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Plan de Recuperación, Transformación y Resiliencia
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ASFAE ASTROFÍSICA Y FÍSICA DE ALTAS ENERGÍAS

Deep Space Microsatellite Power System Development ASFAE/2022/021

LIA7: Space exploration with small satellites

José Manuel Blanes Martínez

Space Power and Electronics System Group

Universidad Miguel Hernández de Elche

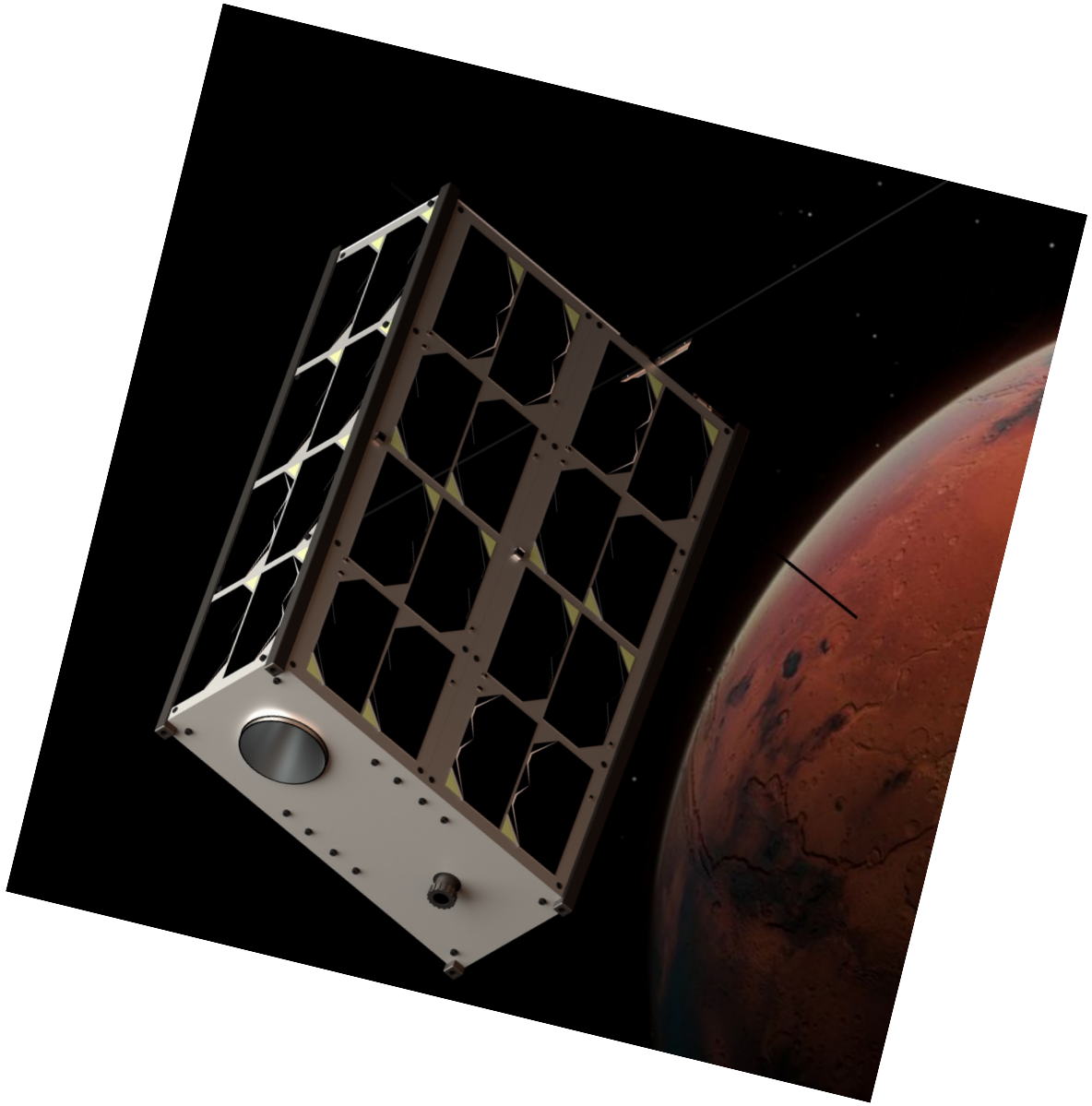
UNIVERSITAS Miguel Hernández

SPES

1ª Reunión Nacional Planes Complementarios
de Astrofísica y Altas Energías
Junio 2024, Zaragoza

Presentation Outline

- Introduction
- Project Goals
- PCDU Proposed Architecture
- Facilities / Equipment Acquired
- Actual Project Status
- Questions



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Introduction – Project Team

More than 20 years working together in Power Electronics for Space Applications

IPs: José Manuel Blanes Martínez jmblanes@umh.es
Ausiàs Garrigós Sirvent augarsir@umh.es

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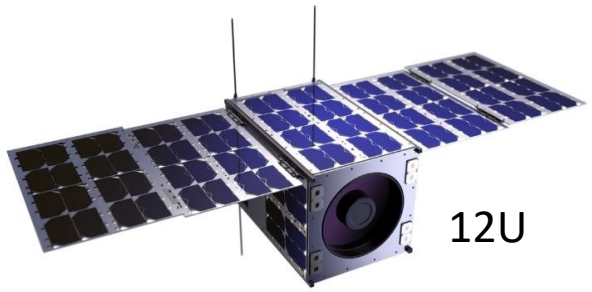
Introduction – Rise of Cubesats

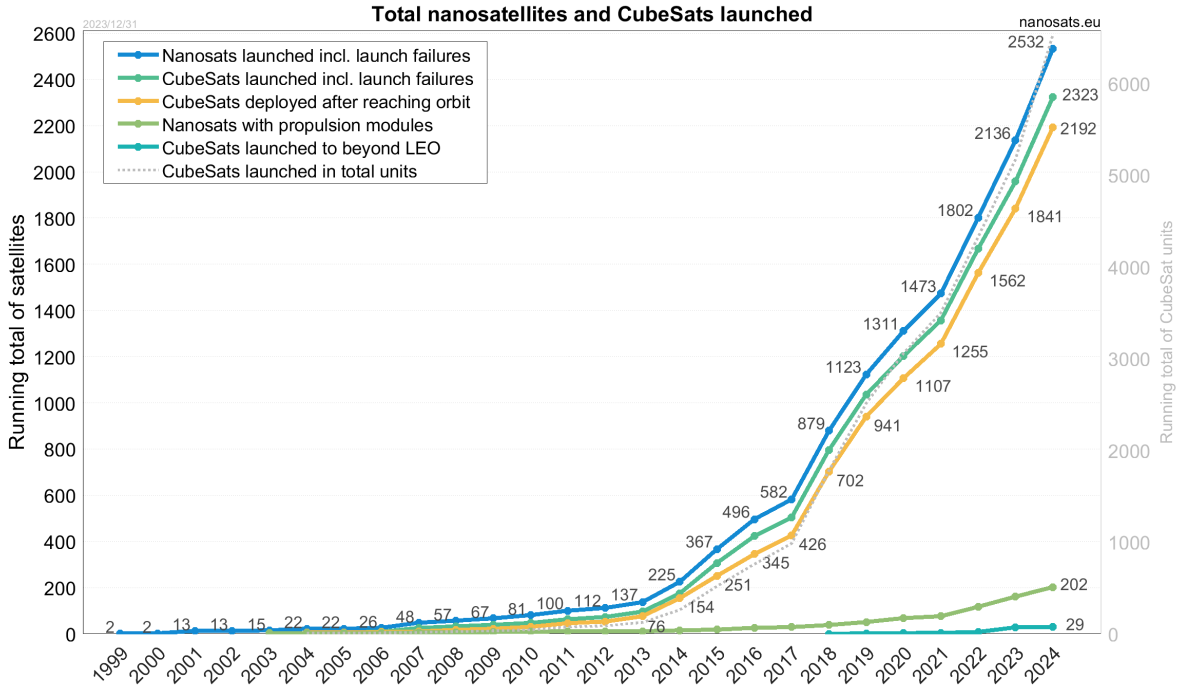
- Traditionally used in the past by universities for educational purposes.
- Exponential grow during the last years of Cubesats (“New Space”).
- Cost effective solution (Reduced Complexity - COTS components)
- Rapid development timelines.

- Reduced complexity at the expense of Higher Risks

1U



12U



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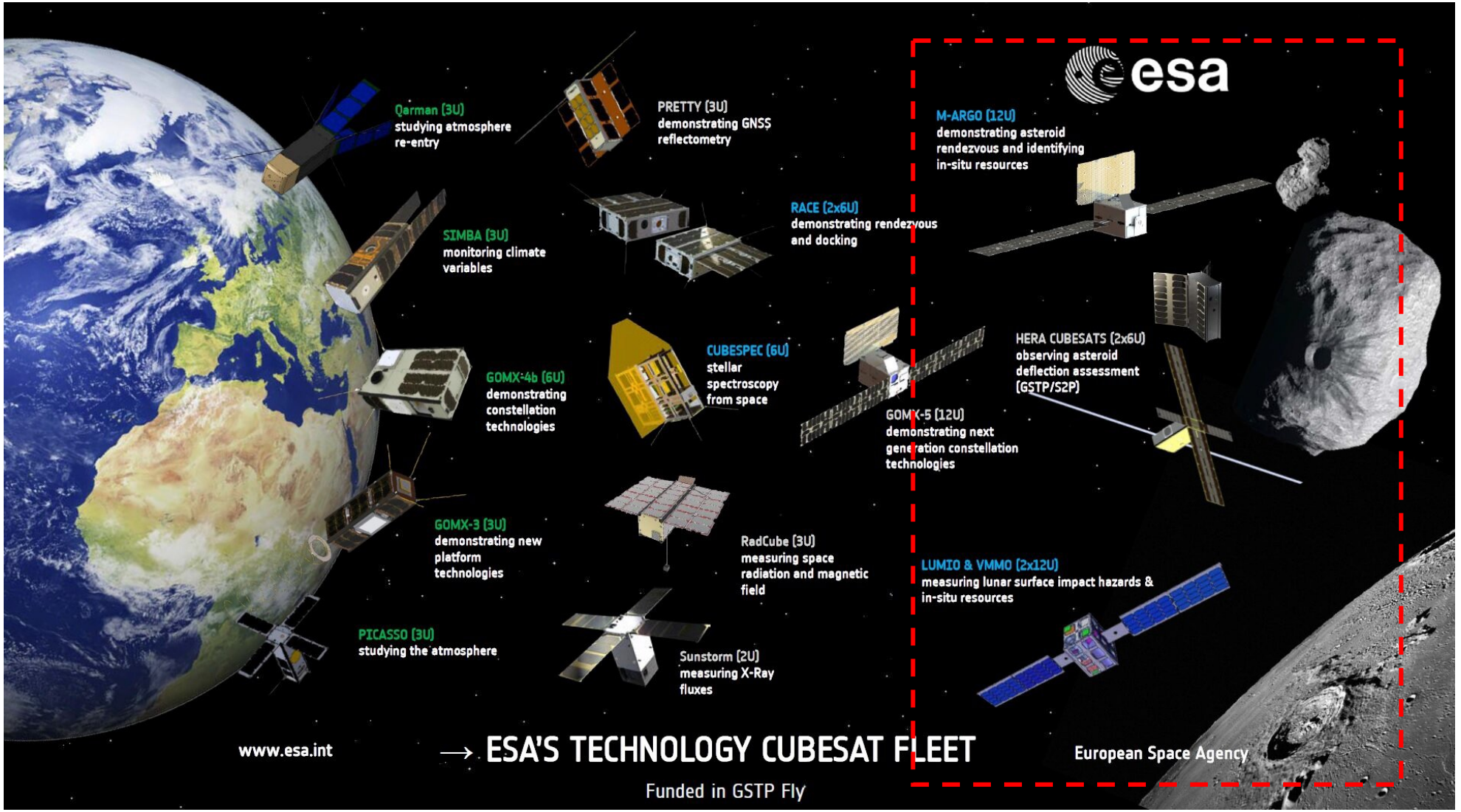
Introduction – Cubesats in Deep Space Missions



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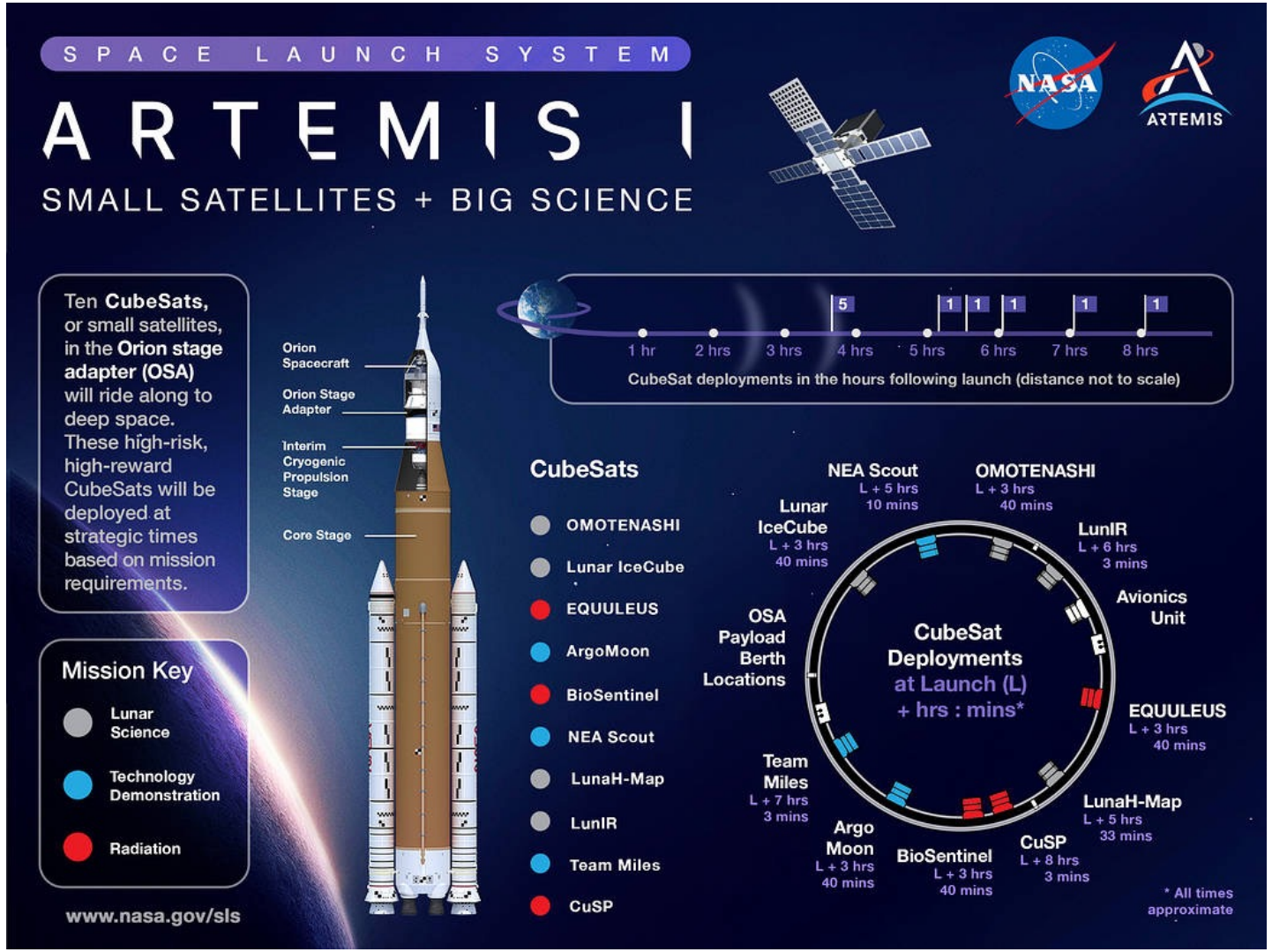
Introduction – Cubesats in Artemis I (Deep Space)



6U Cubesats

BioSentinel
EQUULEUS

Argomoon

LunaHMap
Lunar IceCube
CuSP
LunIR
Omotenashi
Team Miles
NEA Scout

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Introduction – Cubesats Failures

Reliability of CubeSats – Statistical Data, Developers' Beliefs and the Way Forward

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Jasper Bouwmeester
Faculty of Aerospace Engineering, Delft University of Technology
Kluyverweg 1, 2629HS Delft, the Netherlands;
Jasper.Bouwmeester@tudelft.nl

EPS + Unknown Failures > 50 %

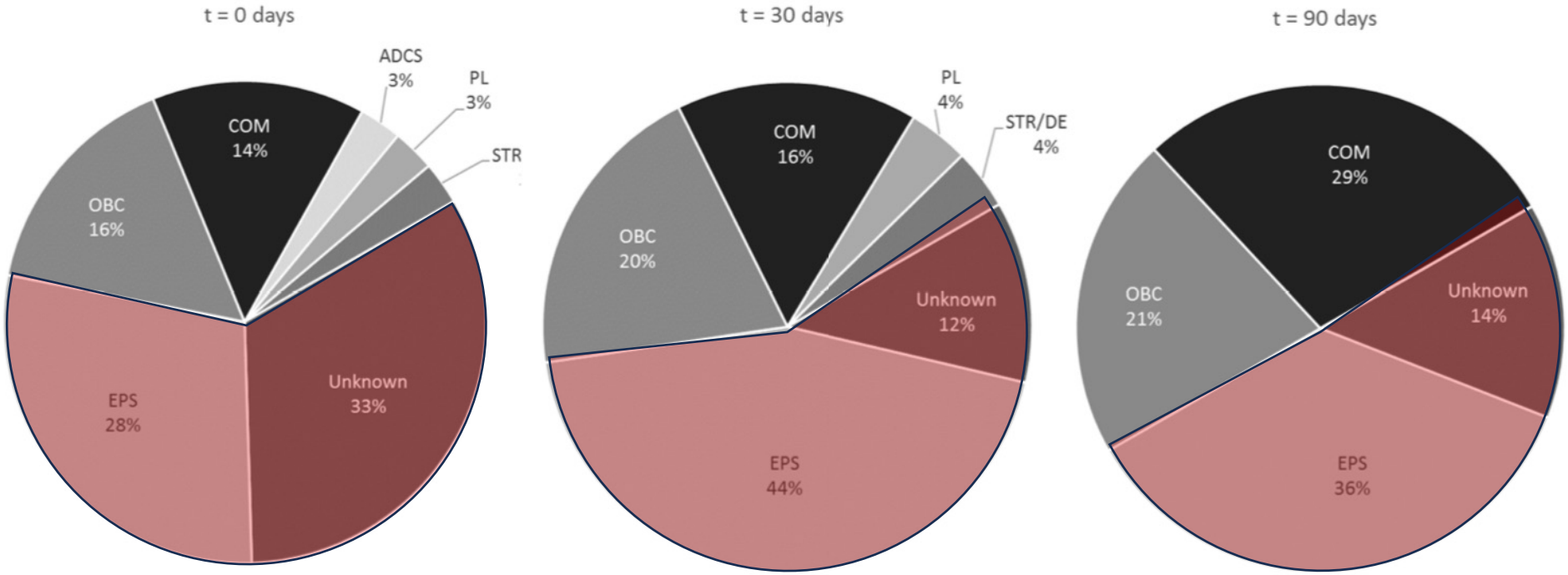

Figure 5: Subsystem contributions to CubeSat failure after ejection (incl. DOA), 30 days and 90 days

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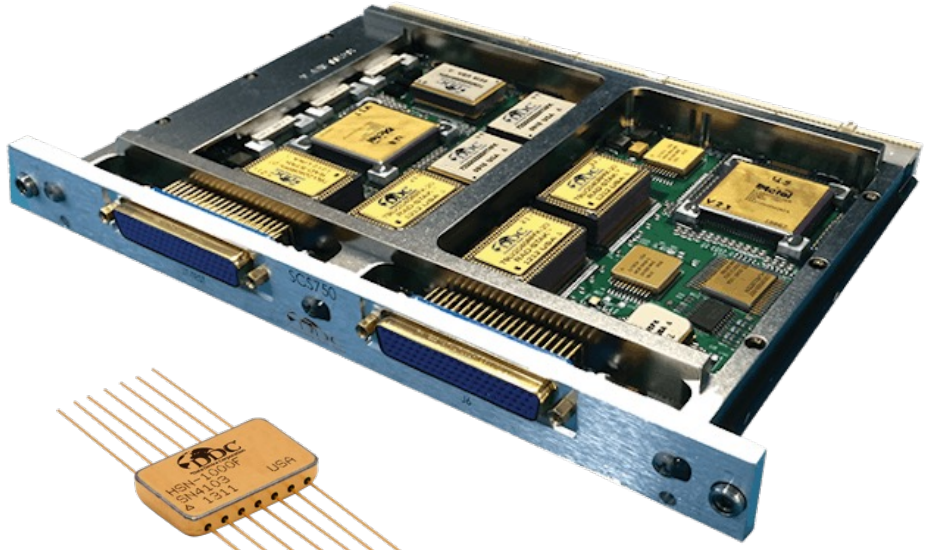
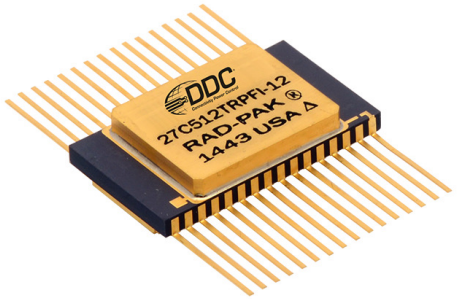
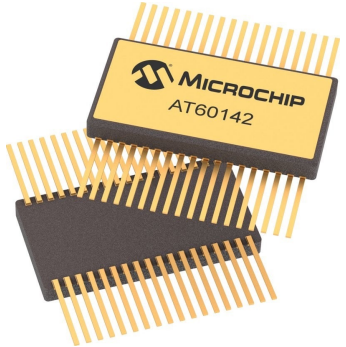
Introduction – “Old Space”

USE OF RAD HARD COMPONENTS

- Large Size
- Expensive
- Long Delivery Times
- ITAR Restrictions







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Project Goals

- Deep Space Exploration Microsatellite PCDU system development
  - Very low temperature
  - Harsh Radiation Environment

  - Use of commercial components (COTS)
    - Identify electronic components, battery cells and solar cells
    - ”Careful COTS approach”

  - High reliability
    - Protections and Redundancy for critical functions
    - Optional Rad-Hard version of critical components in the same PCB

- Validation System development

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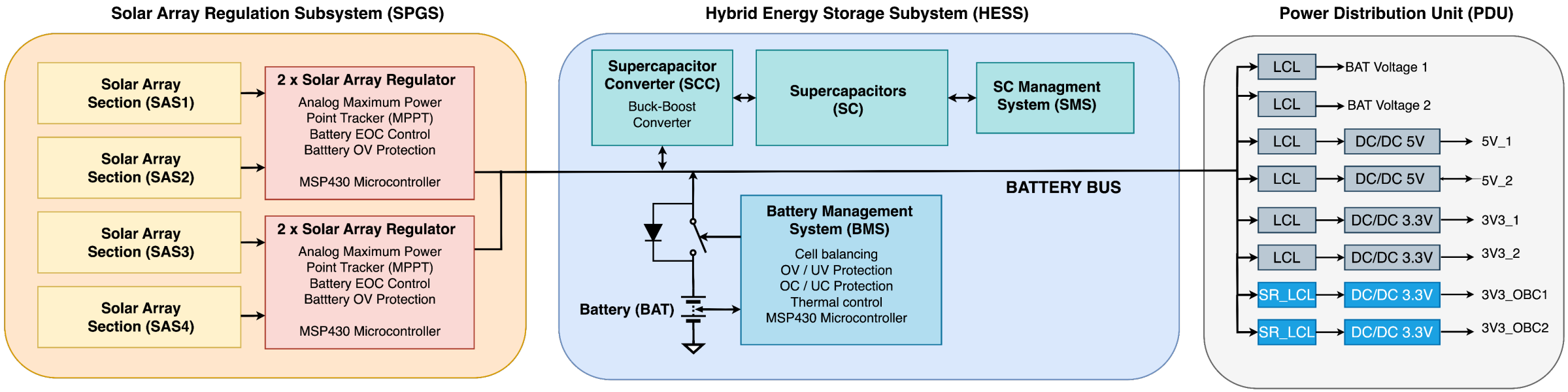
PCDU Proposed Architecture - 6U

- Block diagram



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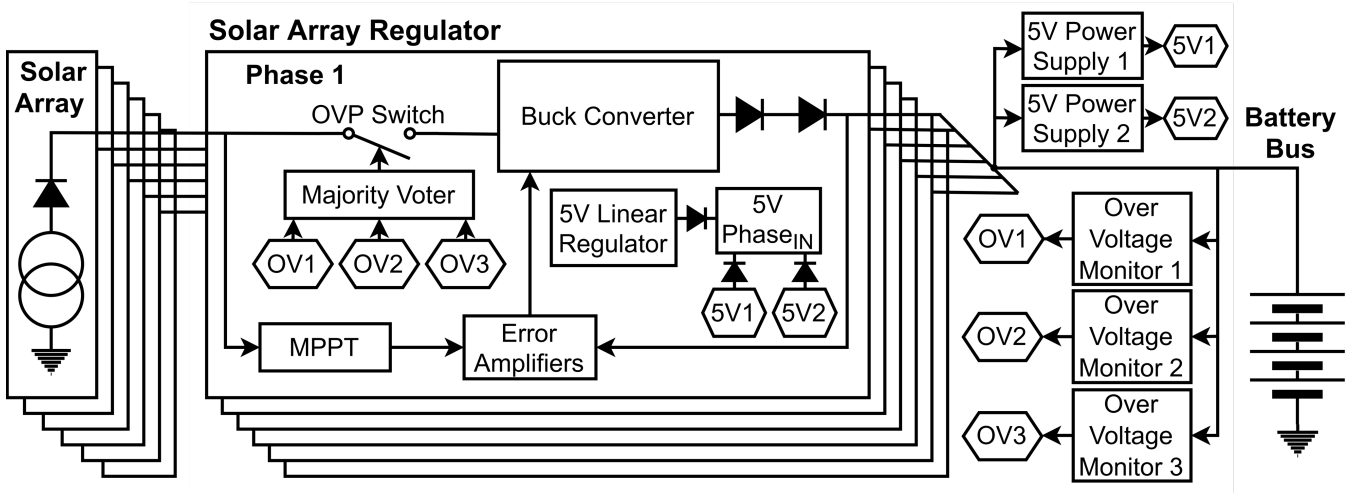
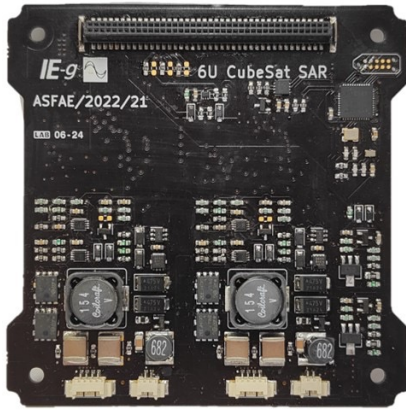
PCDU Architecture – Solar Array Regulator (SAR)

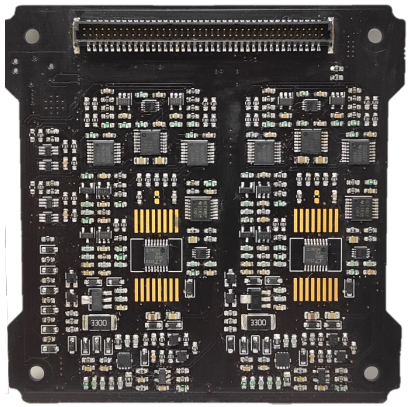


C. Torres, J. M. Blanes, A. Garrigós, D. Marroquí and J. A. Carrasco, ***"High-Reliability Solar Array Regulator for Deep Space Exploration Micro-Satellites"*** in IEEE Access, vol. 11, pp. 94138-94147, 2023

One SAR failure without propagation can be assumed (25% power lost)

- COTS: Extended temperature range automotive qualified components
- Analog MPPT
- LT3845 (RH3845)
- Double control loop
- µController only for Telemetry
- Redundancy and Protections





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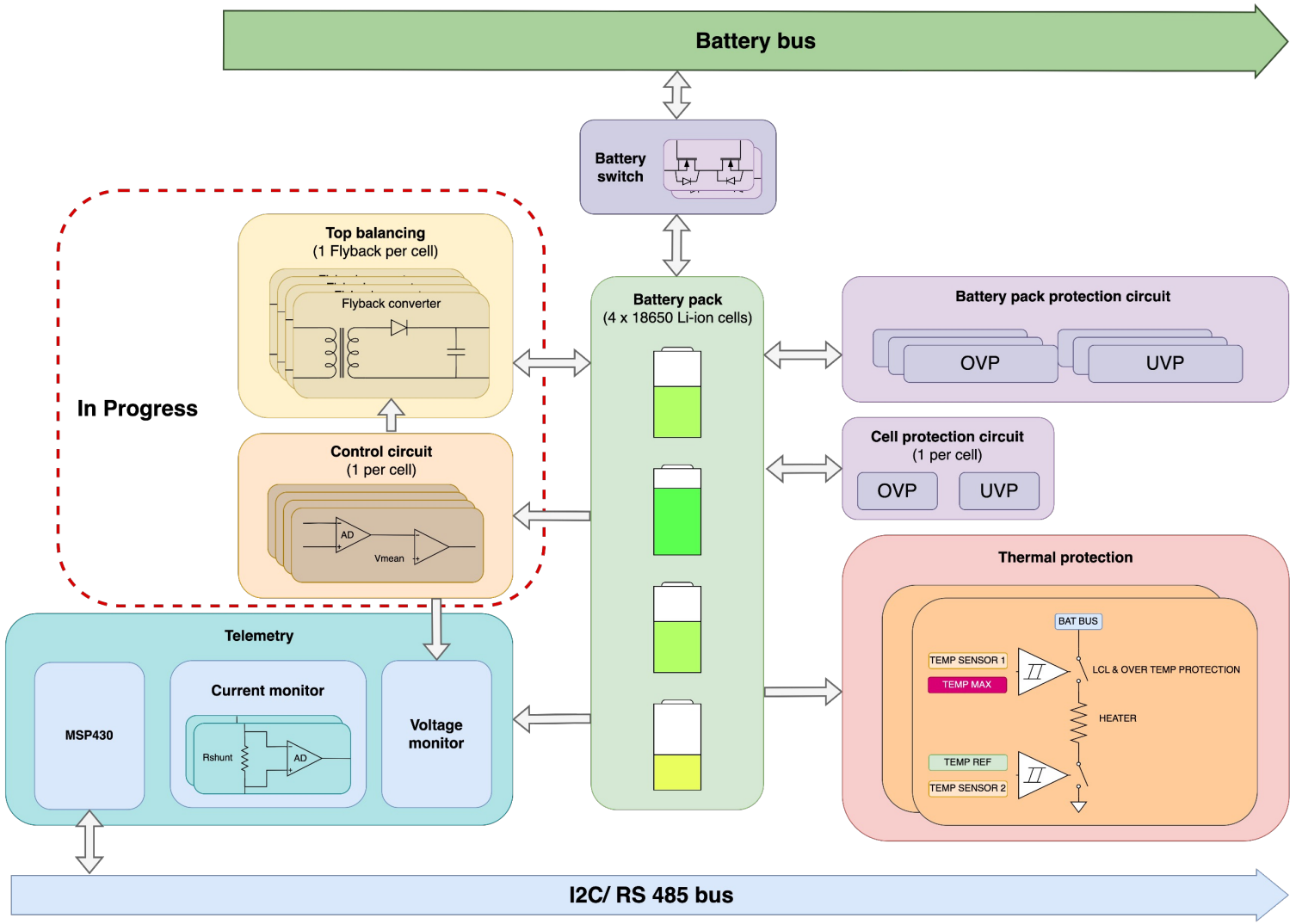
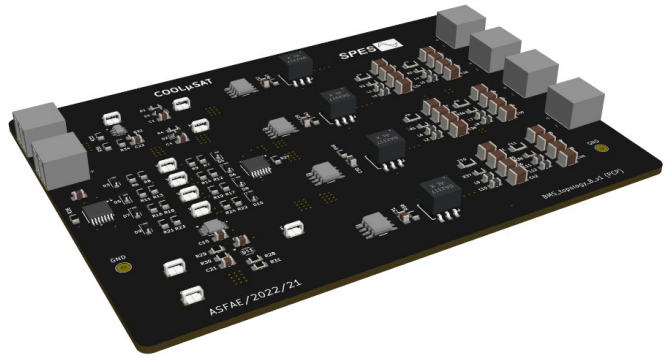
PCDU Architecture – Battery Management System (BMS)





- Battery and Cells OVP / UVP
- Cell voltage equalizar
- Thermal control (Heaters)
- µController only for Telemetry

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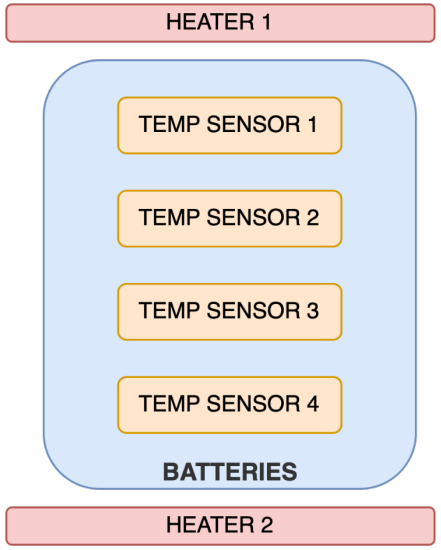
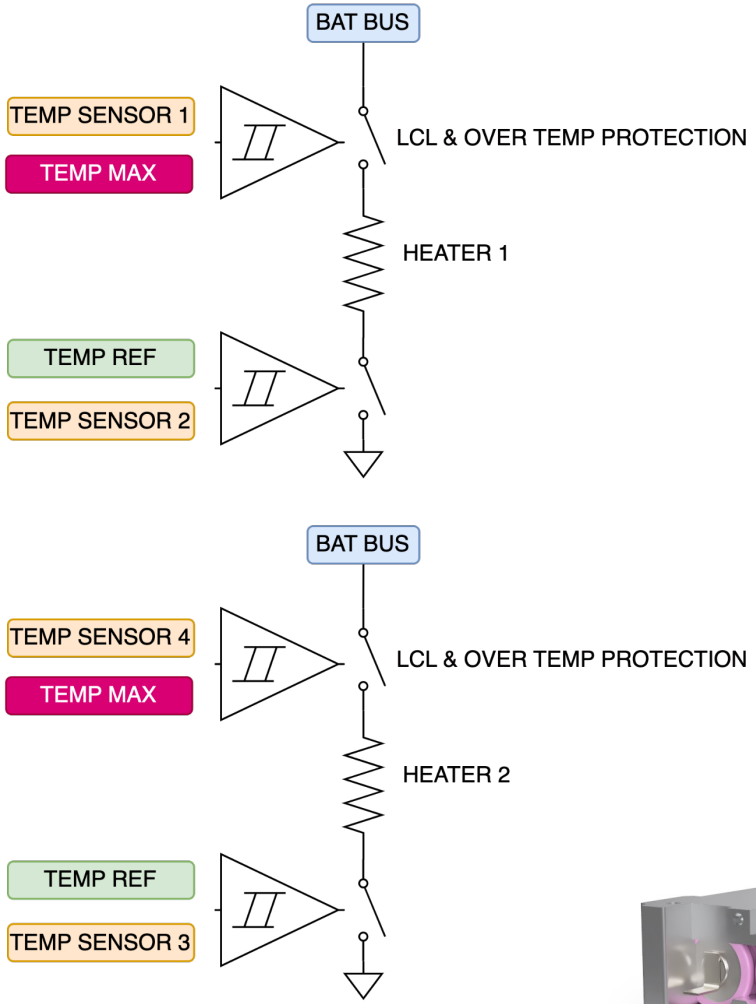
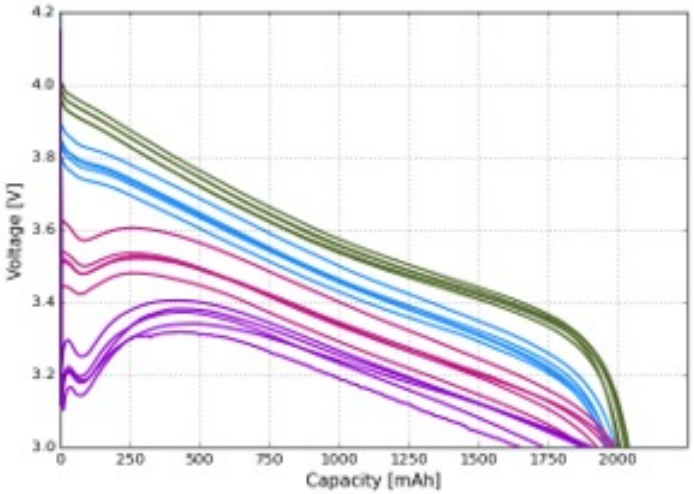
PCDU Architecture - Heaters

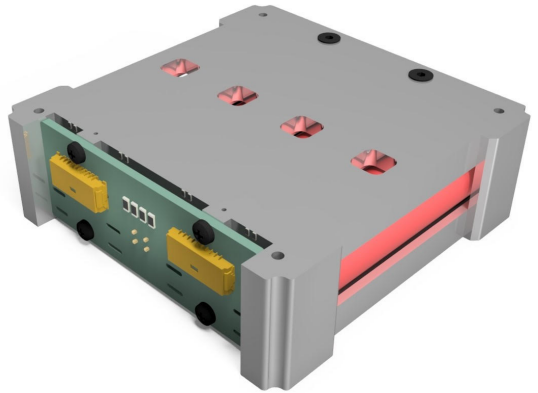
ONE HEATER FAILURE CAN BE ASSUMED





- Critical element
- Redundancy
- 4 Temperature Sensors
- Over Temperature Protection





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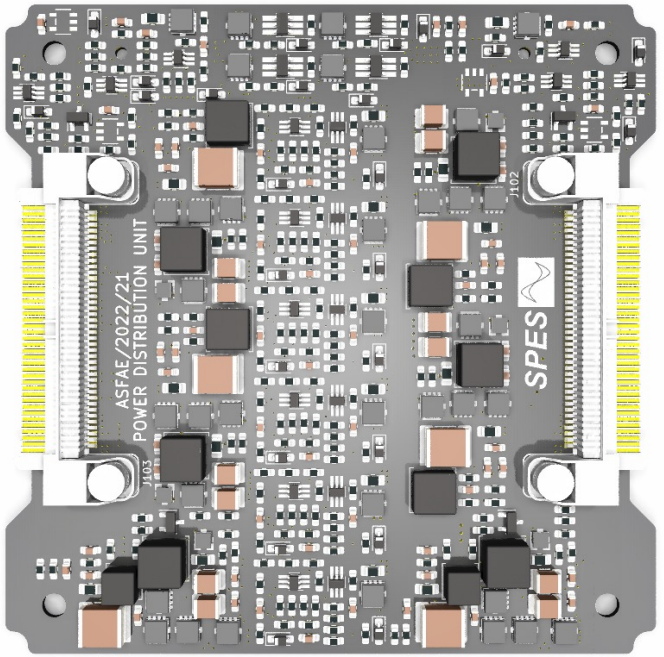
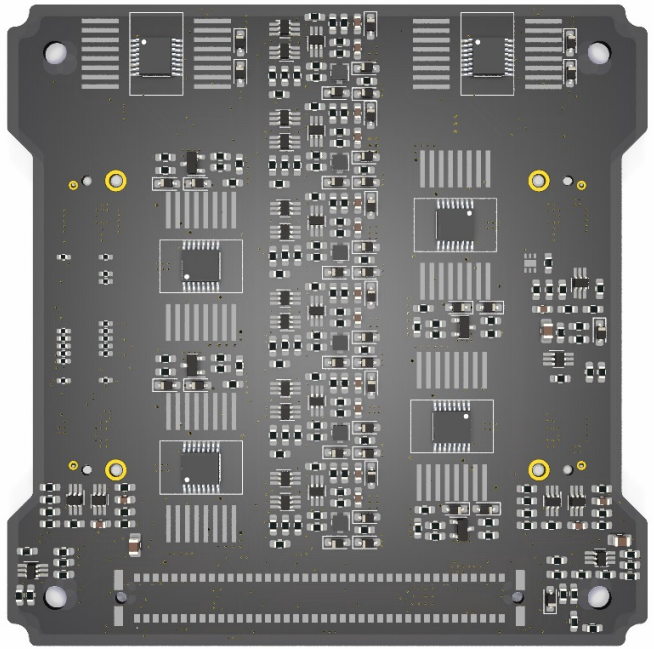
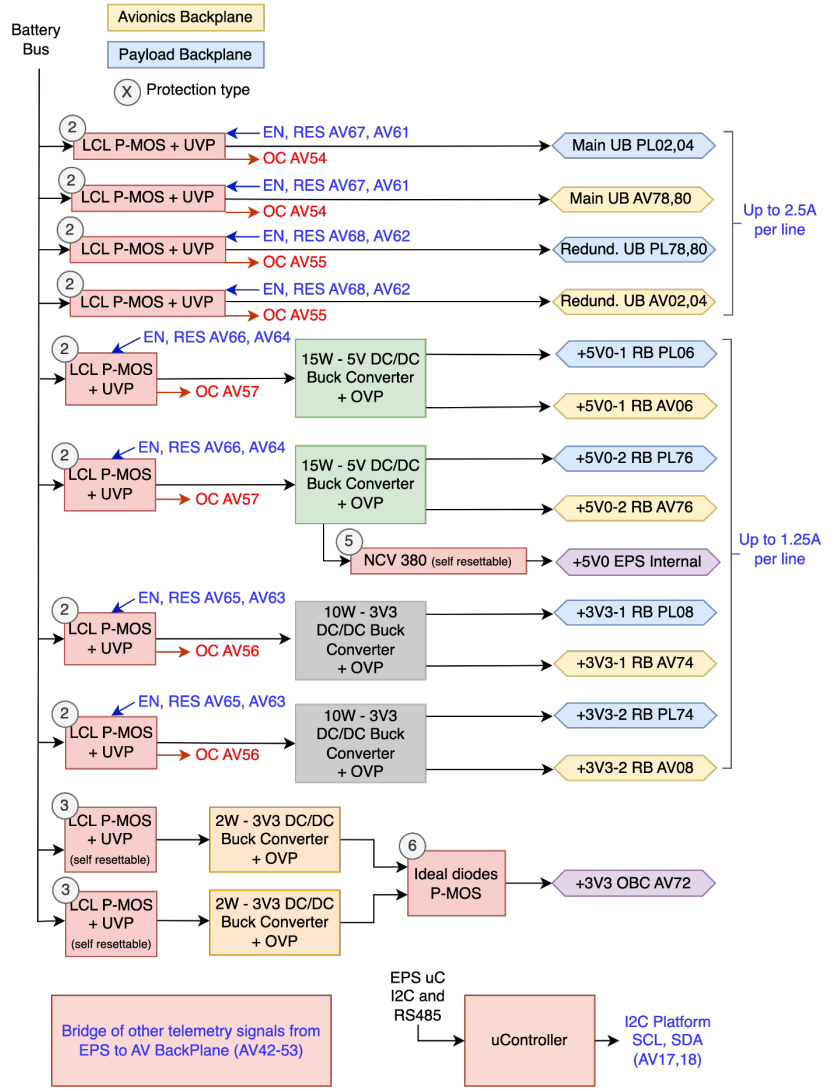
PCDU Architecture – Power Distribution Unit (PDU)

- Vbat, 5V, 3.3V
- Redundancy in all the distributed voltages
- OC and UV protections (LCL)
- OBC dedicated redundant supply lines
- DC/DC LT3845 Controller
- µController only for Telemetry







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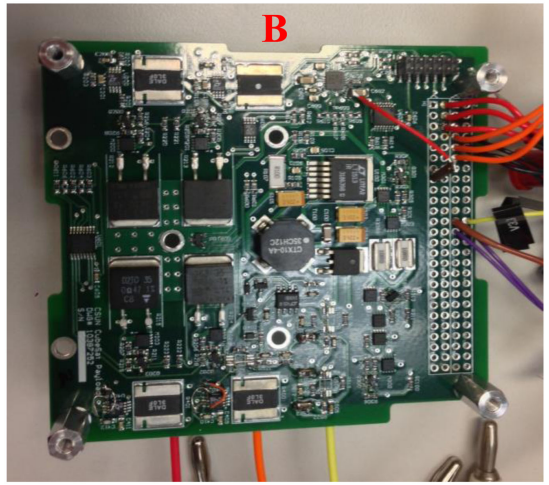
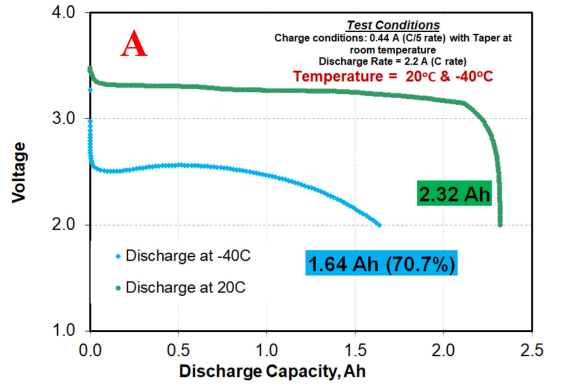
PCDU Architecture – Hybrid Energy Storage Subsystem (HESS)

K. B. Chin *et al.*, "*Flight Demonstration of a Hybrid Battery/Supercapacitor Energy Storage System in an Earth Orbiting CubeSat*" in *IEEE Aerospace and Electronic Systems Magazine*, vol. 36, no. 5, pp. 24-36, 1 May 2021

Jet Propulsion Laboratory
California Institute of Technology

Hybrid ESS can offer additional benefits, particularly with respect to high current capability at lower temperatures, along with greater cycle life.





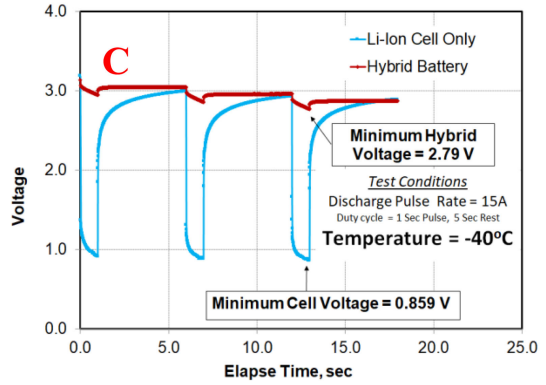


Figure 4.
A) Functional block diagram of payload electronics board. B) Prototype engineering model of JPL's payload electronics board. C) Integrated hybrid ESS, following thermal vacuum testing.

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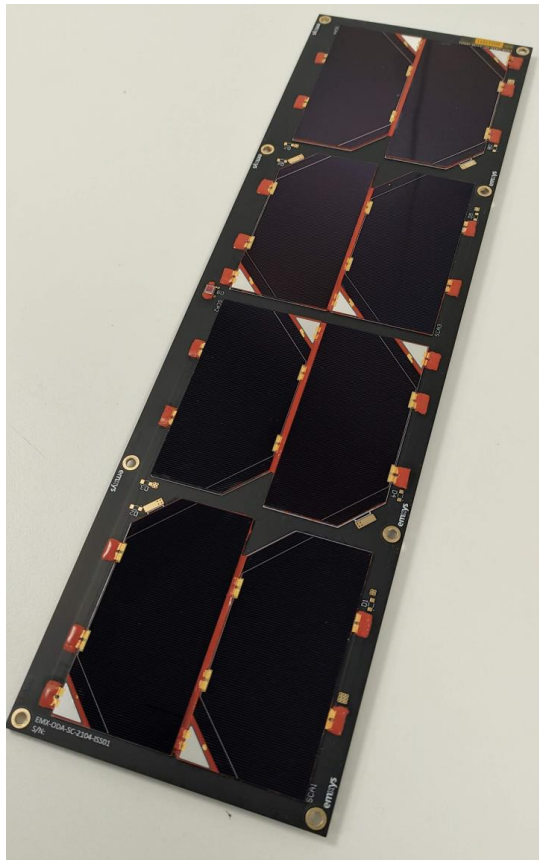
Solar Panels + Structure (6u + 4x8S1P)

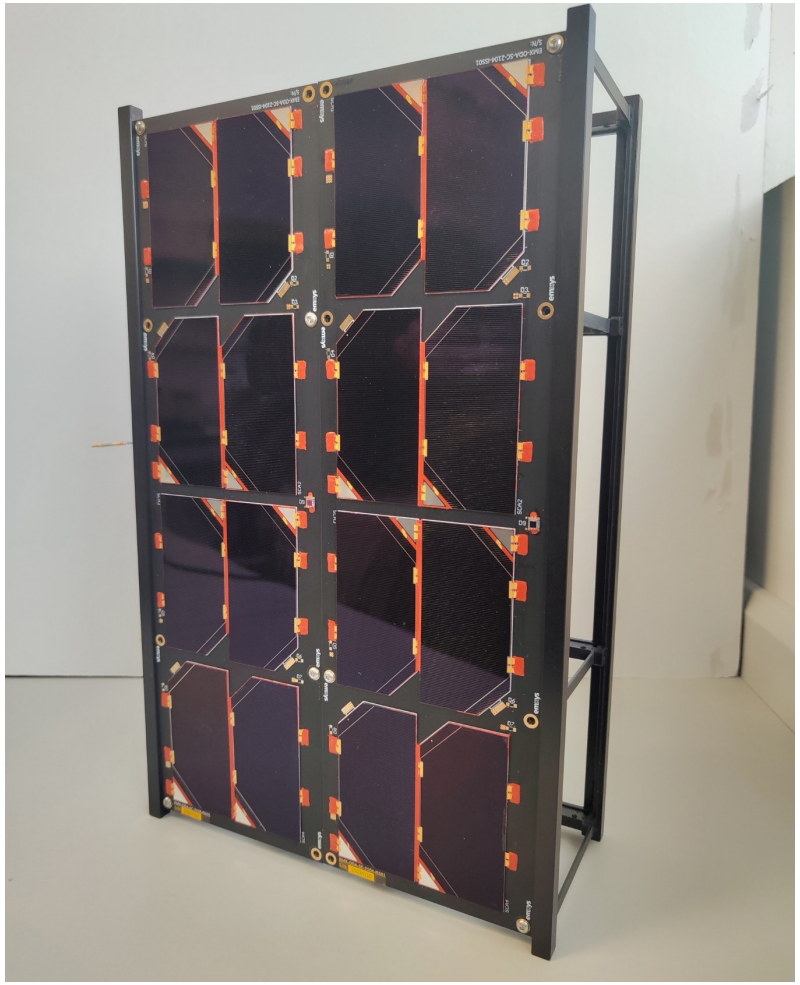
6U Cubesat Structure - EMXYS

CubeSat Design Specification Rev. 14.1



8S1P – EMXYS

Cesi CTJ30-SCA



Structure + 2x8S1P

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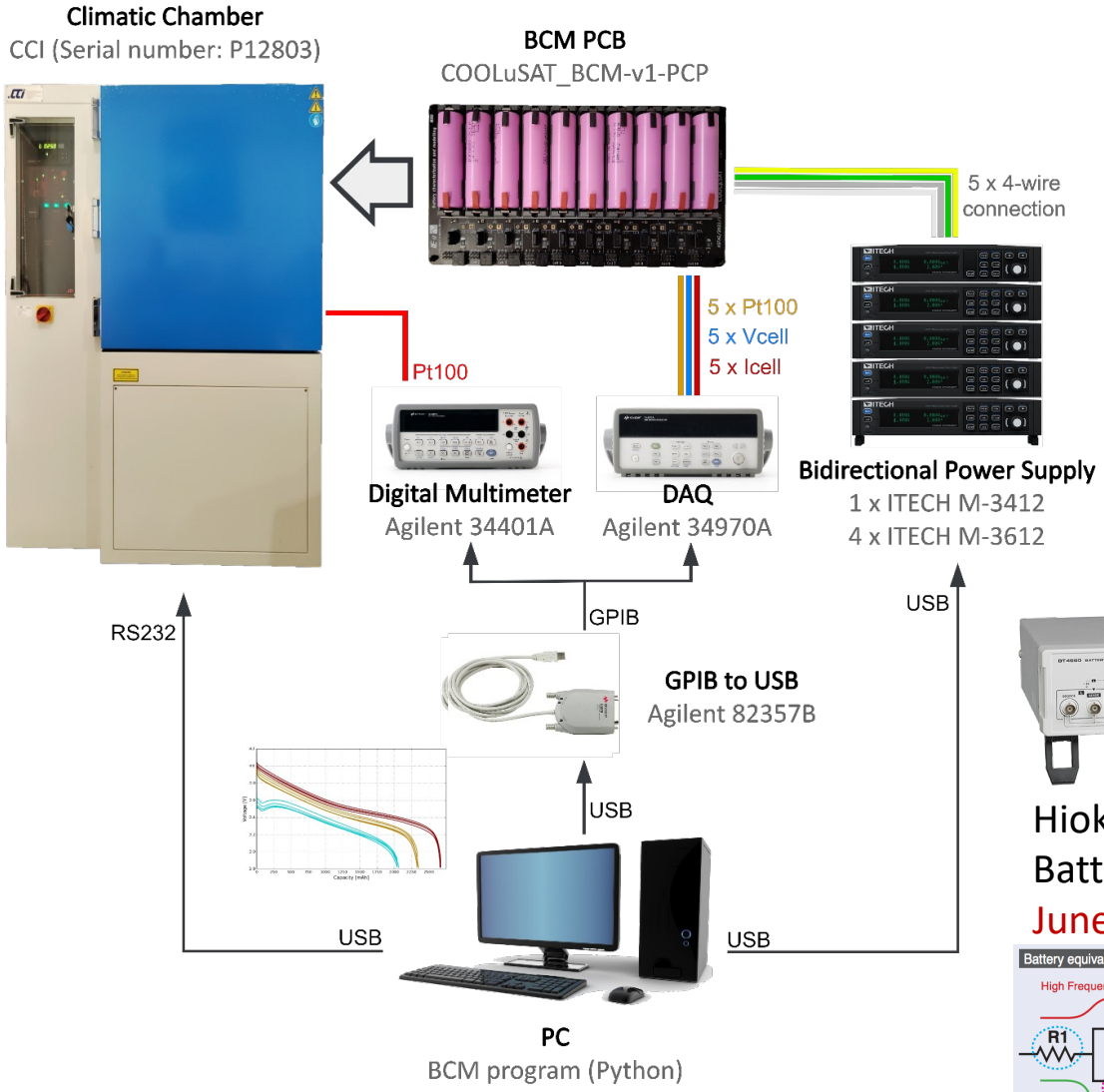
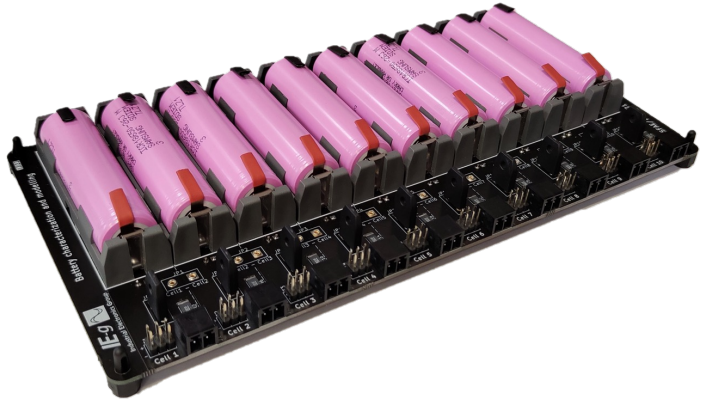
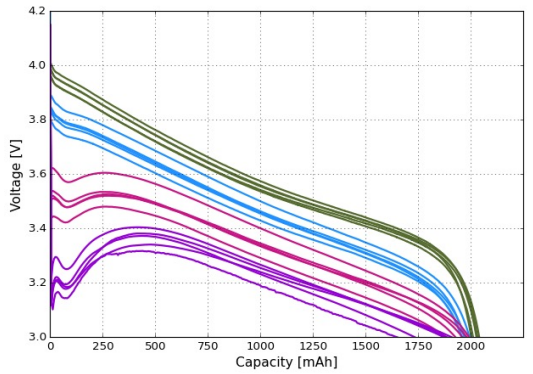
Facilities – Battery Characterization System

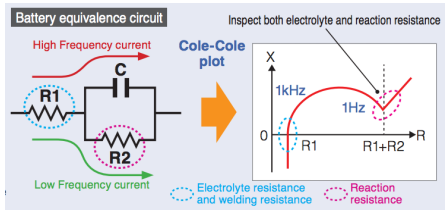






12 different battery cells characterized

Hioki BT4560
Battery Impedance Meter
June 2024



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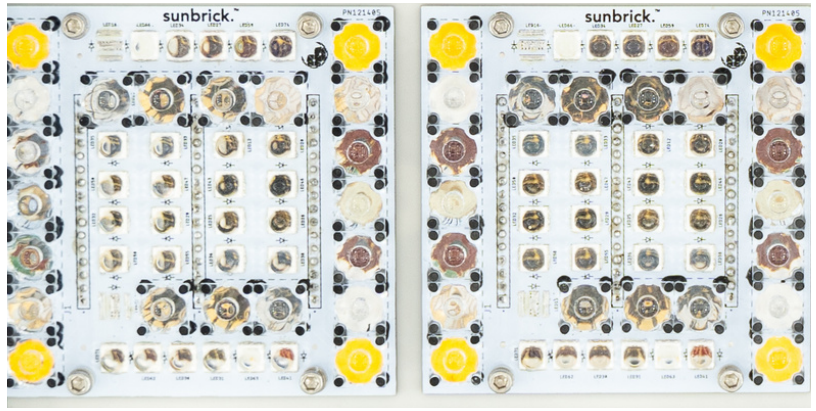
Facilities – Sun Simulator

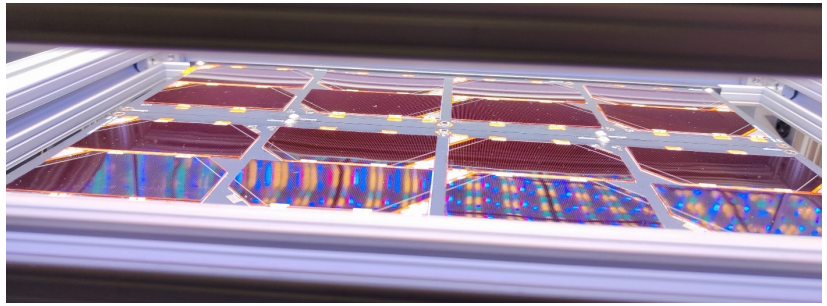
G2V SUNBRICK

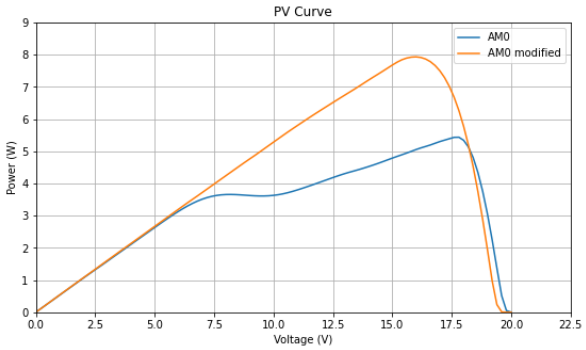
LED LARGE AREA SOLAR SIMULATOR 25x50 cm2

32 Channels

SMU KEITHLEY 2461







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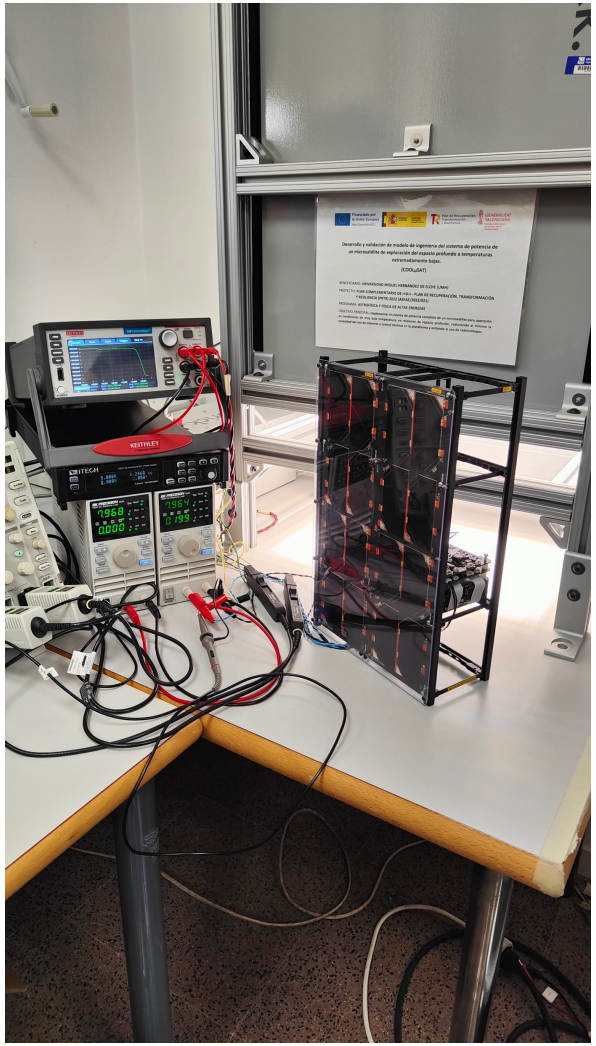
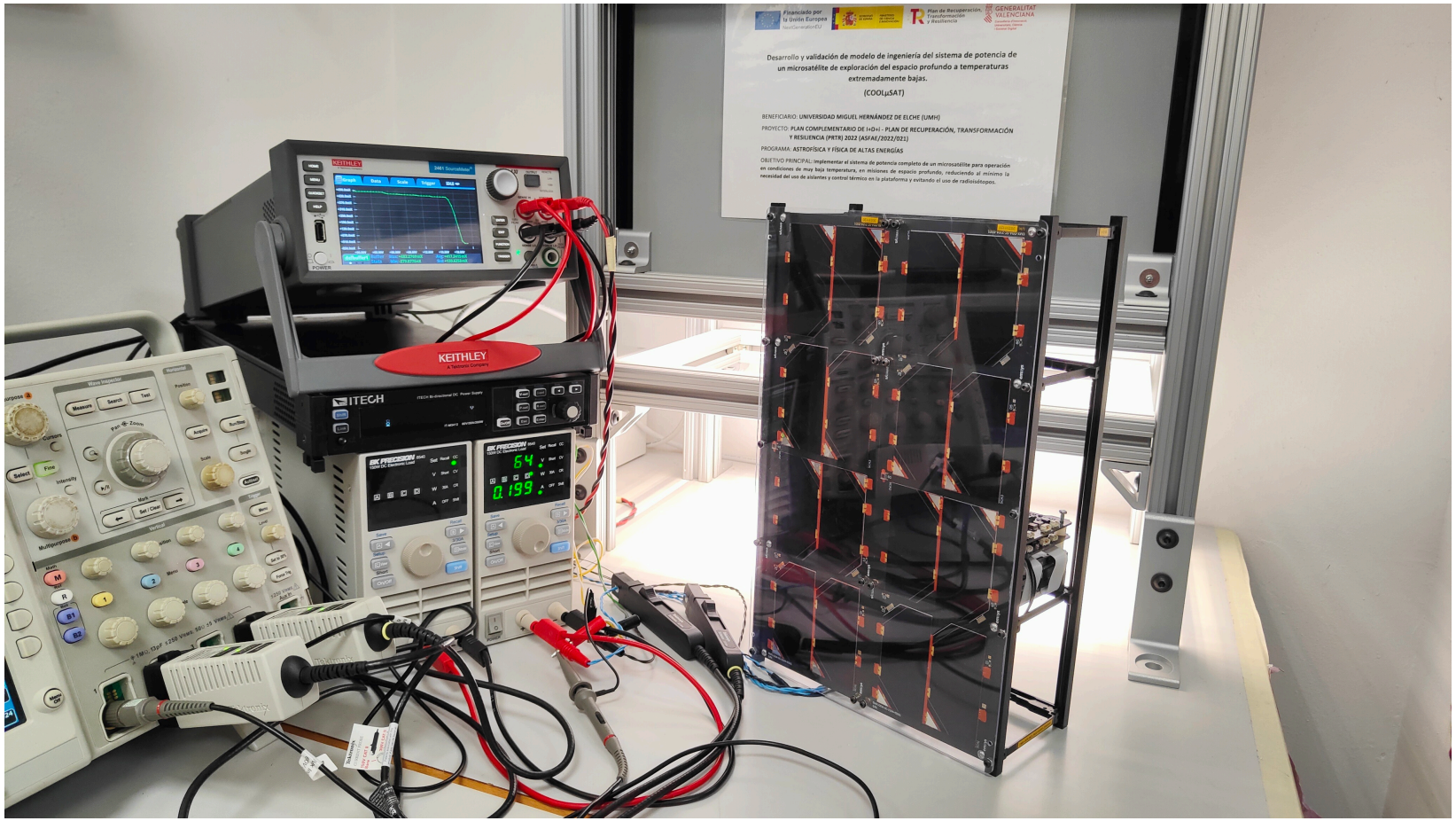
Tasks Ongoing – Functionality Tests





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Tasks Ongoing - Component TID Radiation Tests

CNA
Centro Nacional de Aceleradores

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Summary

- ✓ SAR Implementation – Completed
- ✓ Battery Charge/Discharge Tests – Completed

- ➢ BMS Implementation – Heaters – Ongoing
- ➢ PDU Implementation – Ongoing
- ➢ SuperCapacitors Tests – Ongoing
- ➢ Radiation Tests – Ongoing
- ➢ PCDU Full Integration and Tests- Ongoing

- ❖ HESS Implementation - Remaining
- ❖ Battery Spectroscopy Impedance Tests – Remaining
- ❖ Technology Transfer to Companies & Collaborations – Remaining

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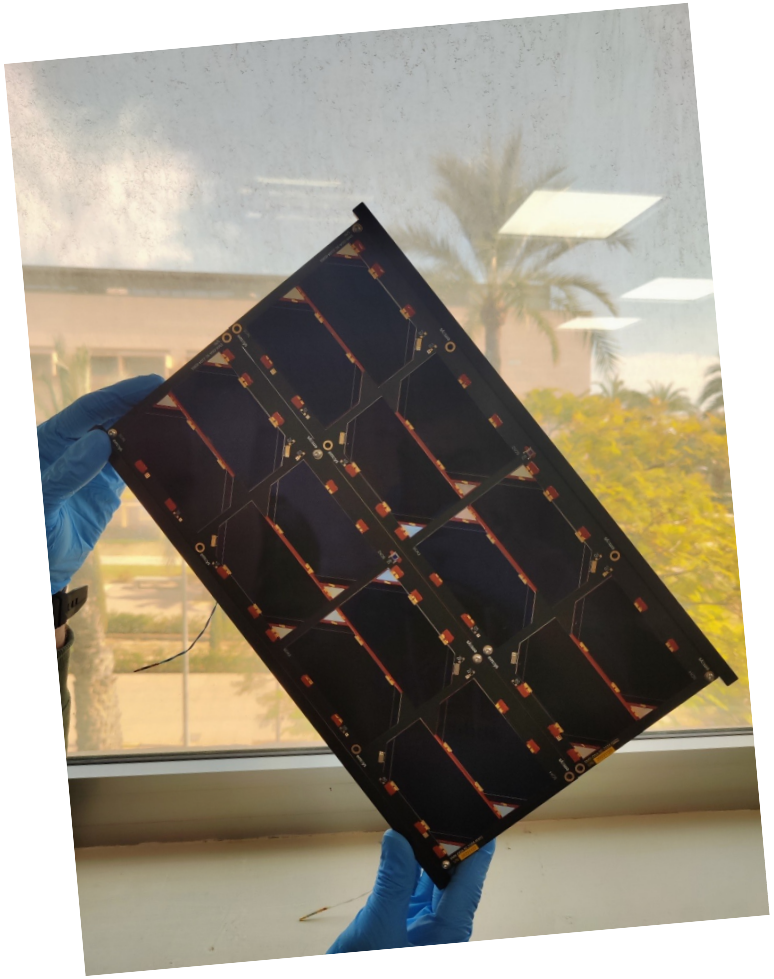

Deep Space Microsatellite Power System Development ASFAE/2022/021

LIA7: Space exploration with small satellites

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