# ESR - Executive Summary Report

**ESR**

**MiniPINS**

**Reference:** FMI-AO1-9777-2019
**ITT:** AO/1-9777/19/NL/KML
**Contract:** 4000128070/19/NL/KML
**Activity No.:** 1000025265
**Consortium coordinator:** Finnish Meteorological Institute
**Edition date:** 28 November 2023
**Edition:** 00.02.00
**Document Id.** FMI-MPINS-RP-015

# Table of Contents

## Study objectives

In 2018 ESA issued an ITT to design a set of Moon and Martian surface sensor packages (SSP) for Exploration missions, as well as payload delivery systems for the Moon and Mars, and to provide prototypes demonstrating the most critical functions of these SSPs. The sensor packages shall measure critical environmental parameters at their landing sites.

The SSP for Mars shall be light (25 kg mass target), deployable in a high altitude from a carrier spacecraft, robust and capable of surviving high G loads, extreme thermal environment, and capable of penetrating the surface and operating from the surface. The SSP for Moon shall be deployable by a rover or a drone and its target mass is 5 kg (increased later to 7 kg). Both SSPs shall be designed according to commonalities to allow cost cutting and synergies between the two environments, for example by sharing a common data handling and communication architecture. Up to 4 SSPs shall be delivered both to Mars and the Moon. The SSPs shall start their scientific observations after landing and stay stationary throughout their mission (2 years).

## Study results

As part of the MiniPINS study, a mission analysis was performed to identify the mission needs and create a high-level functional specification for the SSPs. Different concepts for carrying out the missions were assessed for feasibility, and requirement specifications were formulated for the mission, functionality, design, interfaces, environment, operations, product assurance, and verification. Preliminary Definition of both Mars SSP (MINS) and Moon SSP (LINS) and their delivery systems have been provided. The study also included prototyping activities for key technologies, including the development of an impact test facility, thermal testing of hardware, and testing of flexible solar panel deployment concepts. A development plan was also created to address the methodology for demonstrating compliance with the concept and the verification level needed for the system and subsystems.

## MINS

### MINS Functional tree

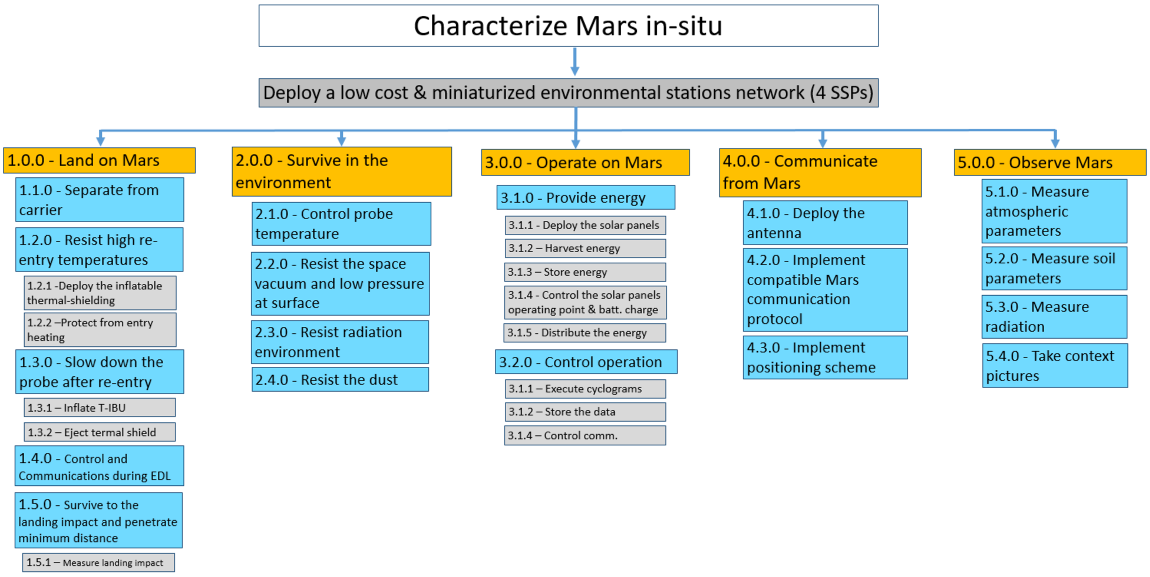


*Figure 1: MINS functional tree.*

### MINS penetrator mechanical design

MINS **external structure** consists of a 3 sections geometry made in 2.5mm thickness aluminium, which contains and protects the payload and the support subsystems during the EDL phase. Its geometry is optimised to contain all the components and to penetrate in Mars soil as desired, without burying up too little or too much. The first section contains those sensors that need to be in direct contact with the ground, the second the electronics holder structure, and the third acts as a stopper to avoid the probe to get too far into Mars soil if the soil hardness is softer than expected and gives room to the accommodation of the potential deployable elements, like solar panels, boom and the attached sensors.

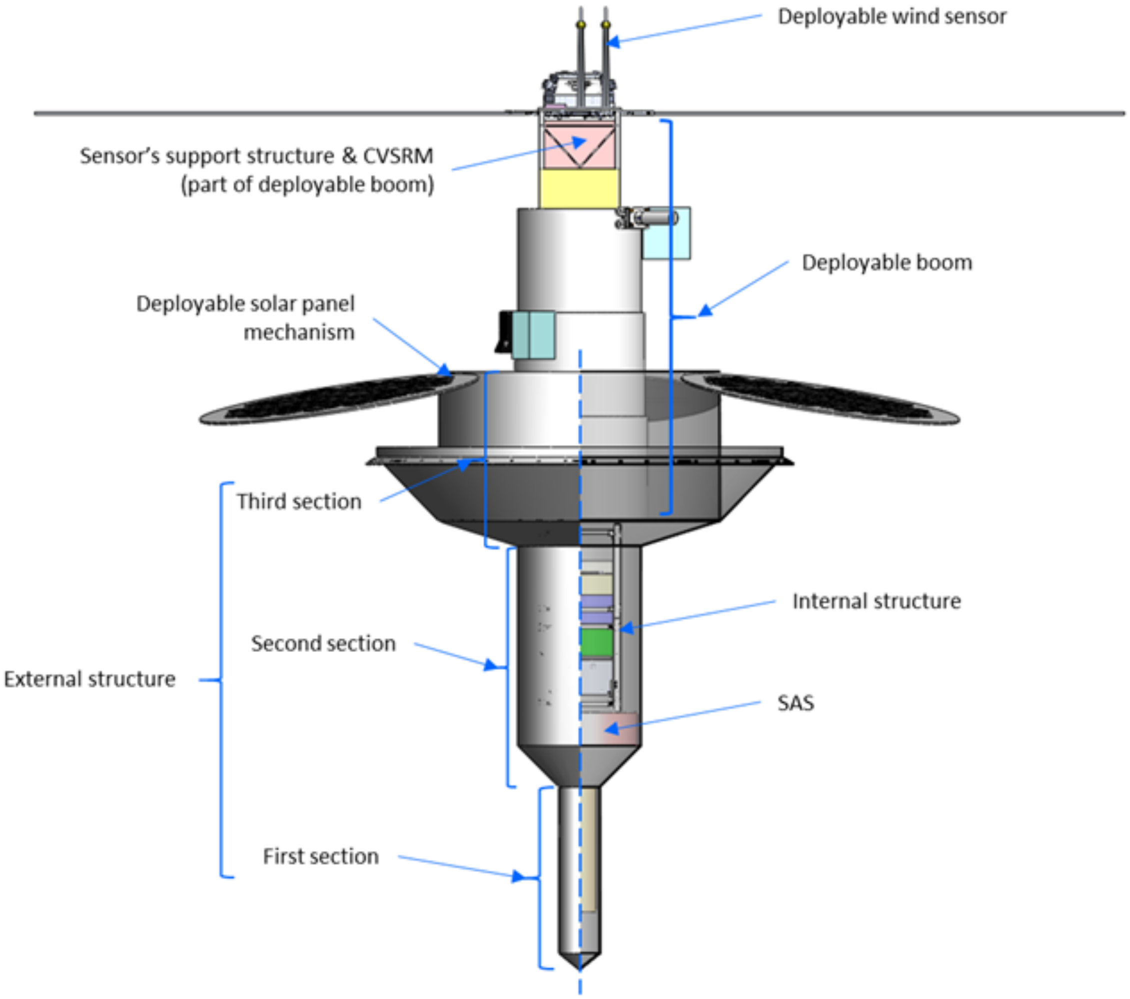


*Figure 2: MINS penetrator mechanical design.*

### MINS delivery system

MINS autonomous Entry, Descent and Landing subsystem is based on inflatable braking units (IBUs) and flexible thermal protection shield. MINS EDL subsystem has a strong heritage from FMI's MetNet project[1], but some parts have been redesigned based on the latest aerodynamical simulations.

---

[1] Ari-Matti Harri et al., The MetNet vehicle: a lander to deploy environmental stations for local and global investigations on Mars, Geosci. Instrum. Method. Data Syst., 6, 103-124, 2017

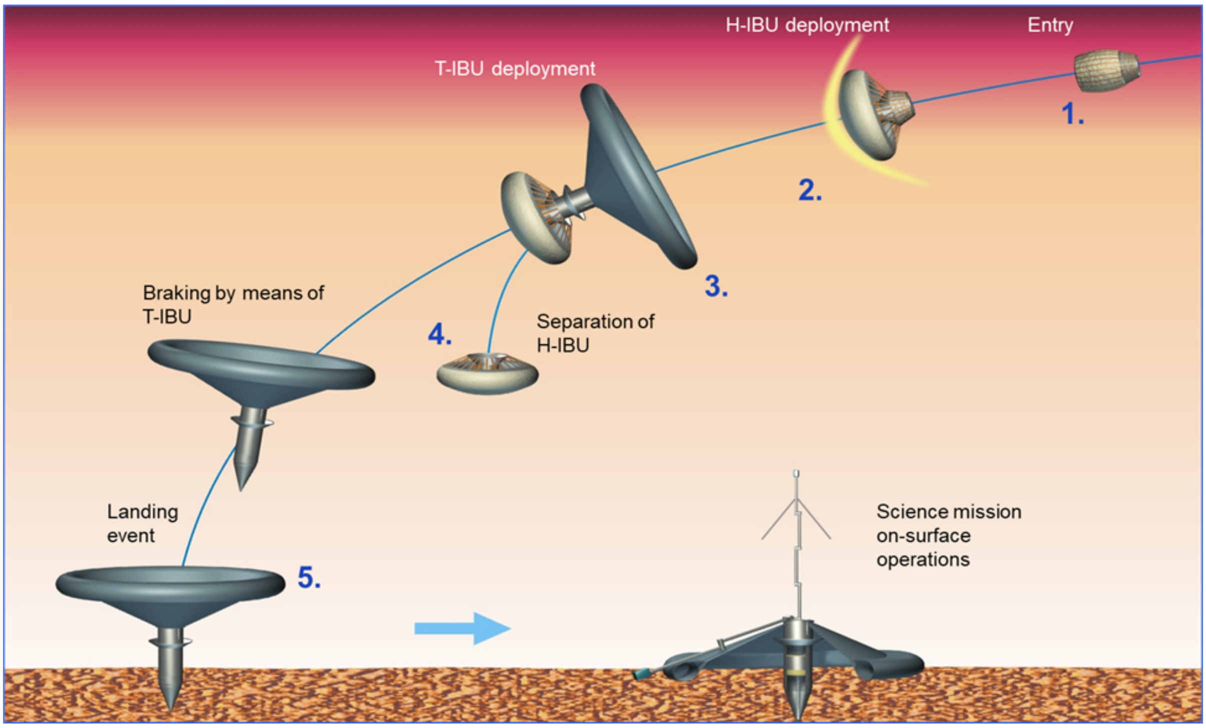


*Figure 3: EDL sequence utilized by MINS*

**The MINS payload** consists of a camera, a visual spectrometer, a meteorological package, an impact accelerometer, soil thermoprobes, a chemistry package, a seismometer and a radiation monitor.

*Table 1: MINS mass budget*

| *Total Mass Budget* | | | |
|---|---|---|---|
| ***System/part*** | ***Mass [g]*** | ***Margin [g, 10-20 %]*** | ***Mass with margin [g]*** |
| *EDL system* | *10850* | *2170* | *13020* |
| *Mechanical system* | *5450* | *1090* | *6540* |
| *Thermal system* | *1100* | *20* | *1120* |
| *Power system* | *1102* | *73.1* | *1175.1* |
| *Communications system* | *670* | *86.0* | *756.0* |
| *Command & Data Handling System* | *316* | *63.2* | *379.2* |
| *Payload system* | *1861* | *186.1* | *2047.1* |
| ***Total Mass Budget*** | *21349* | 3688.4 | ***25037.4*** |
| ***System margin (20%)*** | | | (20% → 25037.4) 5007.48 |
| ***Total with system margin*** | | | ***30044.88*** |

# LINS

## LINS Functional tree

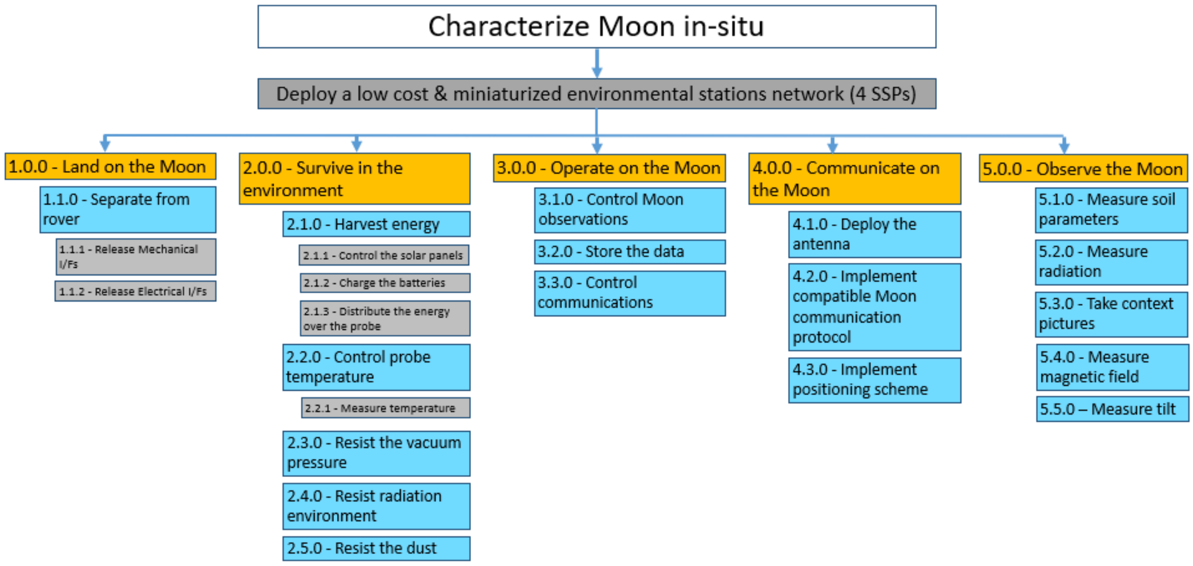


*Figure 4: LINS Functional tree.*

## LINS mechanical and thermal design

The thermal engineering needed to survive in the Moon for two Earth years, close to the South Pole (Schrödinger Crater), was the main driver of the whole LINS design. The mechanical design is based on a double frame structure, with the outer frame in contact with the regolith and supporting LINS mass, and the inner frame thermally isolated from the external environment.

Thermal analysis performed in the project showed that surviving 14-day long darkness in each Lunar 28 days solar cycle would not be possible on batteries and solar panels alone given the mass and volume restrictions of LINS requirements. The problem was solved by adding an RHU (European development) to the design.

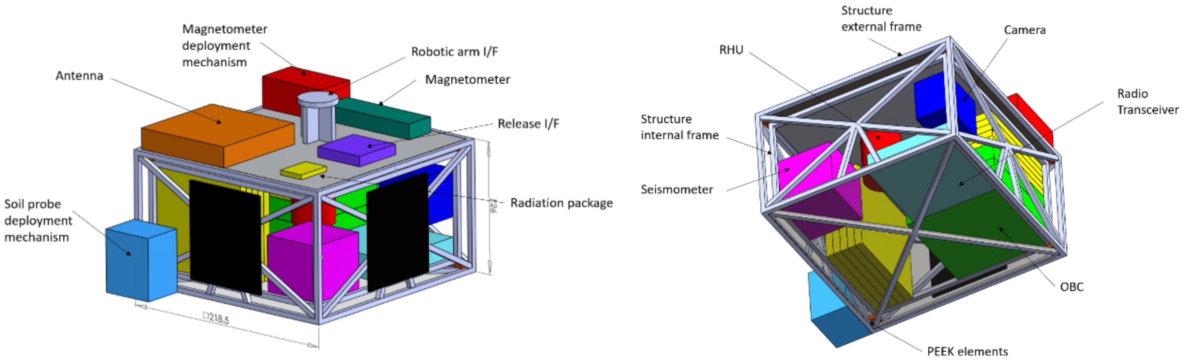


*Figure 5: LINS mechanical and thermal design.*

**The LINS payload** consists of a camera, an accelerometer, soil thermoprobes, a magnetometer, a radiation monitor and a seismometer.

*Table 2: LINS mass budget*

| ***Total Mass Budget*** | | | |
|---|---|---|---|
| ***System/part*** | ***Mass [g]*** | ***Margin [g, 5-20 %]*** | ***Mass with margin [g]*** |
| *Mechanical system* | *1600* | *320* | *1920* |
| *RHU* | *200* | *20* | *220* |
| *Power system* | *2000* | *120* | *2120* |
| *Communications system* | *380* | *20* | *400* |
| *Command & Data Handling System* | *200* | *40* | *240* |
| *Payload system* | *866* | *151* | *1017* |
| *Harness* | *262* | | *262* |
| ***Total Mass Budget*** | *5510* | 650 | 6166 |
| ***System margin (20%)*** | | | 1233 |
| ***Total with system margin*** | | | ***7399*** |

## Commonalities in the design of MINS and LINS SSPs

The development of the subsystems is based on the following approaches: in-house development, customizing COTS products either in-house or by manufacturers and procurement and delta-qualification of COTS subsystems with flight heritage (mainly CubeSat subsystems). The following selected subsystems are common for both designs:

1. Batteries (model MP 176065 XTD)
2. Power supply (NanoPower P31u)
3. Solar panels (Azur 3GG30A)
4. Radio (NanoCom SDR)
5. OBC (ad-hoc design)

From the payloads, the camera, the soil thermoprobes, the radiation monitor, and the seismometer are common to both MINS and LINS.

## Prototyping activities of key technologies

### 1. Impact test facility

The impact test facility prototyped for MiniPINS employs a compressed-air cannon available at INTA within an impact test facility.  Two target containers were designed and manufactured. They can be fixed to existing rails in the floor of the impact test facility and can be filled with different materials simulating the Martian terrain. The facility allows the measurement of the impact speed by two means: photocells at the cannon’s mouth and high-speed video. The inclination angle at impact can also be measured by means of the video images.

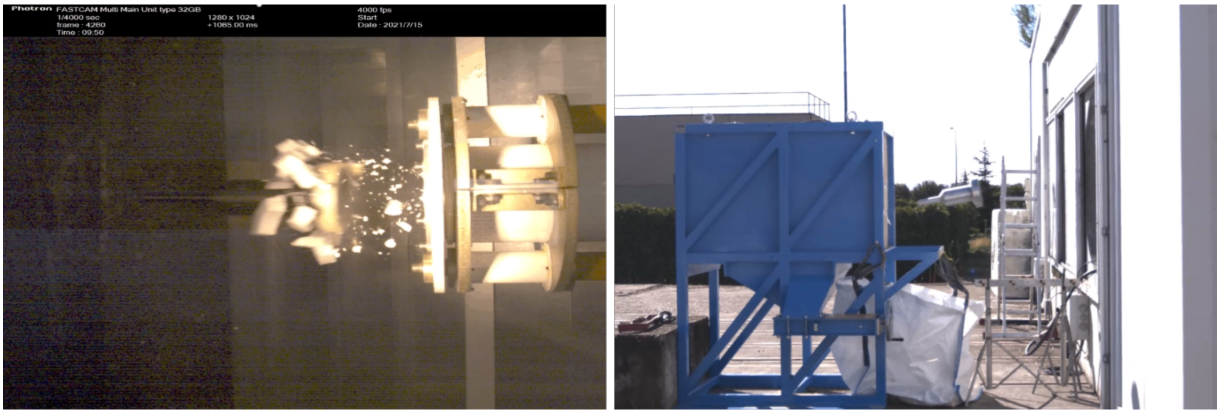


***Figure 6: Left: a plastic 3-sections penetrator initially shot to validate the sabot accommodation. Right: real metallic penetrator.***

## 2. Thermoprobes testing

A set of experiments was performed at UPC in order to test how the spherical thermoprobe can be used to characterize the thermophysical properties of regolith (thermal conductivity and diffusivity).

The results of this work have been published in (Domínguez-Pumar, 2022) [2].

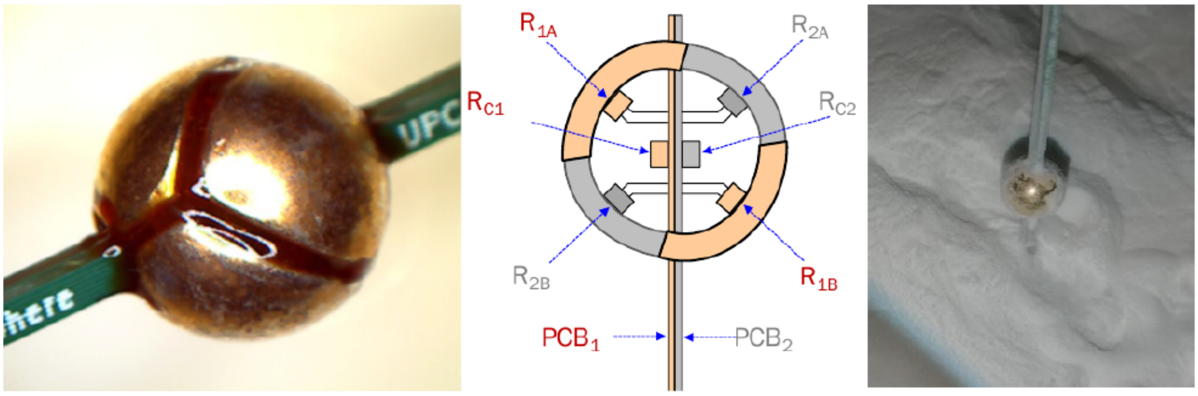


***Figure 7: (Left) Thermoprobe picture. (Center) Diagrammatic cross-section of the thermoprobe showing relative position of Pt sensors (Rxx) and the printed circuit boards (PCBx), (Right) Image showing the thermoprobe being deployed into a regolith simulant.***

## 3. Low-temperature tests of front-end mixed-signals ASICs in CMOS technology

A measurement campaign was performed by the Institute of Microelectronics of Seville (IMSE) at INTA facilities to determine if the AMS 350nm technology, including modifications introduced to make the technology Rad-Hard, is operational at the minimum temperature required in the LINS mission (around -175°C). A mixed-signal ASIC previously designed by IMSE to measure the Solar Irradiance on the surface of Mars in an instrument developed by INTA was used.

---

[2] Domínguez-Pumar, et al (2022). Spherical probe for the thermophysical characterization of regoliths for planetary exploration using frequency methods. Sens. Actuators, A, 348, 114018.

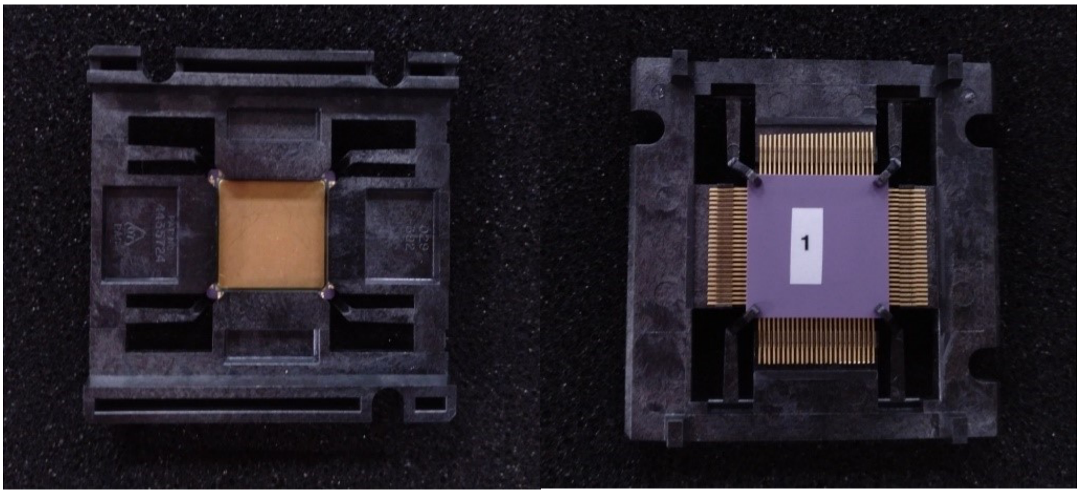


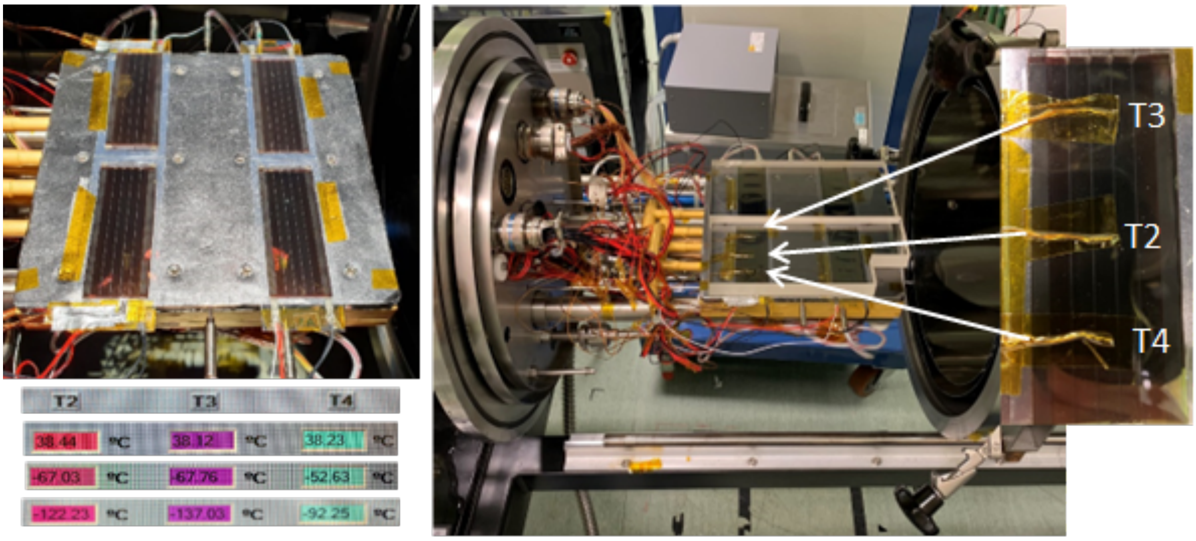
*Figure 8: ASIC inserted in carriers. Top and bottom views*

## 4. Prototyping of flexible solar cells and their deployment proof-of-concept

This prototyping activity by IMDEA Nanociencia describes a non-traditional solution regarding solar energy harvesting and included two main topics:

- Temperature cycling
- Deployment proof-of-concept

The solution would consist of using full-flexible solar cells in combination with tailored deployment systems. Perovskite photovoltaic cells[3] are the newest and the most exciting solar technology and perovskite-based solar cells are the most efficient flexible cells reported.



| T2 | | T3 | | T4 | |
|---|---|---|---|---|---|
| 38.44 | °C | 38.12 | °C | 38.23 | °C |
| -67.03 | °C | -67.76 | °C | -52.63 | °C |
| -122.23 | °C | -137.03 | °C | -92.25 | °C |

*Figure 9: Solar cell modules tested at INTA/SPASOLAB solar simulator (HT/LT) - AM0 spectral irradiance*

---

[3] Tu, Y. et al. “Perovskite Solar Cells for Space Applications: Progress and Challenges” Adv. Mater. 33, April 2021, 37 pp