

Netherlands
Space
Office



Conquering the solar system with CubeSat Technology – first results of CubeSat hardware beyond low Earth orbit

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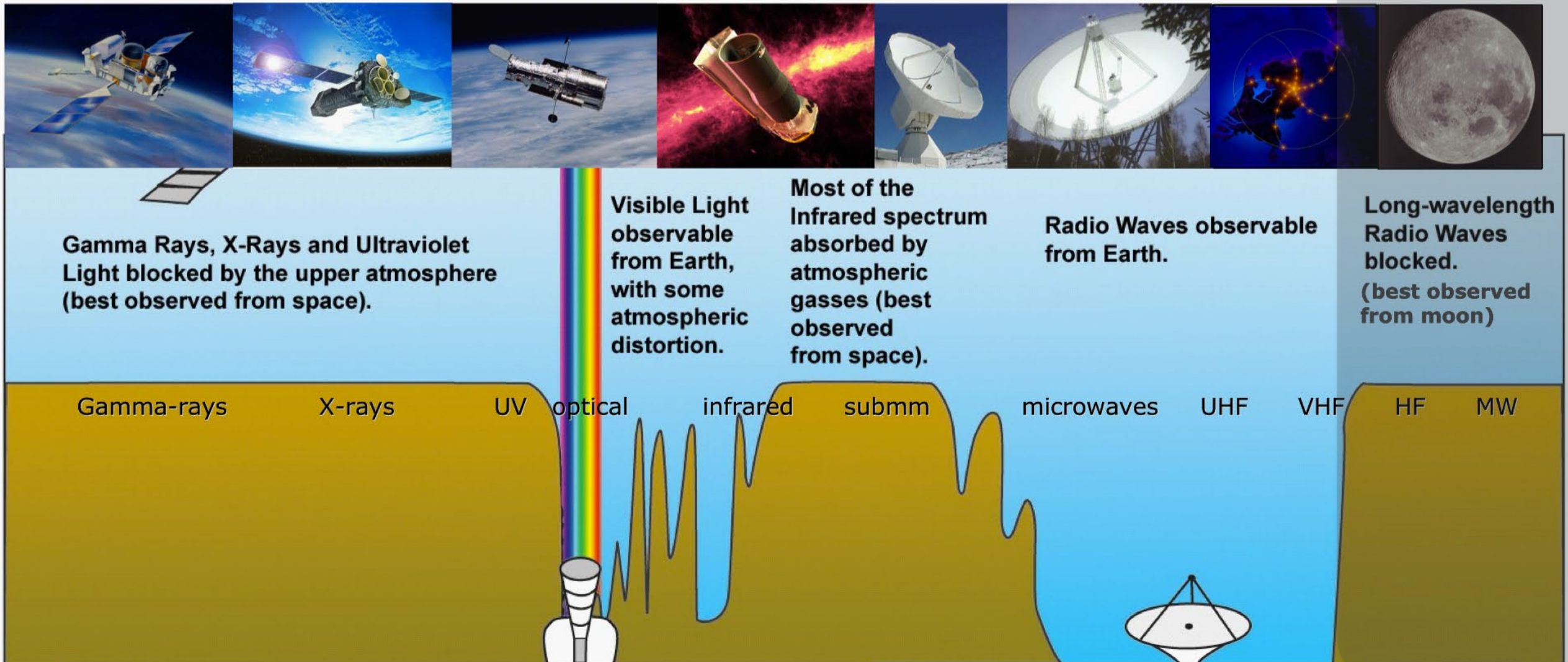
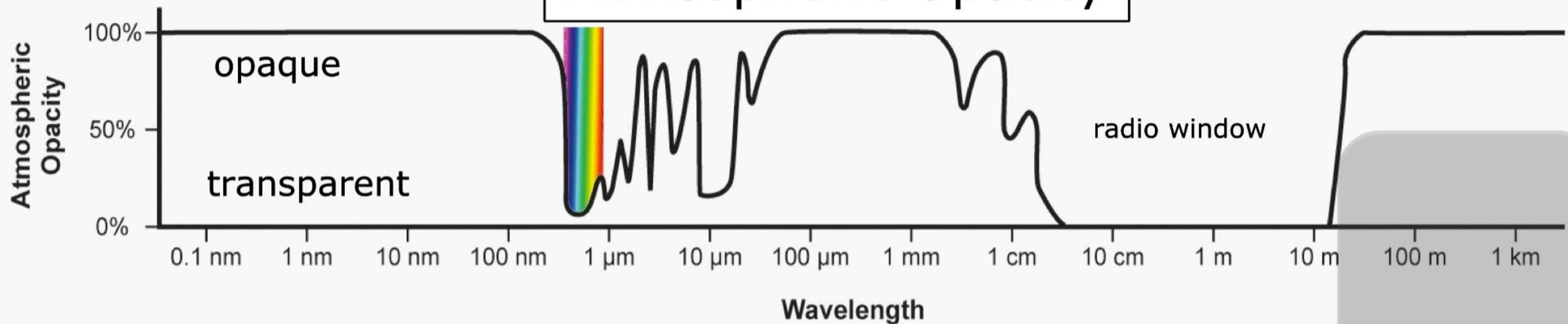
Content

- Science objectives
- The mission
- Engineering
- Results from space
- Future plans

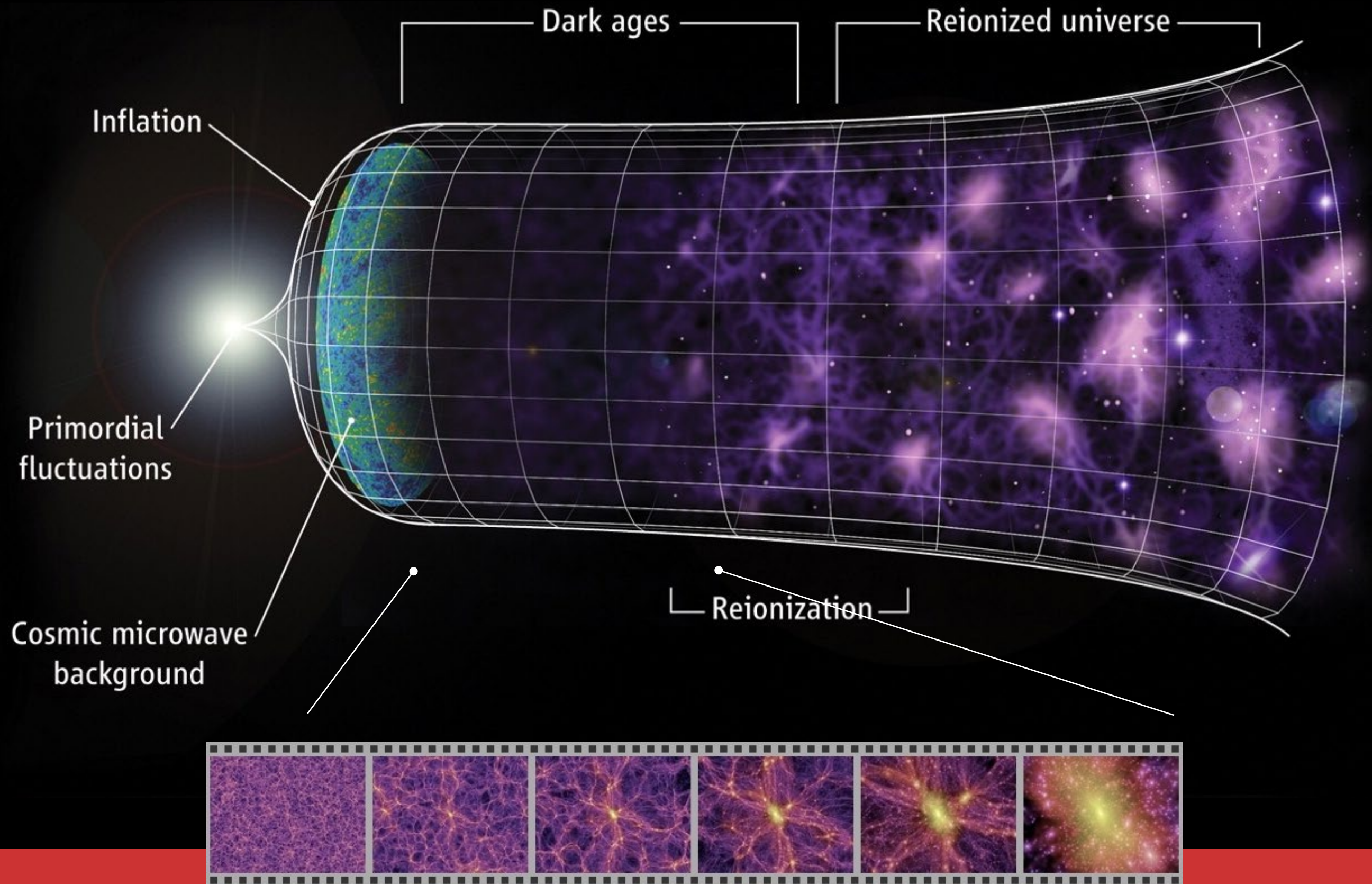


Opening the last unexplored frequency regime

Atmospheric Opacity



HISTORY OF THE UNIVERSE



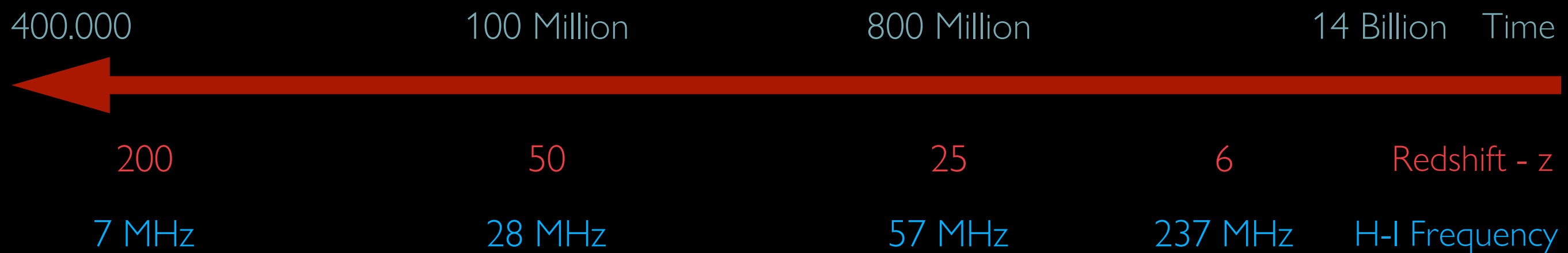
LOOKING BACK IN TIME...

Dark Ages

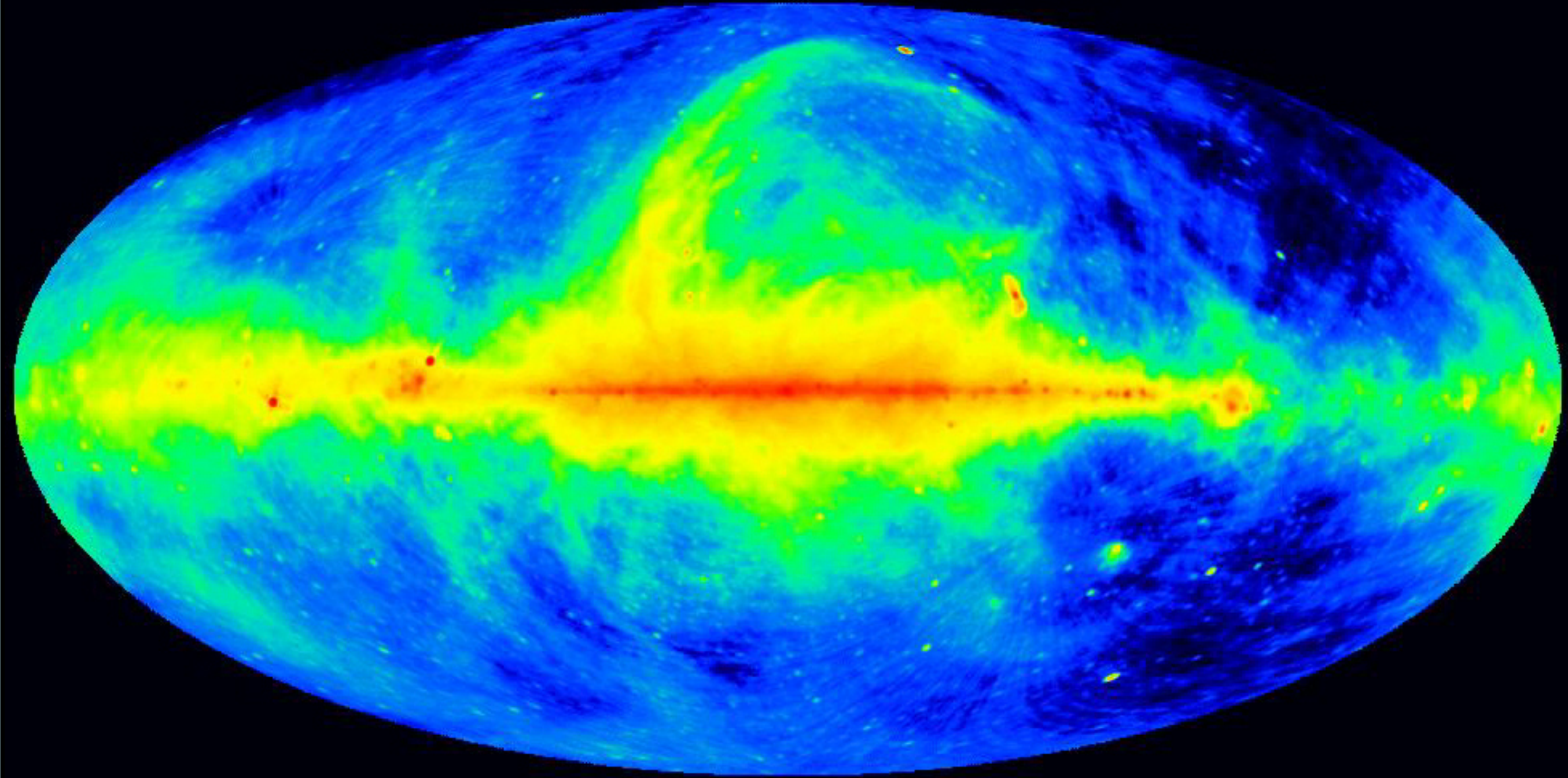
Cosmic Dawn

Reionisation

Present day



RADIO VIEW OF THE SKY AT 408 MHz





Best sky map at lower frequencies

Extremely poor resolution: Angular resolution $\sim 30^\circ$

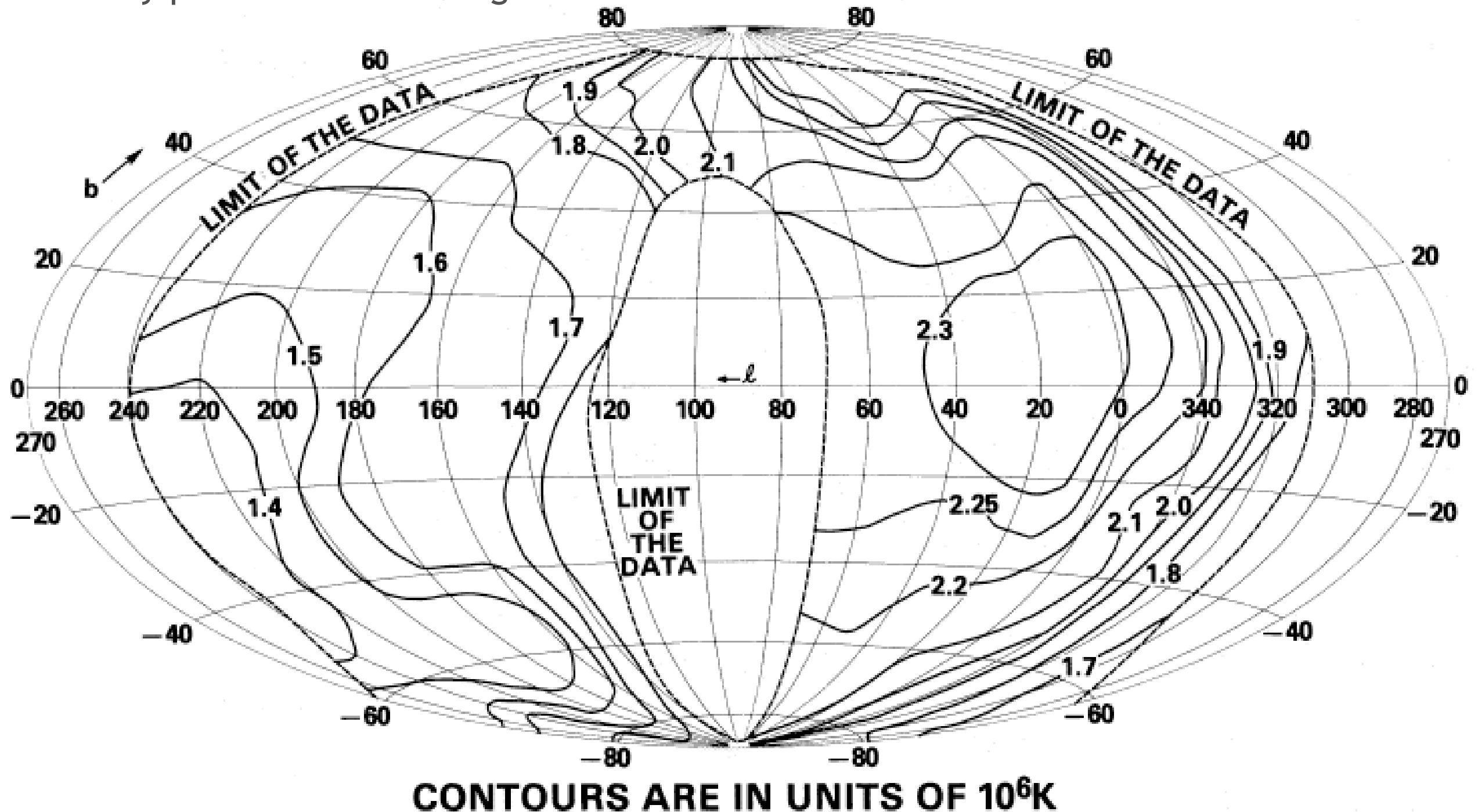


FIG. 5.—Contour map in galactic coordinates of the nonthermal emission observed by *RAE 2* at 4.70 MHz

Chang'e 4 mission



Relay satellite in
Earth-Moon L2
(2018) and Rover on
the Lunar Farside
(2019+)

NCLE is an instrument payload on the relay satellite



Chang'E 4



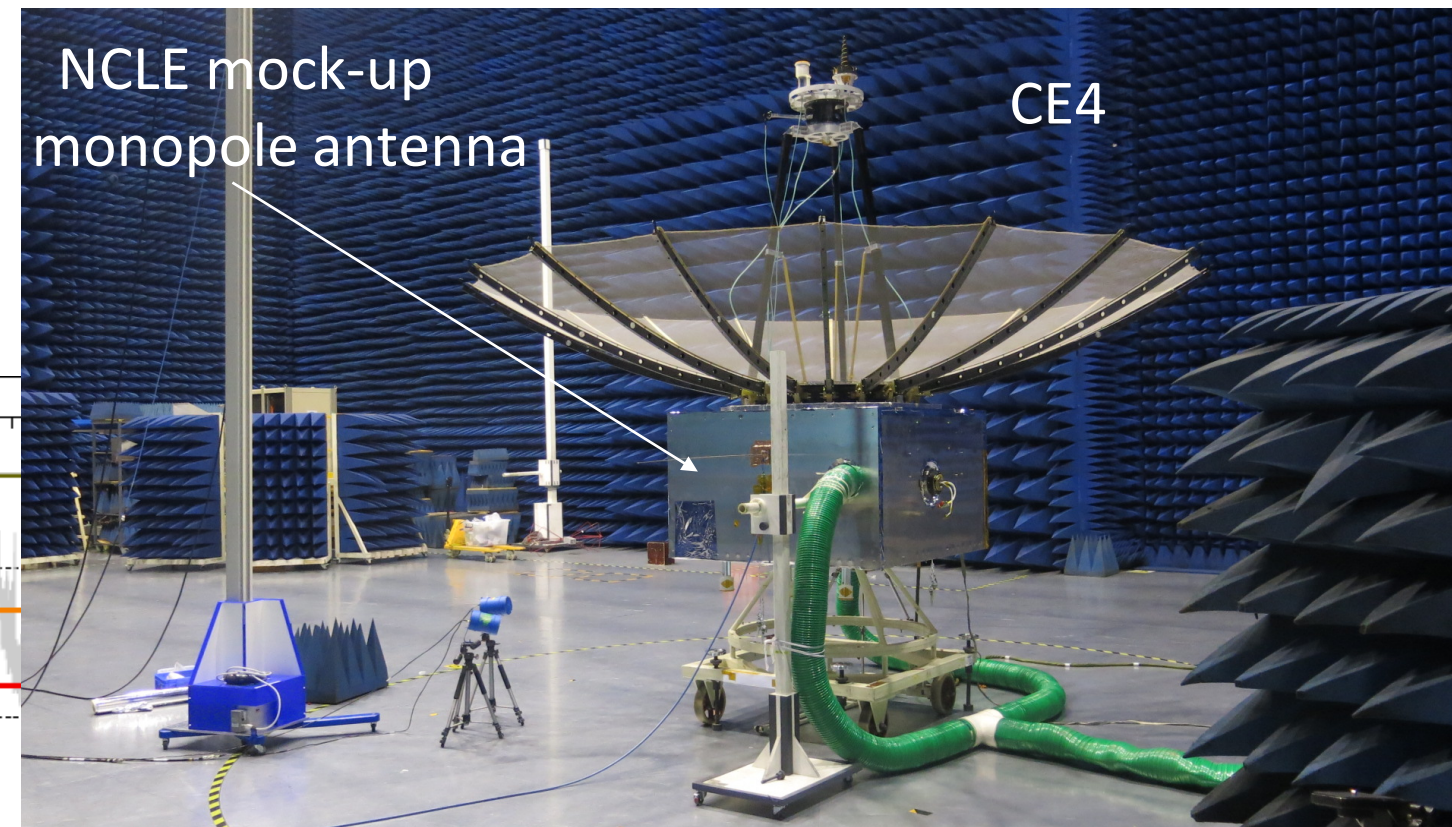
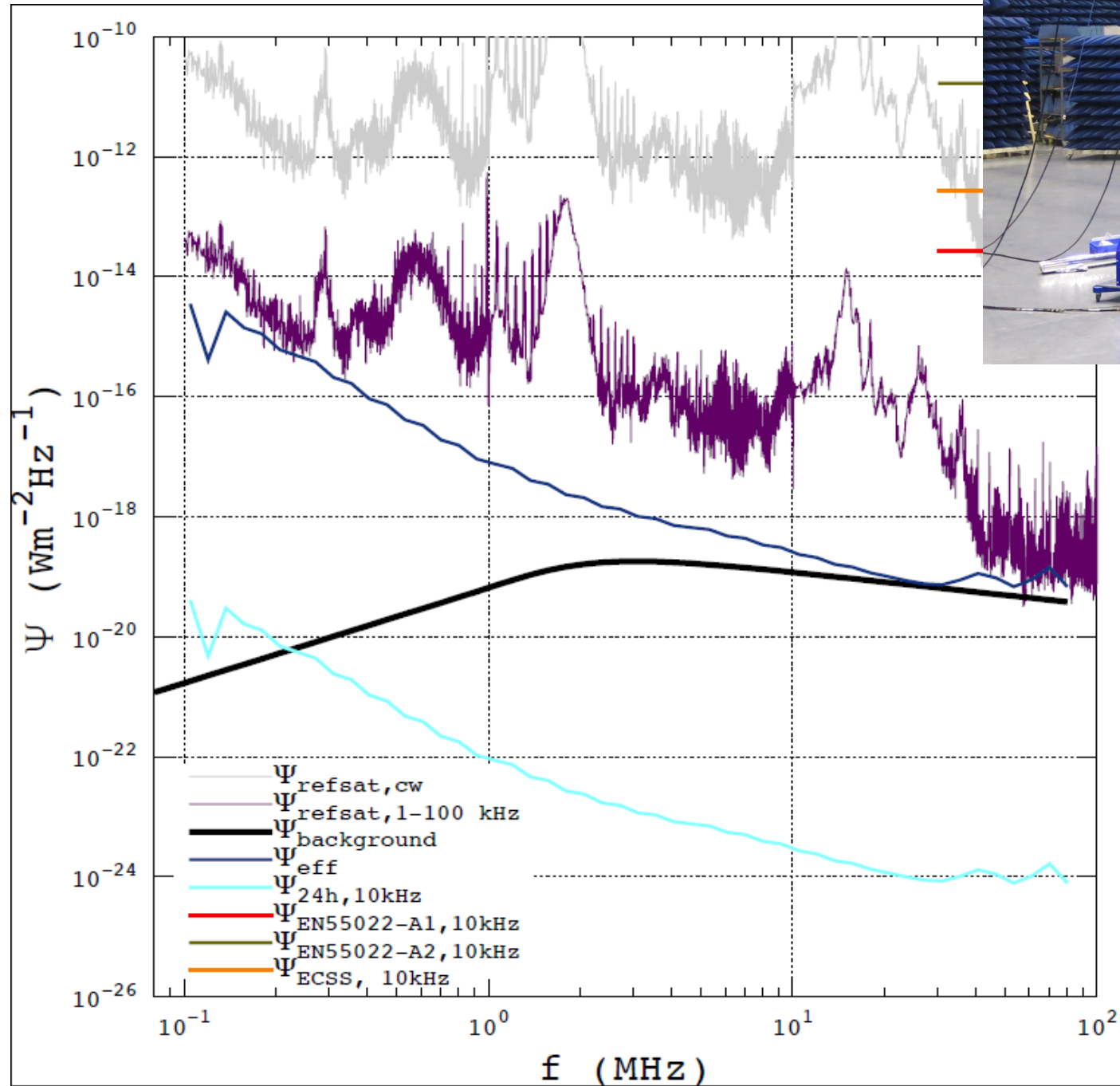
- Backup of Chang'e 3, a robotic lander, rover and relay satellite.
- Part of the Chinese Lunar Exploration Program - CLEP, a series of robotic lunar missions from the Chinese National Space Administration (CNSA): Chang'e 1-6, launched with Long March Rockets
- Launch of the Chang'e 4 relay satellite May 2018, the Lander and Rover follow half a year later.
- Location: Lunar farside,
- **Chang'e 4 mission as a test case for collaboration and opportunity for technology development**





New Challenges

EMC Design





New Challenges:

Temperature?

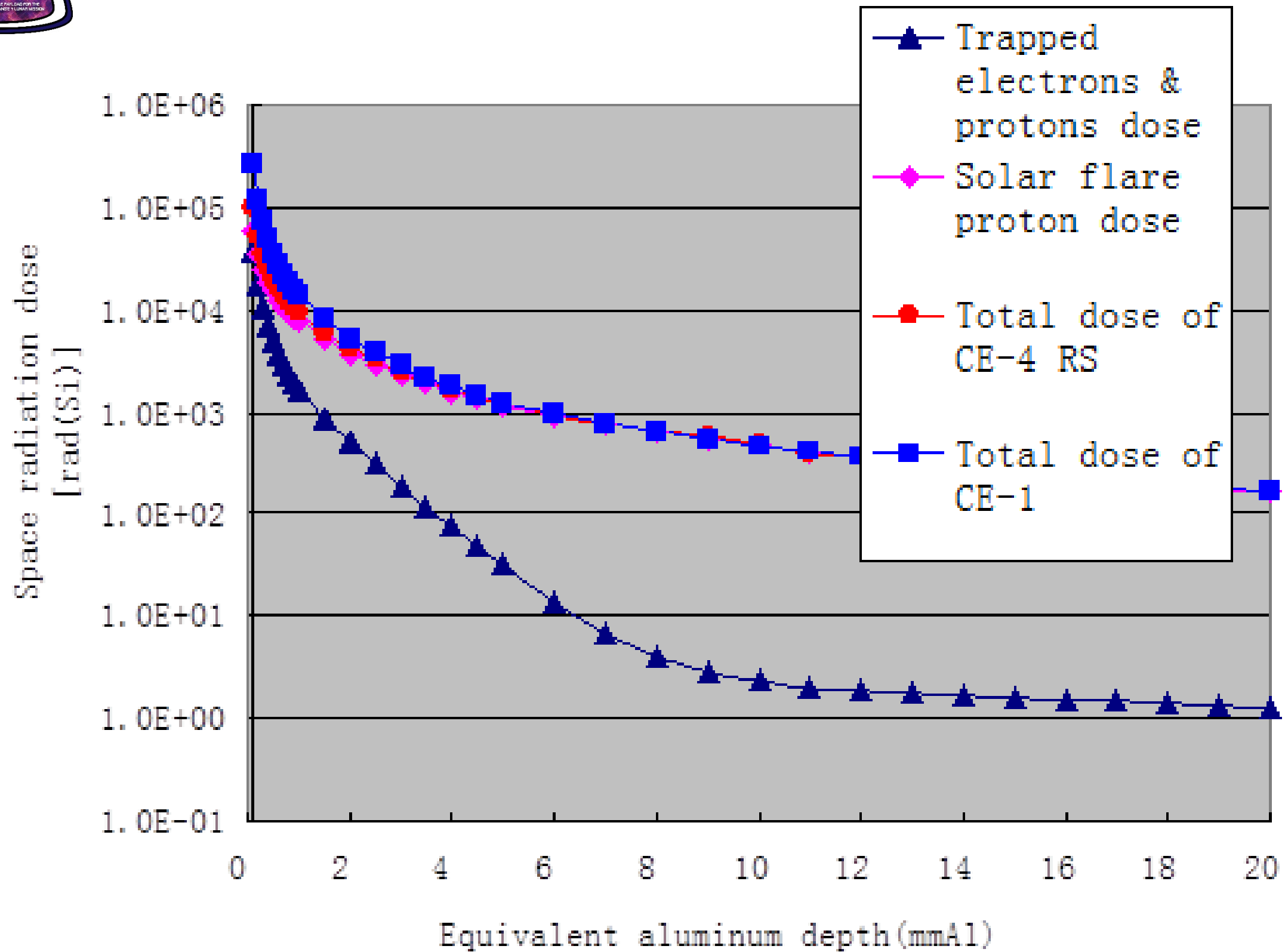
- “Extreme conditions”
- Iteration between CE4 and NCLE team on temperatures:
- Temperatures on the outside of the spacecraft:
 - -90 degC
 - +120 degC
- Inside the spacecraft:
 - -10 degC
 - +45 degC



New Challenges:

Radiation?

- Still mostly inside the Earth's magnetosphere
- Part of the equipment mounted on the outside
- Most hardware mounted inside an avionics box inside the satellite





**MAYBE THE MOON IS NOT SO
SCARY AFTER ALL**



Old Challenges: Schedule

Kick off: April 2016



Interface defined: November 2016



*FM Delivery:
March 2018*

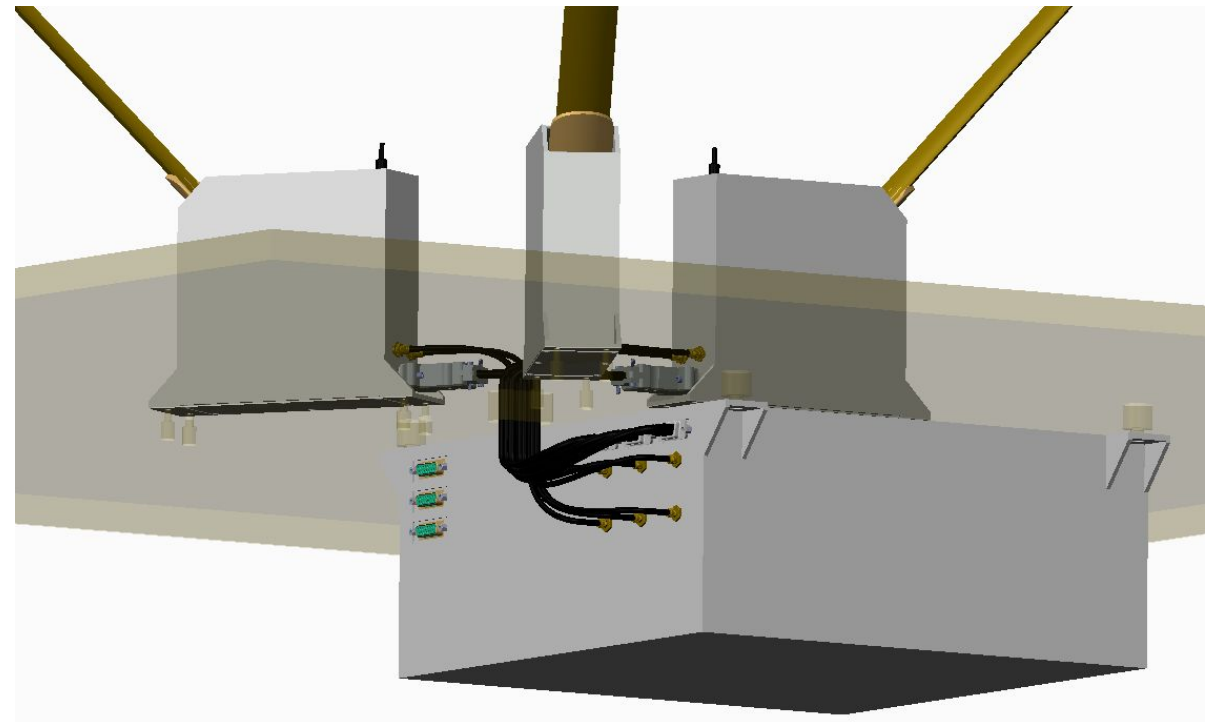




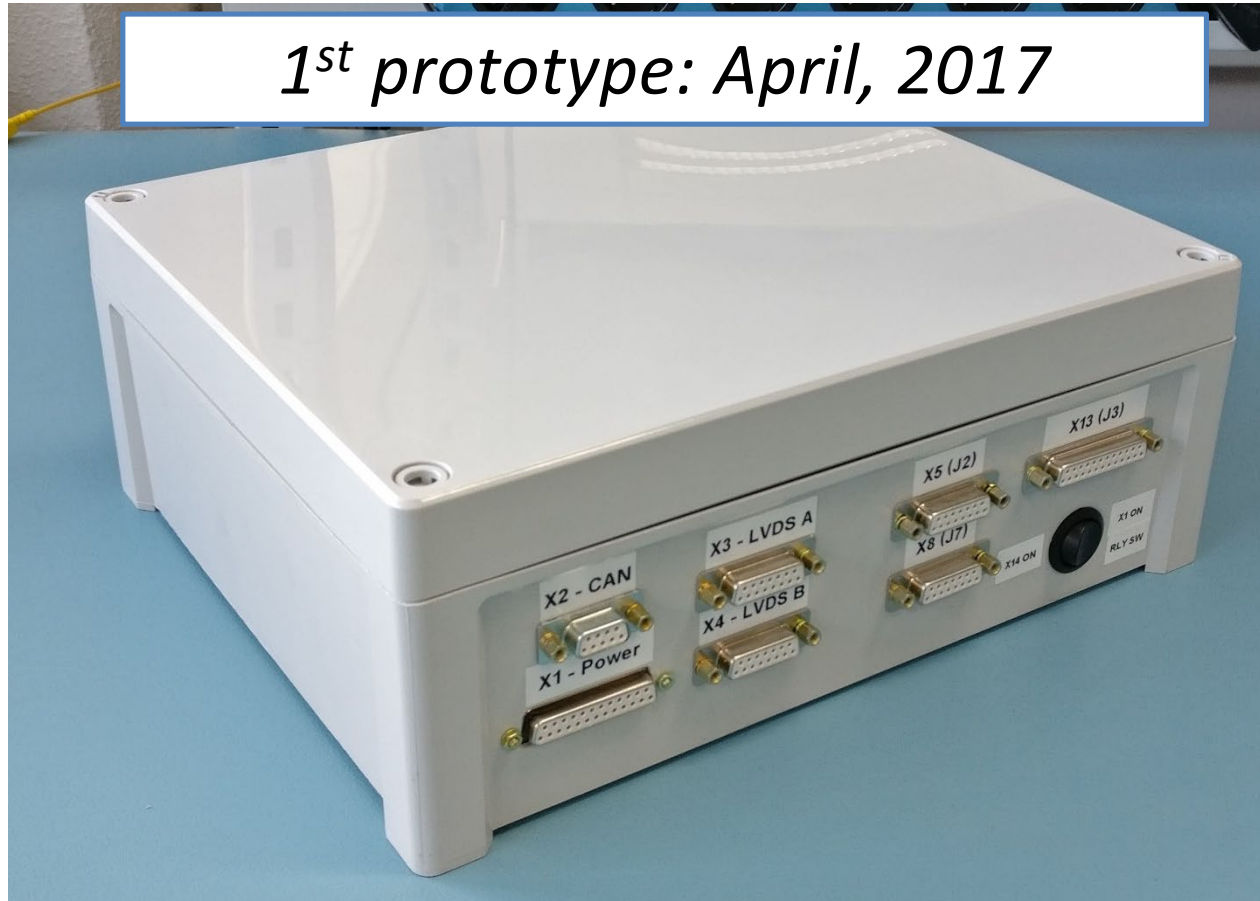
Design flow

Design philosophy: build fast and often

1st concept: January 2017



1st prototype: April, 2017





Design flow

Design philosophy: build fast and often



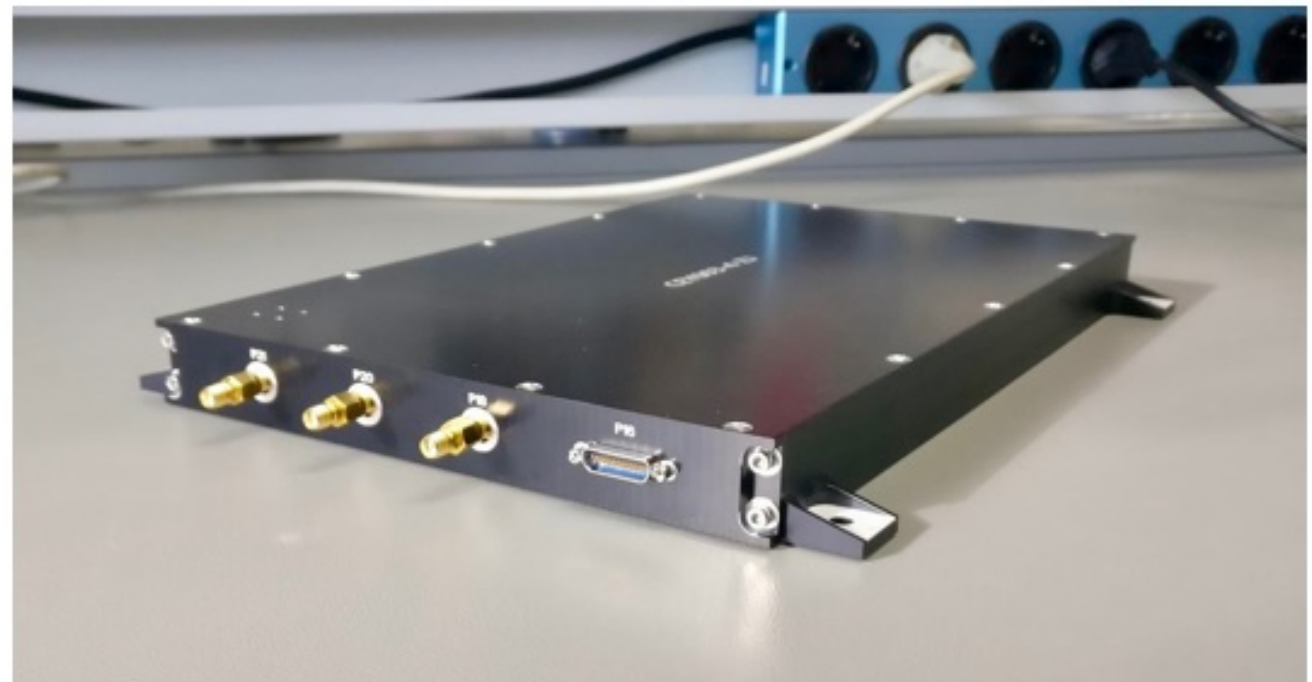
2nd prototype: November, 2017

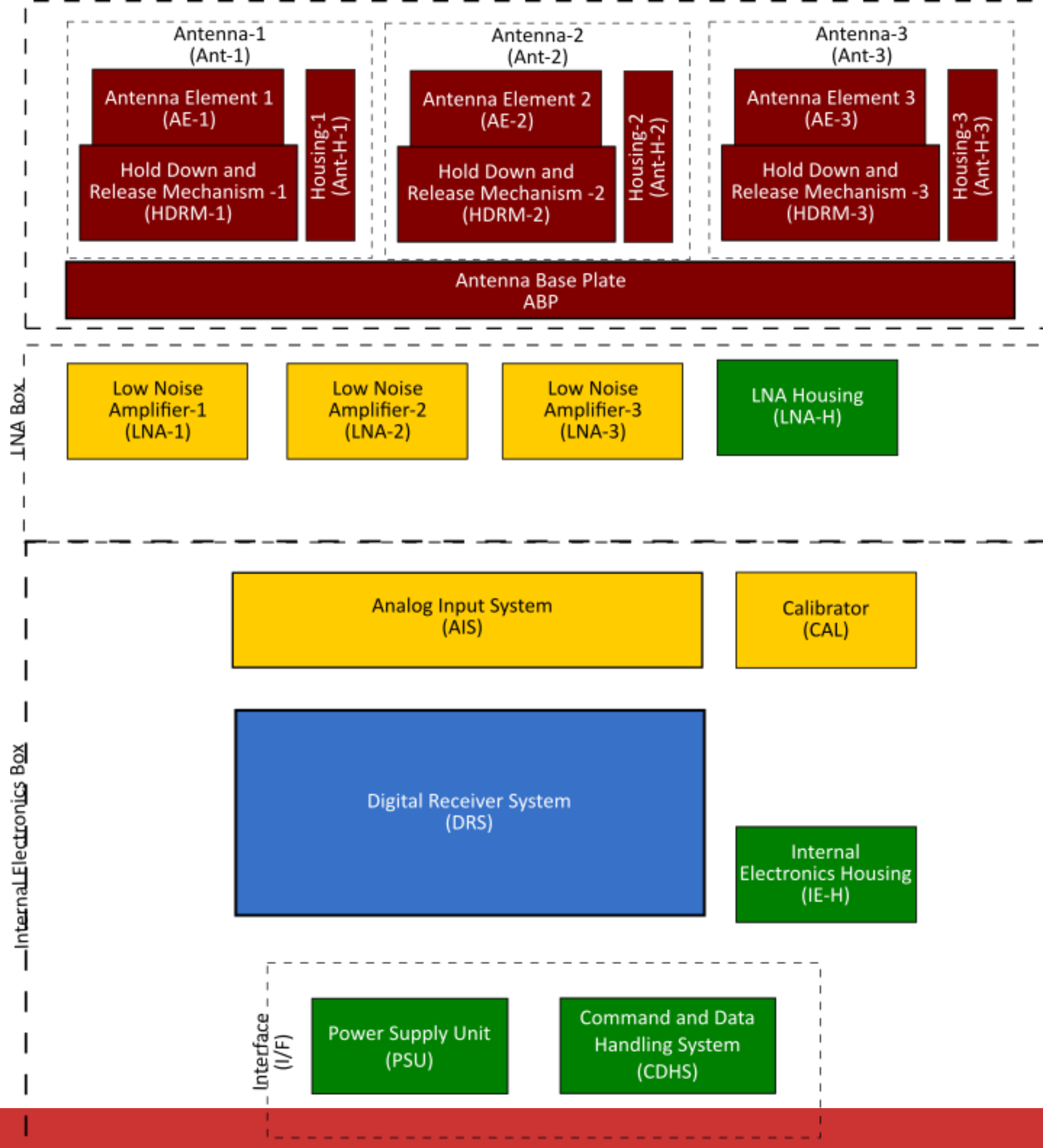


FM: March, 2018



The Hardware

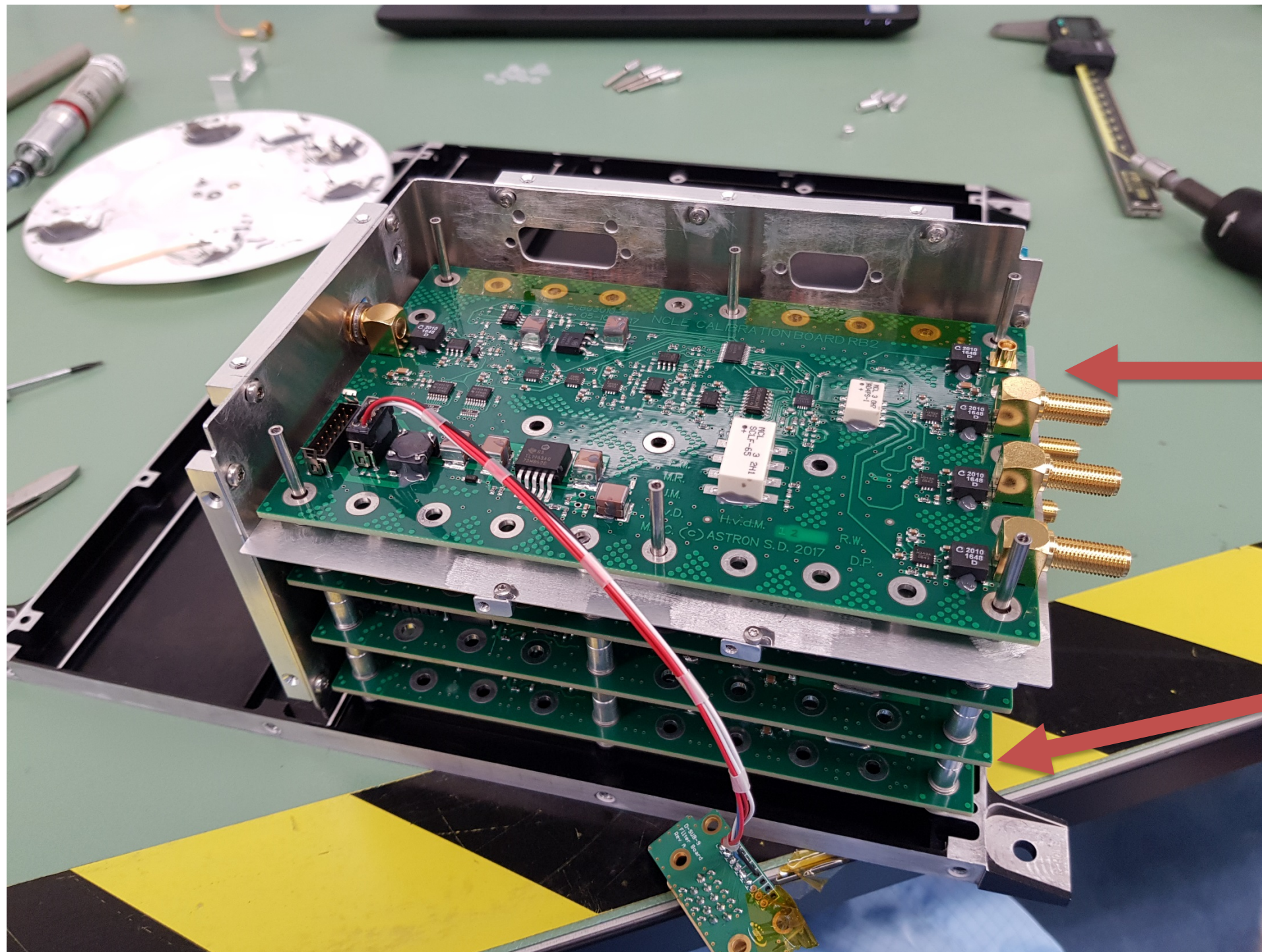






Internal Electronics:

Analog Chain

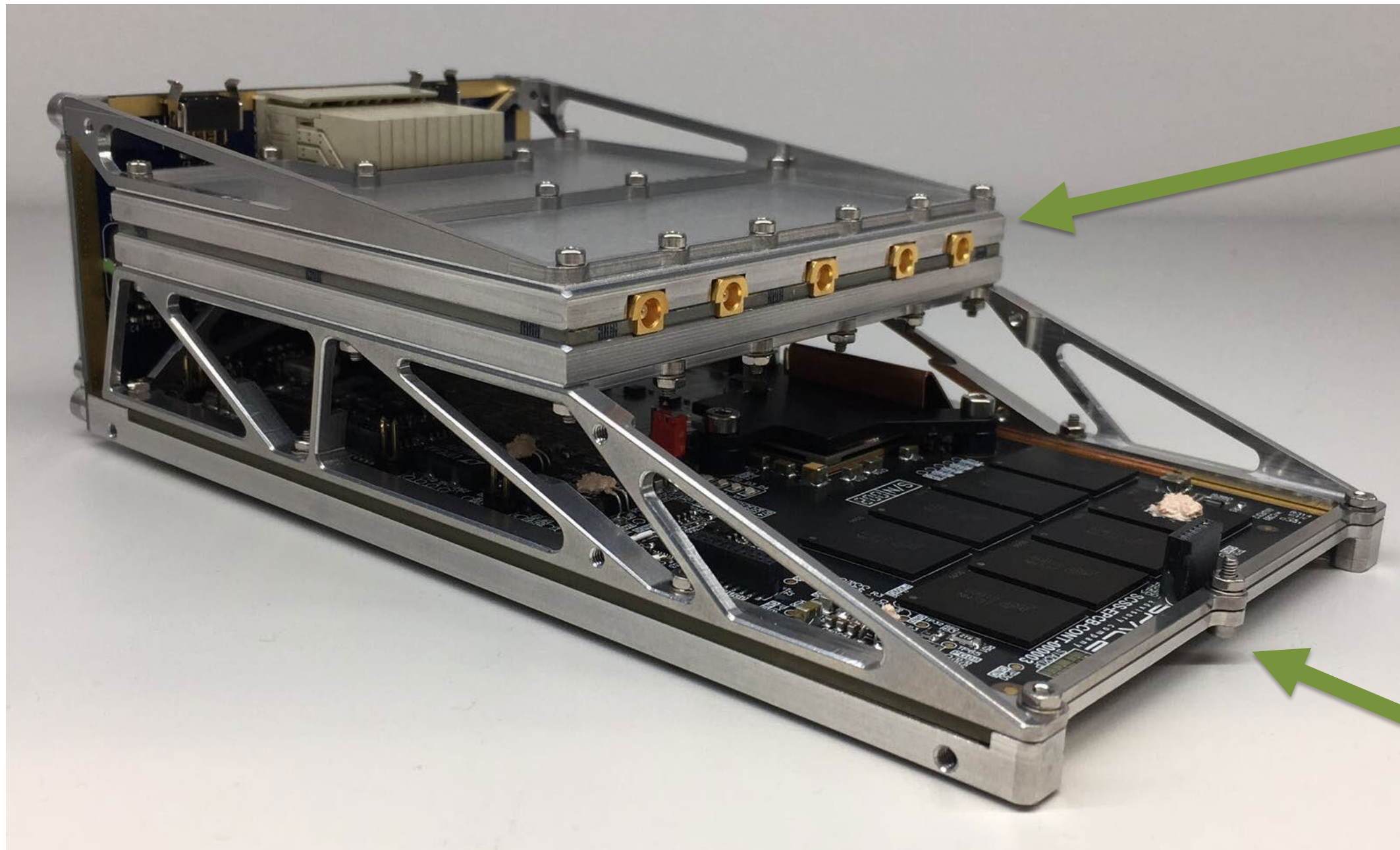


Calibrator

*Analog Input
System*

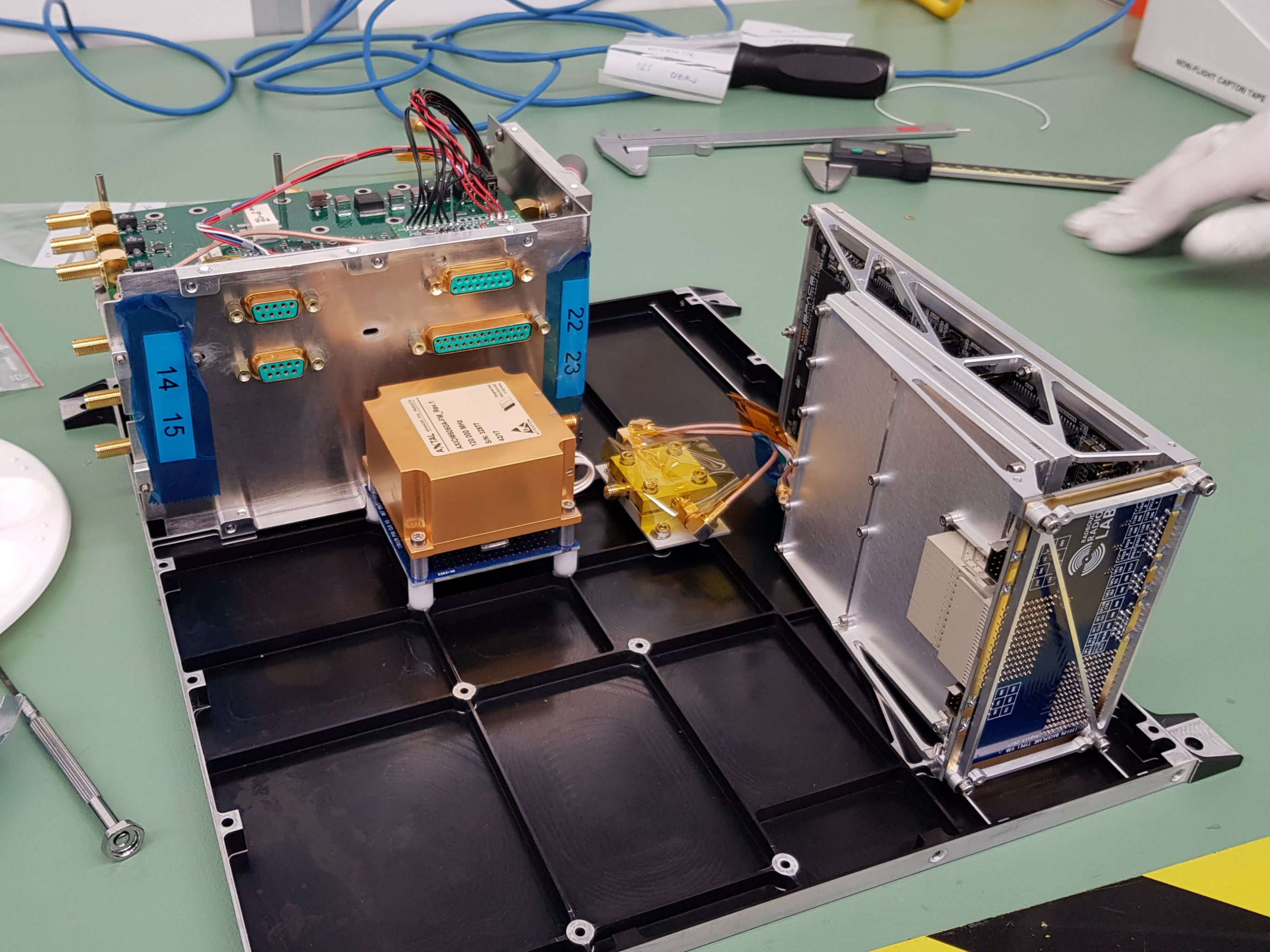


Internal Electronics Box: Receiver



ADC

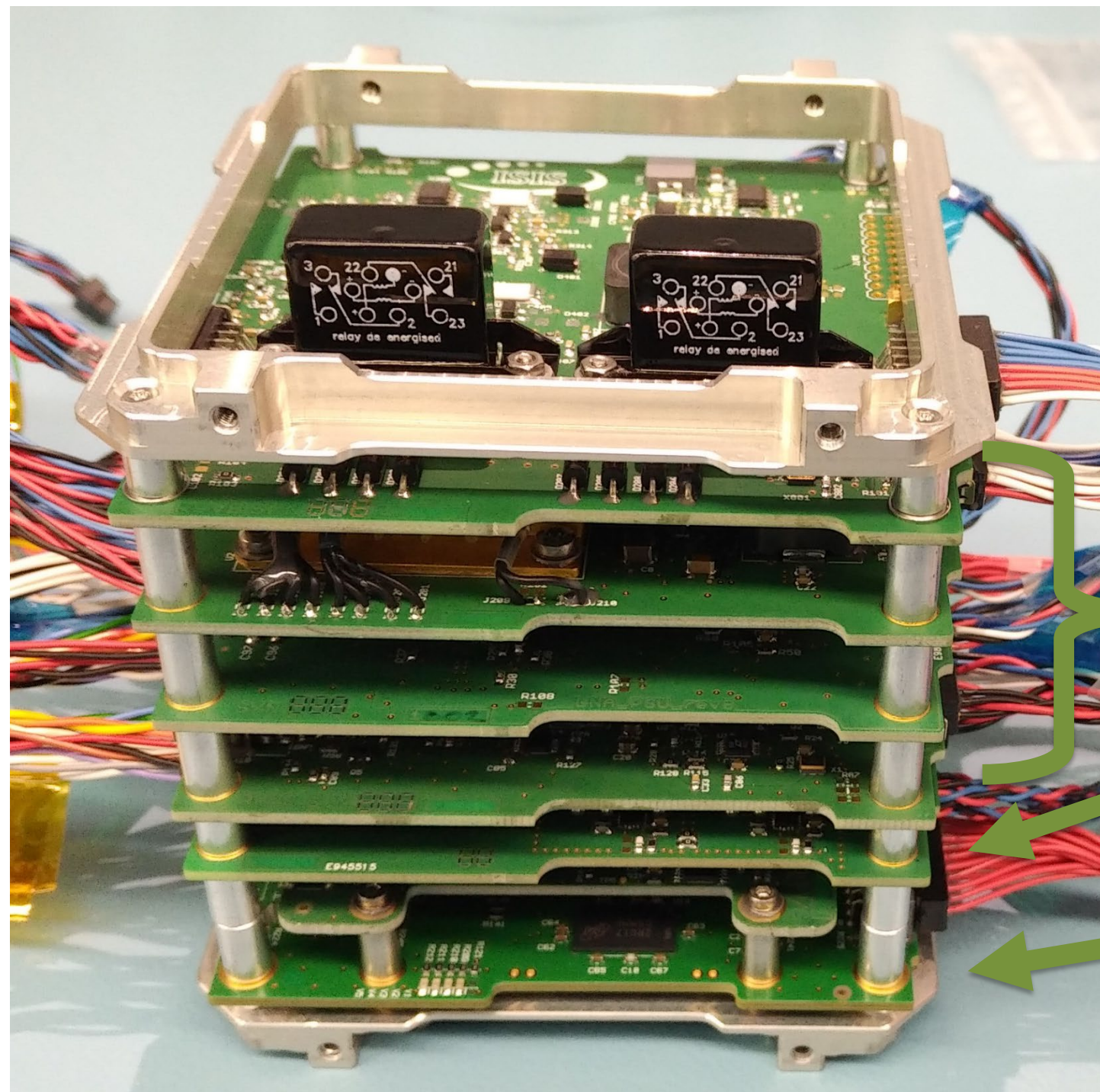
*Digital
receiver*





Internal Electronics:

Interface electronics



Power system

Motor drive system

CDHS system



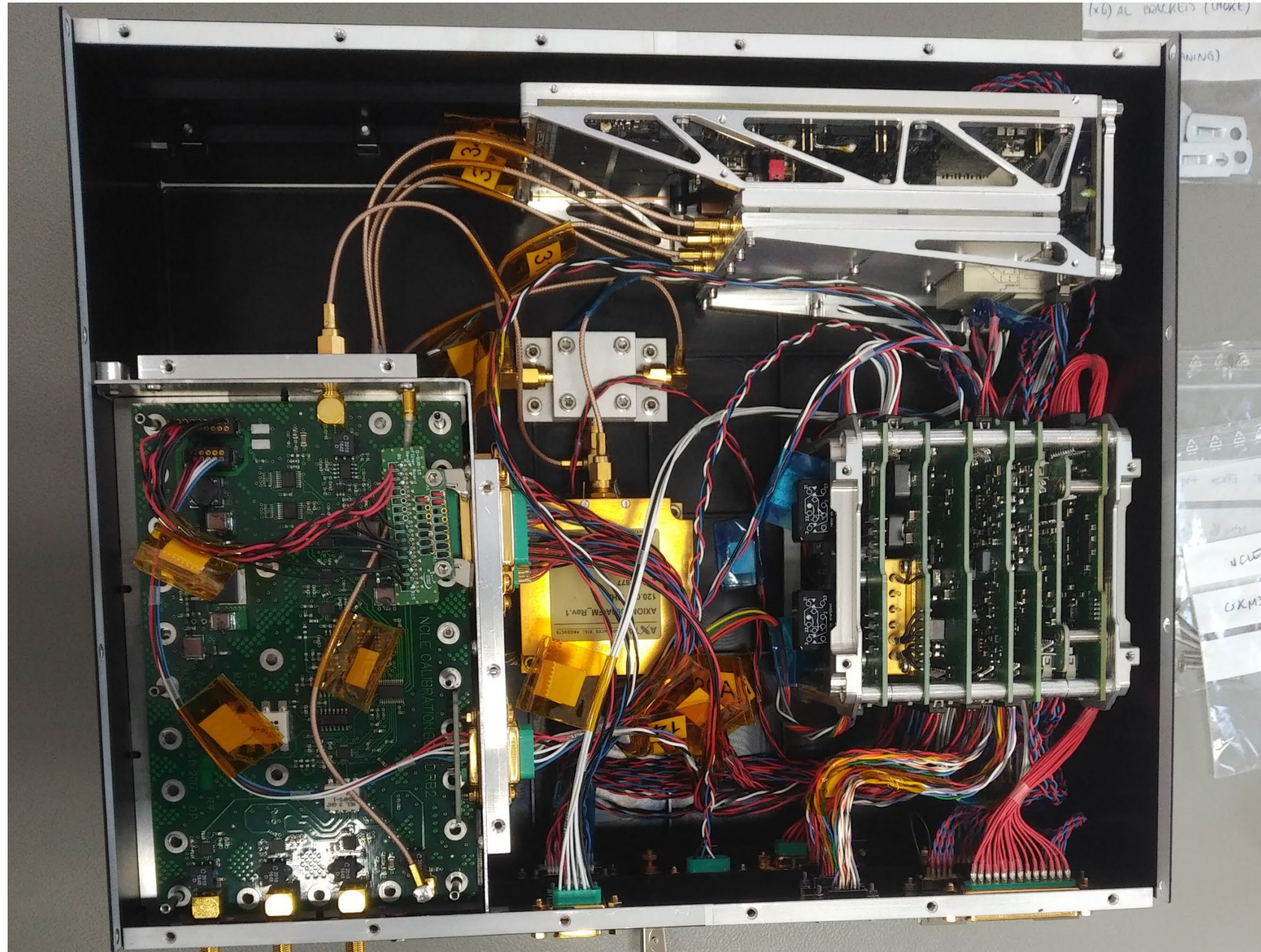
Internal Electronics:

Interface electronics



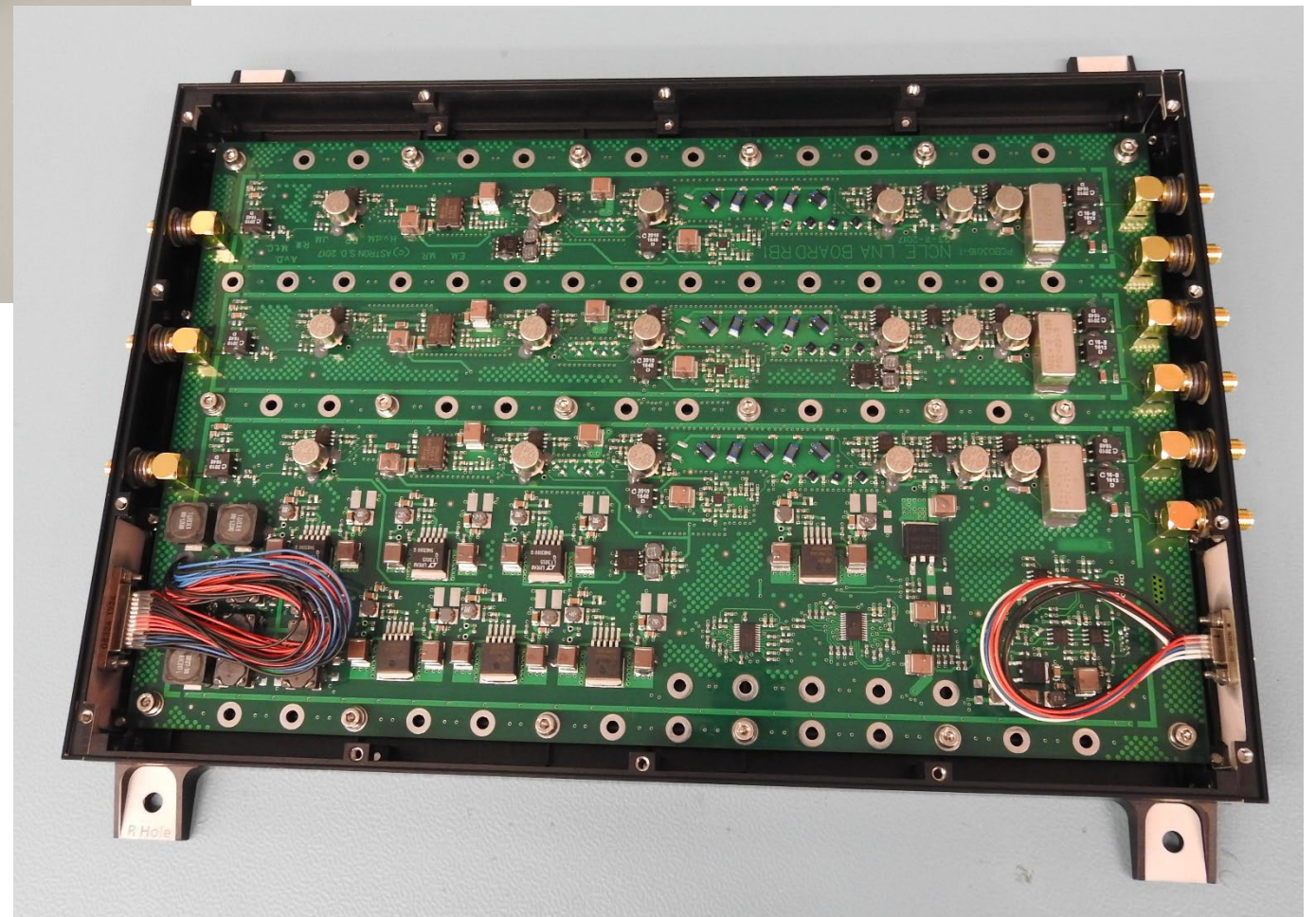
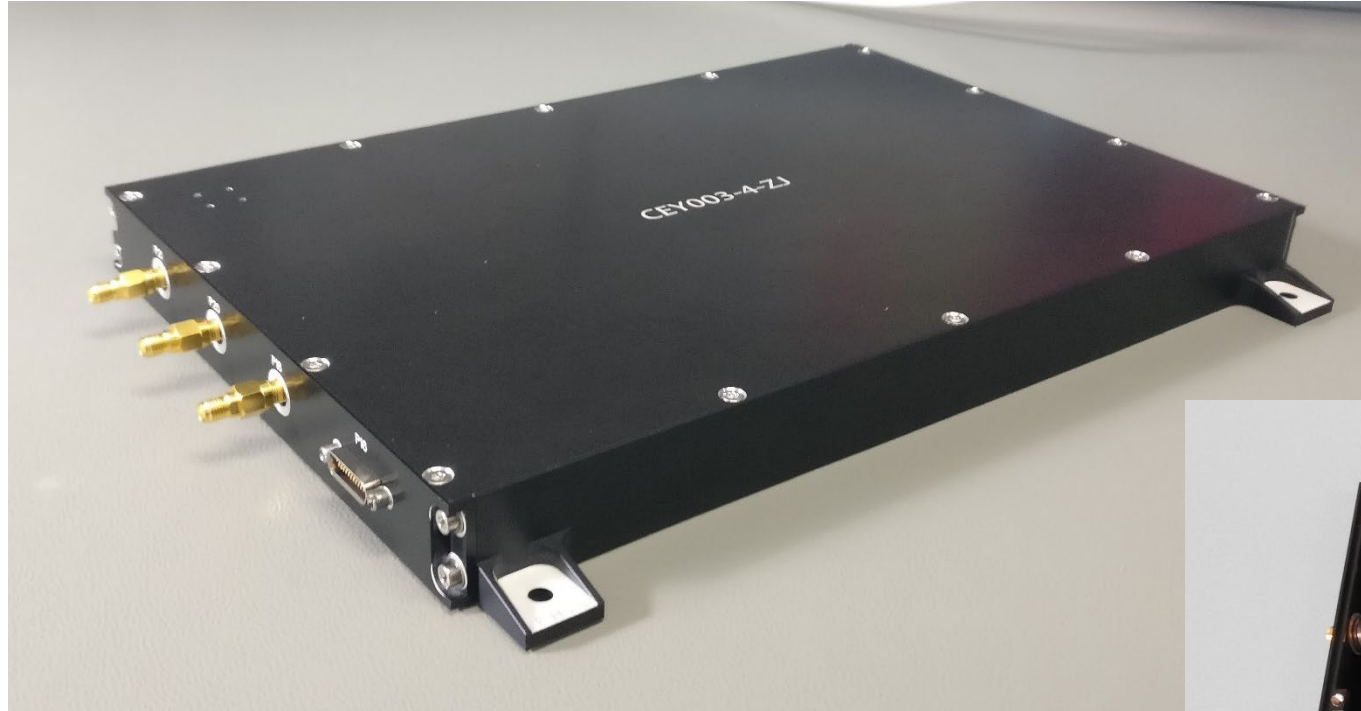


Final Result:





LNA box



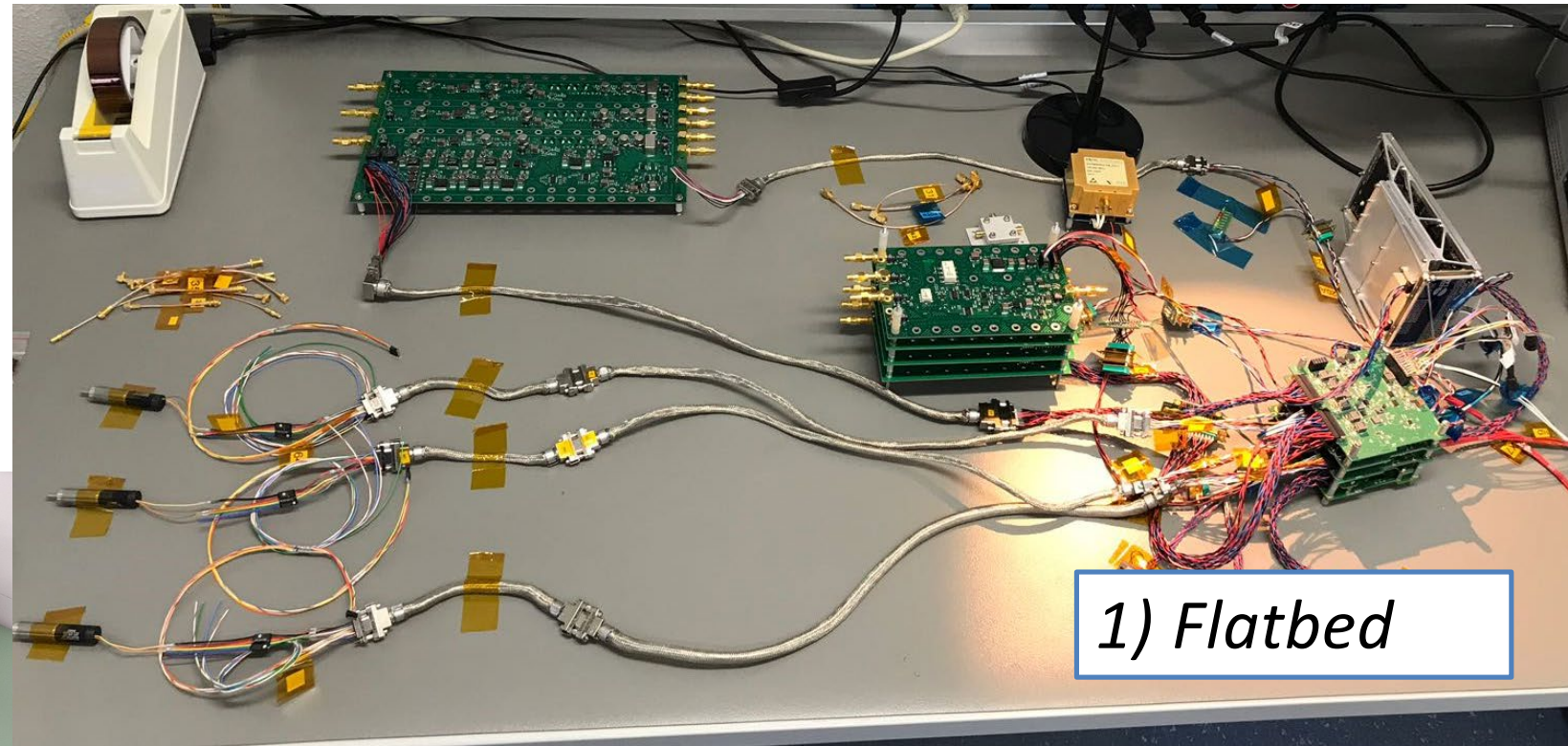


Antenna system

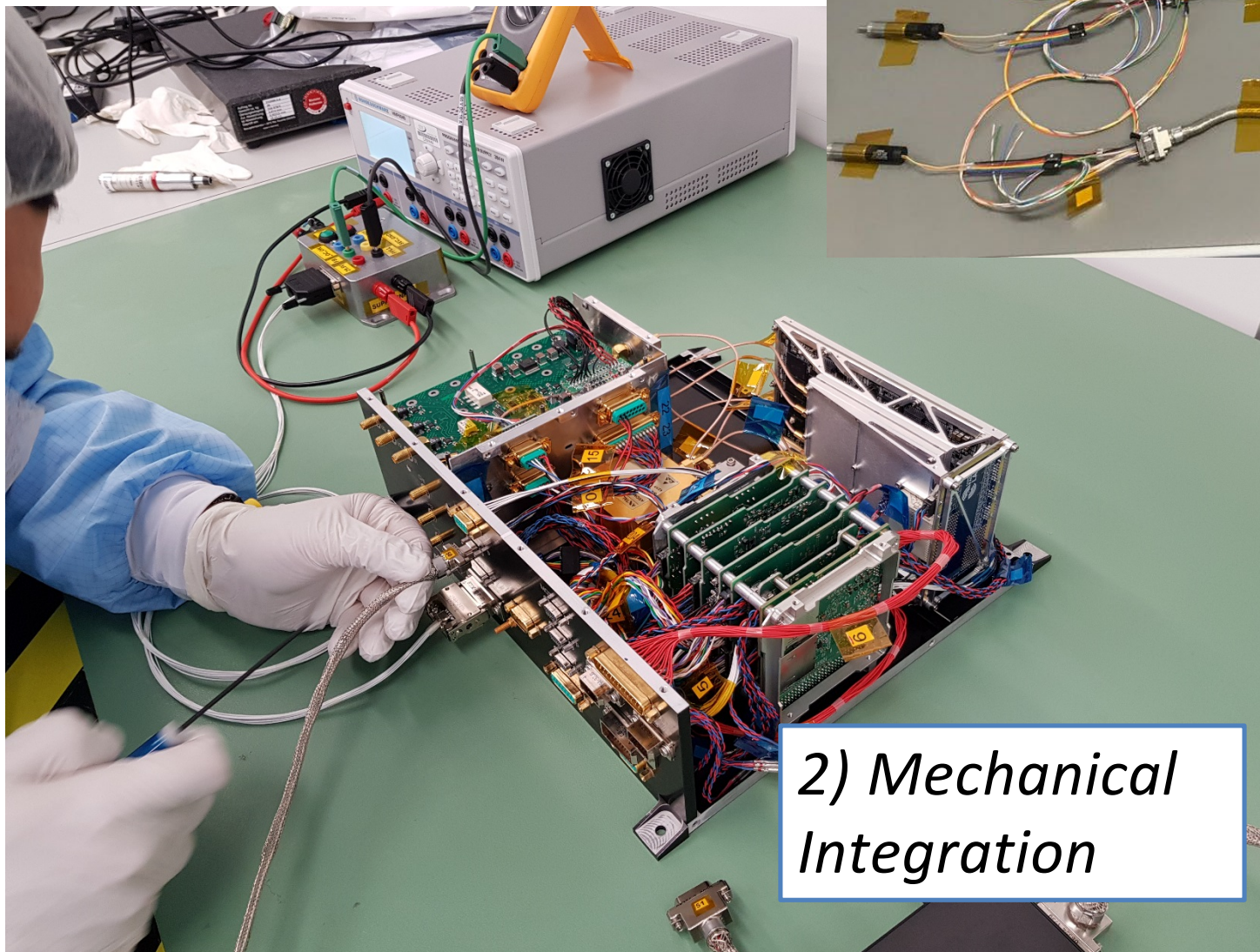




Testing following the CubeSat approach:



1) Flatbed

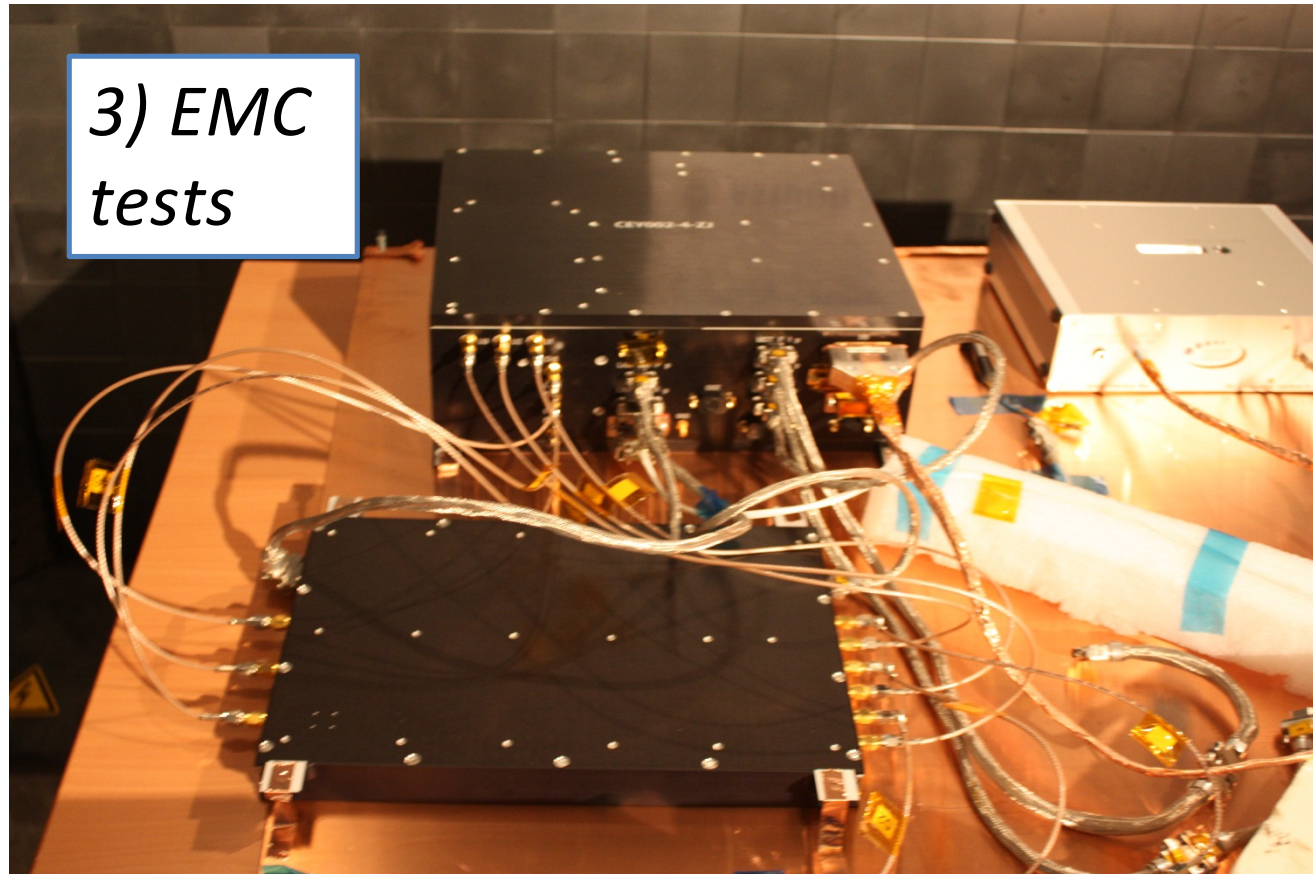


2) Mechanical Integration

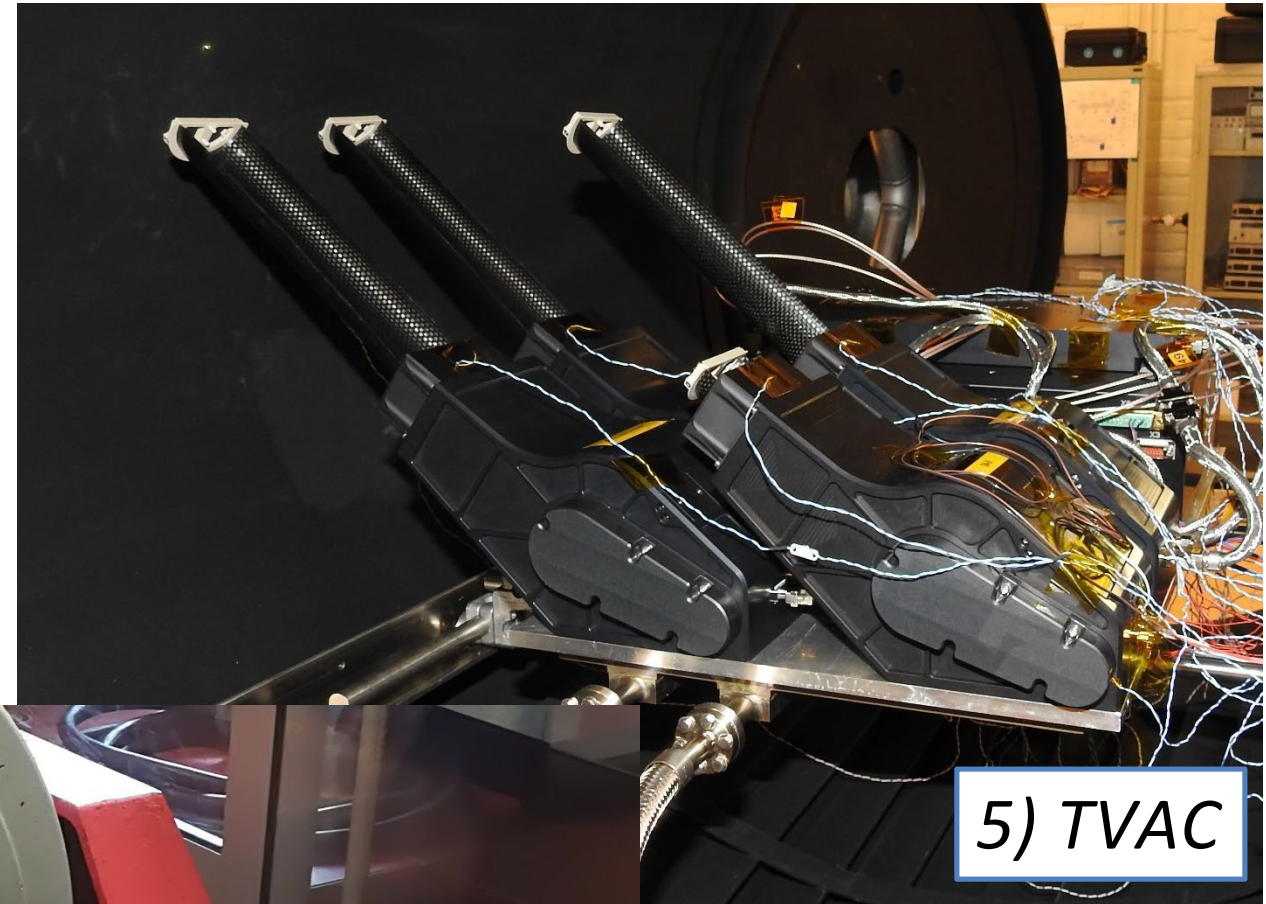


Testing following the CubeSat approach:

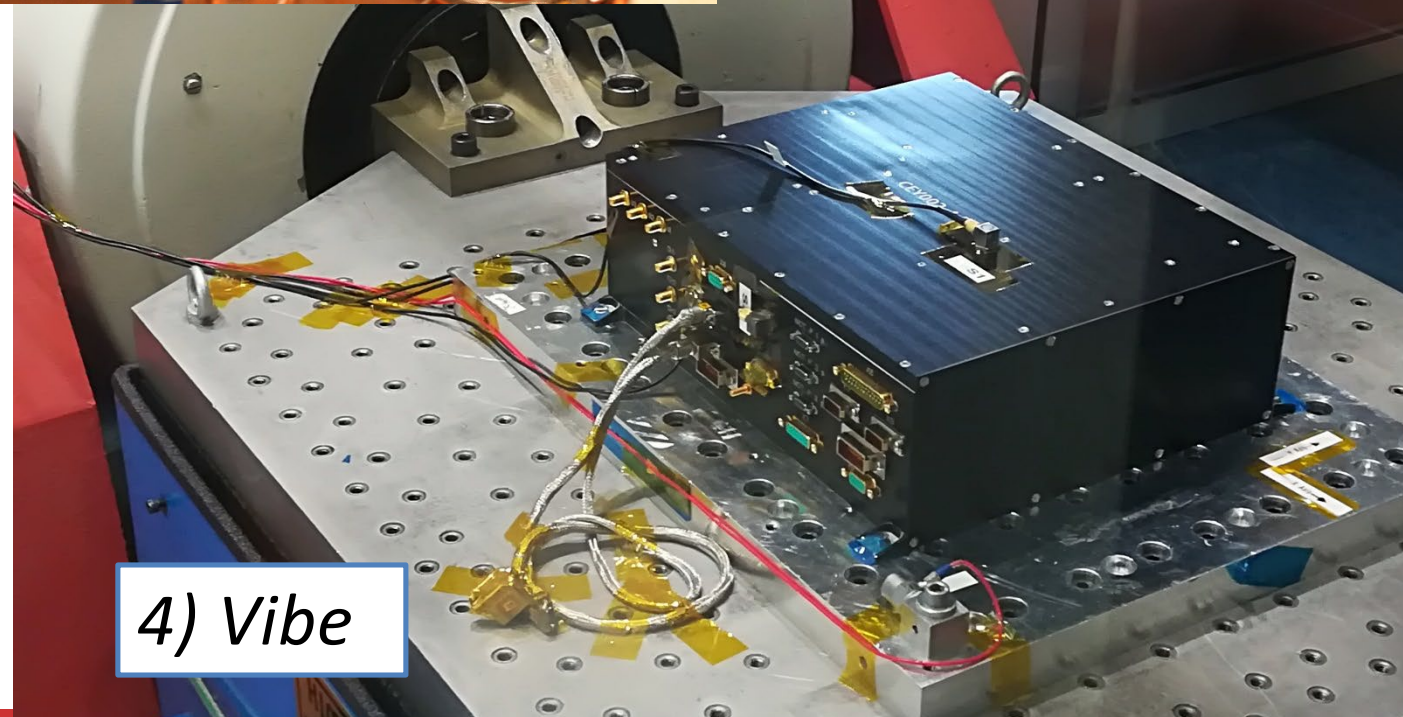
3) EMC tests



5) TVAC



4) Vibe

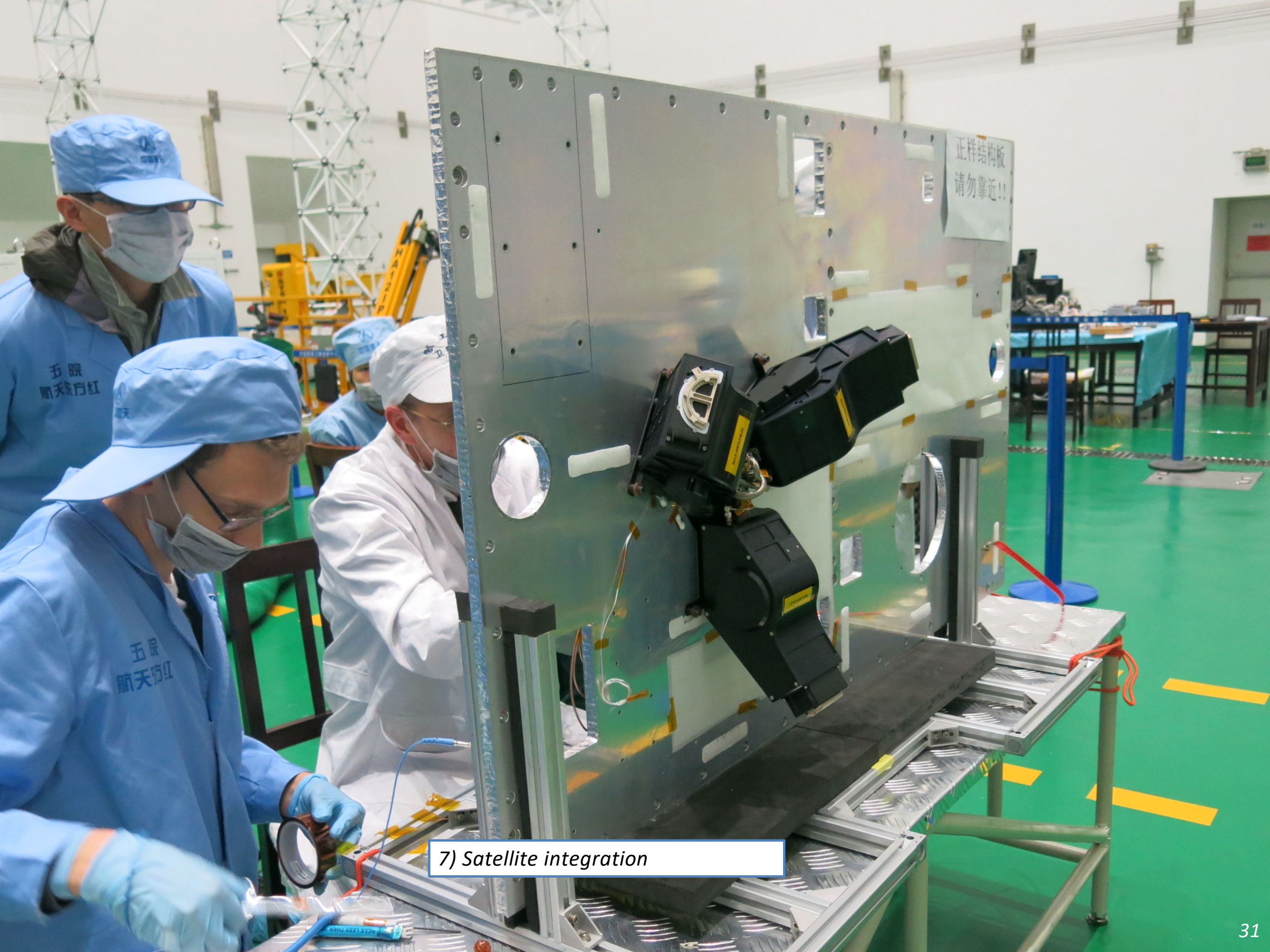




Testing following the CubeSat approach:



6) *End to end*



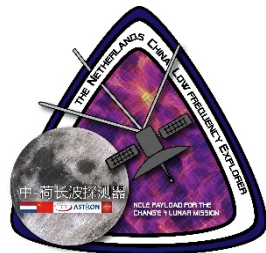
7) Satellite integration



7) Satellite integration



7) *Satellite integration*



WITHIN 6 WEEKS

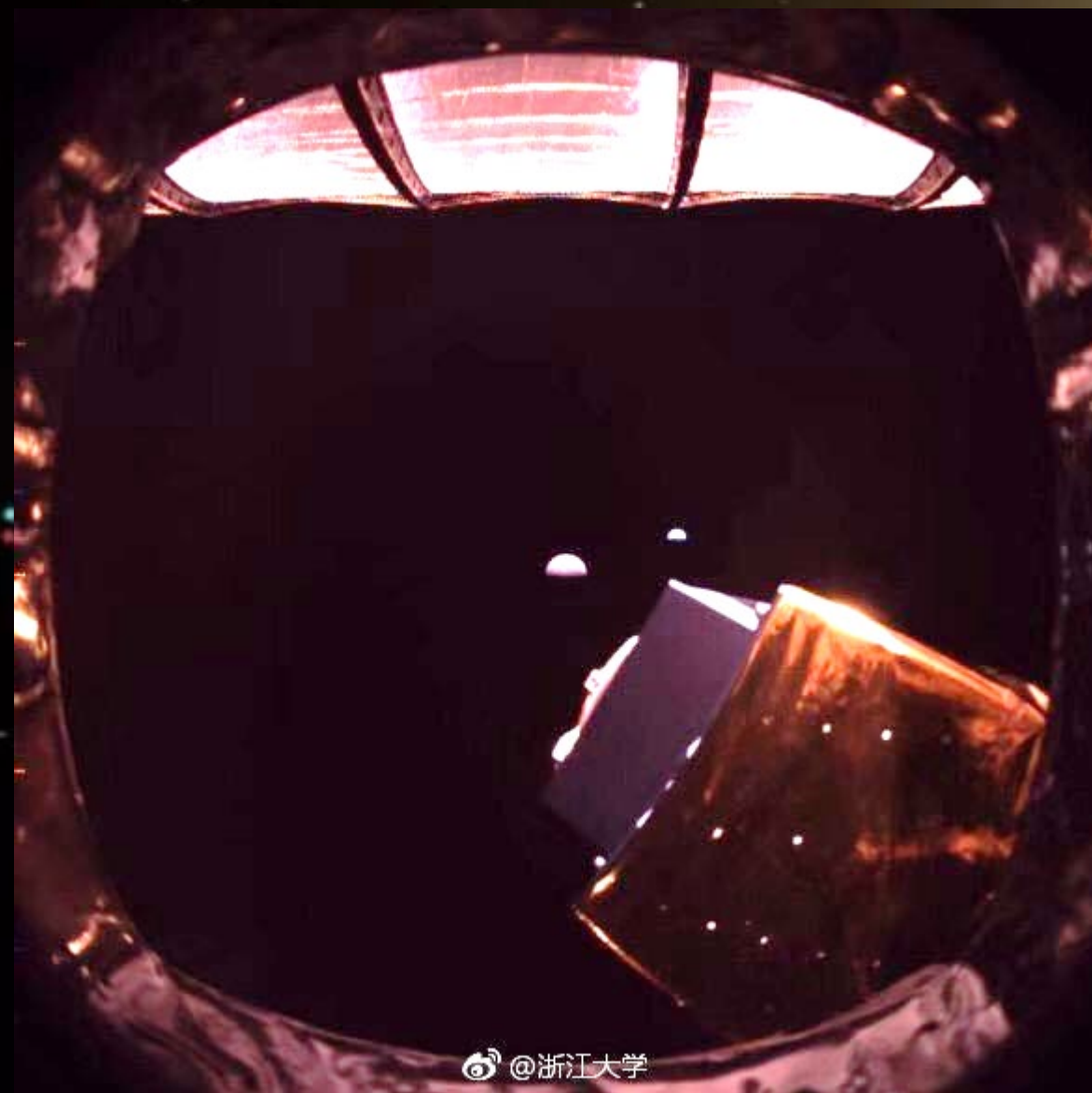
(For all 3 separate units)

*Launched May 21st
2018*





Lunar Insertion: May 25th, 2018

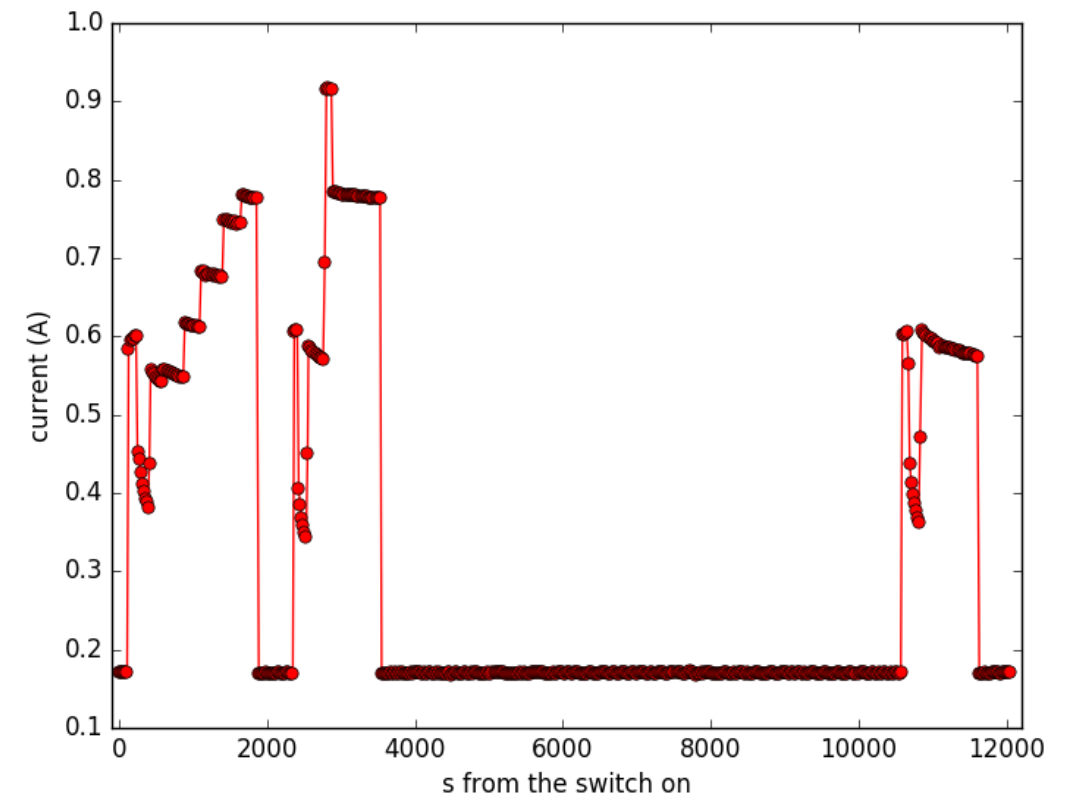
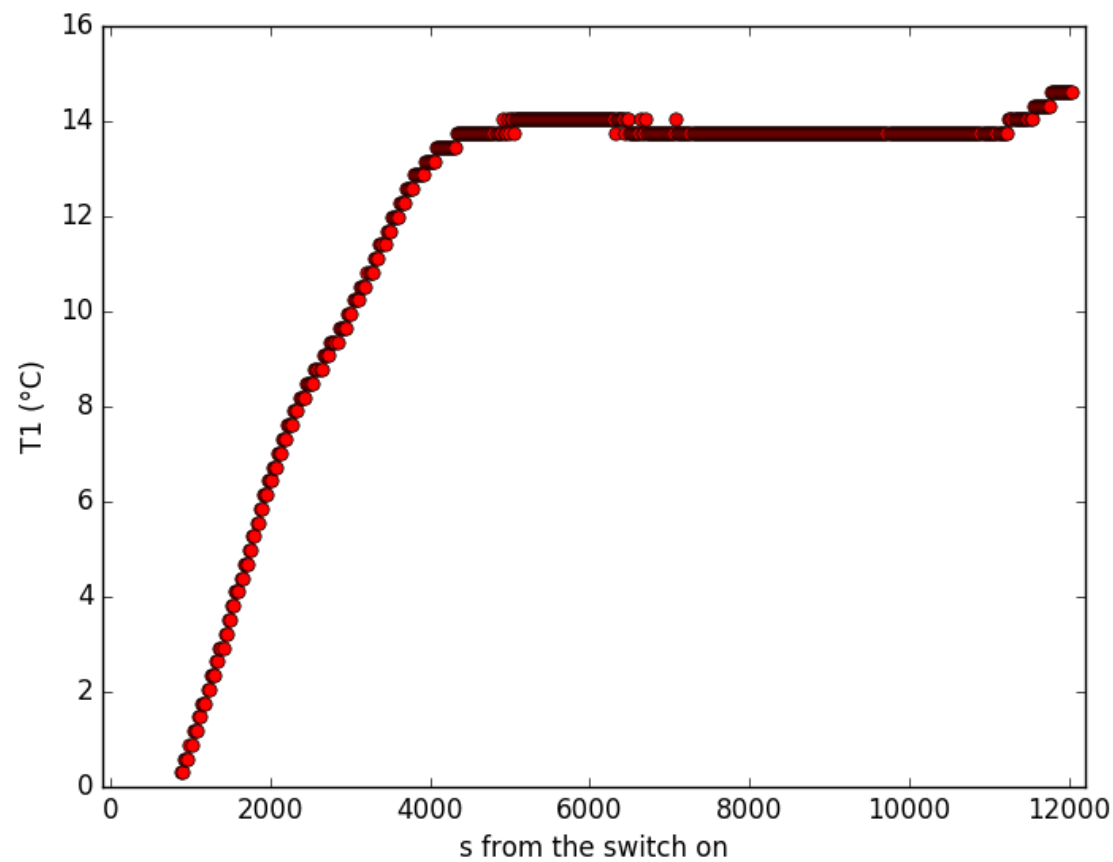


*NCLE Antenna from Spacecraft,
Moon and Earth behind*



Commissioning

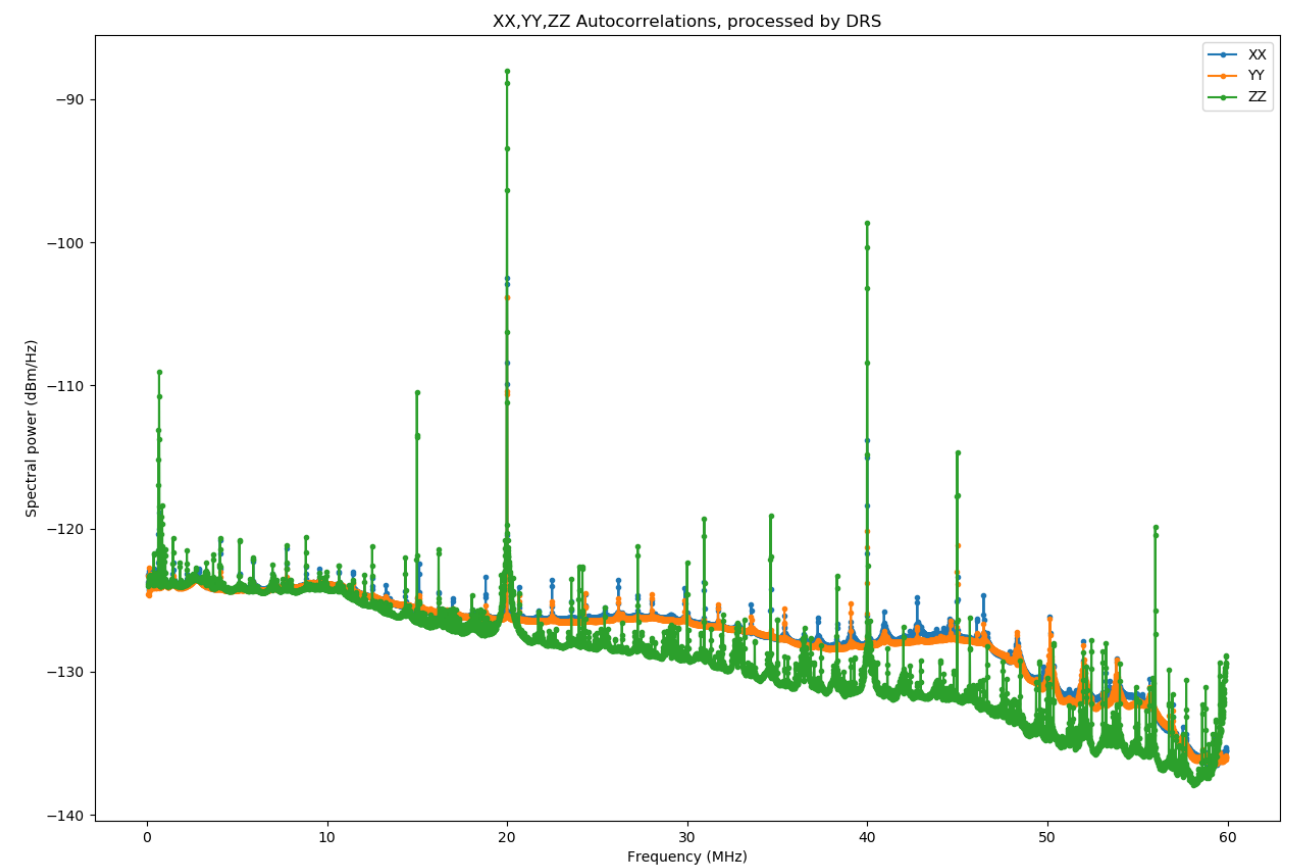
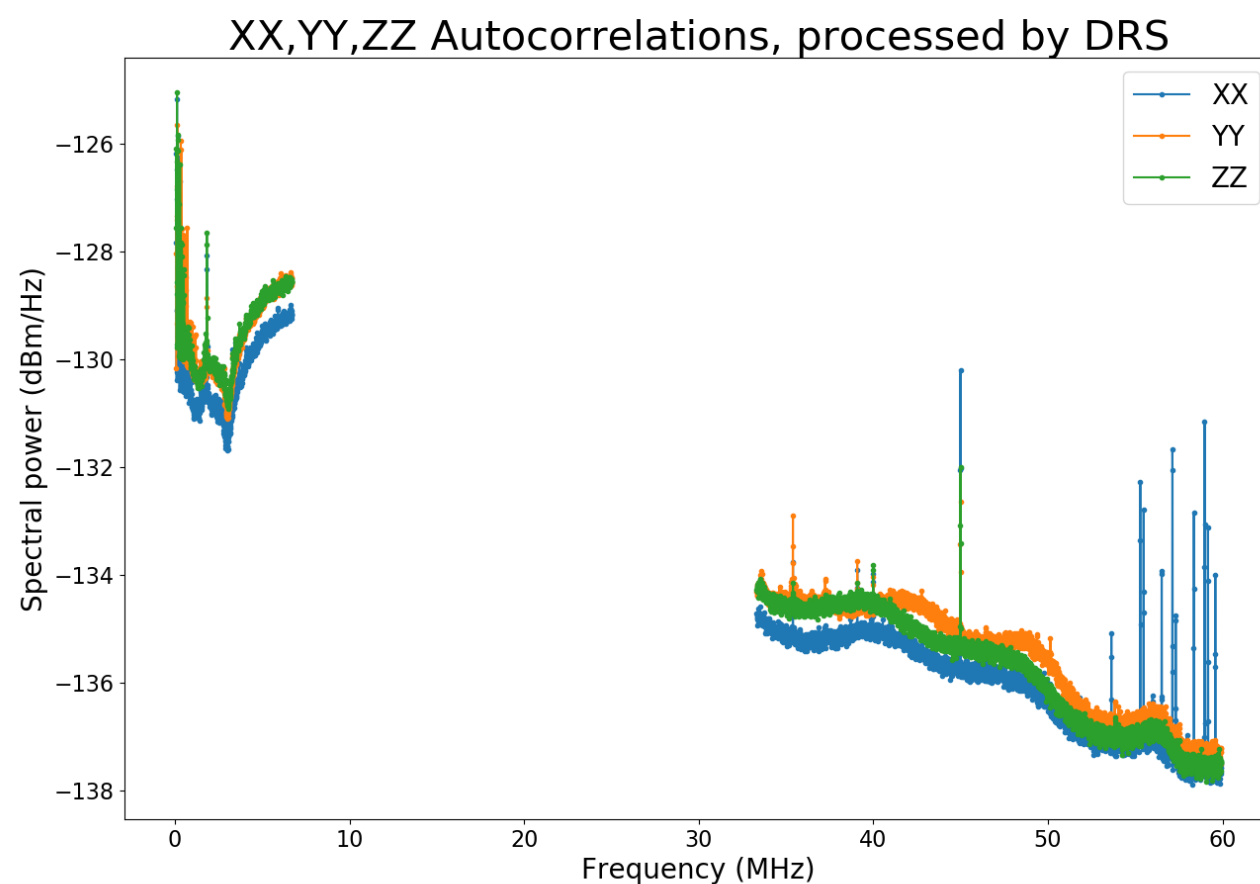
- First switch on: 22nd of January 2019
- All systems behaving as expected





First spectrum obtained

- Currently in the process of calibrating the system with stowed antennas
- Less noisy than expected based on ground tests



Results from space (r) vs results on ground (l)



Why so slowly?





Why so slowly?

文件: C:\Users\A\Desktop\低频开机数据20190122 2019/1/22, 15:58:57

EE	EE	EE	EE	EE
EE	EE	EE	EE	EE
EE	EE	EE	EE	EE
01	C7	36	47	5C
02	58	00	00	00
03	00	00	40	04
04	E1	2E	AC	00
05	11	3F	71	02
06	00	00	00	00
07	00	00	00	00
08	00	00	00	00
09	62	30	32	33
0A	21	00	00	00
01	DB	36	47	5C
02	6C	00	00	00
03	00	00	40	04
04	DF	2E	AC	00
05	E0	3E	71	02
06	00	00	00	00
07	00	00	00	00
08	00	00	00	00
09	62	30	32	33
0A	21	00	00	00
01	EF	36	47	5C
02	80	00	00	00
03	00	00	40	04
04	DE	2E	AC	00
05	B3	3E	71	02
06	00	00	00	00
07	00	00	00	00
08	00	00	00	00
09	62	30	32	33
0A	21	00	00	00
01	03	37	47	5C
02	94	00	00	00
03	00	00	40	04
04	DC	2E	AD	00
05	8A	3E	71	02
06	00	00	00	00
07	00	00	00	00
08	00	00	00	00
09	62	30	32	33
0A	21	00	00	00
01	17	37	47	5C
02	A8	00	00	00
03	00	00	40	04
04	DA	2E	AC	00
05	63	3E	70	02
06	00	00	00	00
07	00	00	00	00
08	00	00	00	00
09	62	30	32	33
0A	21	00	00	00
01	2B	37	47	5C
02	BC	00	00	00
03	00	00	40	04
04	D9	2E	AC	00
05	3F	3E	70	02
06	00	00	00	00



Part of a roadmap

Science

Step-wise approach - science from day one

Lunar Orbit

2015-2018

2018-2022

2022-2030

RFI, SkyMap, Solar Physics, Jupiter/saturn,
21cm global signal

Antenna calibration and gain control

Space qualification analogue and digital
components

Single Antenna Demonstrator

Nano-sats in Lunar Orbit & at the surface

RFI, SkyMap, Solar Physics, Jupiter/Saturn, 21cm global signal,
Extra-Galactic sources, radio transients

Interferometry in space, deployment on the lunar surface, additive manufacturing

Inter-satellite communications & swarm technologies

Multi-element Demonstrator

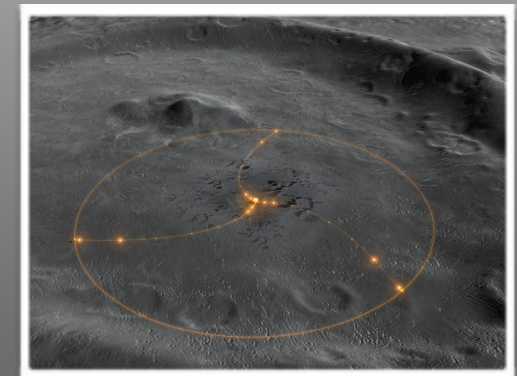
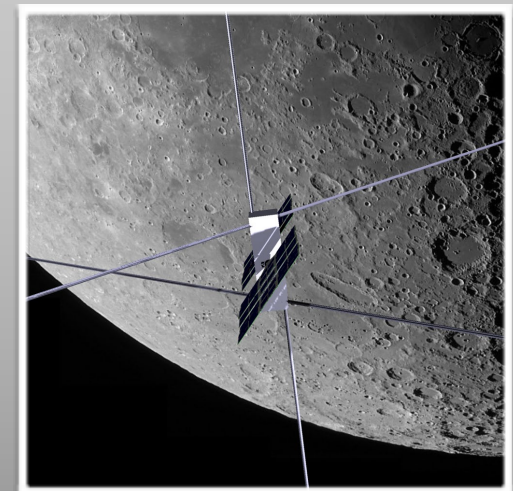
Nano-sats in Lunar Orbit or Sun-Earth L2

SkyMap, Solar Physics, Jupiter/Saturn, 21cm tomography, Extra-Galactic sources, transients

Interferometry in space, deployment on the lunar surface, additive manufacturing

Inter-satellite communications & swarm technologies

Multi-element Interferometer





Part of a roadmap

Engineering

- Interfaces towards larger satellites
 - Power
 - EMC
 - Data bus
 - Software
- Enables more opportunities to fly CubeSat like hardware further
- Ready for the next interplanetary step



Thank you for your attention

