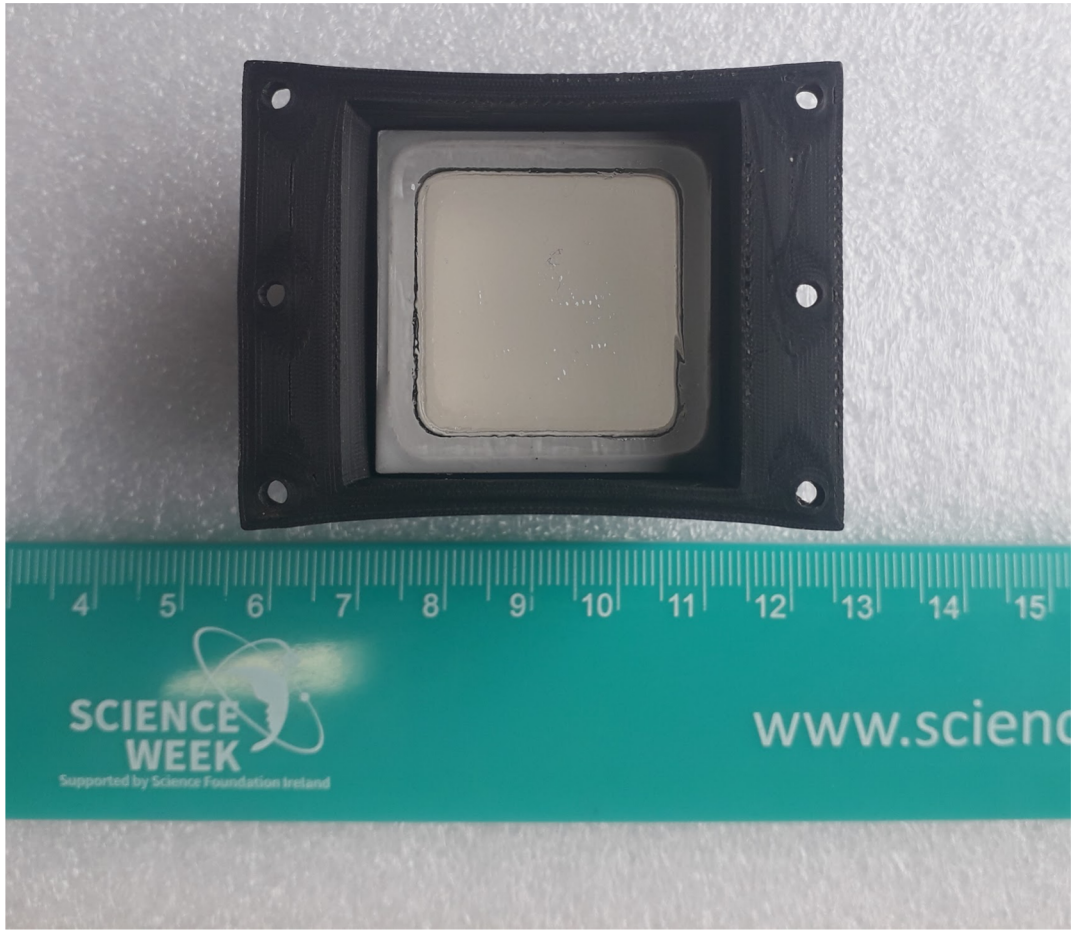


GMoDem – Flight Spectrum

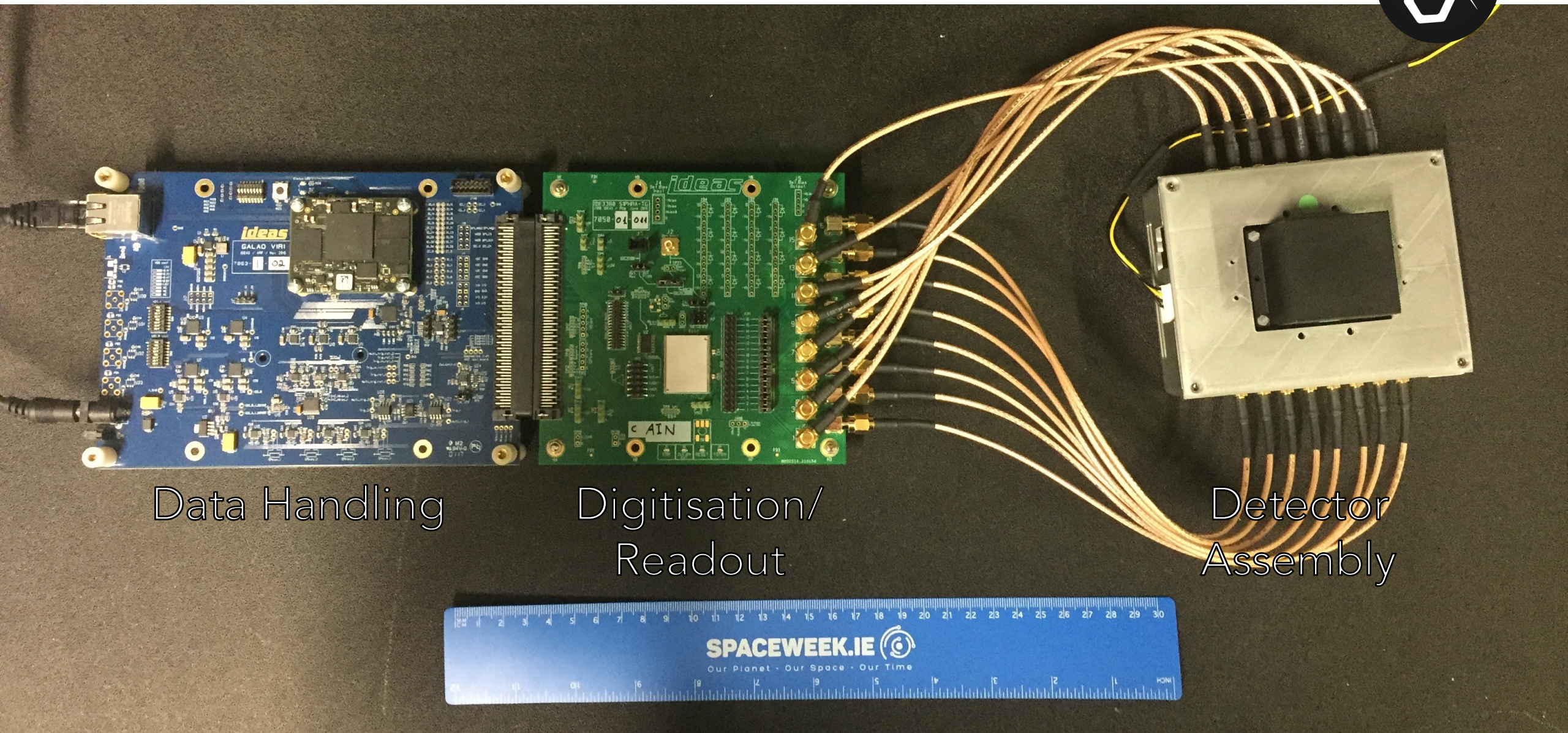


GMoDem

- Detector recovered with very loose and warped enclosure
- Preflight Sodium 22 calibration: 511keV @ Ch1526
- Inflight: 511keV @ Ch 798
- Poor optical coupling explains bad resolution – reduction in scintillation light of ~2 = degradation in resolution of ~√2



Development Strategy

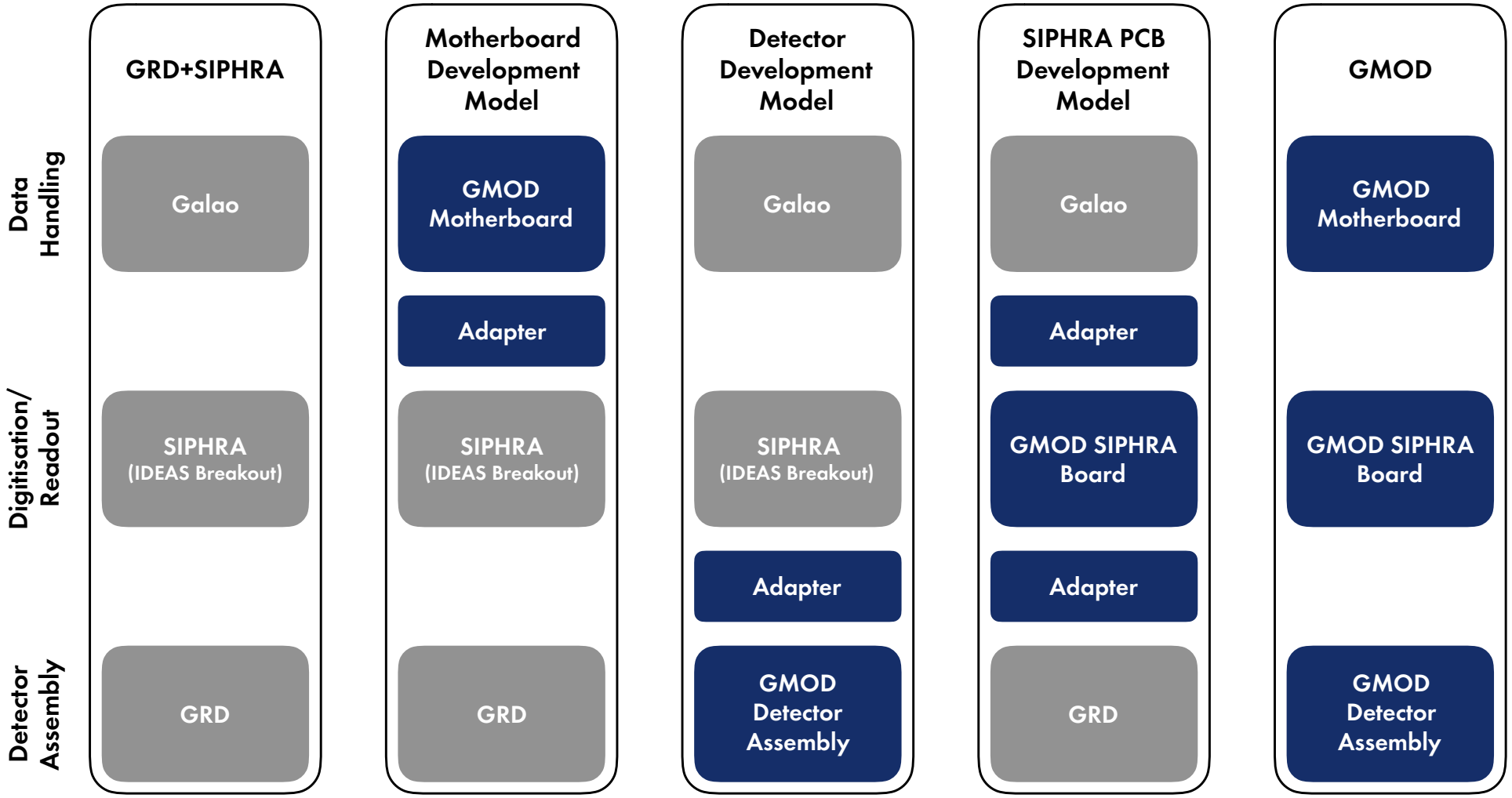


Data Handling

Digitisation/
Readout

Detector
Assembly

Architecture / Dev Strategy



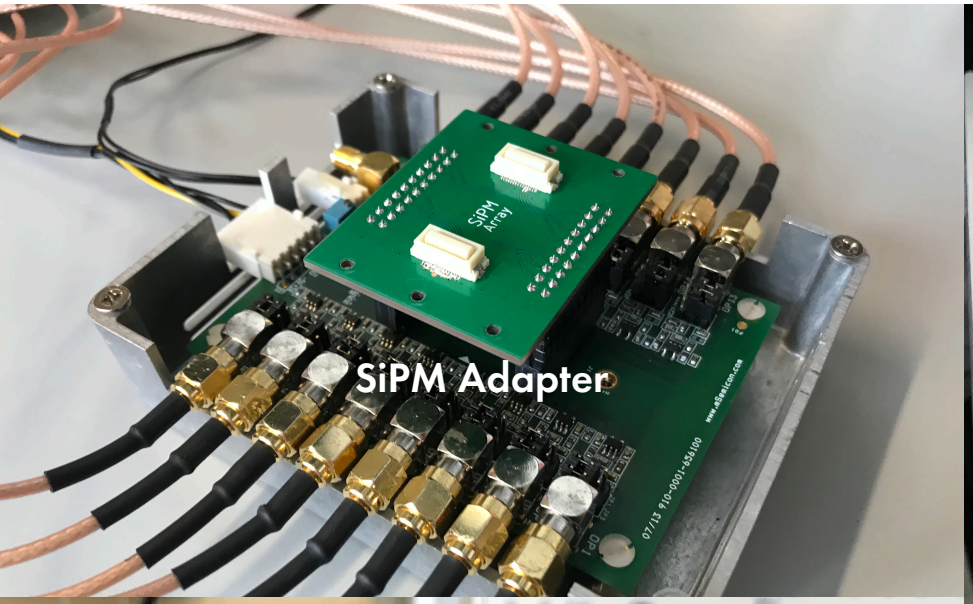
Detector Dev Model

Galao

SIPHRA (IDEAS Breakout)

Adapter

GMOD Detector

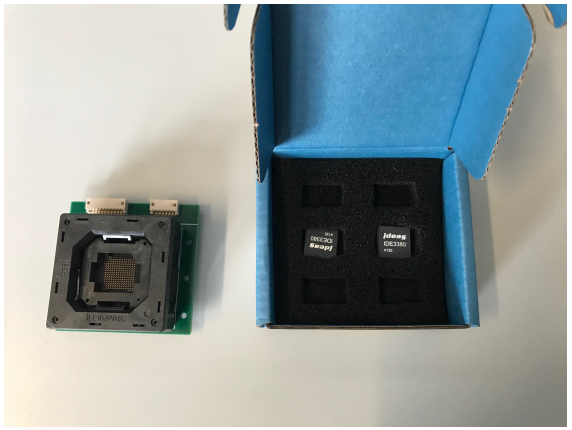


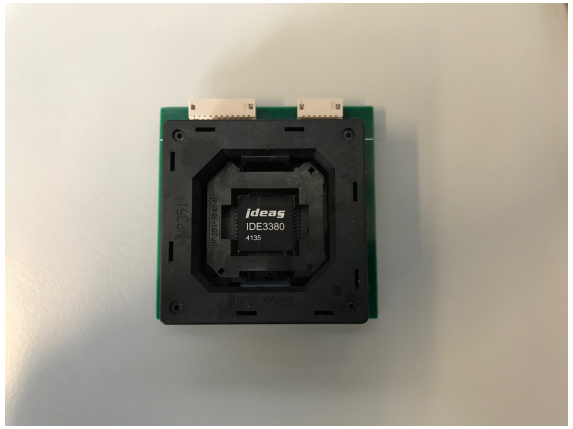




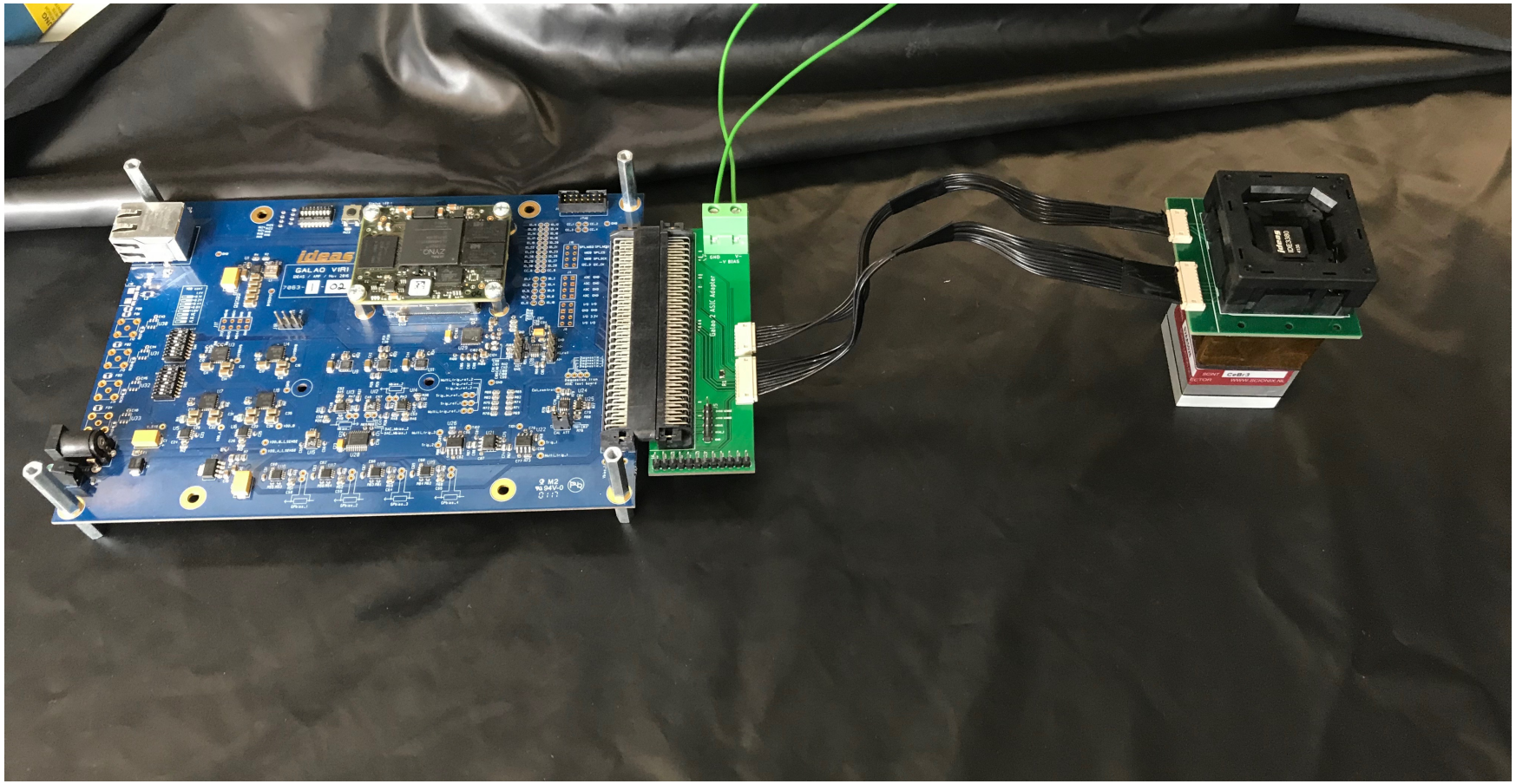
SIPHRA Dev Model

Galao | Adapter | GMOD SIPHRA Board | GMOD Detector



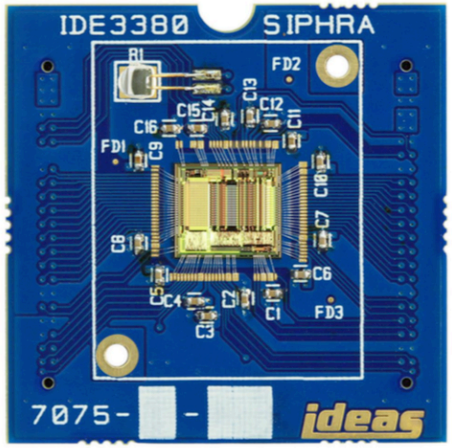


SIPHRA BGA



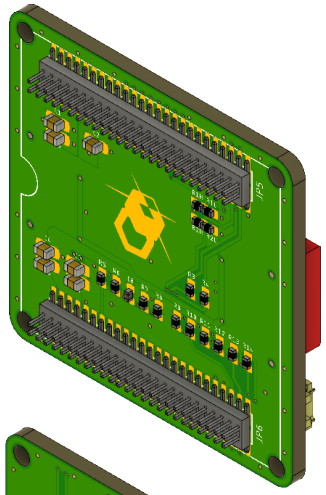
SIPHRA Dev Model

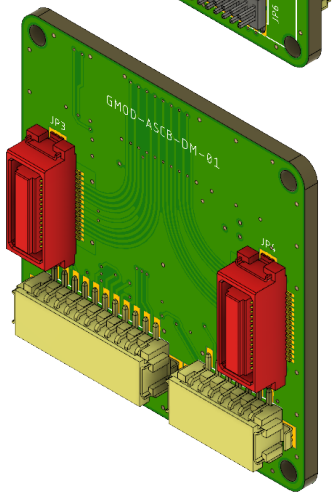
Galao | Adapter | GMOD SIPHRA Board | GMOD Detector

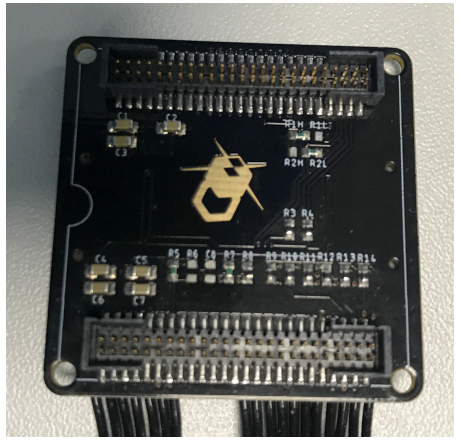


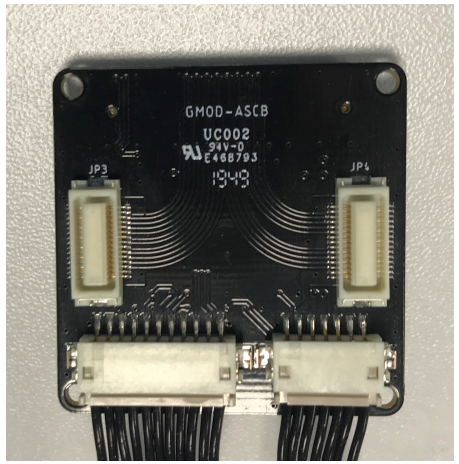


SIPHRA CoB

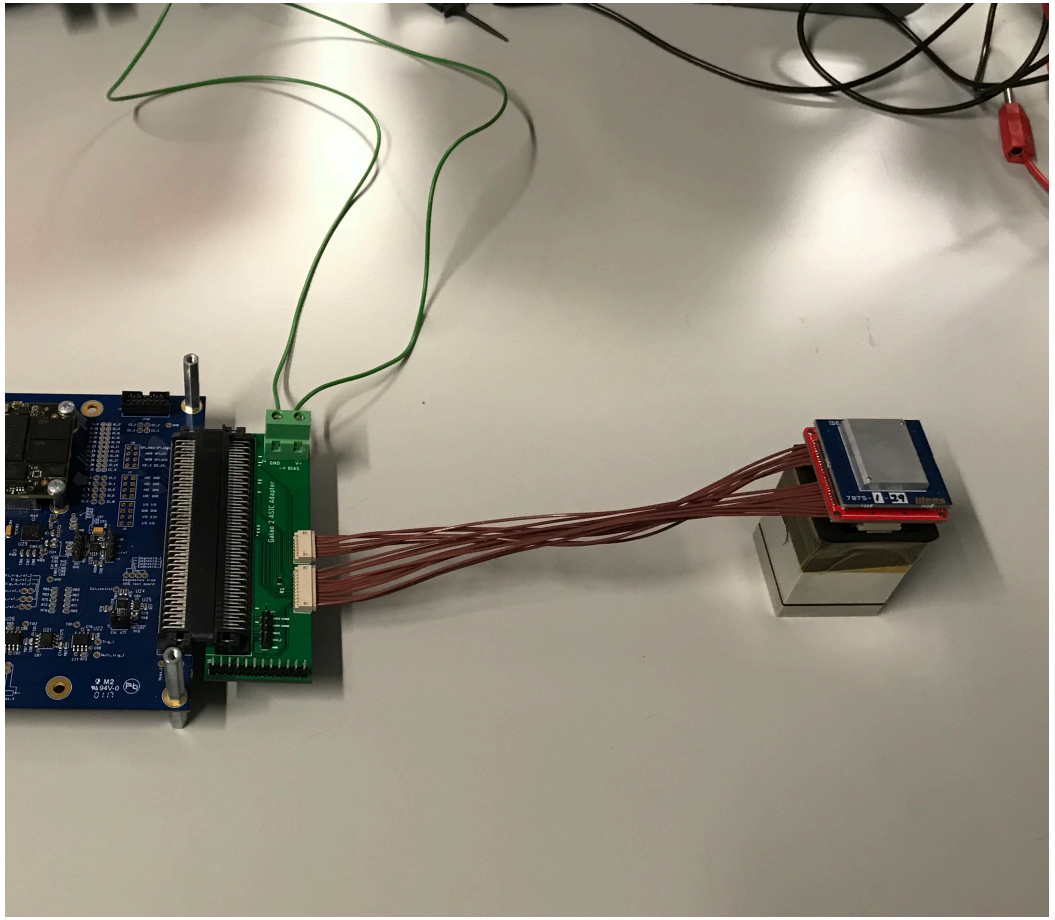






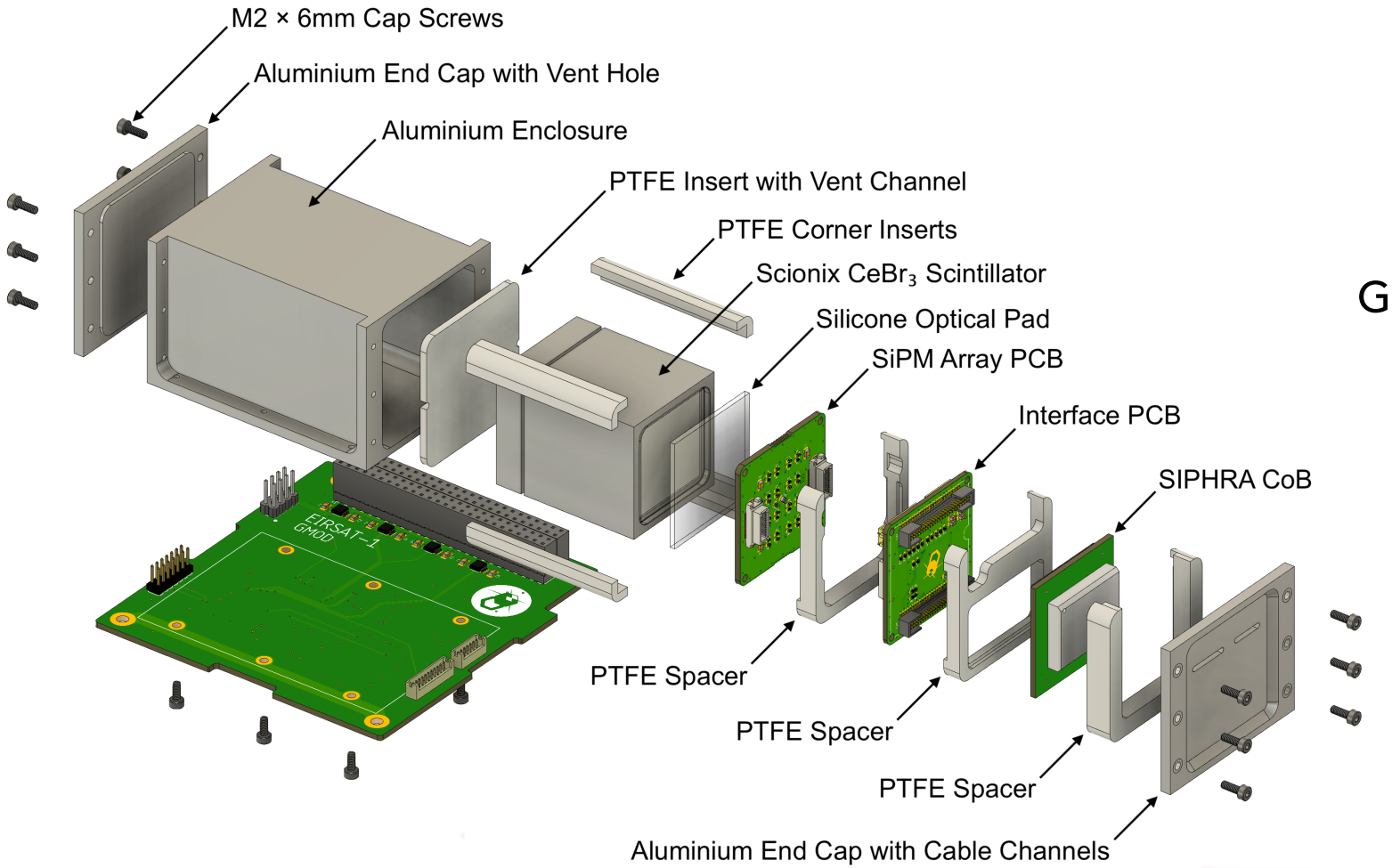


CoB Interface PCB



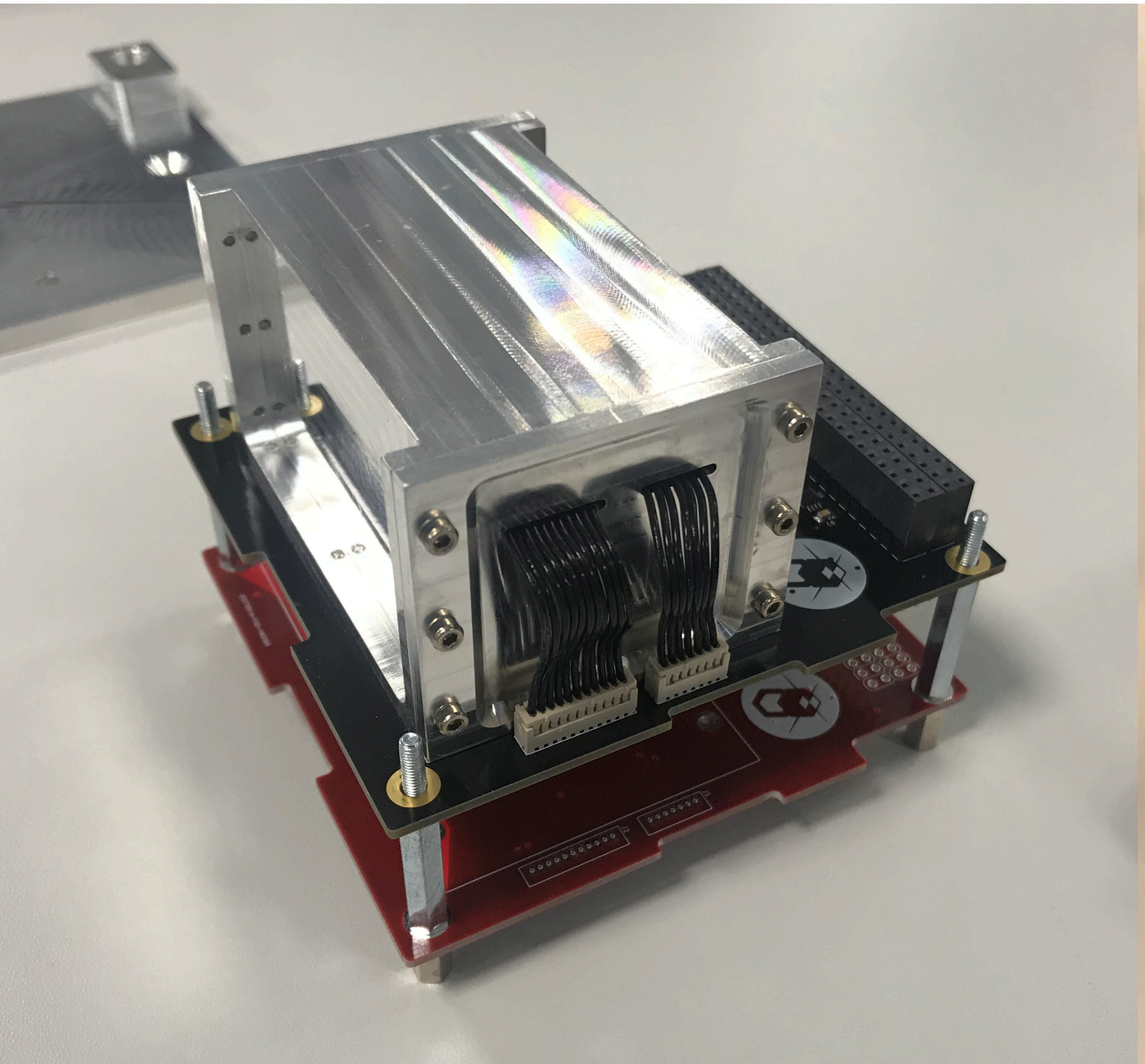
SIPHRA CoB with J-Series Array and CeBr3

Final EIRSAT-1 + GMOD





GMOD EQM





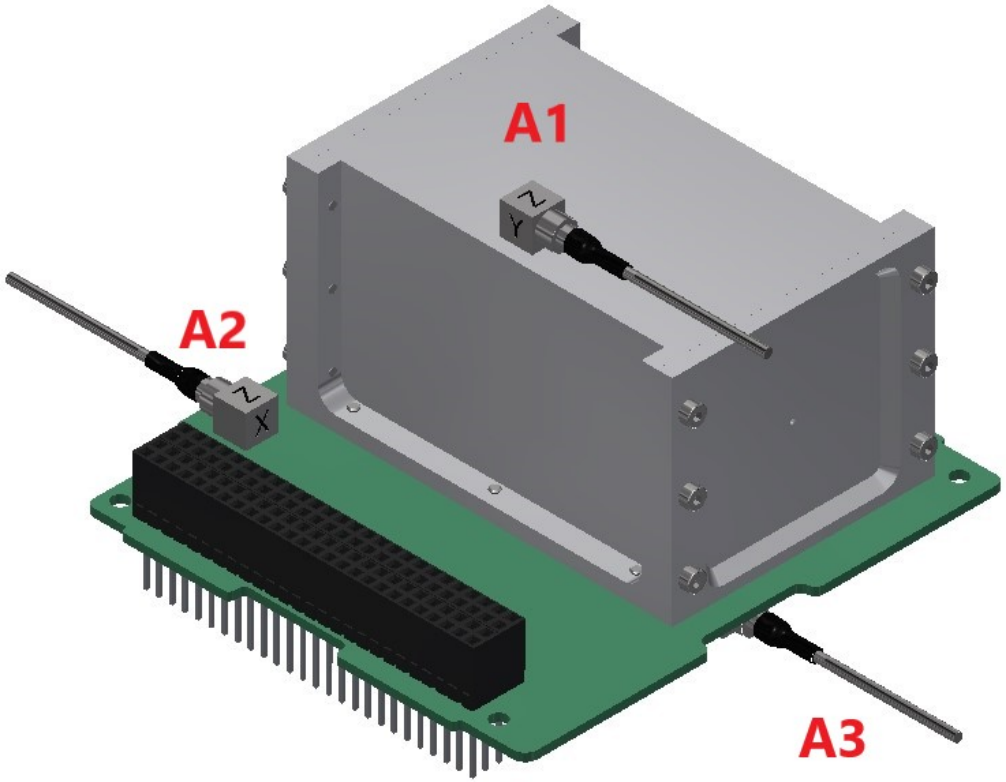
Vibration – Levels and Durations

Frequency (Hz)	Level	Unit
Sine		
5 - 21	11	mm
21 - 60	20	g
60 - 65	20 – 6	g
65 – 100	6	g
Random: 9.47g RMS		
20	0.057	g^2/Hz
20 - 153	0	dB/oct
153	0.057	g^2/Hz
153 - 190	7.67	dB/oct
190	0.099	g^2/Hz
190 - 250	0	dB/oct
250	0.099	g^2/Hz
250 - 750	-1.61	dB/oct
750	0.055	g^2/Hz
750 - 2000	-3.43	dB/oct
2000	0.018	g^2/Hz
Resonance Search		
5 - 2000	0.5	g

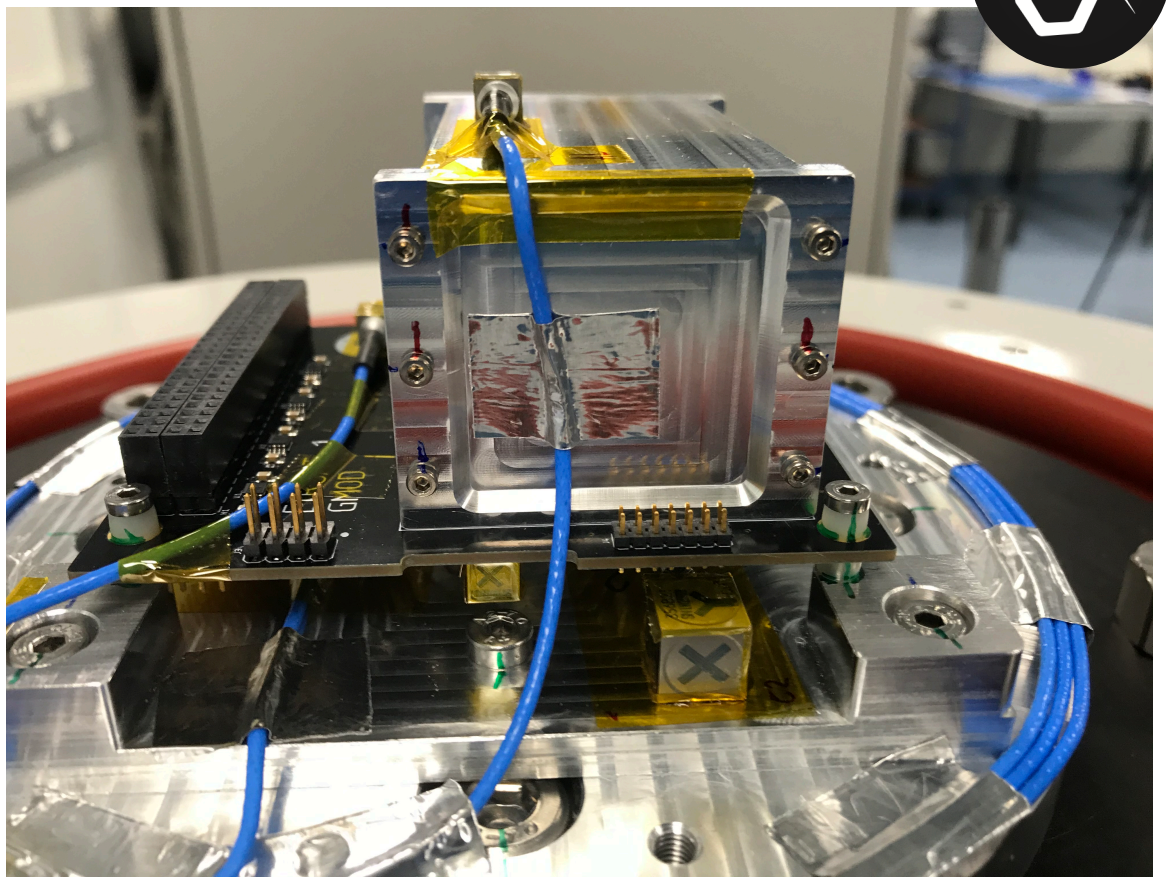
- Sine: 5 – 100Hz at 2 octaves / minute
- Random:
  - 10s at -9dB
  - 10s at -6dB
  - 10s at -3dB
  - 120s at 0dB (9.47g RMS)
- Resonance Search: 5 – 2000Hz at 2 octaves / minute

- Sequence:
  - Resonance Search
  - Sine
  - Resonance Search
  - Random
  - Resonance Search

Vibration – Accelerometers

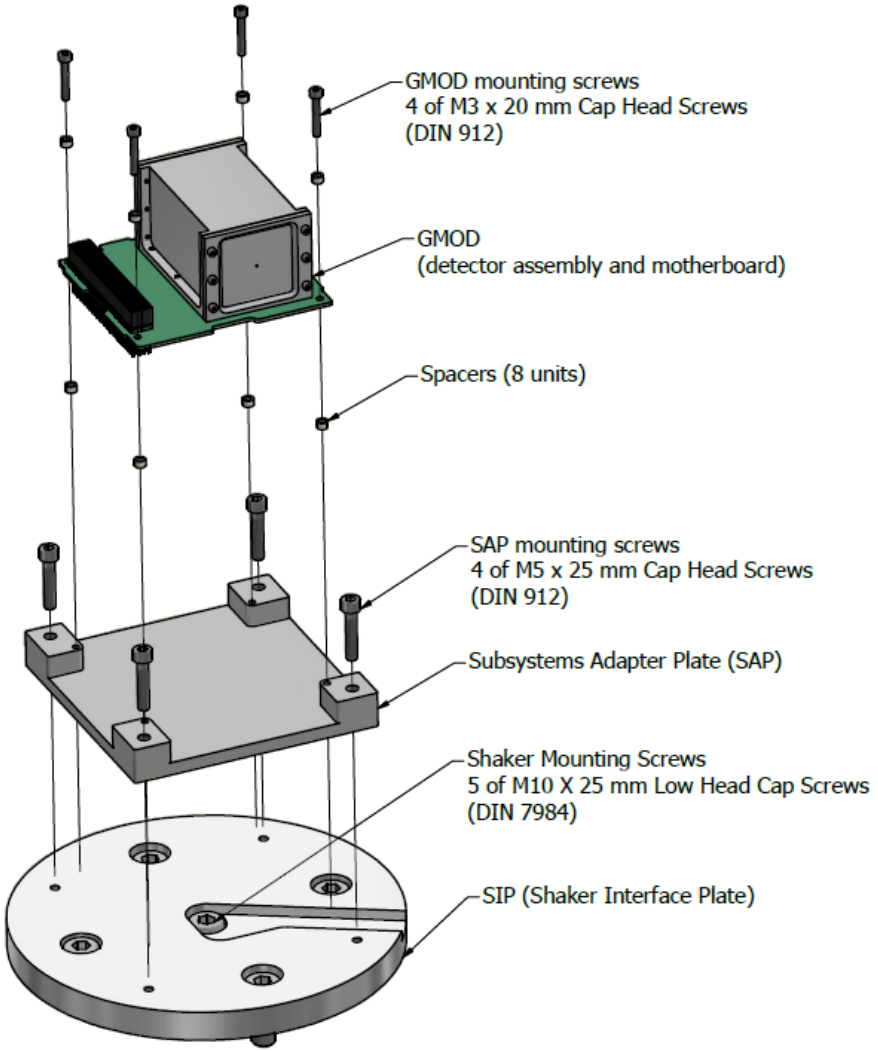


- 3 triaxial measurement accelerometers
  - A1: GMOD Housing
  - A2: Top of motherboard
  - A3: Bottom of Motherboard

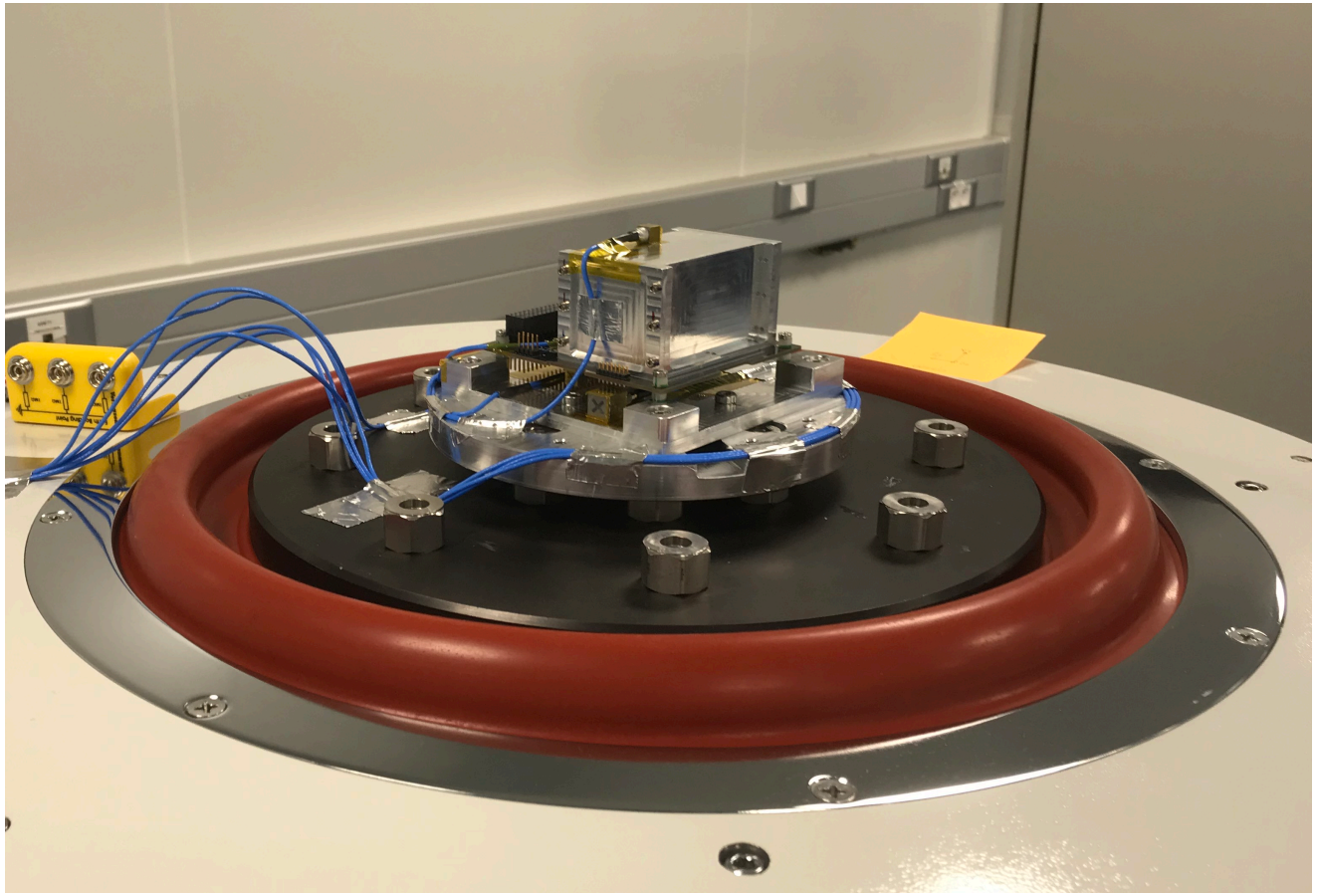


- 2 triaxial control accelerometers
  - Mounted to Subsystem Adapter Plate

Vibration – MGSE/Mounting

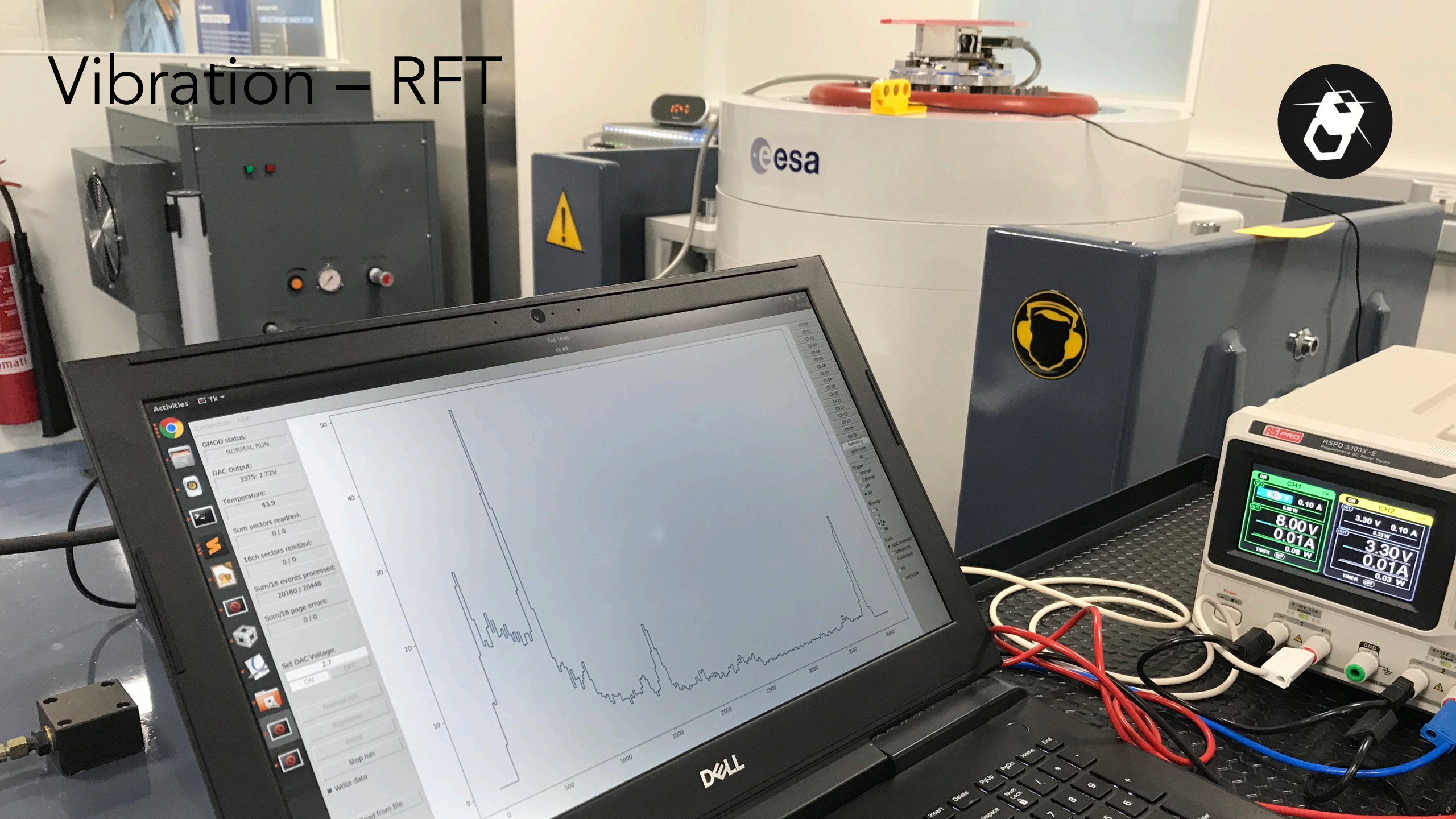


Mounting Exploded Diagram



GMOD Mounted on Z-Axis Armature

Vibration – RFT



TVAC – Profiles and Durations

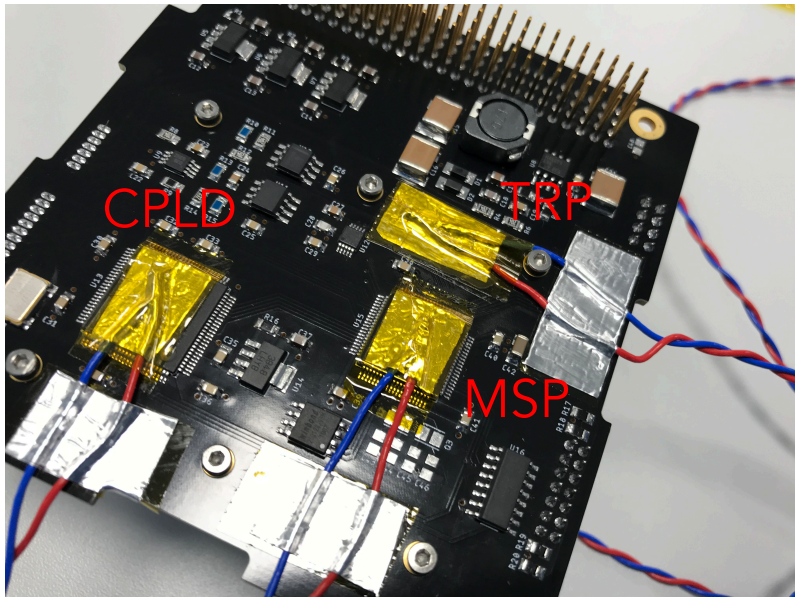
- Temperature: -31° – +75°
- Pressure: 10E-6 mBar

- 1 Non-operational Cycle
- 3 Operational Cycles

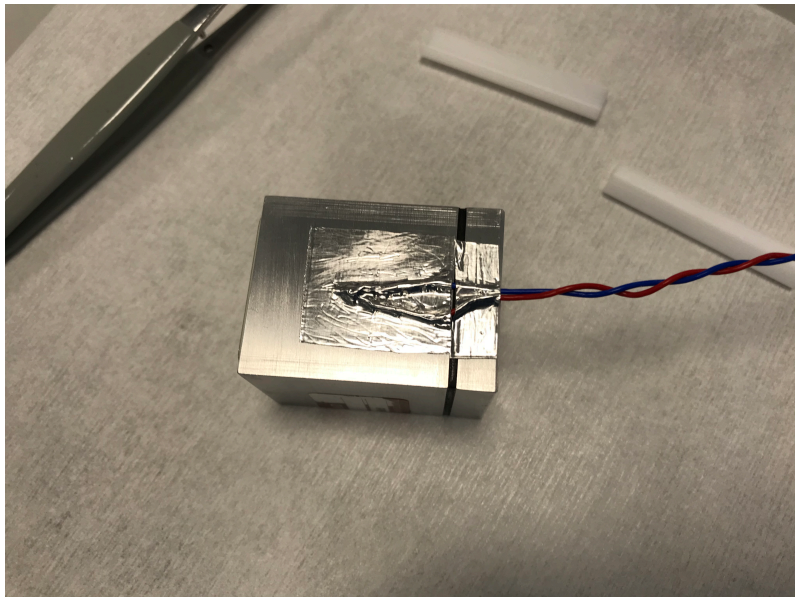
- >1 hour dwell at hot and cold temperatures

- Hot temperature:
  - SiPM array at 55° while operational during Solstice.
  - 75° = 55° + 10° modelling uncertainty + 10° qualification margin.
- Cold temperature:
  - MSP at -11° while non-operational during cold case.
  - -31° = -11° - 10° modelling uncertainty - 10° qualification margin.

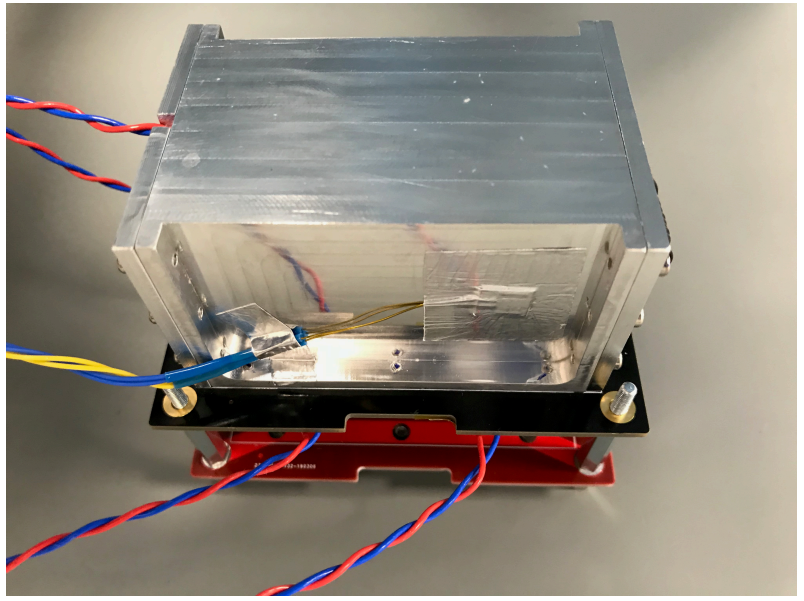
TVAC – Thermocouple Placement



- 3x TCs on Motherboard

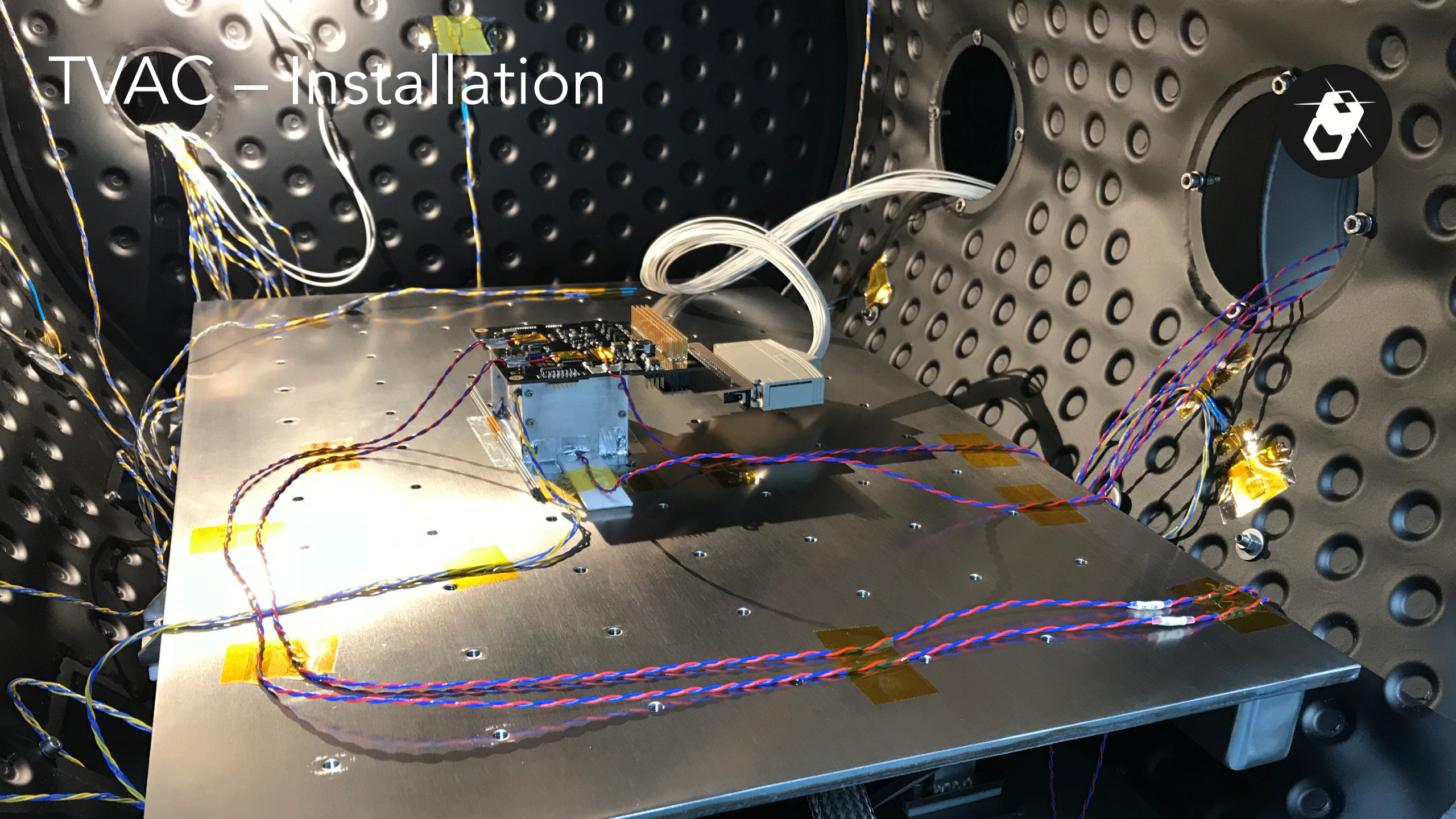


- 1x TC on Crystal

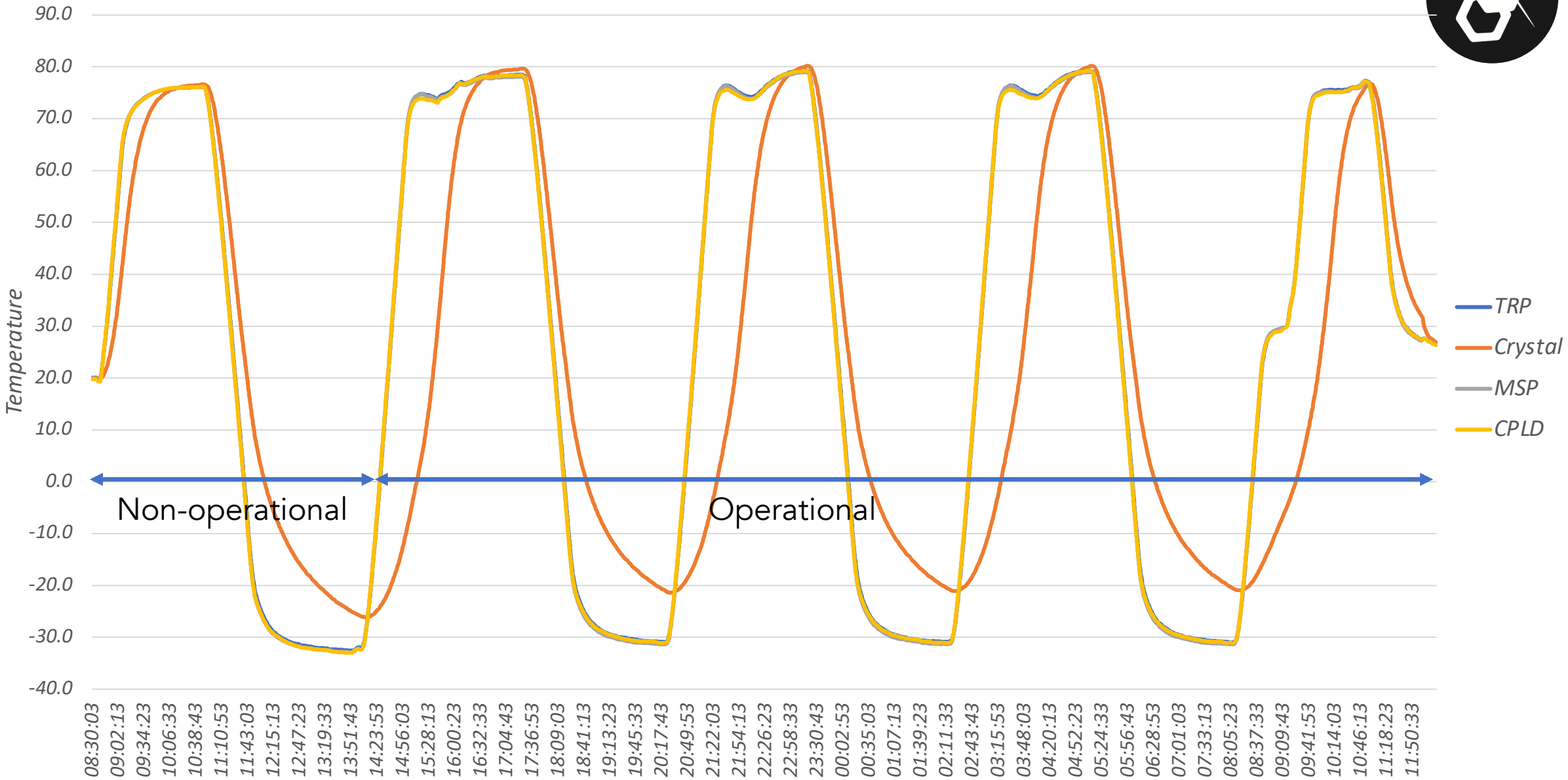


- 1x PT100 on Housing

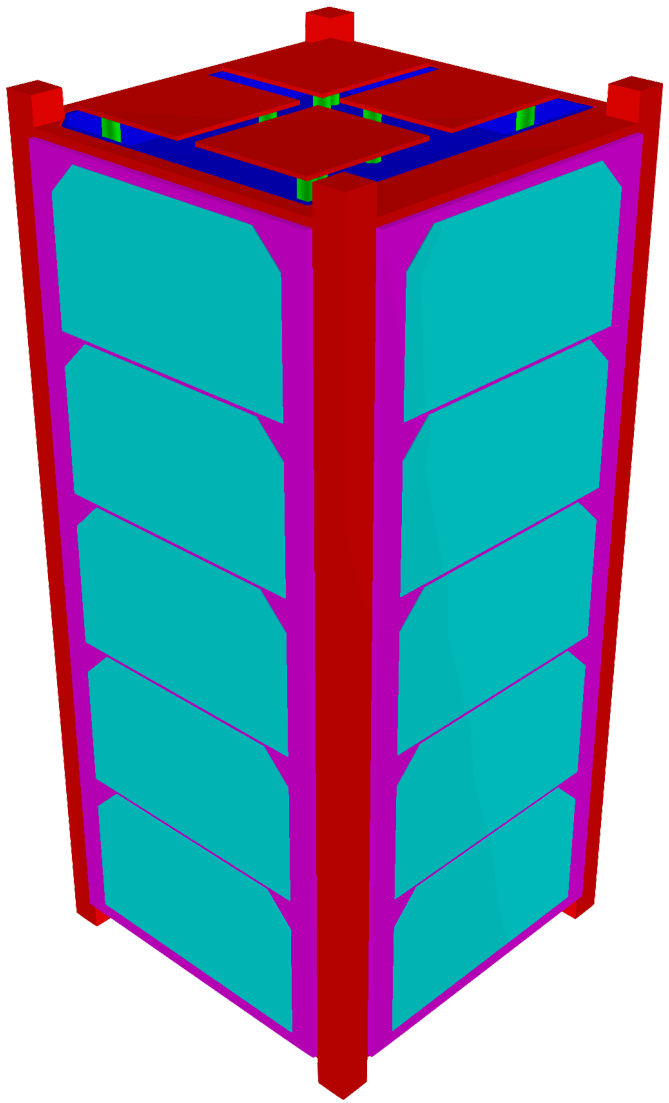
TVAC – Installation

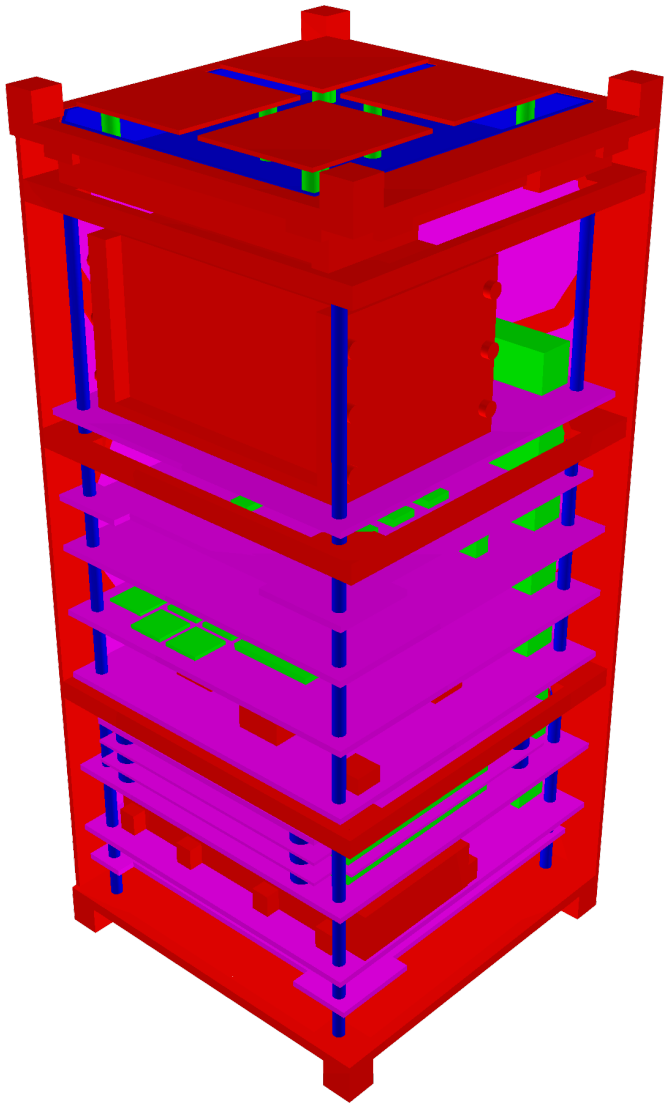


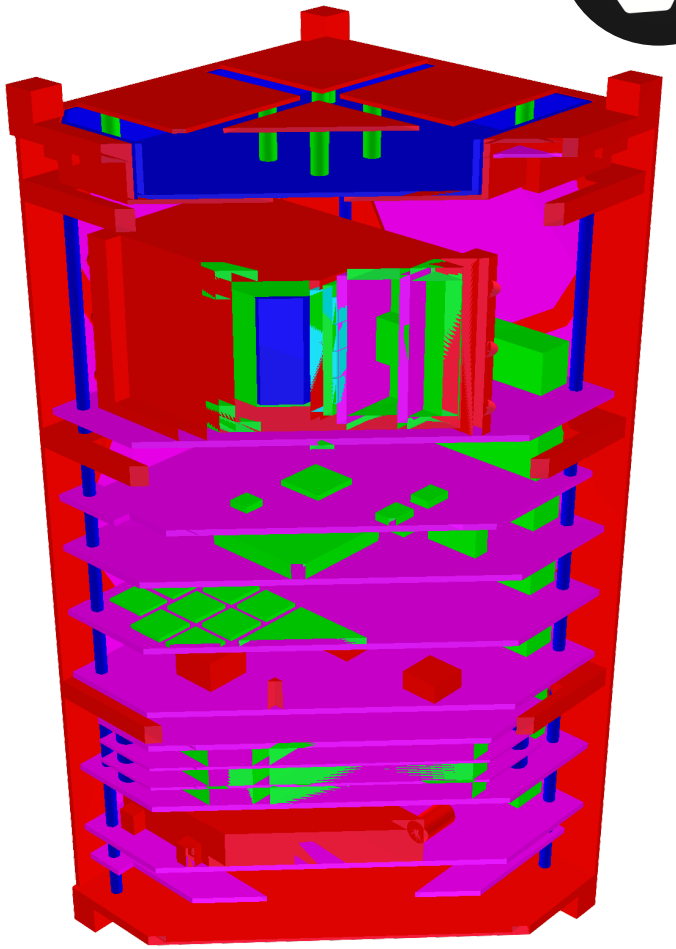
TVAC – Cycles


90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
Temperature
Non-operational
Operational
TRP
Crystal
MSP
CPLD
08:30:03
09:02:13
09:34:23
10:06:33
10:38:43
11:10:53
11:43:03
12:15:13
12:47:23
13:19:33
13:51:43
14:23:53
14:56:03
15:28:13
16:00:23
16:32:33
17:04:43
17:36:53
18:09:03
18:41:13
19:13:23
19:45:33
20:17:43
20:49:53
21:22:03
21:54:13
22:26:23
22:58:33
23:30:43
00:02:53
00:35:03
01:07:13
01:39:23
02:11:33
02:43:43
03:15:53
03:48:03
04:20:13
04:52:23
05:24:33
05:56:43
06:28:53
07:01:03
07:33:13
08:05:23
08:37:33
09:09:43
09:41:53
10:14:03
10:46:13
11:18:23
11:50:33

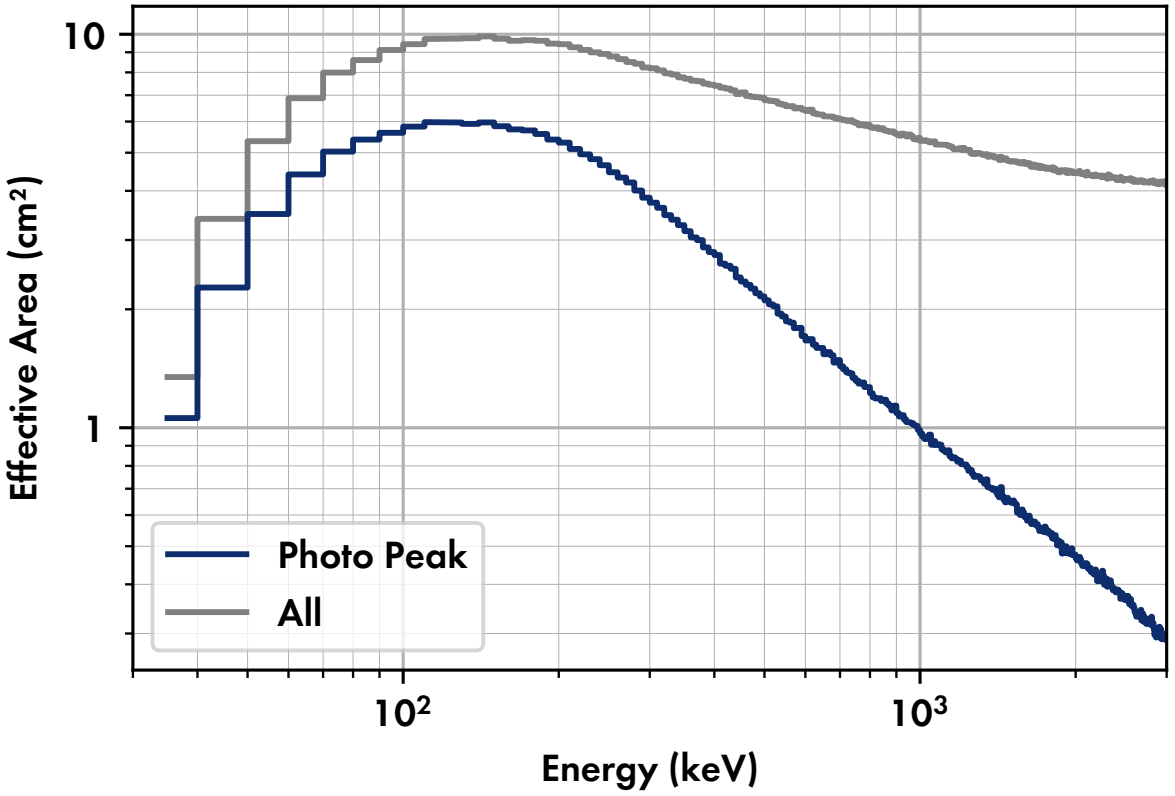
MEGAlib

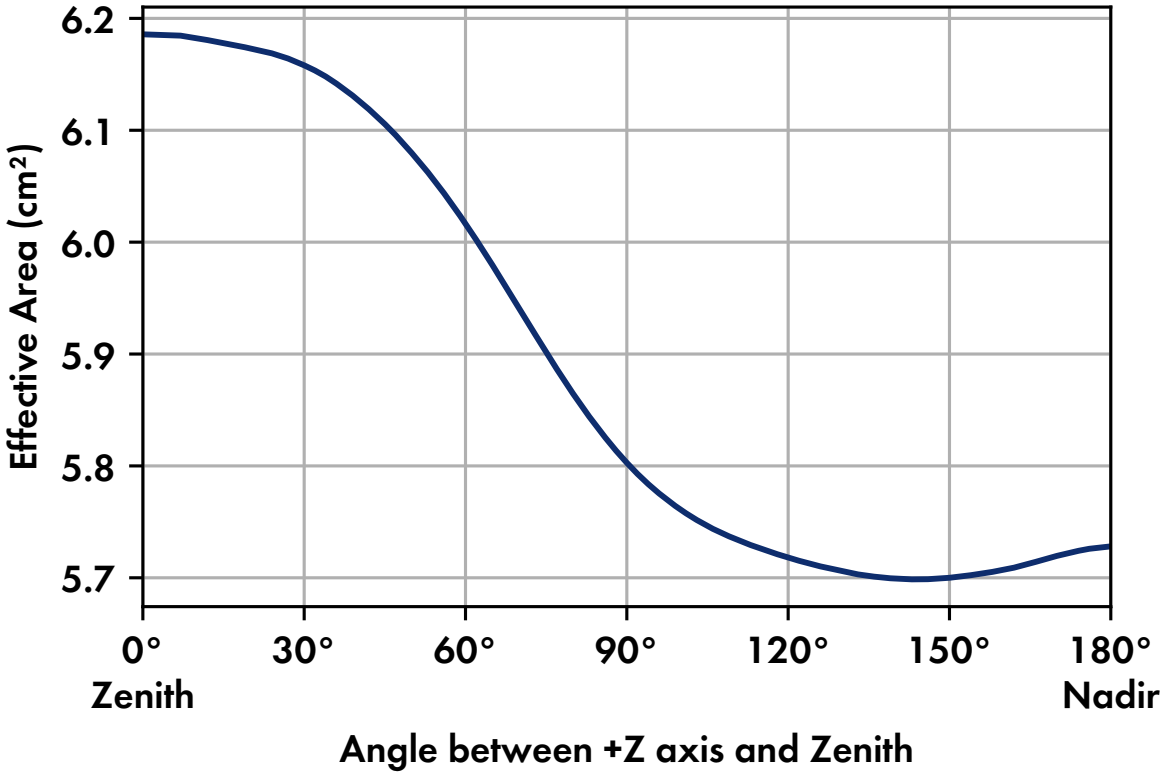






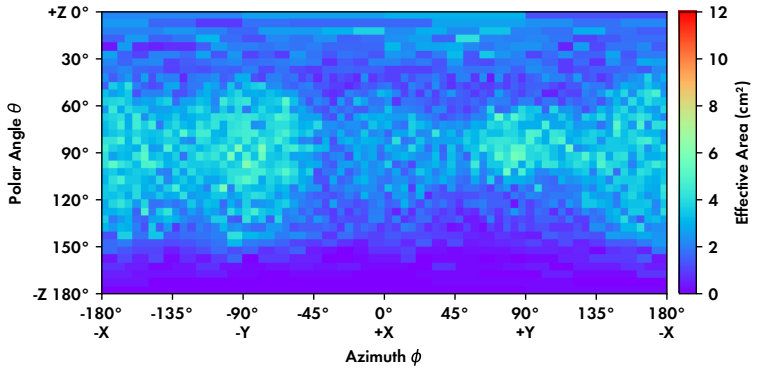
Simulations – Effective Area



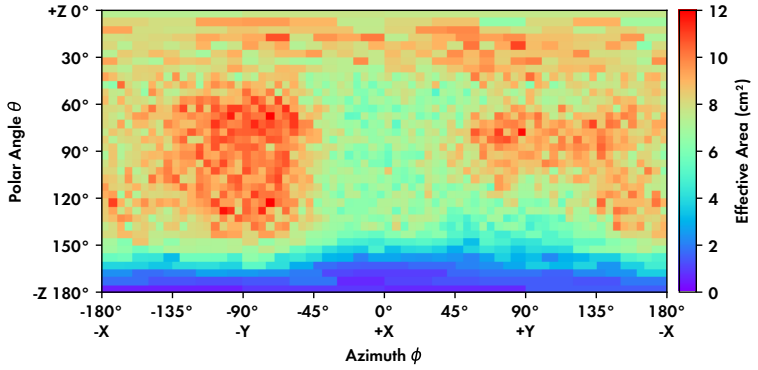


Simulations – Effective Area

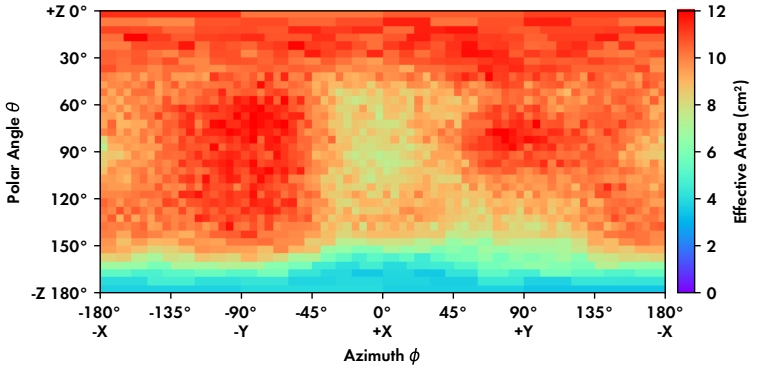
30 – 50 keV



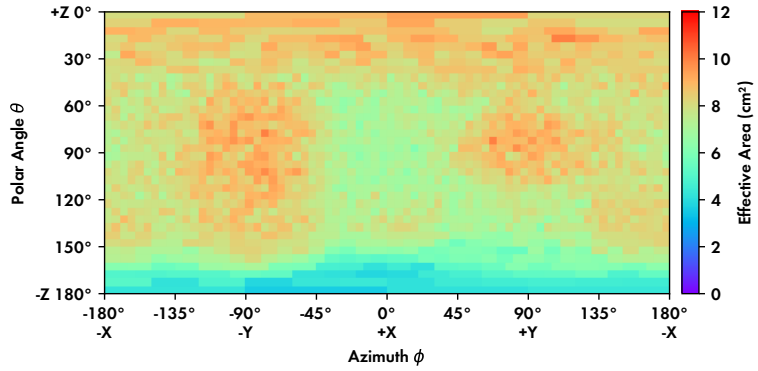
50 – 100 keV



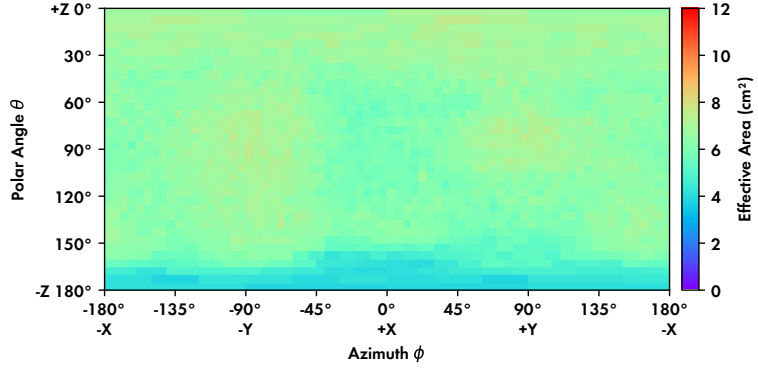
100 – 300 keV



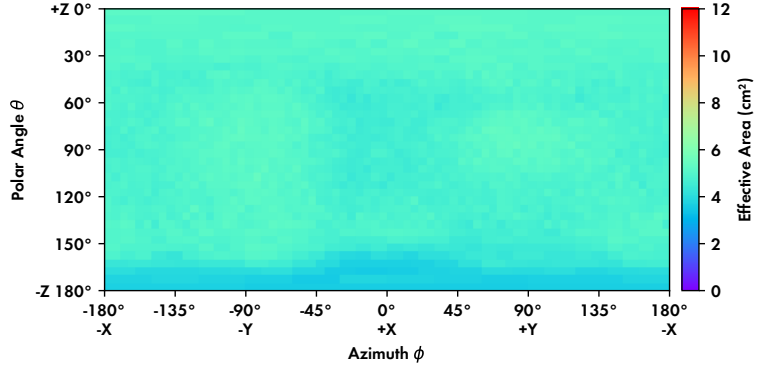
300 – 500 keV



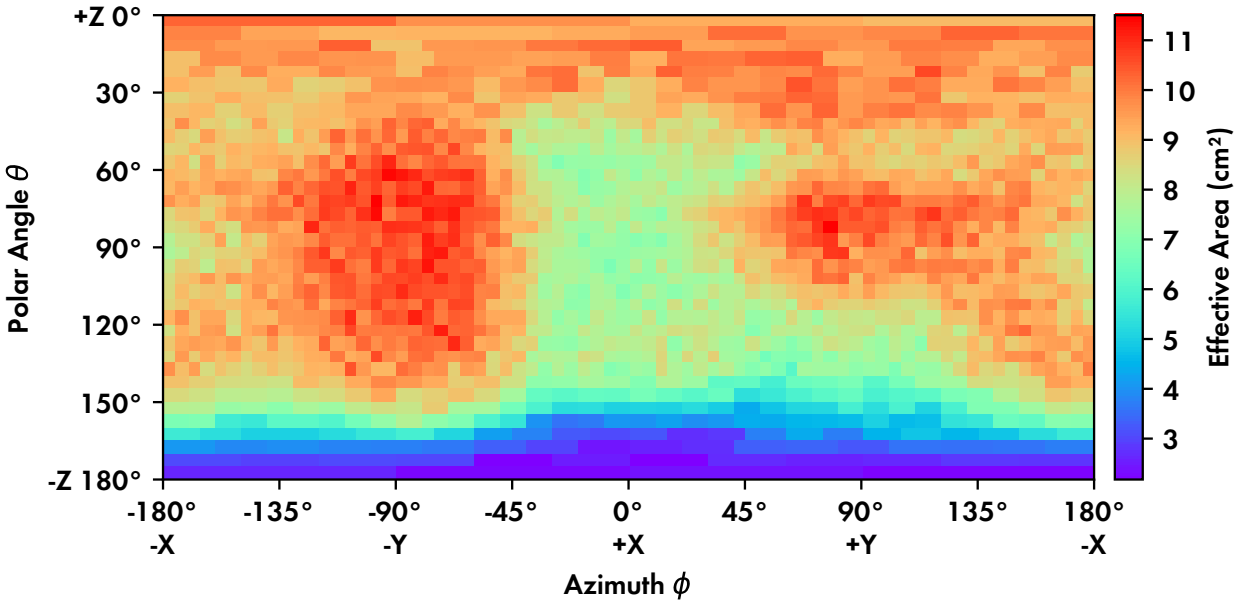
500 – 1000 keV

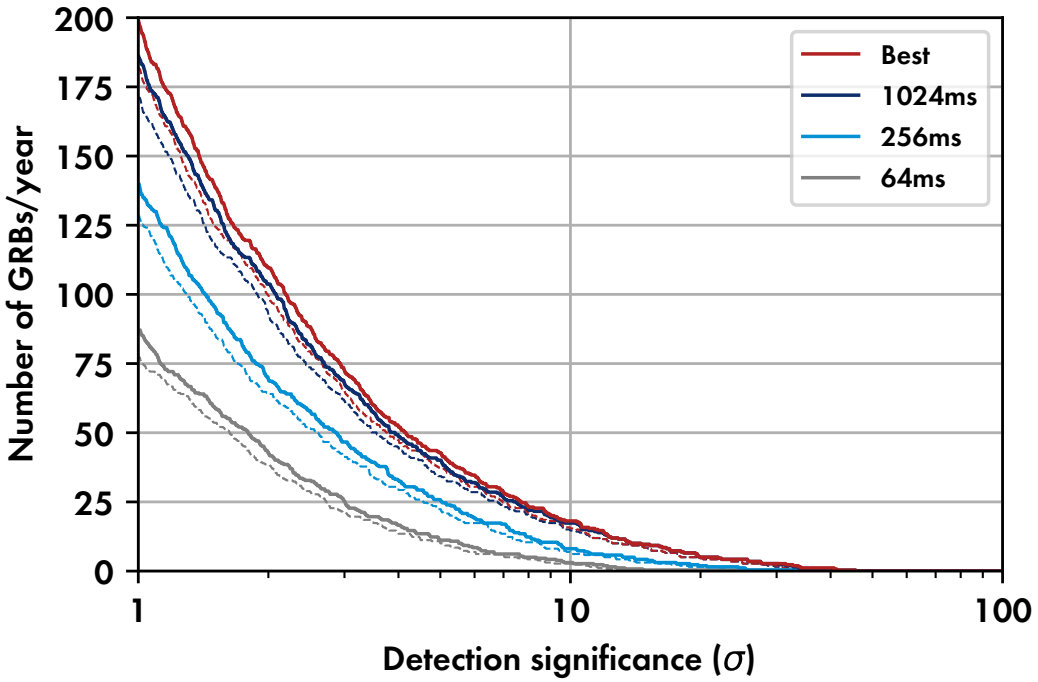


1000 – 3000 keV



Simulations – GRBs



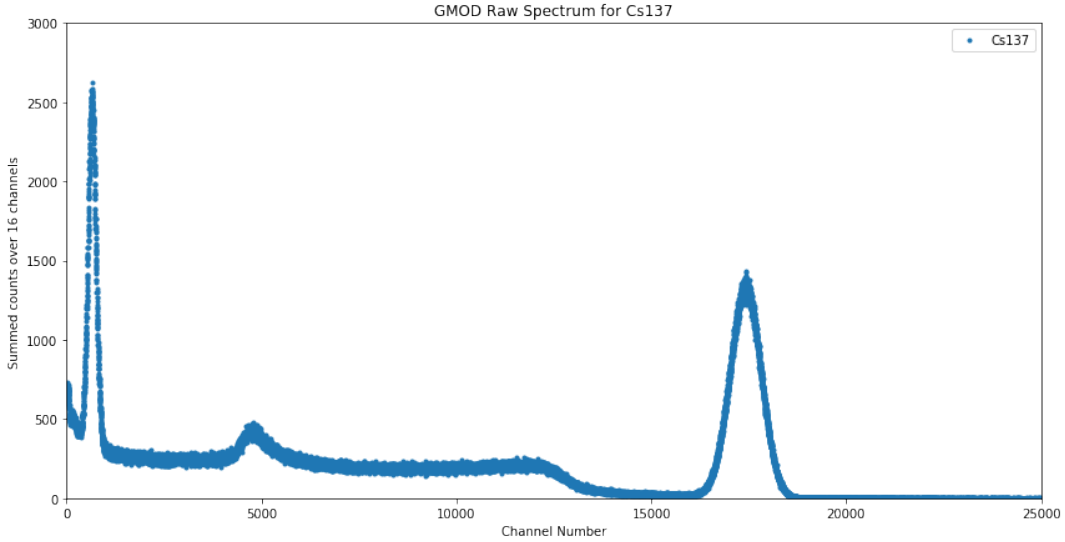


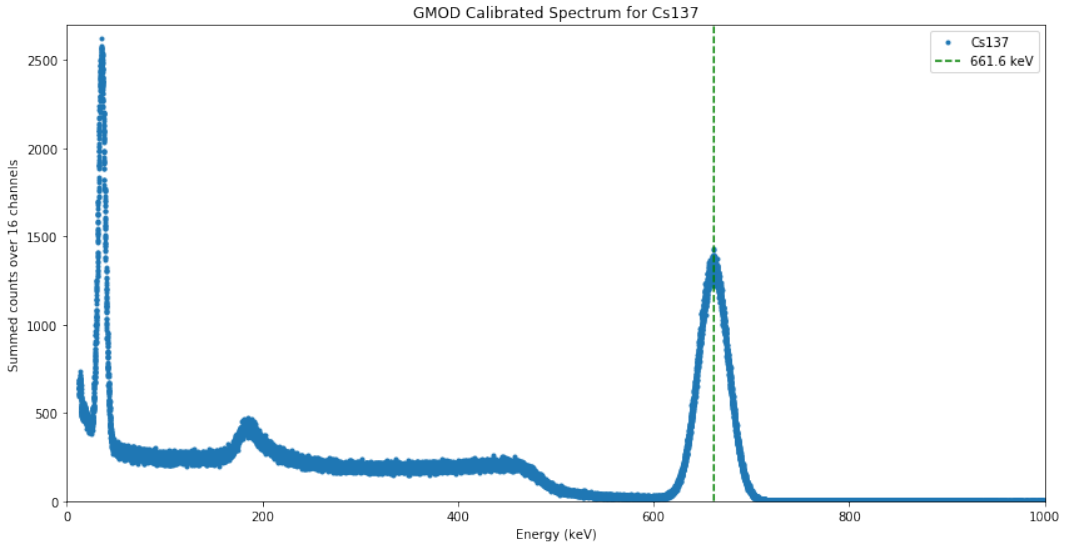
- 50 – 300 keV for a GRB with α=-1.1, β=-2.3, Epeak = 300 keV.

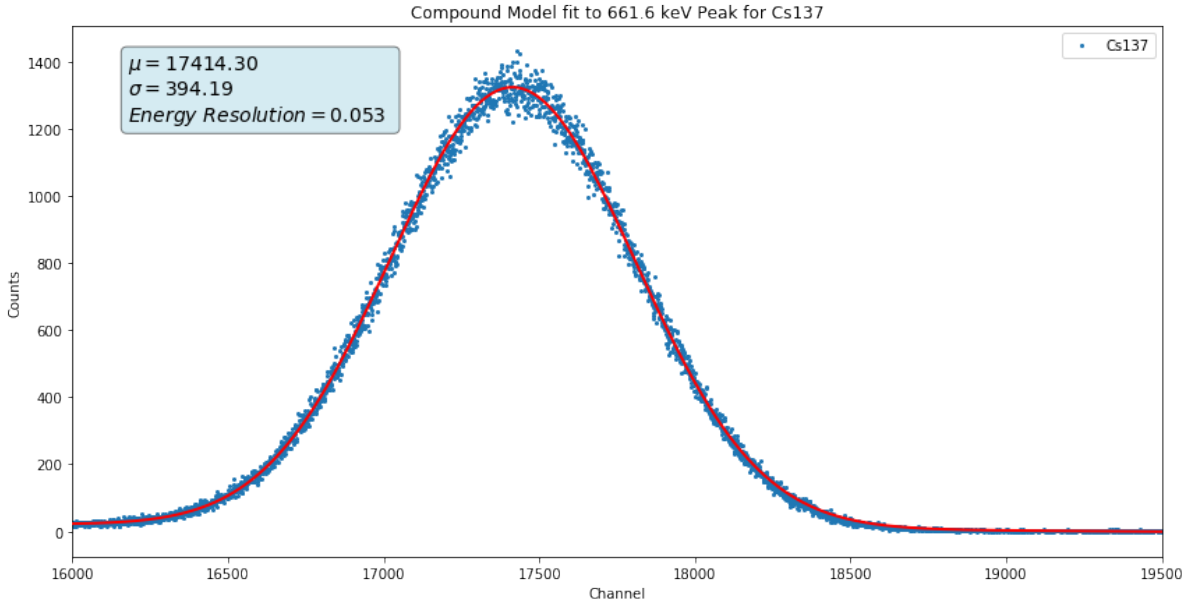
- Based on BATSE4B catalog.
- ~18/year at 10 sigma.



GMOD Spectrum

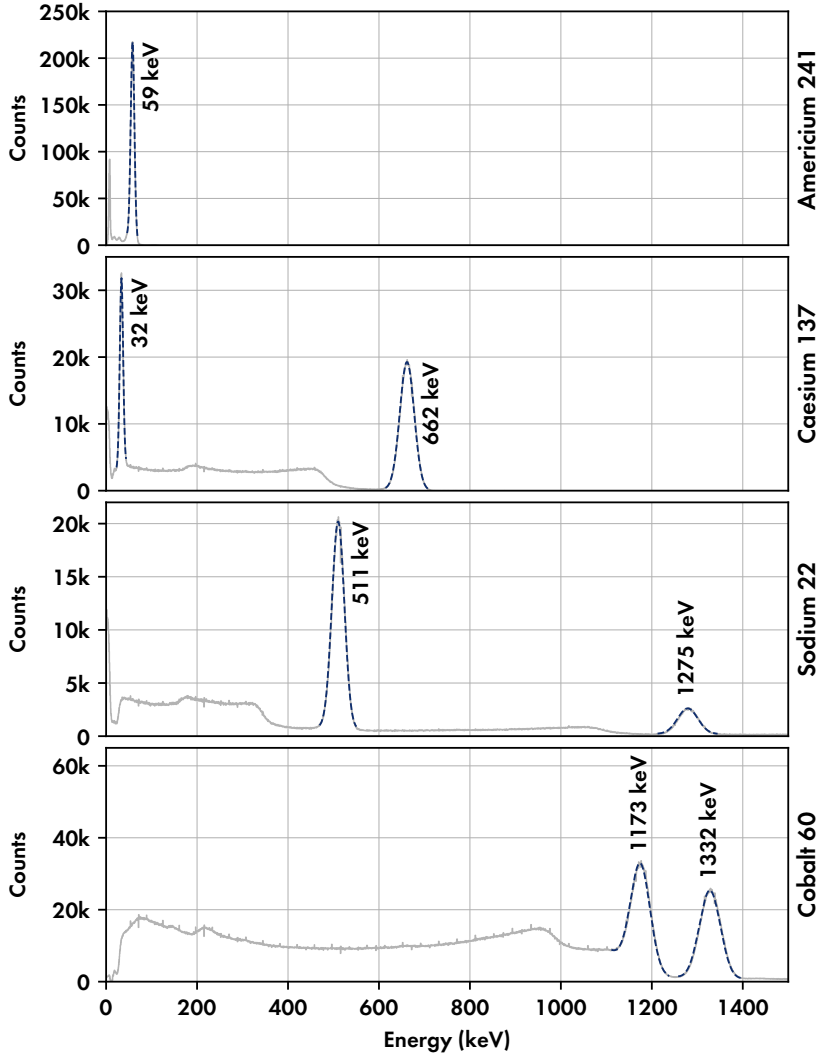




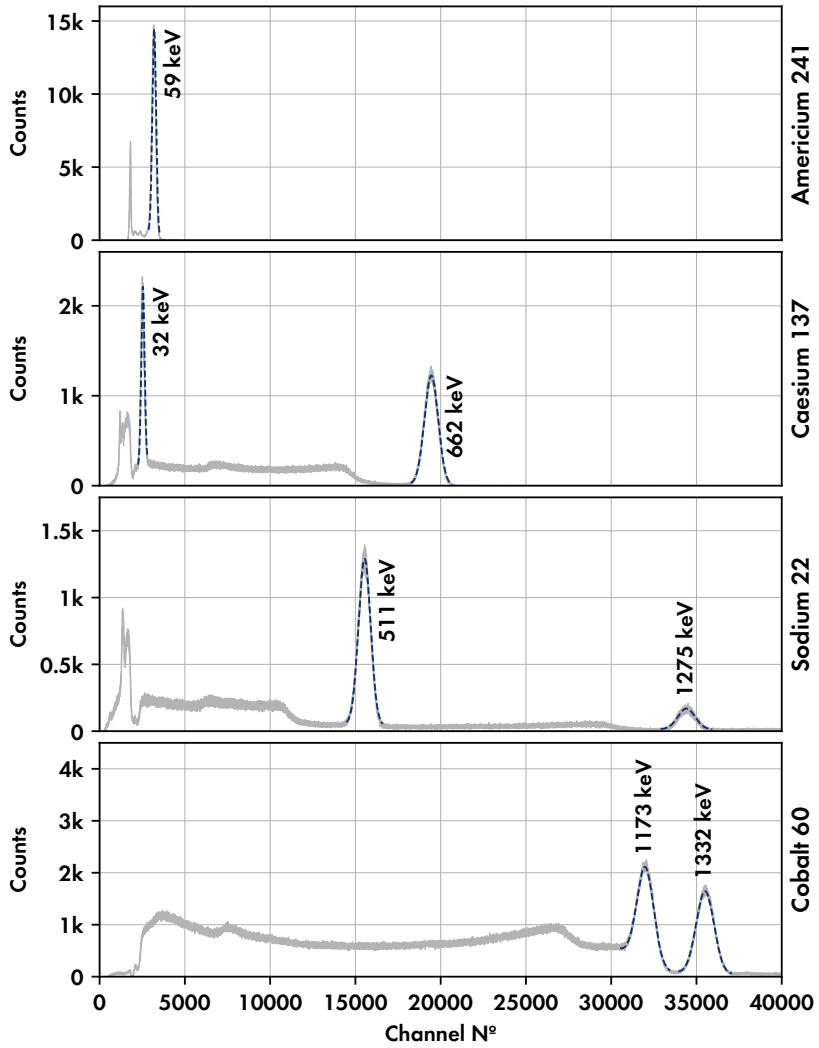


Rachel Dunwoody

Spectra - Calibrated

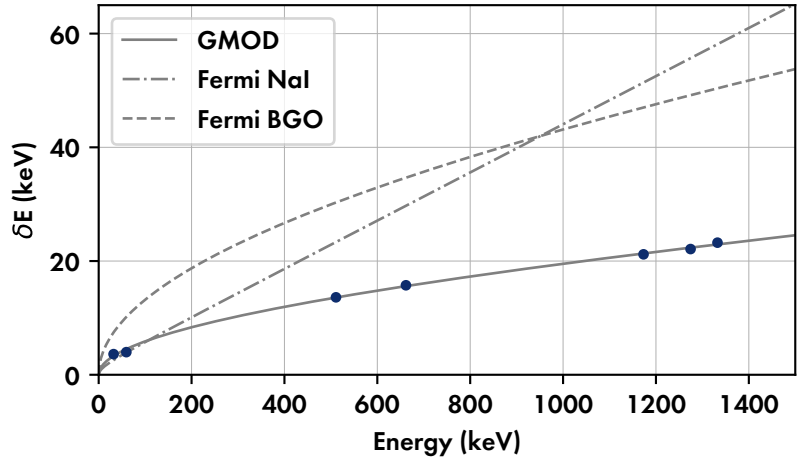


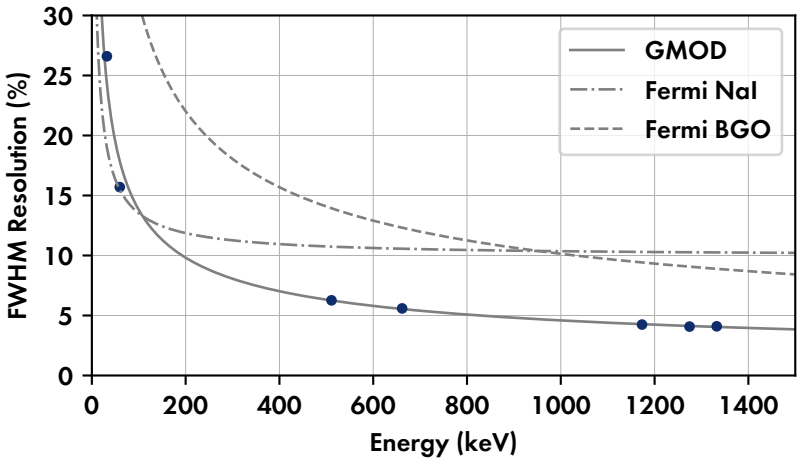
Summed Mode



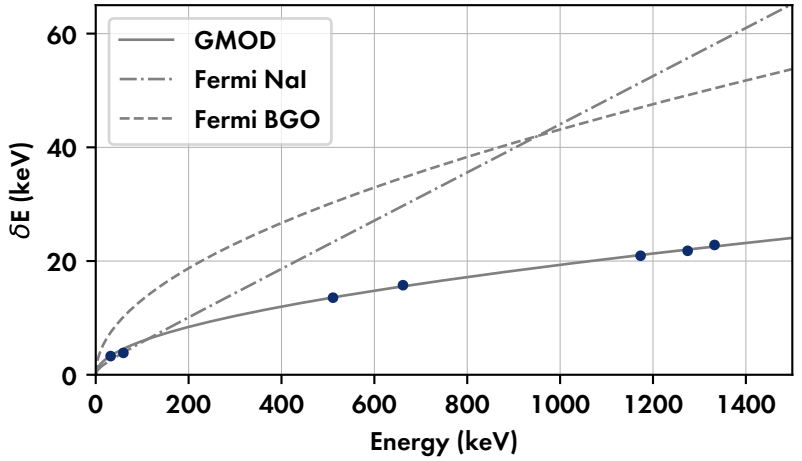
'14-channel' Mode

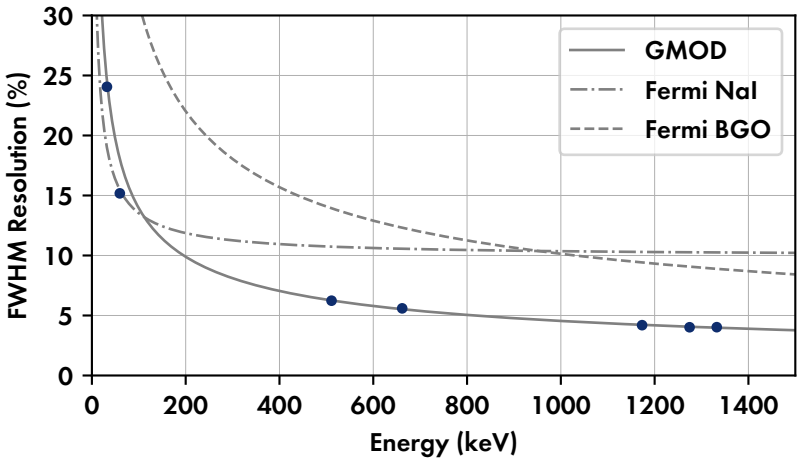
Resolution





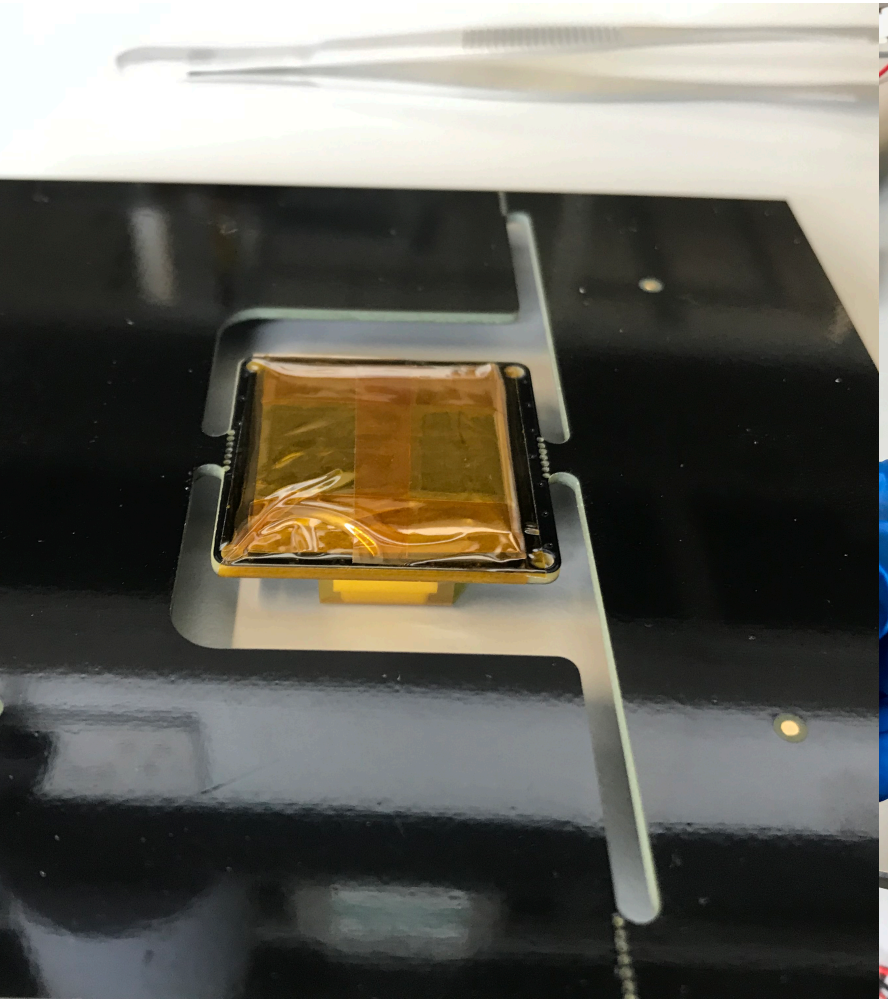
Summed Mode

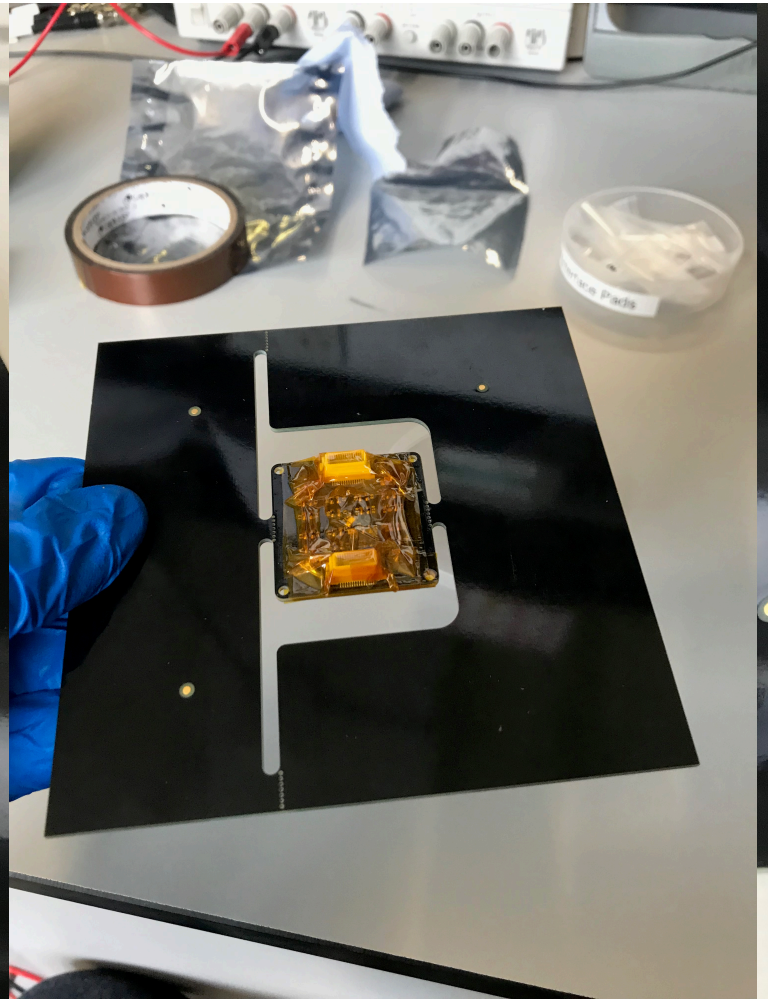


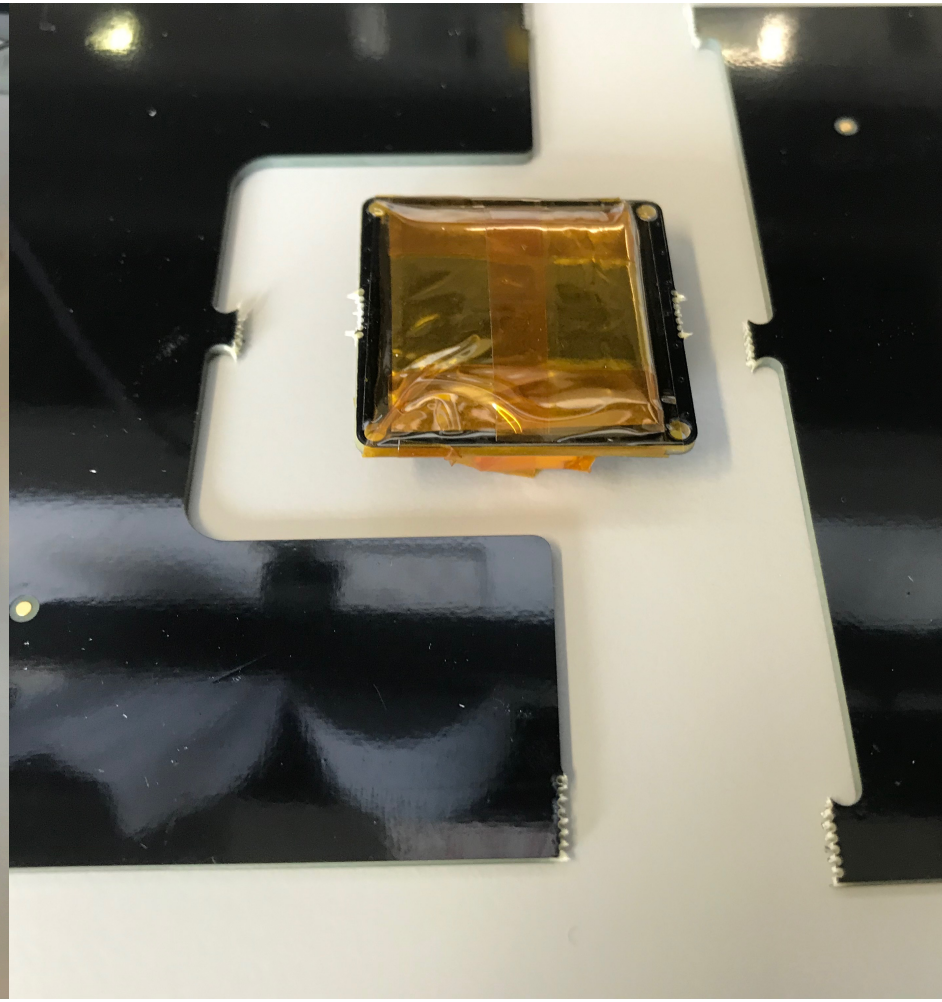


'14-channel' Mode

SiPM Array







Removing SiPM array from larger PCB

SiPM Array

