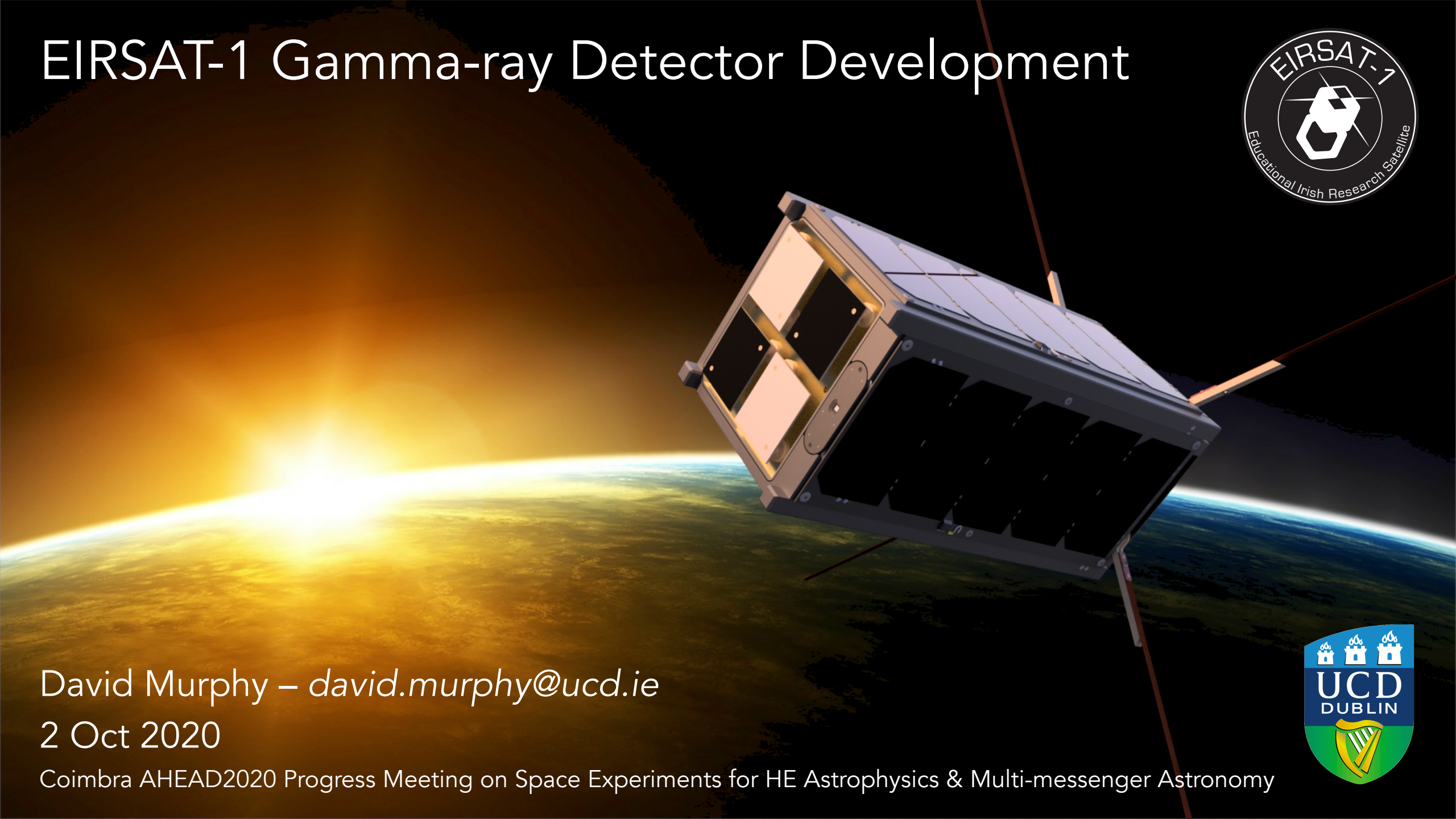
EIRSAT-1 Gamma-ray Detector Development

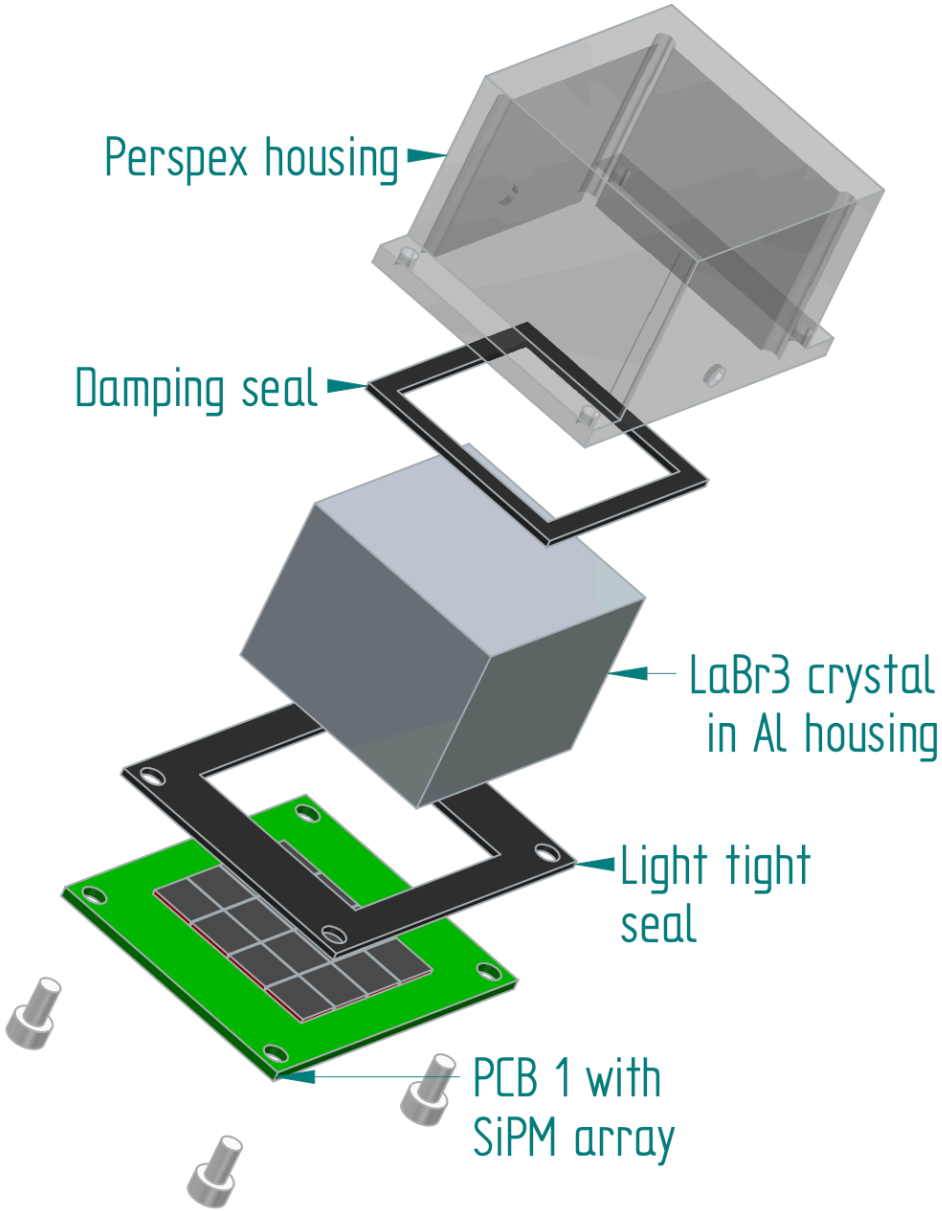


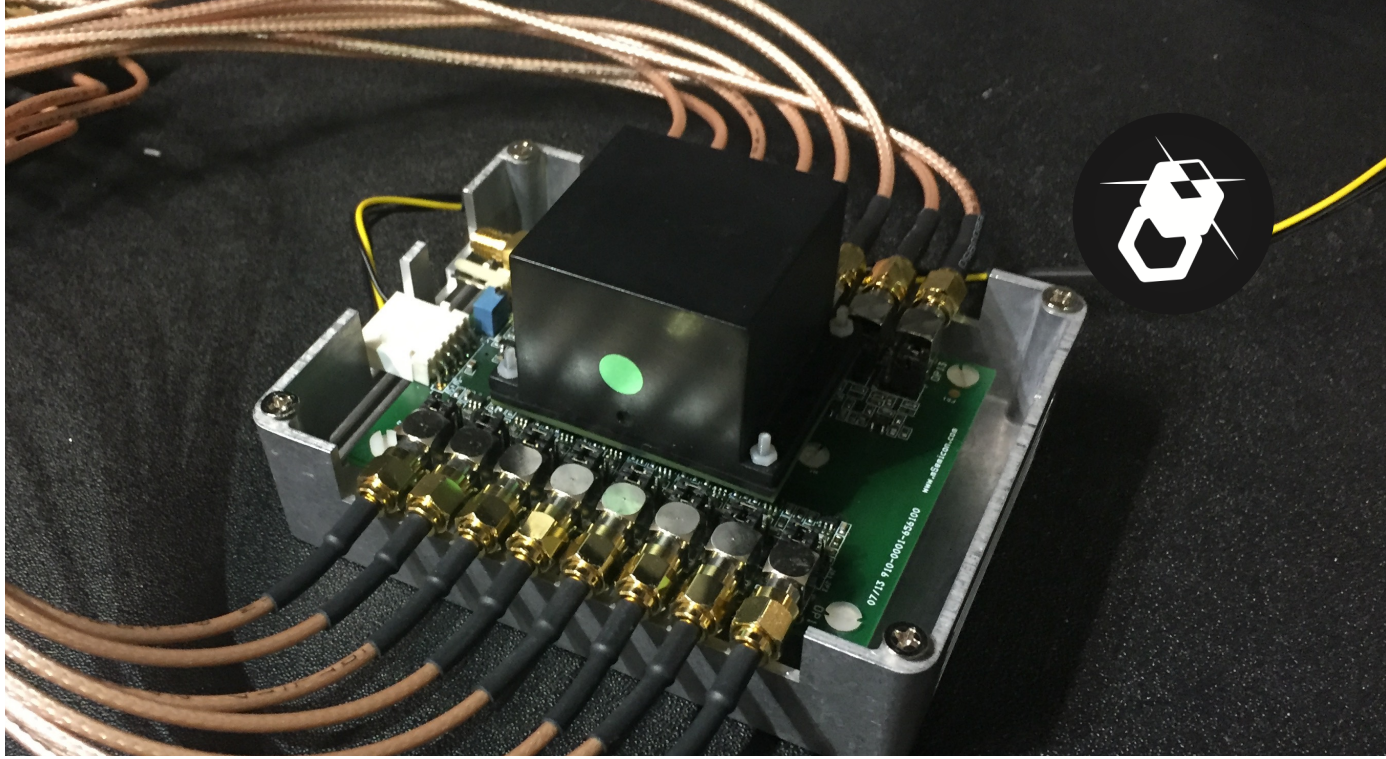
David Murphy – *david.murphy@ucd.ie*

2 Oct 2020

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

GRD





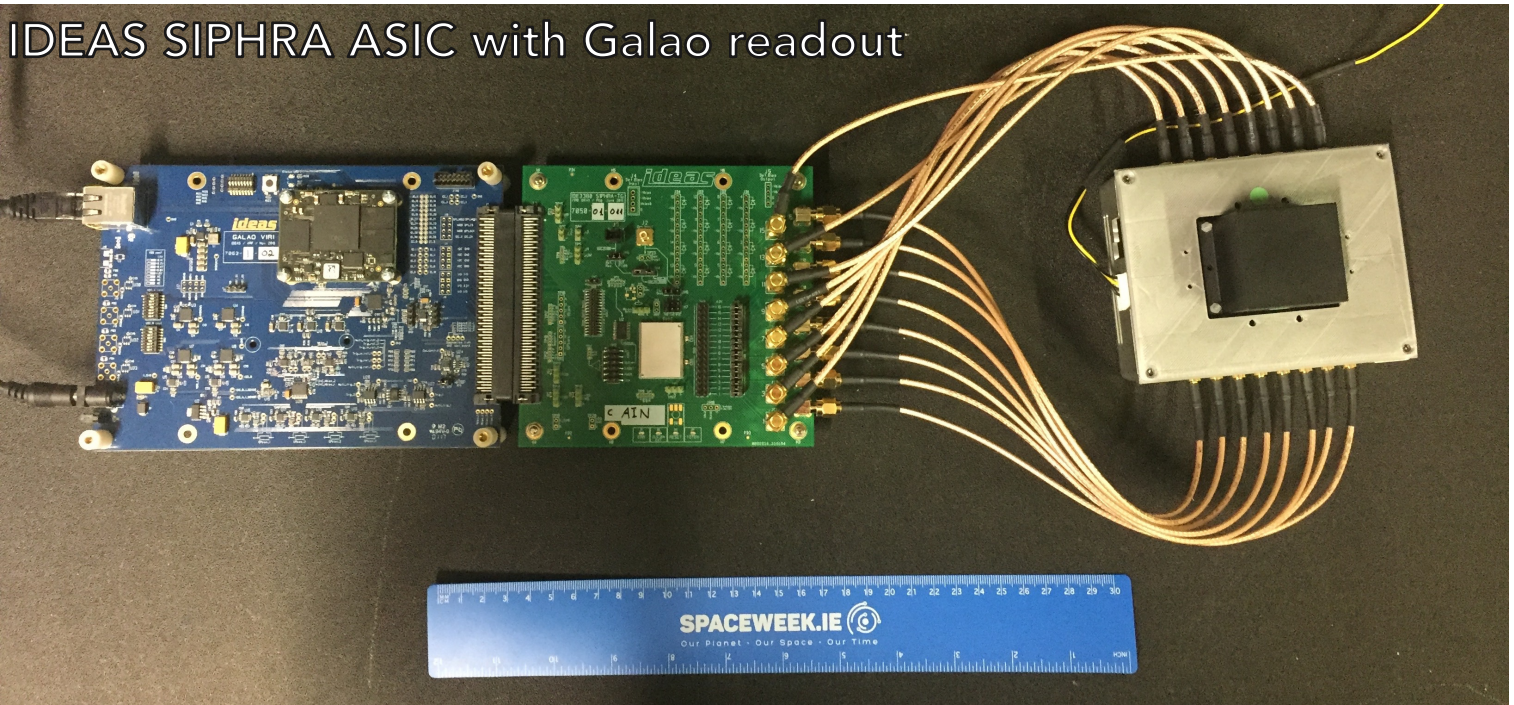
- 4×4 array of Sensl C-series SiPMs
- 28mm × 28mm × 20mm $LaBr_3$:Ce
- Later, 25mm × 25mm × 20mm $CeBr_3$

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

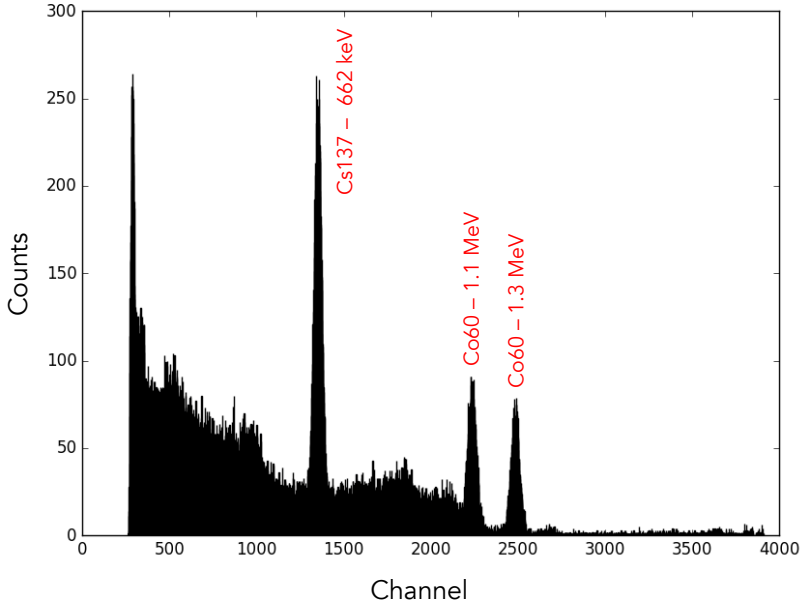
SIPHRA

- 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

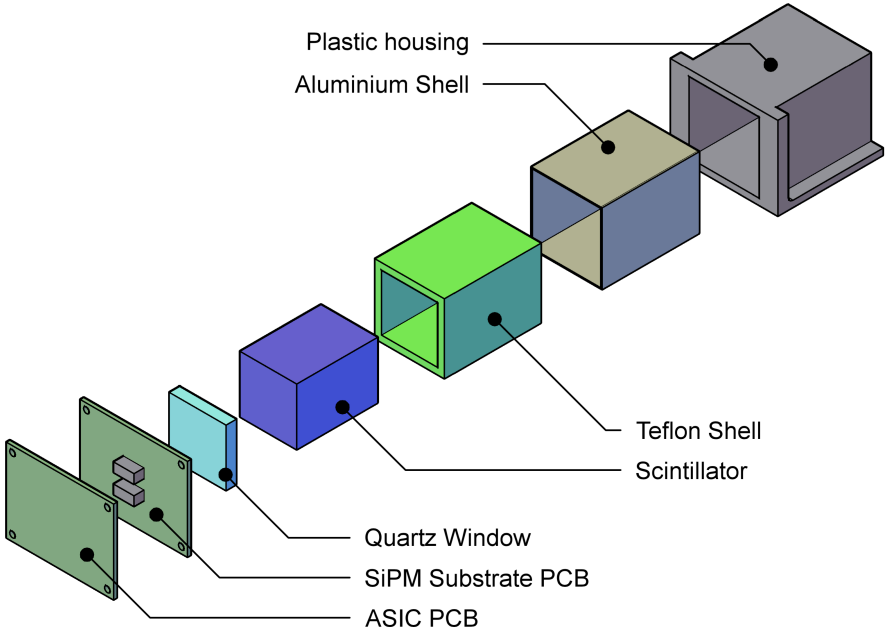
Meier et al. 2016 – AMICSA, Ulyanov et al. 2017 – IEEE

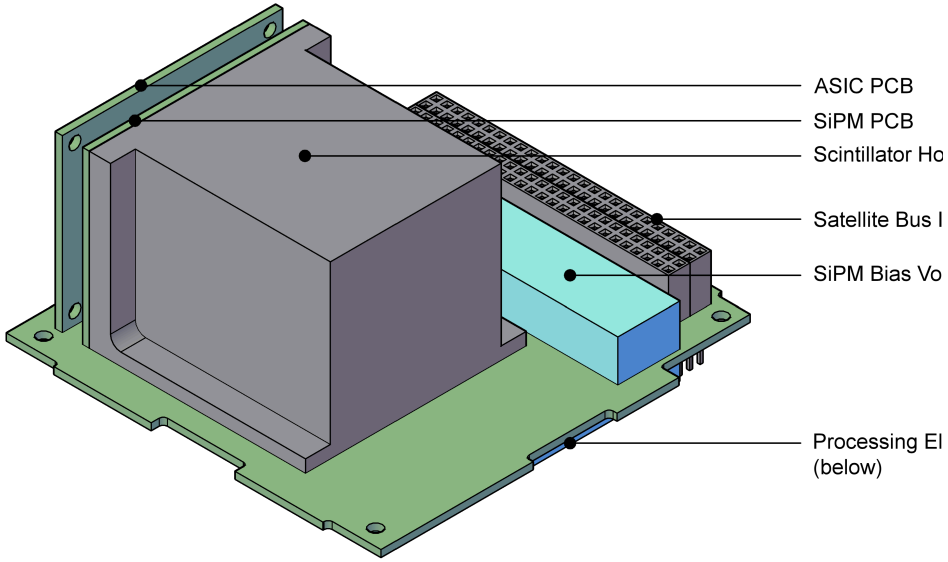


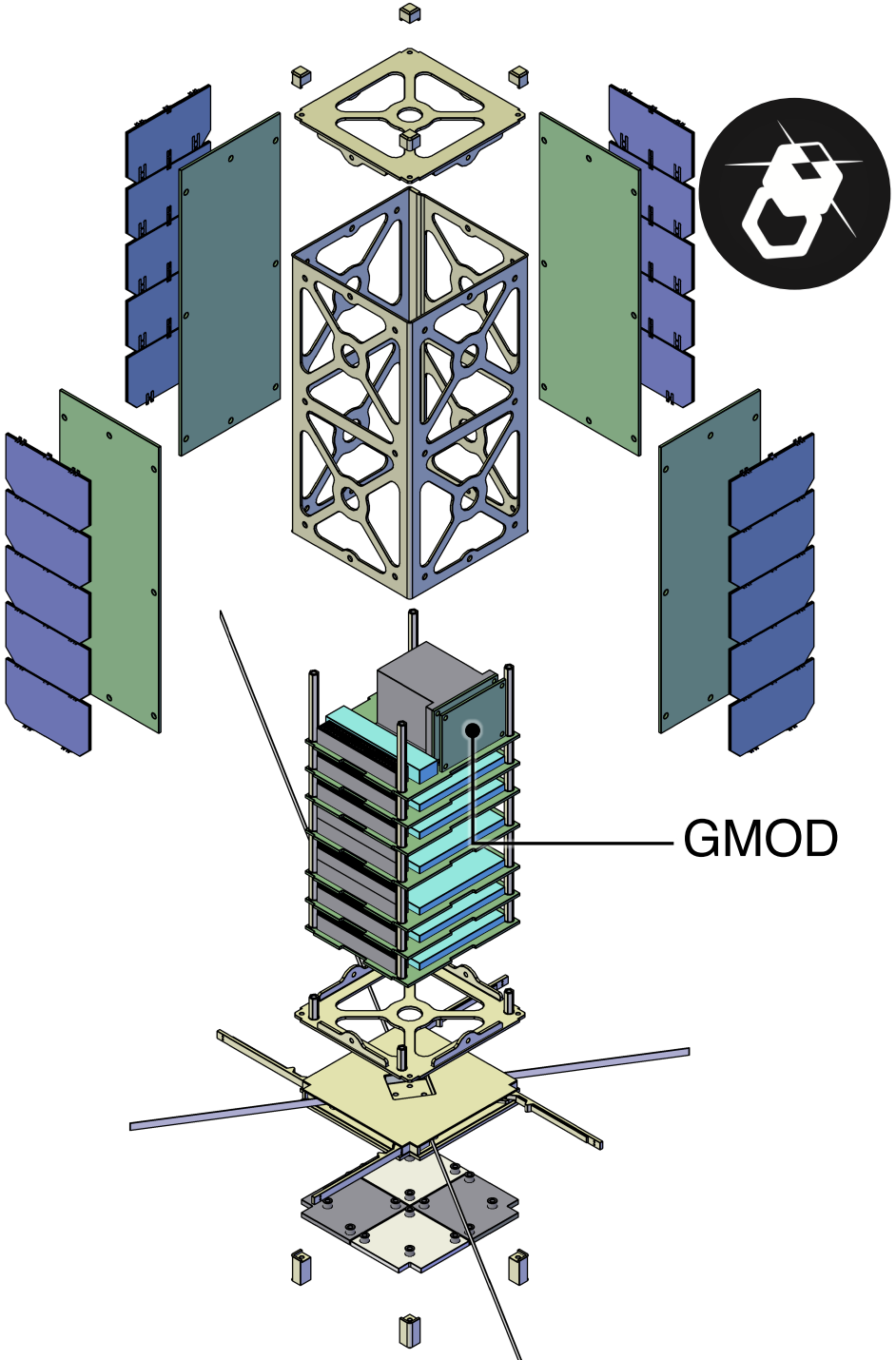
Sample spectra taken with SIPHRA



Early 2017 EIRSAT-1 + GMOD

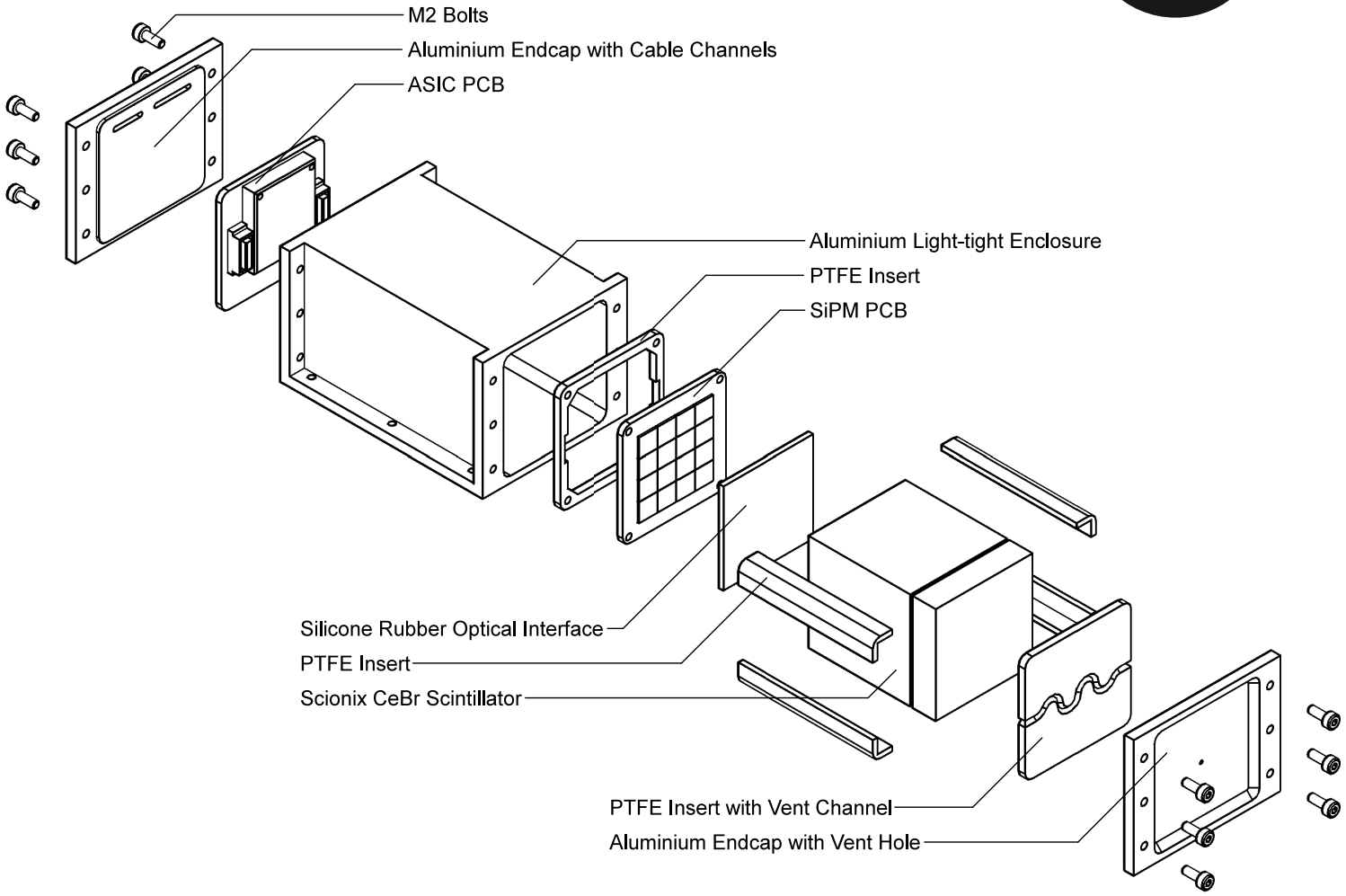






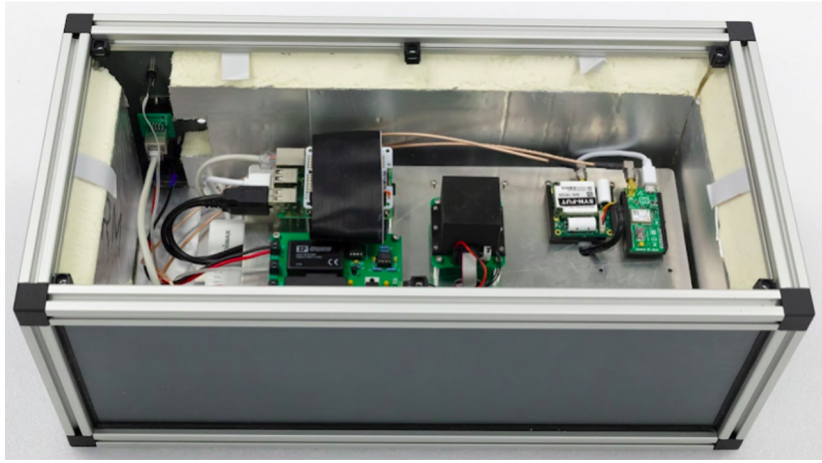
Late 2017 GMOD

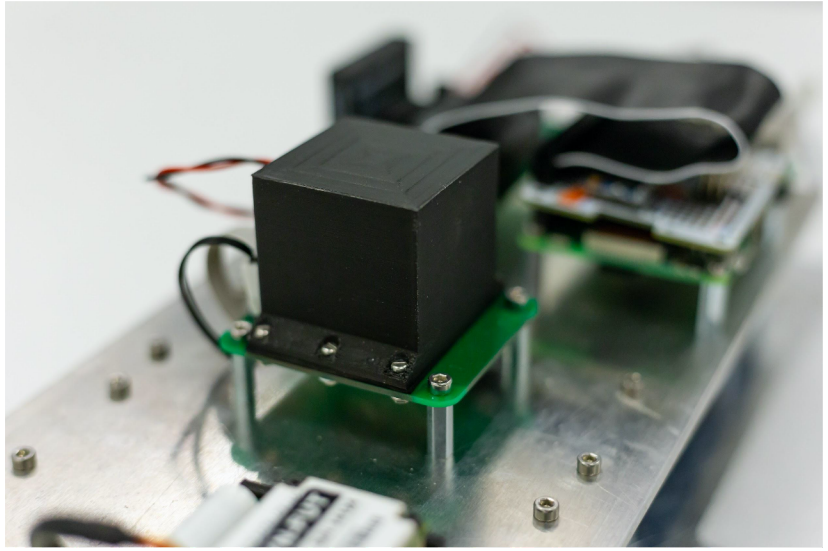
- Based on previous GRD detector built at UCD
- Designed to fit in approx 0.5U of a CubeSat
- Uses several novel technologies:
  - SiPMs by Irish company SensL
  - SIPHRA ASIC by IDEAS
  - Modern, bright scintillator – CeBr3

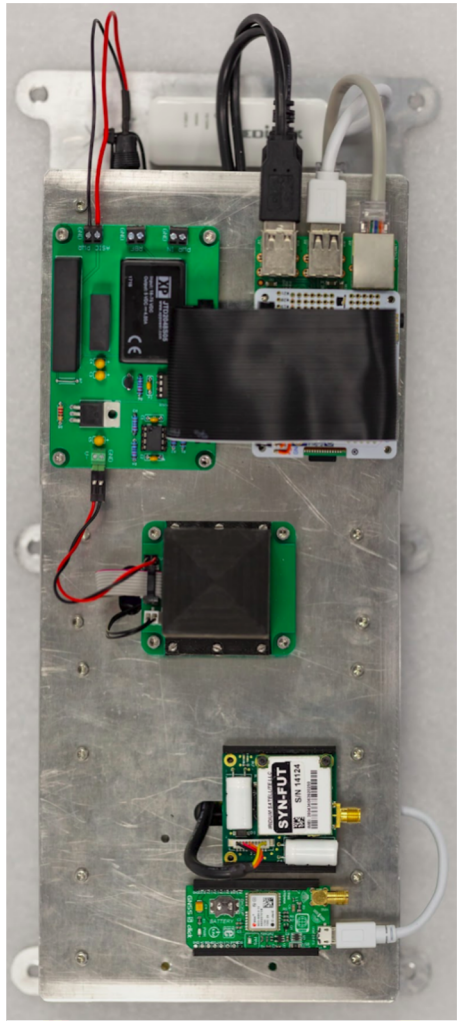


GMoDem
Gamma-ray Module Demonstrator

- 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



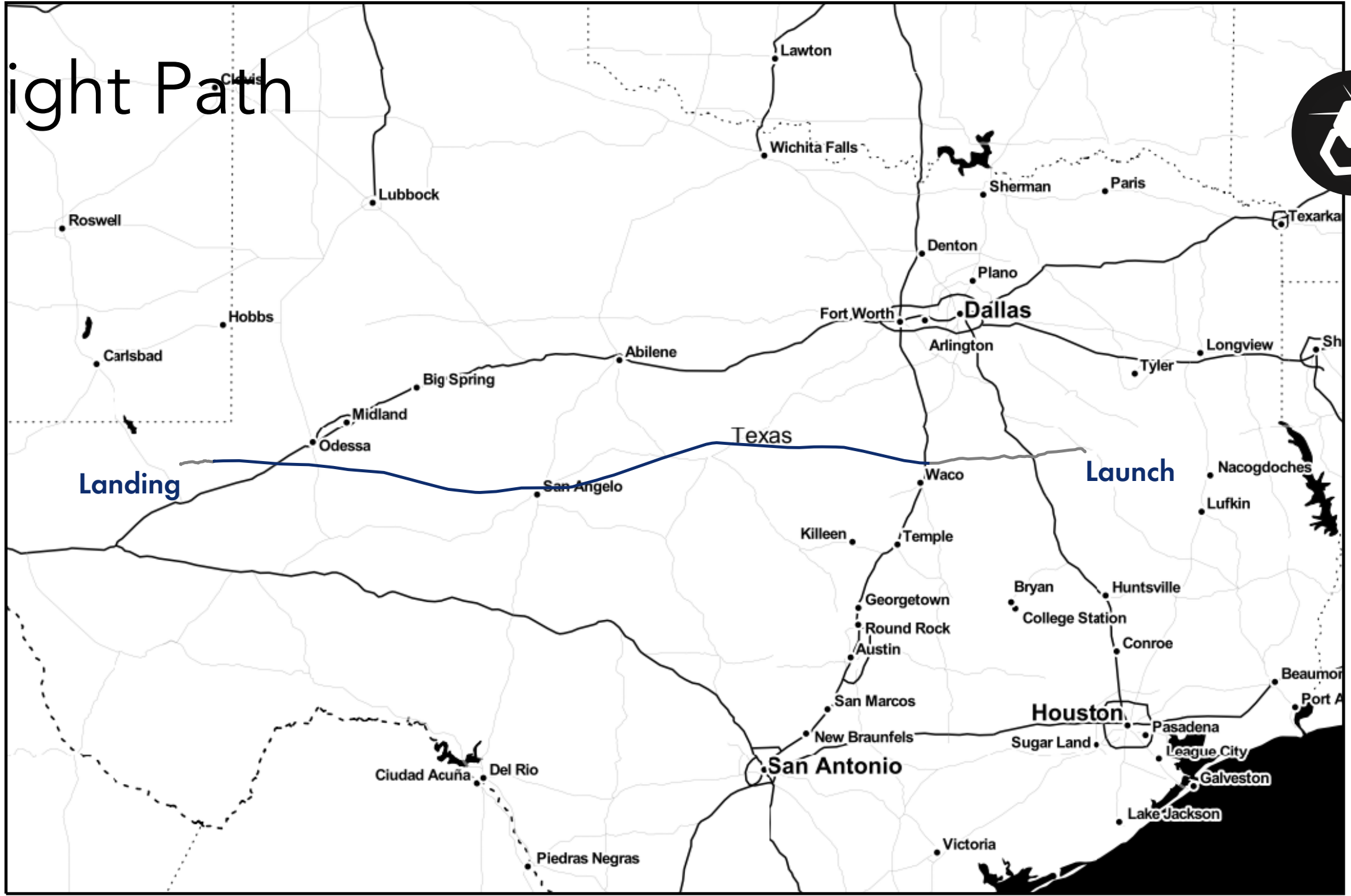




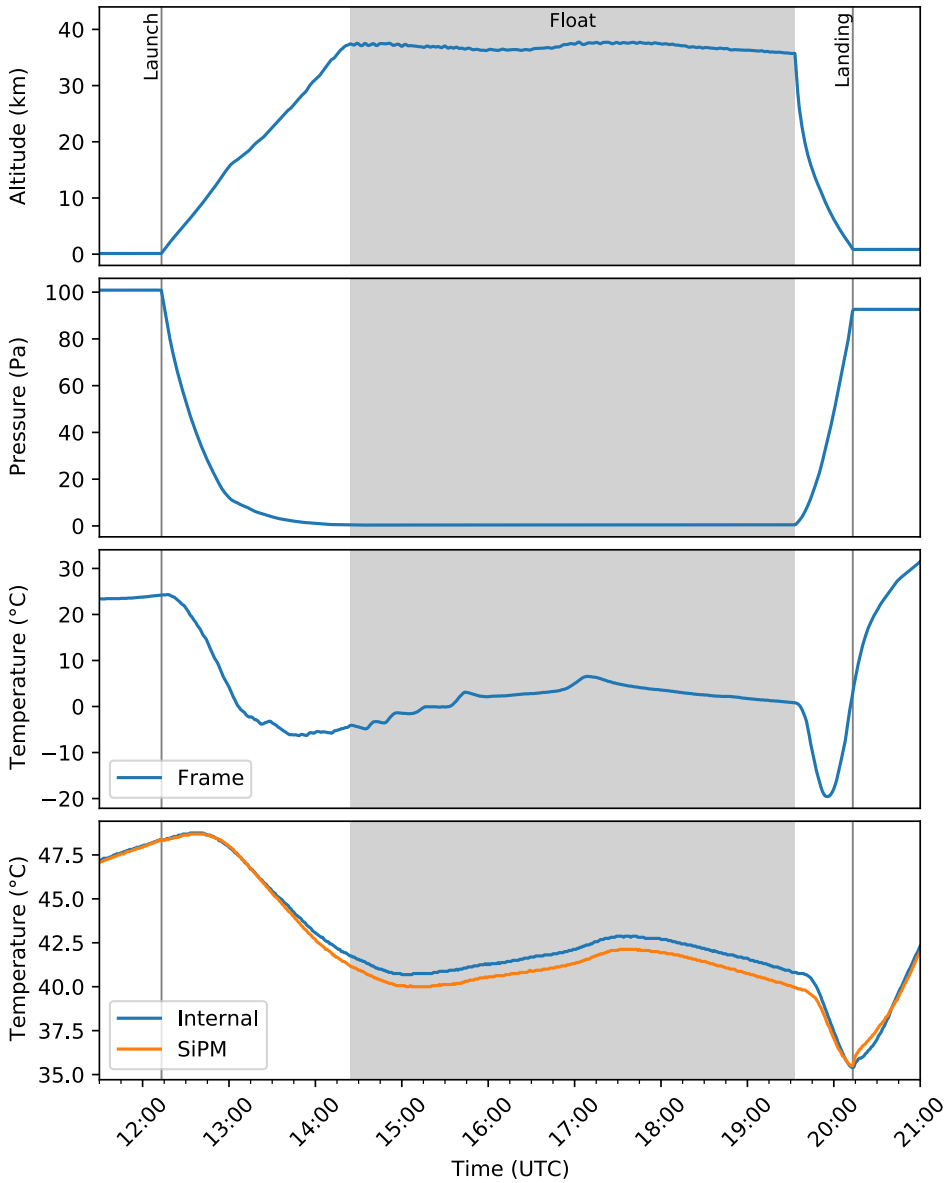
GMoDem

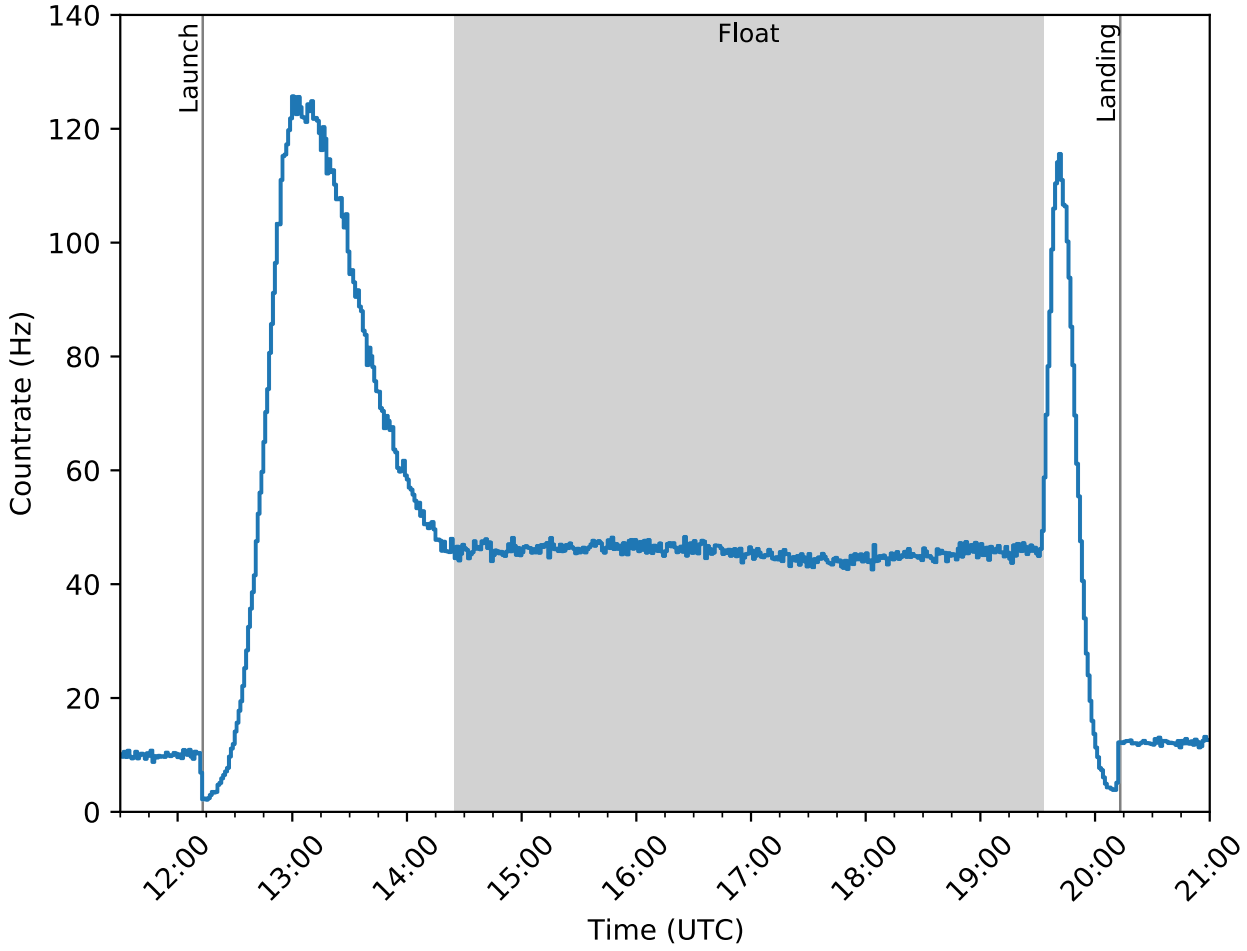
- Launch from NASA Columbia Scientific Balloon Facility
- Float altitude 37.4km for >5 hours

Flight Path


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

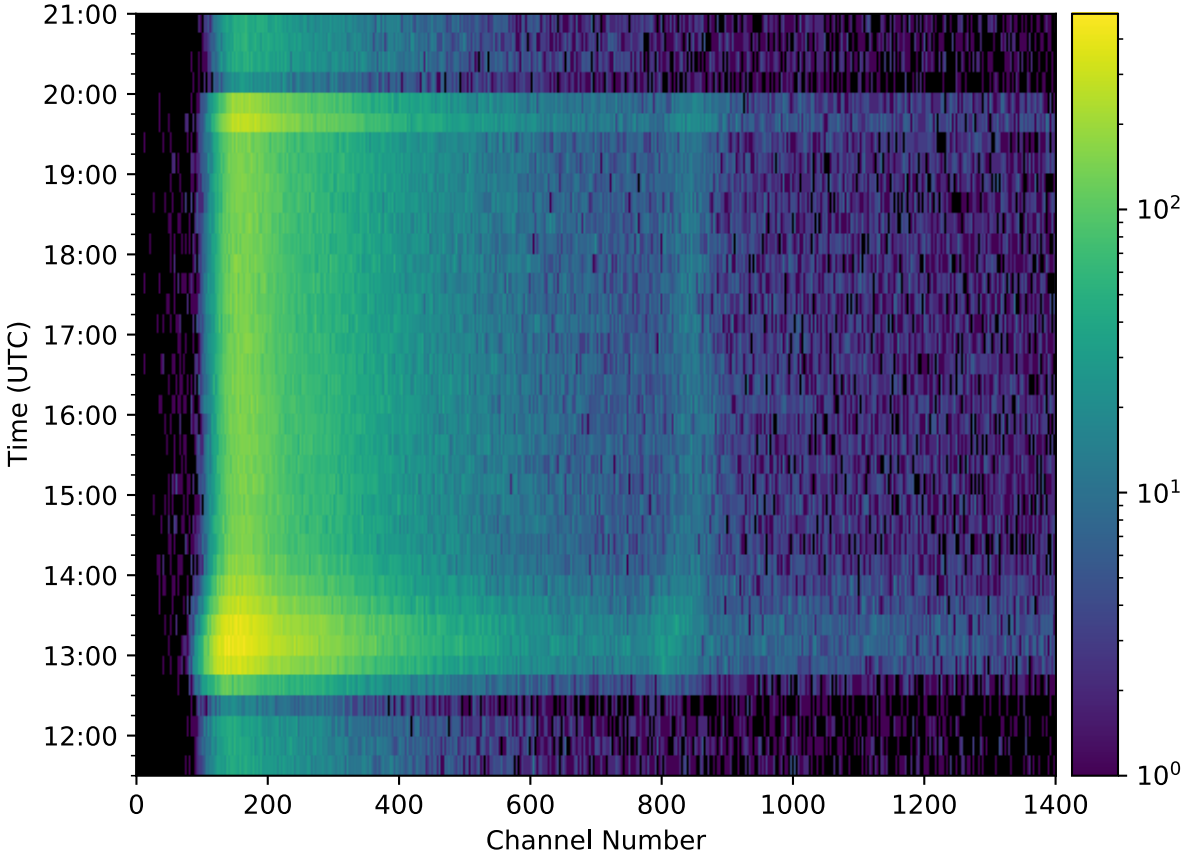
GMoDem - Telemetry

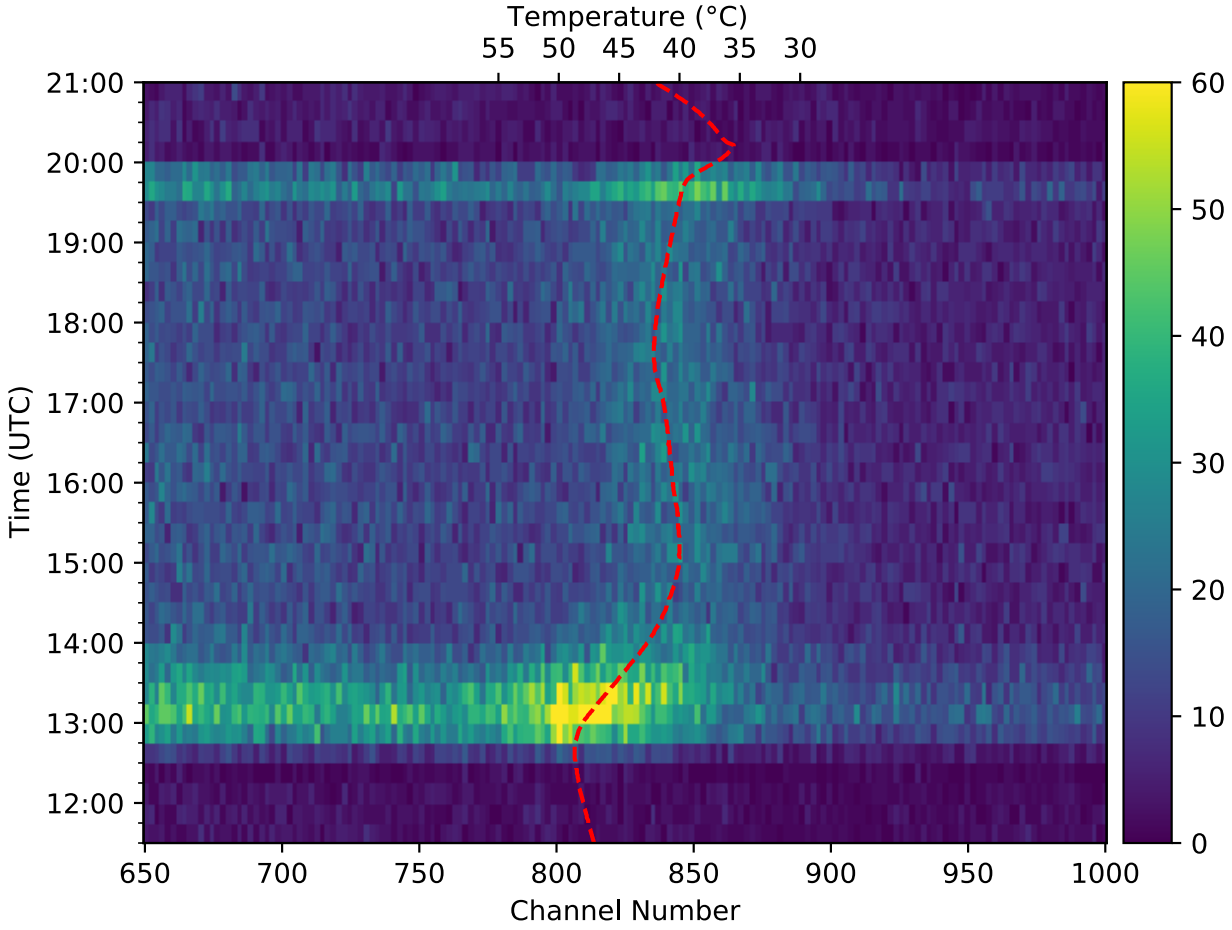




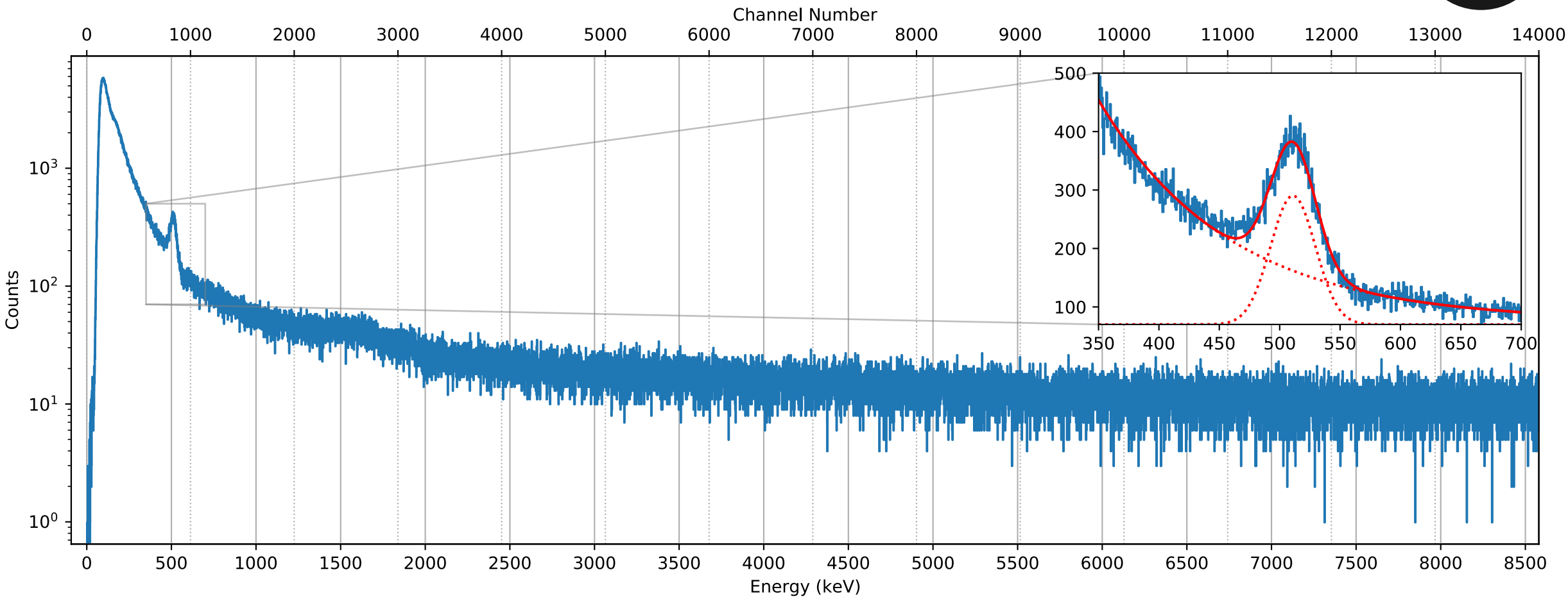
gmodem.spacescience.ie

GMoDem – Time Resolved Spectrum



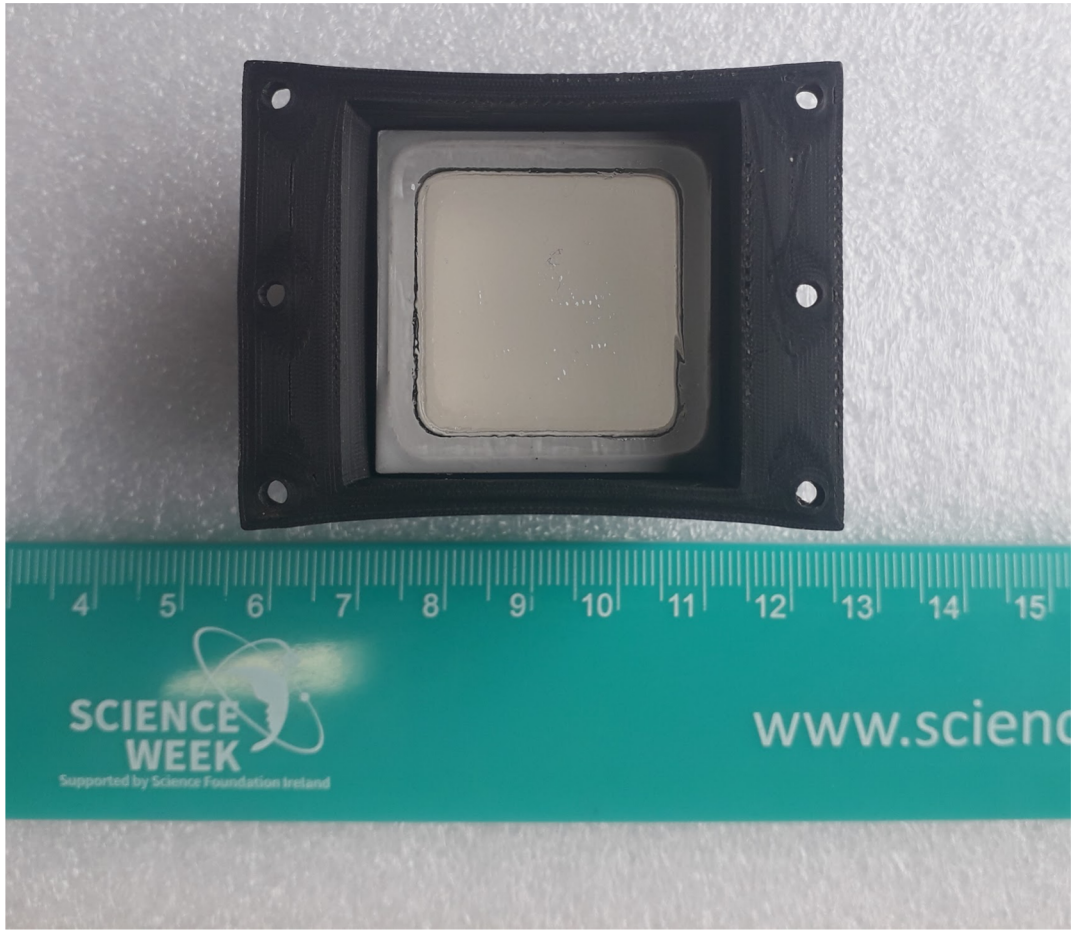


GMoDem – Flight Spectrum

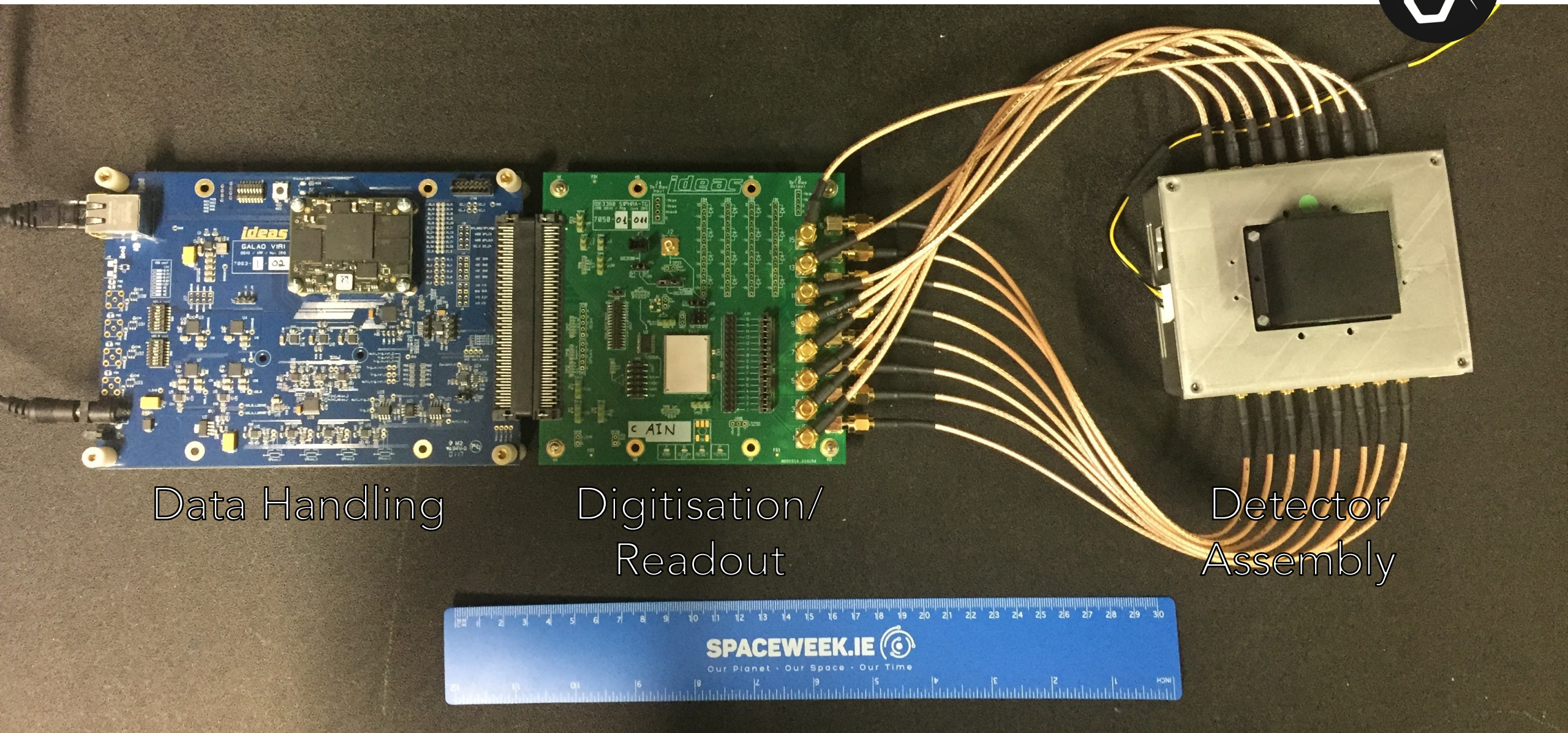


GMoDem

- 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

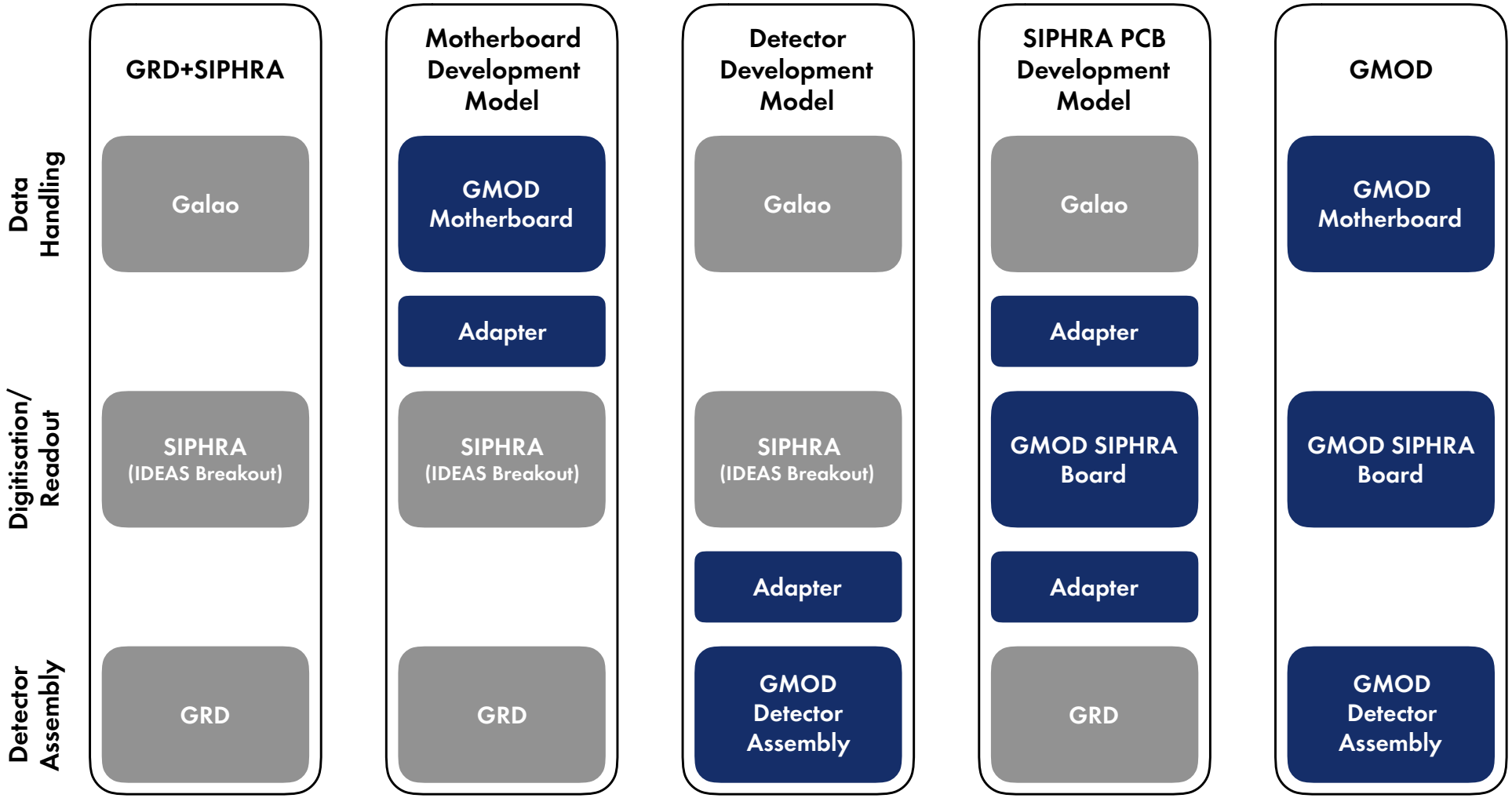


Data Handling

Digitisation/
Readout

Detector
Assembly

Architecture / Dev Strategy



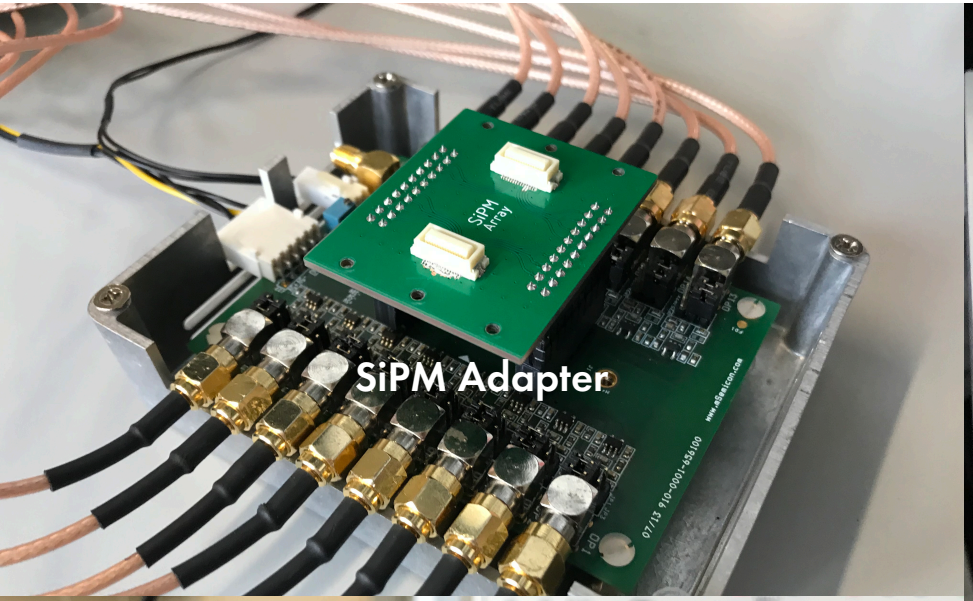
Detector Dev Model

Galao

SIPHRA (IDEAS Breakout)

Adapter

GMOD Detector



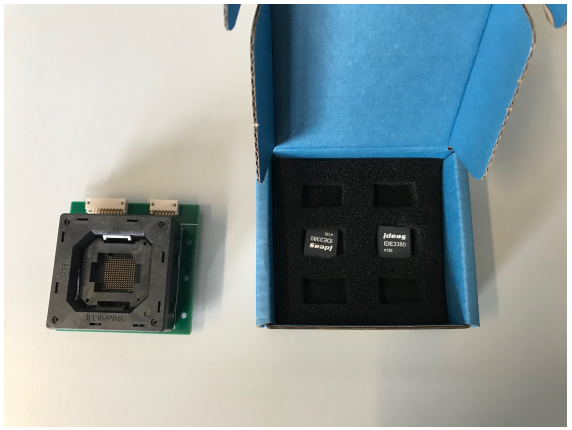
SIPHRA Dev Model

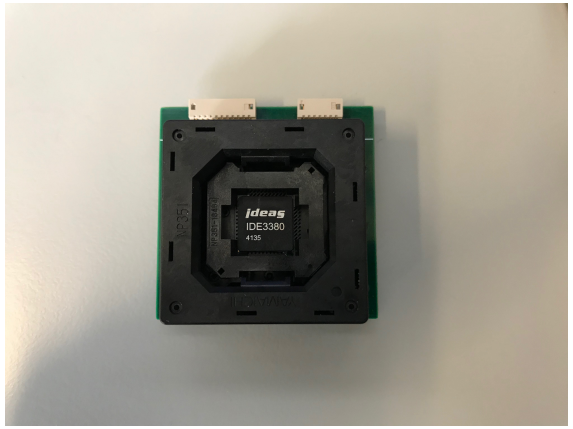
Galao

Adapter

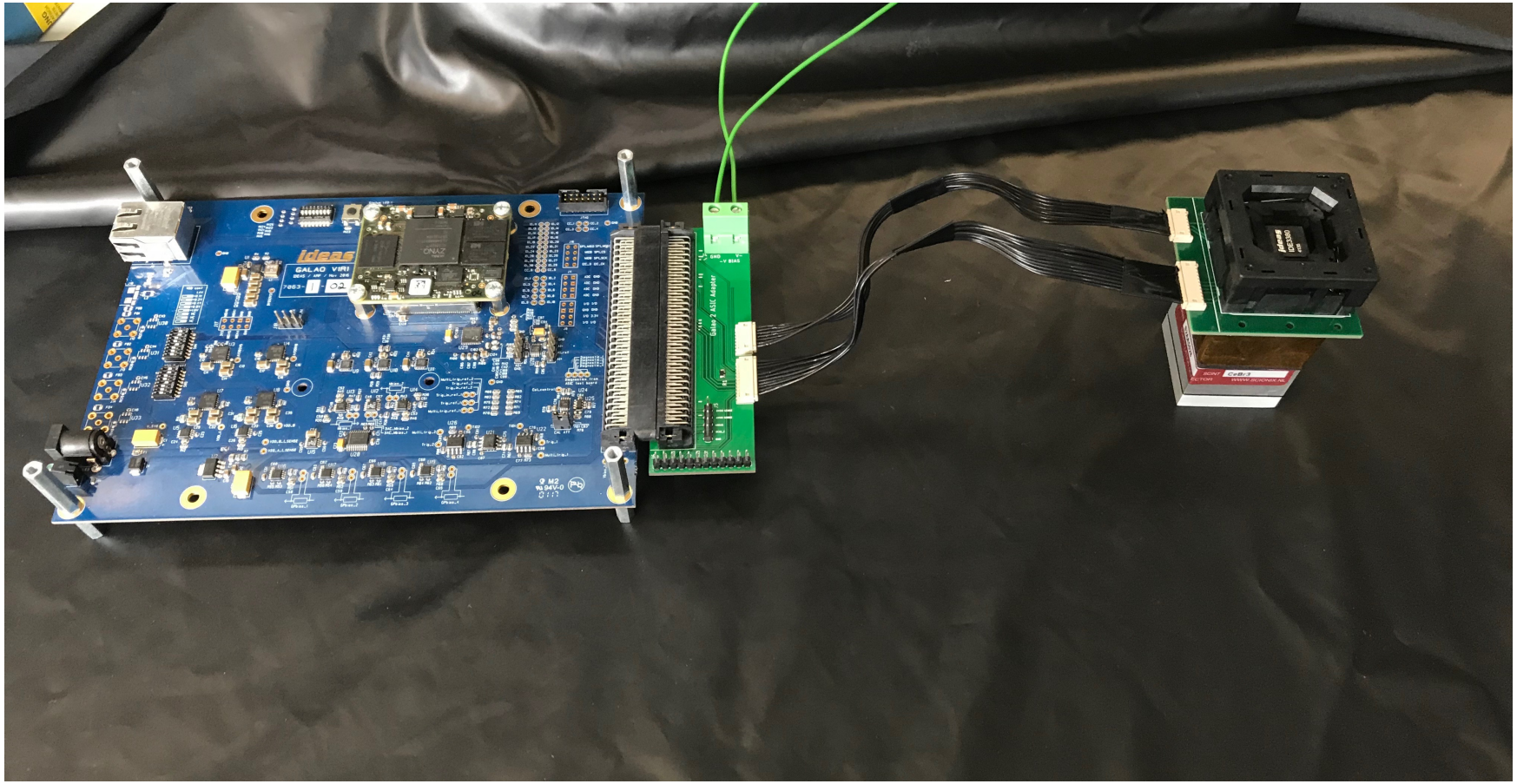
GMOD SIPHRA Board

GMOD Detector



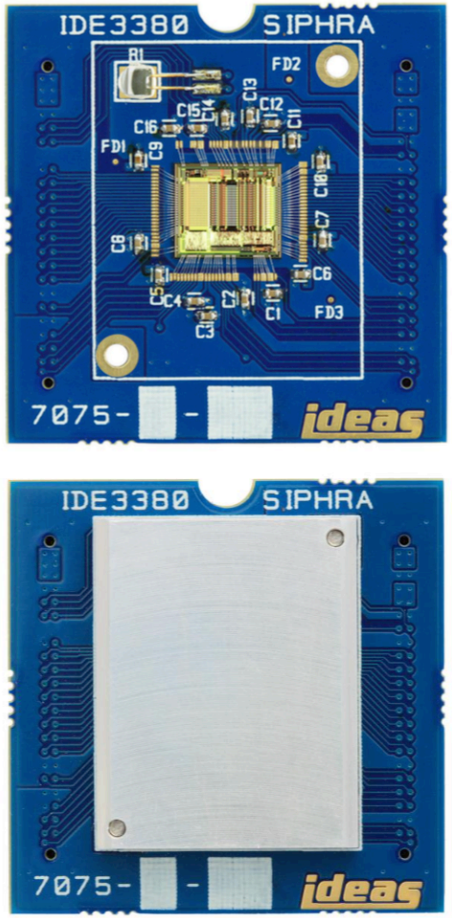


SIPHRA BGA

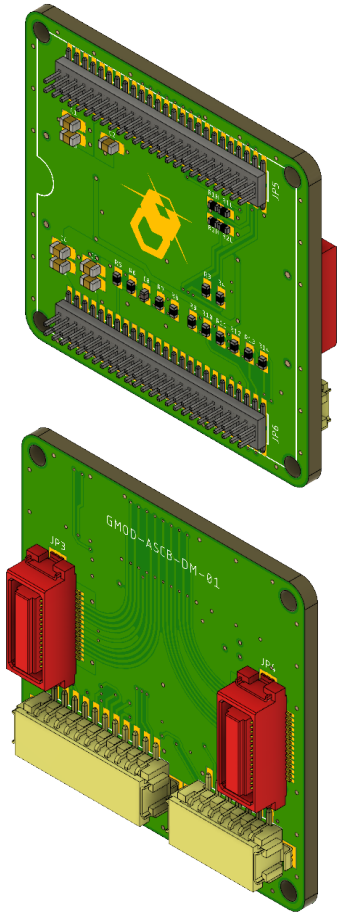


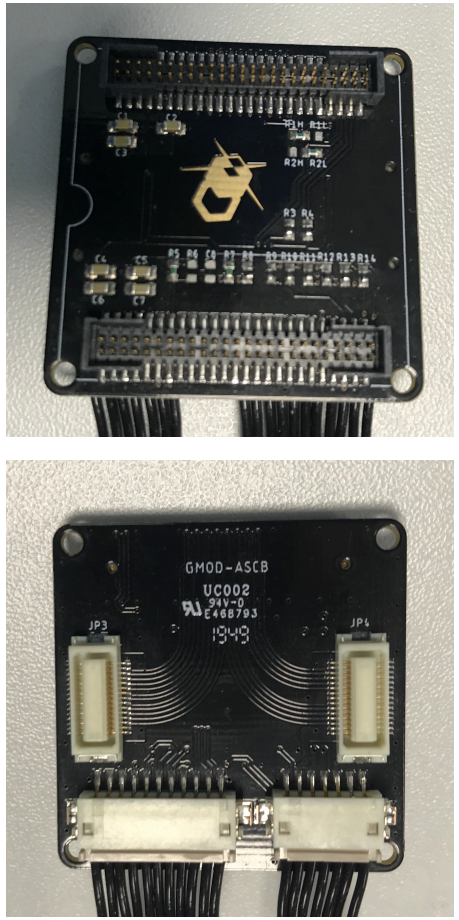
SIPHRA Dev Model

Galao | Adapter | GMOD SIPHRA Board | GMOD Detector

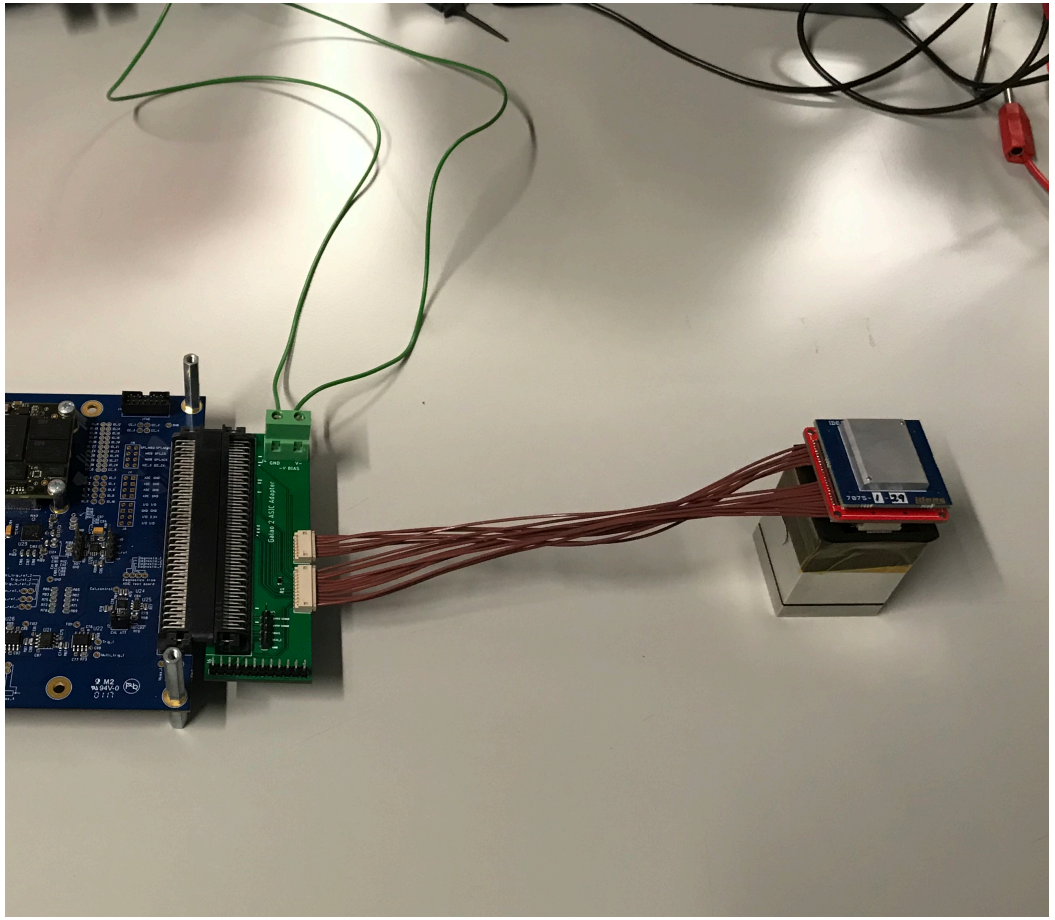


SIPHRA CoB



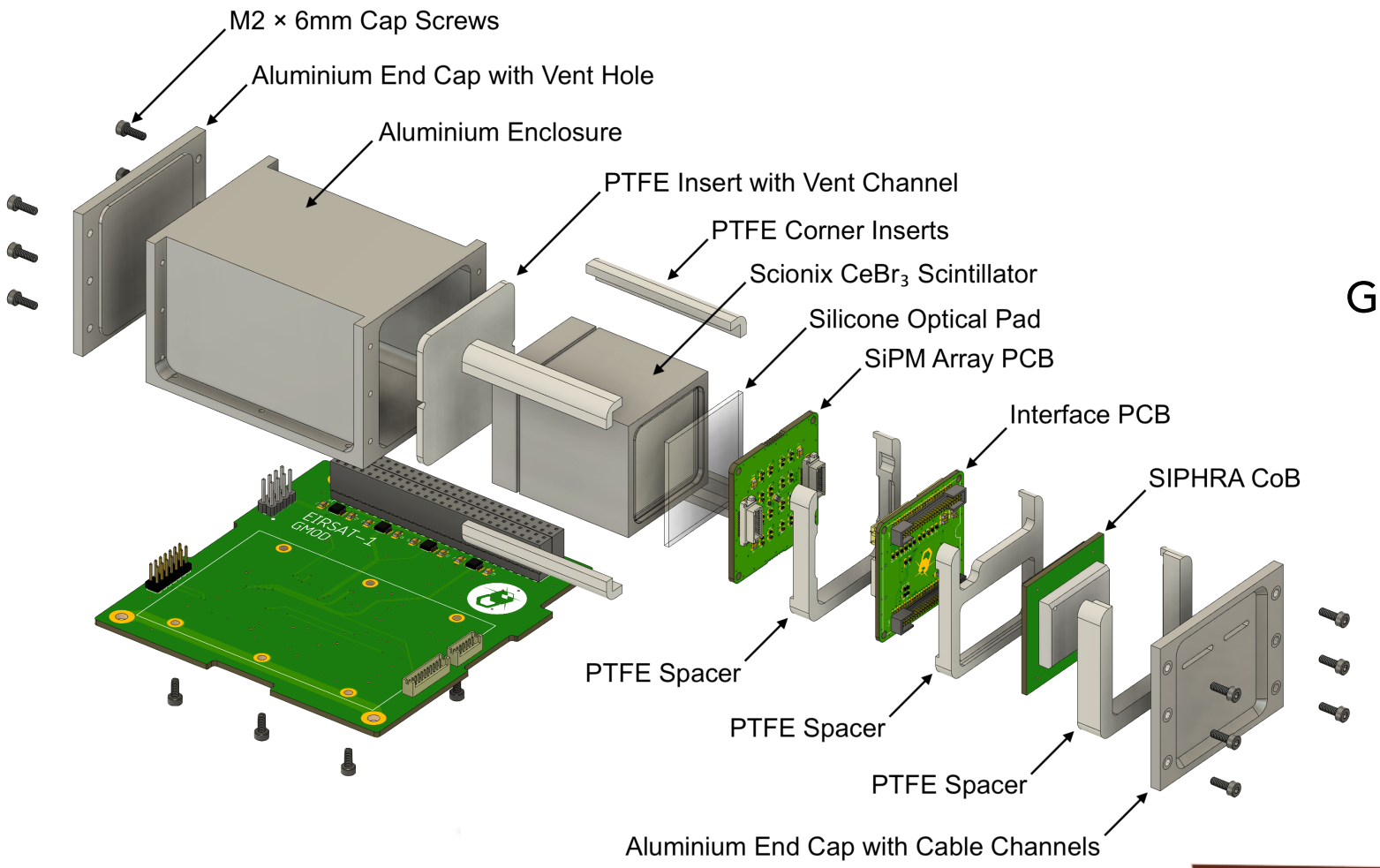


CoB Interface PCB

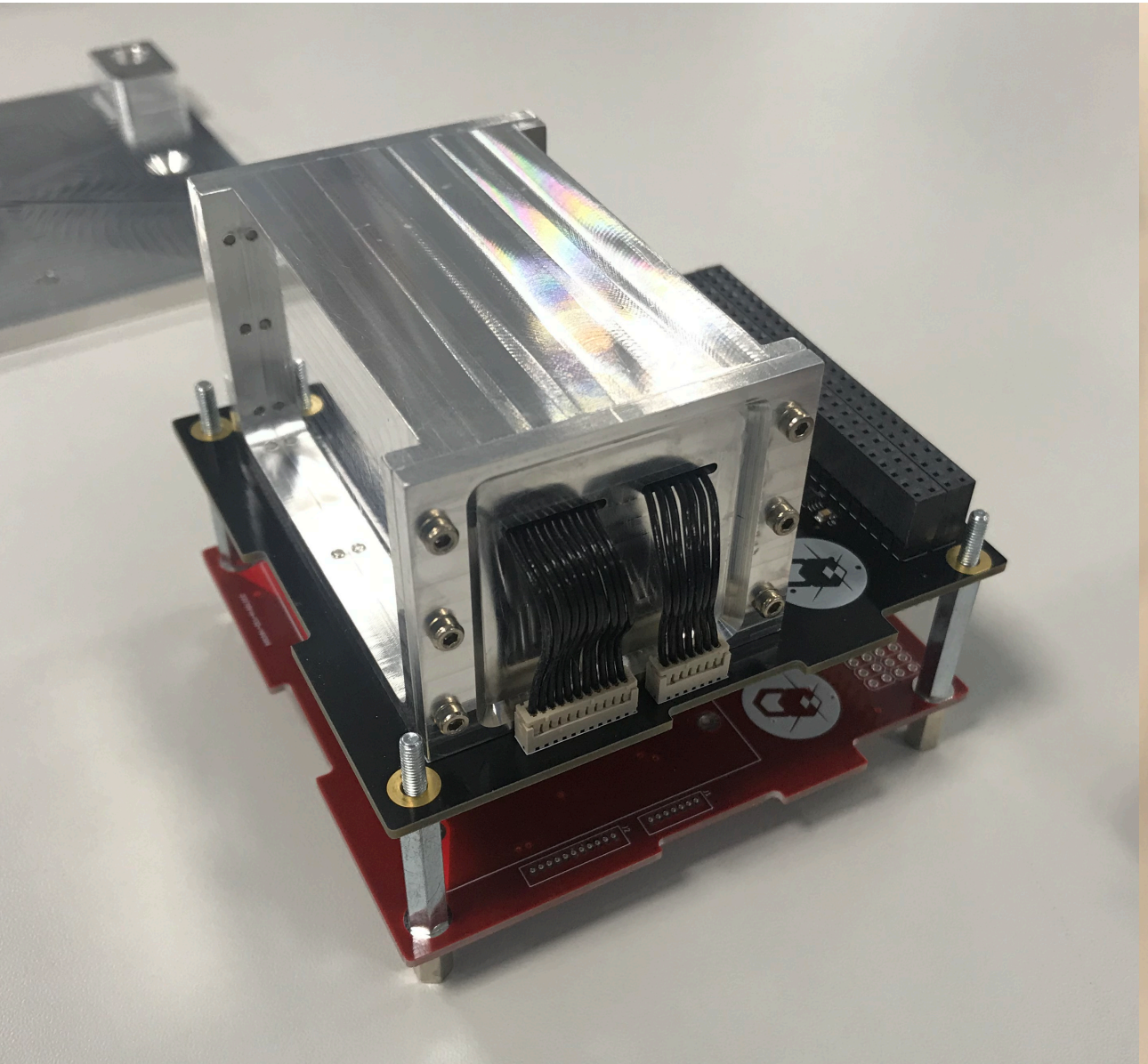


SIPHRA CoB with J-Series Array and CeBr3

Final EIRSAT-1 + GMOD



GMOD EQM



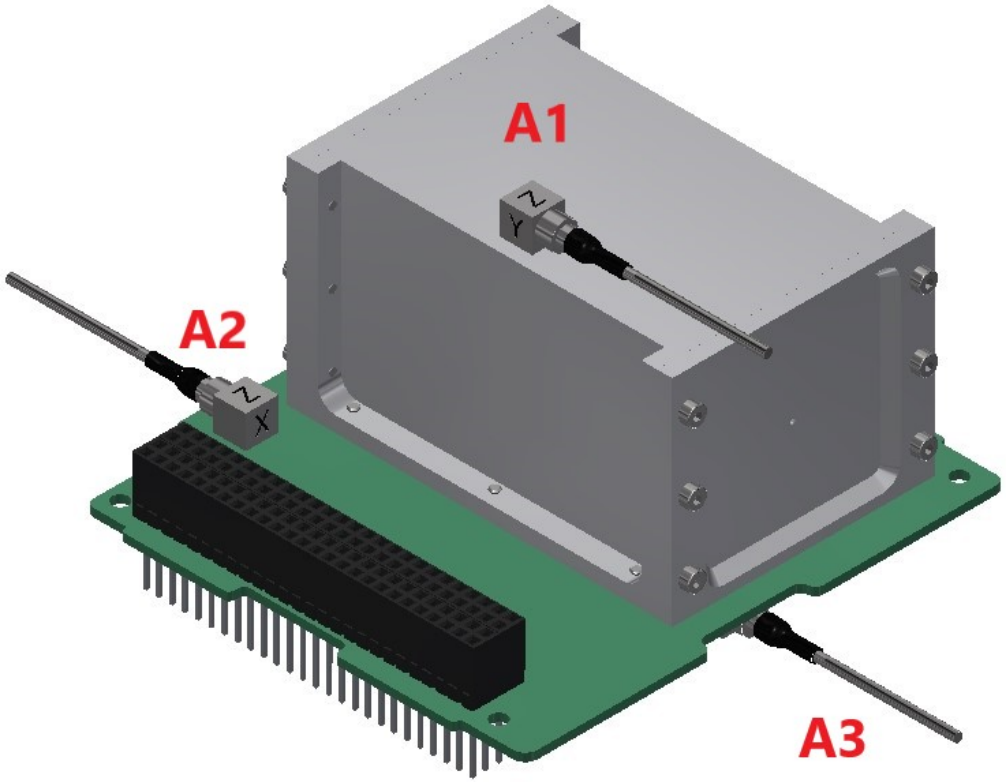
Vibration – Levels and Durations

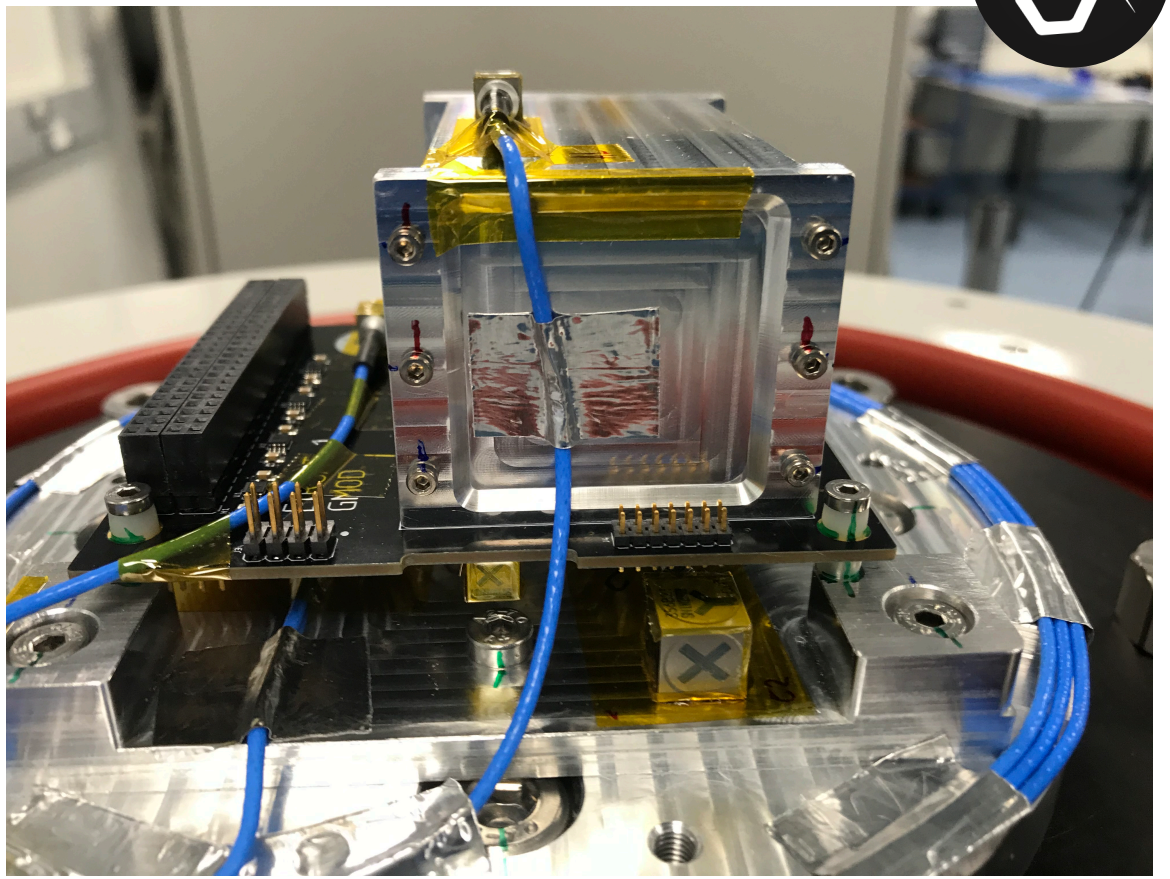
Frequency (Hz)	Level	Unit
Sine		
5 - 21	11	mm
21 - 60	20	g
60 - 65	20 – 6	g
65 – 100	6	g
Random: 9.47g RMS		
20	0.057	g^2/Hz
20 - 153	0	dB/oct
153	0.057	g^2/Hz
153 - 190	7.67	dB/oct
190	0.099	g^2/Hz
190 - 250	0	dB/oct
250	0.099	g^2/Hz
250 - 750	-1.61	dB/oct
750	0.055	g^2/Hz
750 - 2000	-3.43	dB/oct
2000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

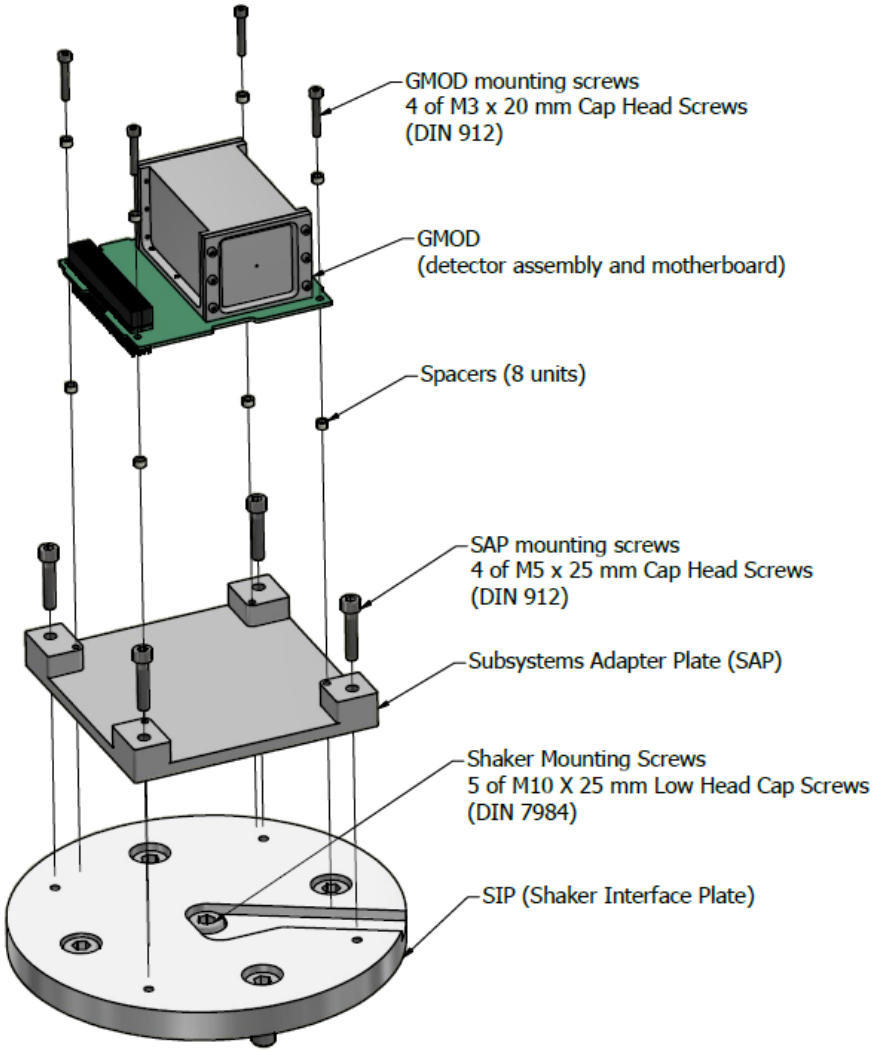
Vibration – Accelerometers



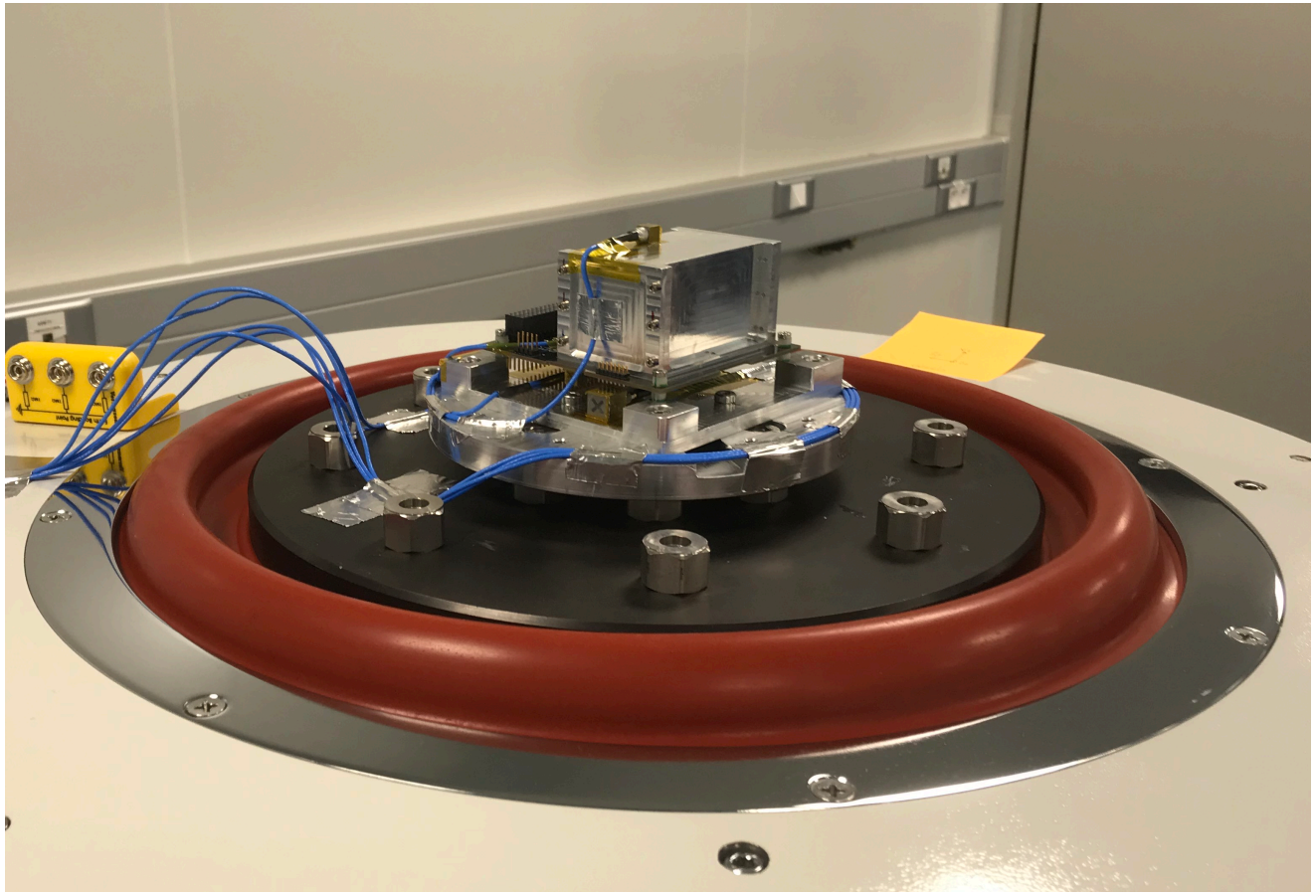


- 3 triaxial measurement accelerometers
  - A1: GMOD Housing
  - A2: Top of motherboard
  - A3: Bottom of Motherboard
- 2 triaxial control accelerometers
  - Mounted to Subsystem Adapter Plate

Vibration – MGSE/Mounting

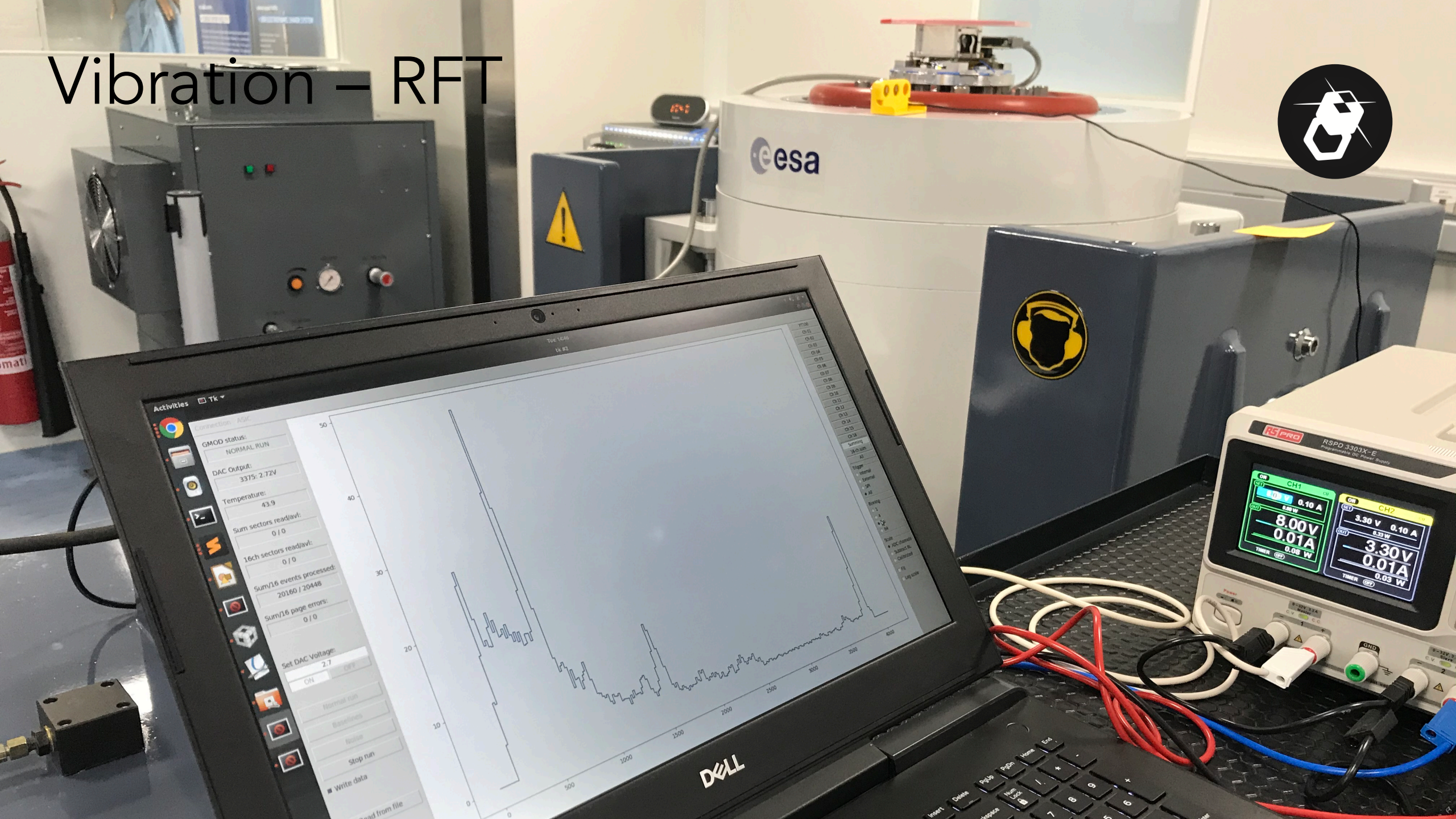


Mounting Exploded Diagram



GMOD Mounted on Z-Axis Armature

Vibration – RFT



TVAC – Profiles and Durations

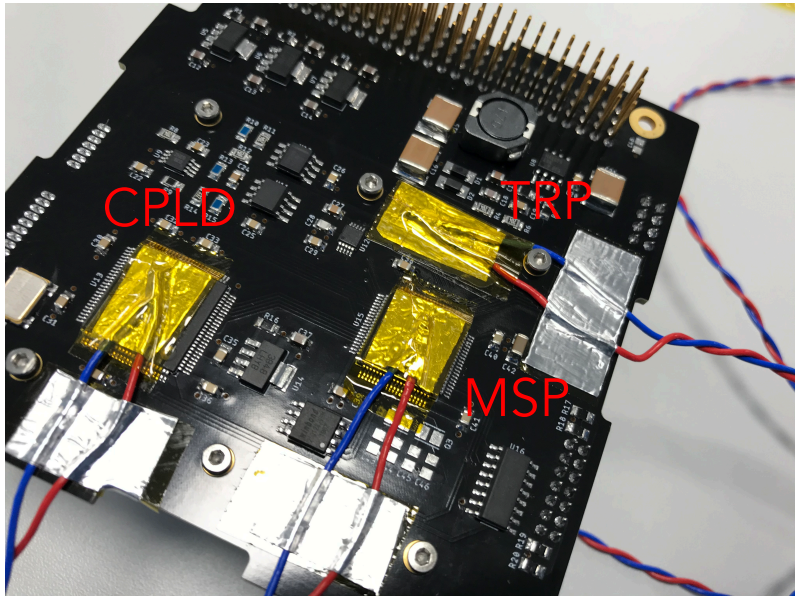
- Temperature: -31° – +75°
- Pressure: 10E-6 mBar

- 1 Non-operational Cycle
- 3 Operational Cycles

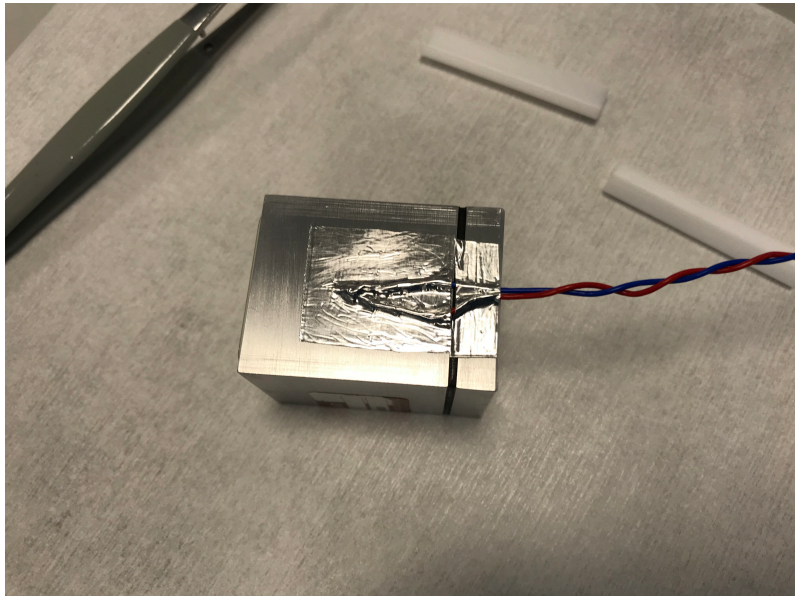
- >1 hour dwell at hot and cold temperatures

- 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.

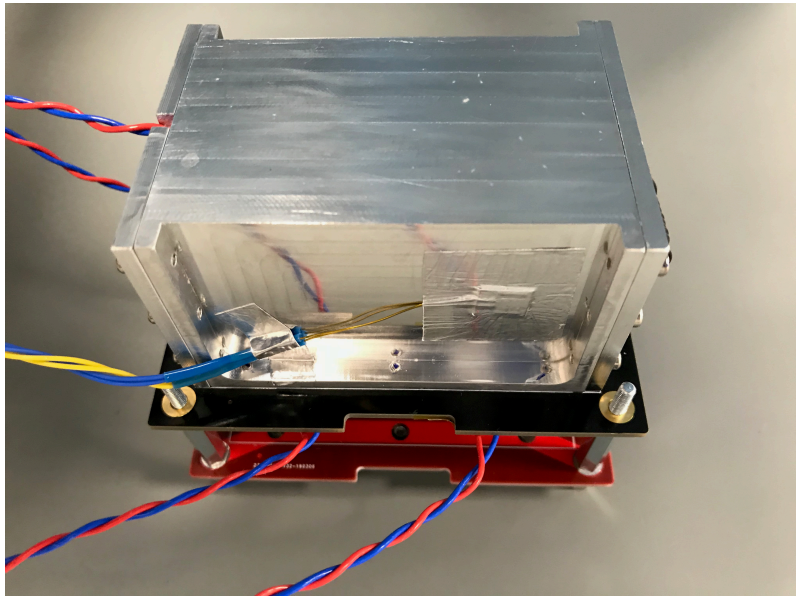
TVAC – Thermocouple Placement



- 3x TCs on Motherboard

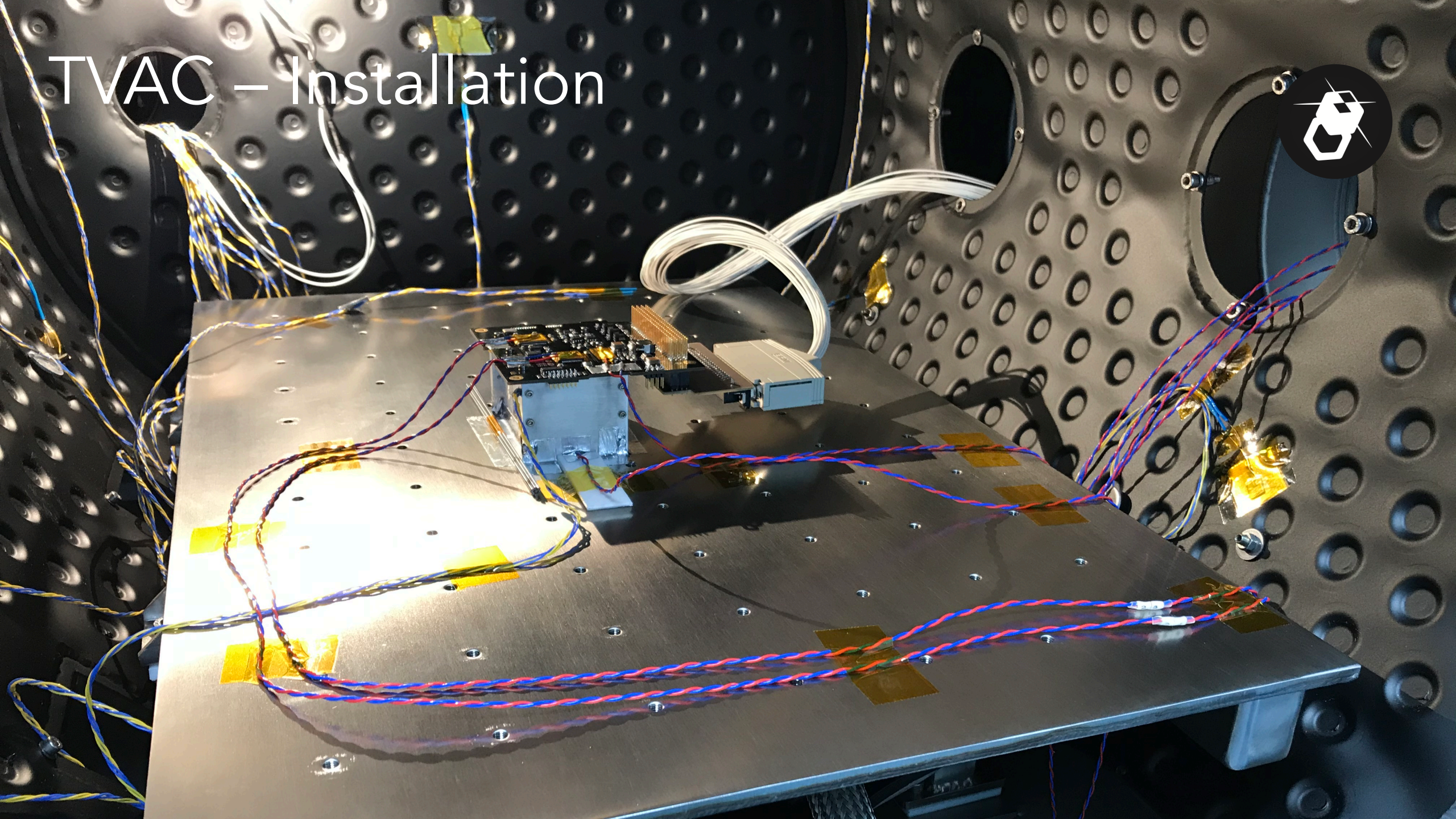


- 1x TC on Crystal

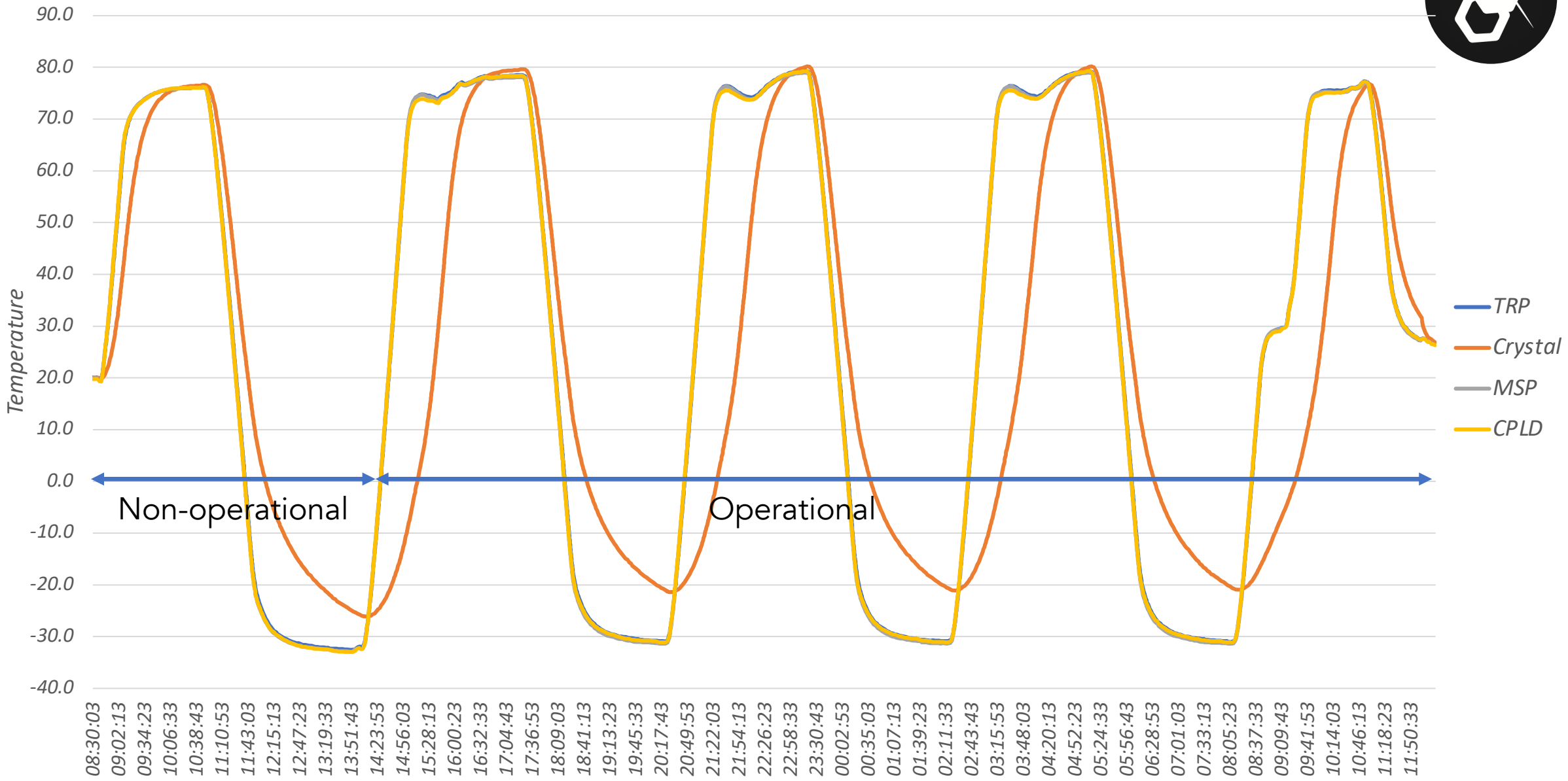


- 1x PT100 on Housing

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