# EUROPEAN CHARGING STATION PRE-PHASE A - Executive Summary

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| ***Written by*** | |
| Morsaniga PierLuigi | Written on 27/06/2023 10:43 |
| ***Verified By*** | |
| Gervasio Giuseppe | Verified on 27/06/2023 12:16 |
| Pioli Stefania | Verified on 27/06/2023 18:03 |
| ***Approved By*** | |
| Morsaniga PierLuigi | Approved on 28/06/2023 08:44 |
| *Released By* | |
| Pioli Stefania | Released on 28/06/2023 10:46 |

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# EUROPEAN CHARGING STATION PRE-PHASE A

## EXECUTIVE SUMMARY

**Date:** 27/06/2023
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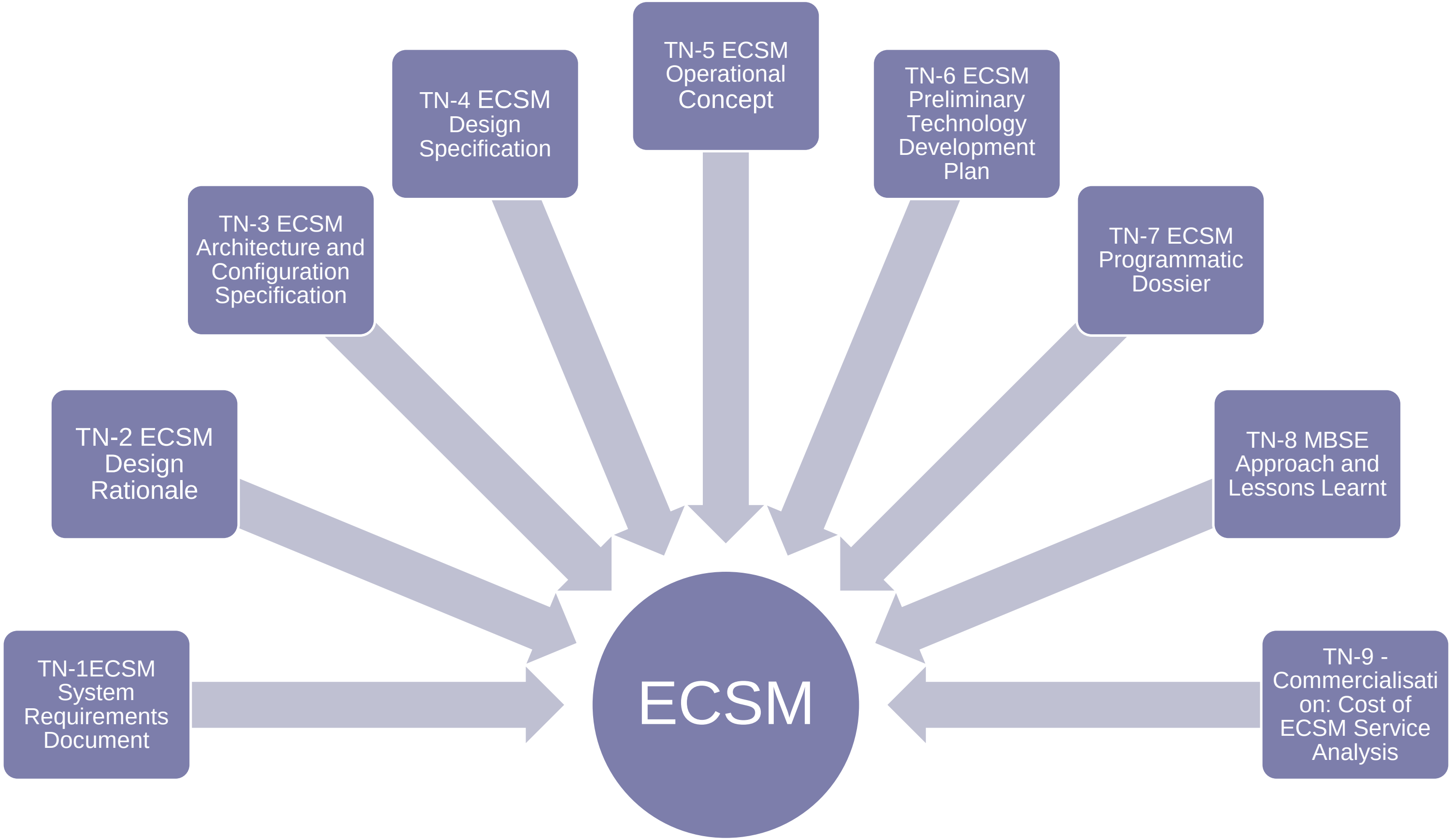
# LAYOUT OF THE FINAL REVIEW DATA PACKAGE



# SYSTEM & MISSION OVERVIEW

The European Charging Station for the Moon (ECSM) is to be integrated within the EL3 Architecture, which provides the function of transportation of ECSM to the lunar surface.
The Power Station mission is envisaged as possible EL3 payload and it aims at providing power, at a strategic location on the lunar surface, during lunar day and night to ESA and International partner assets. It is in line with the envisioned international lunar exploration architecture.
The EL3 architecture elements are:

- Lunar Descent Element (LDE), which is a fixed asset, recurrent among EL3 mission.
- The Cargo Platform Element (CPE), which is the interface between the Lunar Descent Element (LDE) of EL3 and its cargo or scientific payloads, a versatile element and can be used to interface different payloads and to provide functions requested by the user.

The major requirements and design drivers were imposed by the programmatic and technical constrains of the EL3 programme framework. In particular:

- Launch not earlier than 2029 and not later than 2033,
- Full compliance with EL3 in terms of environment and performance.

An Astronaut Science Enabler (**AstroSci**) will be used as ECSM reference use case, aimed at making available a targeted continuous power (7.7kW) to the users during lunar day and at providing a reduced amount of power to the users during lunar night.
In addition, an Astronaut Science Enabler with Peak Power Capability (**PeakPwr**), aimed at maximizing the continuous power provision to the users during lunar day, providing a peak power boost for a short time period to the users, was also studied during the CDF.

These two designs of the Astronaut Science Enabler use case will be addressed through the activity's objectives.
The two primary use cases AstroSci and PeakPwr will be hereafter referred to as "missions".

In addition, a secondary priority will reside in investigating the use case of an ISRU Power Plant Enabler, namely how the ECSM could provide the whole power for such Pilot Plant [RD4] – noting that it is expected that updates on Pilot Plant requirements and performances should be provided at Kick-Off or during the activity.

A third priority will reside in investigating the opportunity to integrate a local surface communications hub to the ECSM.

# OPERATIONAL CONCEPT

## Mission scenarios

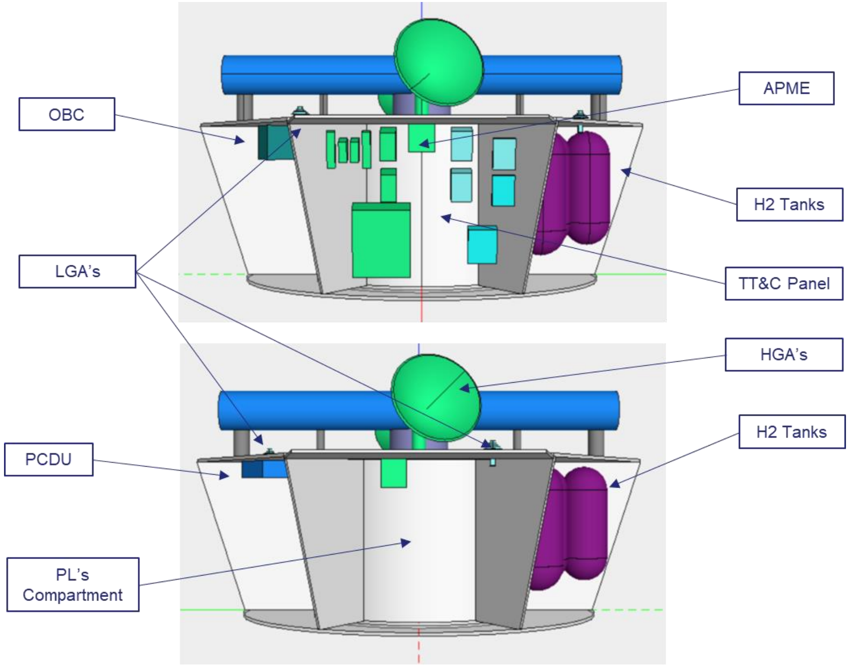
The ECSM will be launched on-board an EL3 mission, with Ariane 6 launcher from Kourou Spaceport.

After launch and LEOP phase, the transfer phase to the Moon could last from a few days in case of a direct injection into Lunar Transfer Orbit (LTO), up to 4-6 months in case of a Weak-Stability Boundary (WSB) transfer strategy.

From LEOP to post-landing the LDE supplies power to the ECSM, and ECSM HK data are transferred to ground via LDE by means of the LDE communications system. All manoeuvres during transfer, descent and landing are performed by LDE.

After landing, ECSM Solar Array will be deployed and the LDE resources will be disconnected. A commissioning phase will be run for about 1 day to check ECSM subsystems. After Commissioning the nominal operational phase providing power to the Users can start.

The mission EOL and the ECSM passivation is planned 2 years after the launch date



# OPERATIONAL CONCEPT

## Power Users

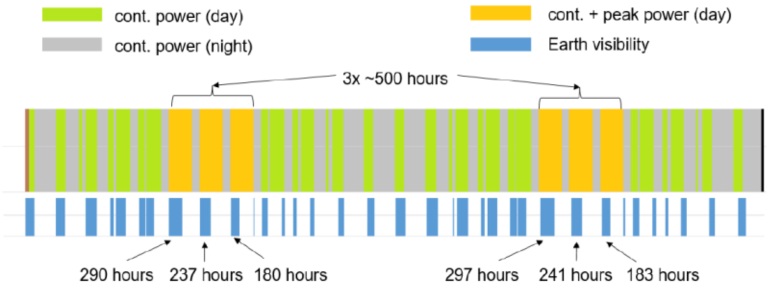
Two utilization scenarios have been considered for ESCM design dimensioning:

- Astronaut Science Enabler Baseline (AstroSci)
- Astronaut Science Enabler Peak Power (PeakPwr)

***ASTROSCI MISSION SCENARIO***

AstroSci requires continuous power supply during lunar day to 2-3 ISS-like racks, and reduced power during eclipse:

- 7700 W to external users during lunar day
- 260 W during the eclipse/lunar night




For AstroSci, the battery is requested to supply power in the deployment phase and during the peak loads, while the RFC is in charge to satisfy the internal and external loads in the eclipse period.

***PEAKPOWER MISSION SCENARIO***

PeakPwr requires continuous power supply during lunar day to 2-3 ISS-like racks, with peak power for a limited time period, and no power during eclipse:

- 7700 W to external users during lunar day
- 8300 W peak power for 3 hours during lunar day, (provided on top of the 7700W nominal)

the battery is sized for the 3 hours peak power request from external users in sunlight period, while the RFC  satisfies only the internal ECSM loads during the eclipse period, with no external power request. After the 3 hours of peak power provision, the battery will be recharged for 21 hours to restore peak power provisioning capability (while still providing nominal power to an user).

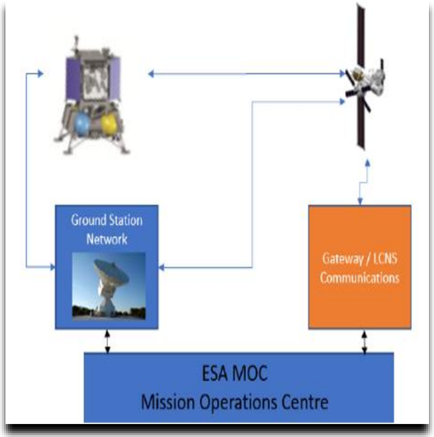
The periods were chosen based on the illumination conditions (longest Lunar days), as all interfacing operations require an illuminated site. The timing to conduct the interfacing operations are assumed to be the same as for the AstroSci user, regardless if the user connects or disconnects from the ECSM.

# OPERATIONAL CONCEPT

## Ground Segment and Communication Scenario

The operations are primarily automatically conducted, based on an event and/or scheduler driven system. Real-time operations will be needed during mission critical operations, e.g. solar panel deployment, users interfacing operations, and decommissioning activities. ECSM users perform manual connections operations during illuminated periods, and when Direct to Earth (DTE) is available.

ECSM will produce Housekeeping Telemetry, and store it in non-volatile memory. The Control & Data Handling System will provide ECSM management, using standard PUS Services (TC, HKTM), either autonomously, or controlled from Ground Centre. ECSM will report, and annunciate faults for alerts, caution, warning, and emergency events to the Ground Centre.




ECSM needs different communication during the different phases of the mission. In addition to using a network of ground stations, it will use the Gateway NASA communications capabilities (option LCNS) when DTE communication is not available. The communication links considered for the ECSM mission are:

- DTE (Direct-to-Earth): ECSM to Earth G/S
- Proximity: ECSM to Gateway

ECSM TT&C subsystem will feature two communication chains:

- S-band LGA
- S/K-band HGA

### DTE

S-LGA: The S-band DTE link through Low Gain Antennas will assure omnidirectional coverage regardless of the spacecraft attitude

- Uplink data rate: 4 kbps
- Downlink data rate: 10 kbps

K-HGA: The K-band link employs High Gain Antennas only, as it will be used only in nominal operations. This architecture supports a data rate of 25 Mbps.

### GATEWAY

S-LGA: The S-band Forward link through Low Gain Antennas will assure omnidirectional coverage regardless of the spacecraft attitude with the Gateway

- Forward data rate: up to 1 kbps,.
- Return data rate: up to 500 bps.

S-HGA: The S-band Forward link through High Gain Antennas will assure omnidirectional coverage regardless of the spacecraft attitude, with the Gateway.

- Forward link data rate: 5 kbps
- Return link data rate: 25 kbps

K-HGA: The K-band Proximity link employs High Gain Antennas only, as it will be used only in nominal operations and for high data rates.

- Forward data rate: 10 Mbps
- Return data rate: 25Mbps

# KEY DESIGN DRIVER

## ECSM EPS Sizing case

Solar Array, battery, RFCS and PCDU are sized to comply with the defined system power budget and relevant margins by considering worst case scenarios including the contribution of environmental factors, failure conditions and End of Life (EoL) performance.

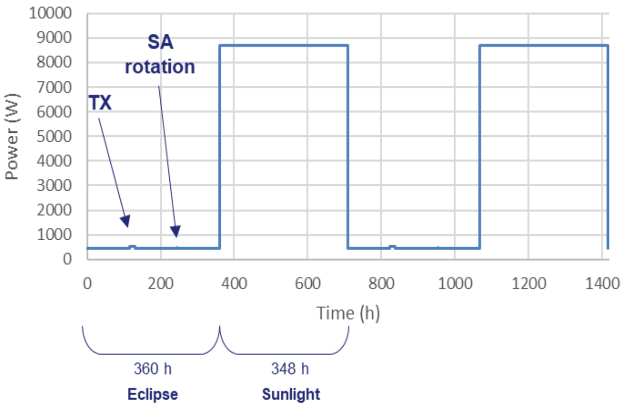
The number of peak power request depends on the period of the year. In fact, sun availability and Earth visibility are needed. Only 3 lunar days per year have been selected for peak power operability. When allowed, the peak power request follows cycles of 24 h, considering 3 h in discharge and 21 h for charging.

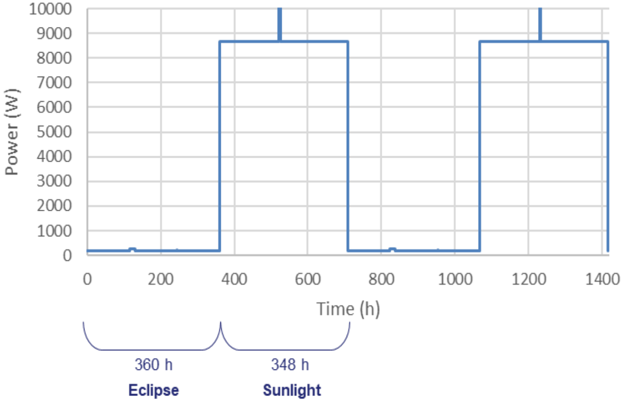
The sizing cases considers repetitive cycles of 360 h continuously in eclipse and 348 h continuously in sunlight.

The constant power requested by the load in eclipse is higher in the AstroSci case with respect to PeakPwr. While the constant power requested in sunlight is the same. This is mainly due to the power requested by the external loads.

In the eclipse period also the power used to transfer data to ground and to rotate the solar array in order to be in the right position when the sun in back has been considered. These requests are satisfied by the battery. To be noticed that the power request for these two operations in the graphs are depicted as if they were concentrated in two peaks but in real operation the TX is performed periodically in the eclipse period and the SA rotation is linked to the sun path. However, for the purpose of EPS sizing analysis only the energy and power values are needed.

The SA provides power to the loads and to the storage system during the sunlight period. The power which is not used by the loads flows toward the battery and once it is fully charged it goes to the electrolyzer which converts the H2O filling the tanks of the reactants.

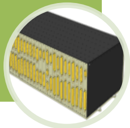


# SOLUTIONS DERIVING FROM MAIN DRIVERS

- EPS (Electrical Power Subsystem) copes with all the consumption modes of the module.
- It grant power to the external loads in line with the requirement
- EPS guarantees growing capability in terms of both internal and external power

## EPS

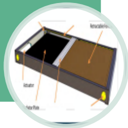


- The RFCS has to provide power during the exceptional long eclipse time
- Single stacks of FC and electrolyzer is implemented for both the use cases.
- The number of tanks depends on the energy request of on the single use case

## RFCS

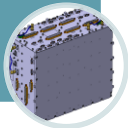
- Robust subsystem based on both well mastered technologies and with elements that allow improving system performances even though specific development is deemed necessary to achieve requested TRL.
- TCS guarantees that the equipment temperature range is respected.

## TCS



- DHS is based in the classical well proven configuration OBC + RTU. OBC embarks the intelligence on board and manages all the commands.
- The RTU distributes the commands and collects sensors data. It has a strong heritage recent program.

## DHS

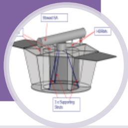


- The architecture is a fully redundant, flexible and modular design optimizing simplicity of equipment design and development.
- The S-Band section provides communications in all scenarios, including contingency.
- The K-Band section provides communications in nominal scenarios only, supporting high data rates both toward Earth and the Gateway

## TT&C

- ECSM primary structure is formed by Central Tube plus 6 shear panels, closed by top and bottom panel.
- The six shear panels have a trapezoidal shape and create six compartment inside the S/C.
- Two lateral panels are also introduced to accommodate the TT&C equipment's.
- The top panel has also function of radiator.

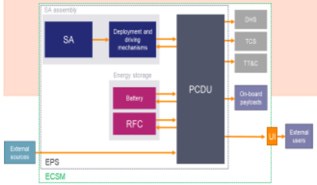
## Structure



# SYSTEM PERFORMANCES

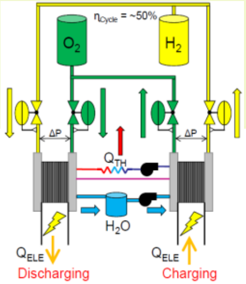
## EPS

- Maximum input from SA – 11.3 kW
- Maximum power output to the loads at 28 V - 1050 W
- Maximum output power to the electrolyzer – 1800 W
- Maximum input power from the FC – 2000 W
- Solar array power generation - 10.0 kW (EOL @213 W/m2)
- SARA output torque 310 Nm
- Vertical deployment of the telescopic mast ~ 1 m
- Vertical deployment of the blankets ~ 16 m
- HDRM actuators 55,6 kN and 11,1 kN



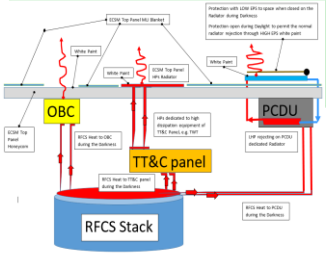

## RFCS

- FC operative voltage
  - 21V Astro-Sci / 22V PeakPwr
- Electrolyzer operative voltage
  - 50V Astro-Sci / 47V PeakPwr
- FC operative electrical power
  - 430W Astro-Sci/190W PeakPwr
- FC dissipated thermal power
  - 260W Astro-Sci / 90W PeakPwr
- Electrolyzer operative electrical power
- 800W Astro-Sci / 340W PeakPwr
- FC electrical energy capability
  - 185kW Astro-Sci / 64kW PeakPwr
- RFCS specific electrical energy
- 342kW/kg Astro-Sci / 227kW/kg PeakPwr



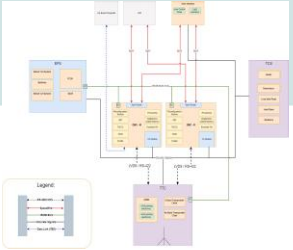

## TCS

- Astro-Sci power dissipation - 880 W in daylight and 145 W in Darkness.
- Daylight power rejection through a global radiator area of 4.35 [m2].
- Usage of heat from RFCS (115 W)
- Peak-Pwr power dissipation: 839 W in daylight and 129 W in Darkness.
- Radiator sizing equal to the one for Astro-Sci
- During darkness usage of both RFCS heat power (72 W) and heaters (58 W).



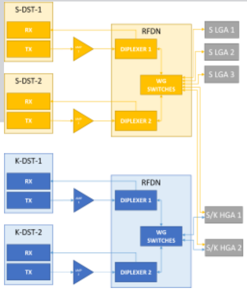

## DHS

- Main OBC: IPAC Plus – Leon 4 quad-core
- Co-Processor (Navigation Board) : Teledyne Qormino, 10000 DMIPS
- Storage capability: up to 2 Tbit (with dedicated board), or up to 500 Gbit (platform storage)



## TT&C

- DTE Downlink/S-Band/LGA
  - Link Margin 9.74db
- DTE Uplink/S-Band/LGA
  - Link Margin 19.63db
- DTE Downlink/K-Band/HGA
  - Link Margin 10.54db
- Proximity forward/S-Band/LGA
  - Link Margin 3.45db
- Proximity return/S-Band/LGA
  - Link Margin 3,10db
- Proximity forward/S-Band/HGA
  - Link Margin 17,46db
- Proximity return/S-Band/HGA
  - Link Margin 7,11db
- Proximity forward/K-Band/ GA
  - Link Margin 5,65db
- Proximity return/K-Band/HGA
  - Link Margin 6,09db



# ECSM BUDGET - MASS

***Mass***

The total mass budget of ECSM is:

- AstroSci configuration - 1594 kg including 18% margin (resulting from margin policy applied to each individual items)
- PeakPwr - 1551 kg including 17% margin (resulting from margin policy applied to each individual items)

- *ECSM-SYS-REQ-0290 - ECSM Dry mass shall not exceed 1.5 ton TBC*

| ECSM - AstroSci - Mass Budget | | | |
|---|---|---|---|
| Platform | Without margin [Kg] | Margin [%] | Including margin [Kg] |
| Electrical Power SubSystem | 294 | 18% | 346 |
| Data Handling System | 12 | 20% | 14 |
| TTC | 94 | 12% | 105 |
| Thermal Control System | 78 | 20% | 94 |
| RFCS | 387 | 16% | 450 |
| Structure | 258 | 20% | 309 |
| Subsystem USER-IF-SS | 8 | 20% | 9 |
| Total mass without system margins | 1130 | 18% | 1328 |
| Total mass including all margins | | | 1594 |

| ECSM - PeakPWR - Mass Budget | | | |
|---|---|---|---|
| Platform | Without margin [Kg] | Margin [%] | Including margin [Kg] |
| Electrical Power SubSystem | 464 | 15% | 533 |
| Data Handling System | 12 | 20% | 14 |
| TTC | 94 | 12% | 105 |
| Thermal Control System | 78 | 20% | 94 |
| RFCS | 200 | 17% | 234 |
| Structure | 258 | 20% | 309 |
| Subsystem USER-IF-SS | 8 | 20% | 9 |
| Total mass without system margins | 1107 | 17% | 1292 |
| Total mass including all margins | | | 1551 |

# ECSM BUDGET - POWER

***Power***

The Power subsystem provides about **9 kW** continuous power in both scenarios (in sunlight conditions) considering the 20% system margin.

Specifically for PeakPwr the EPS provides more mode than **17 kW** for a duration not exceeding the specified **3 hours** (in sunlight conditions). Both Solar Array and Battery are used simultaneously as ECSM power sources during peak power mode

| ECSM - AstroSci - Power Budget | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Power Source | | CRUISE-LANDING<br>LDE | DEPLOYMENT<br>Battery | COMM.<br>Solar Array | ECLIPSE-SURV<br>RFCS | ECLIPSE-TX<br>RFCS | ECLIPSE-SAROT<br>RFCS | DAYLIGHT-STANDBY<br>Solar Array | DAYLIGHT<br>Solar Array | DAYLIGHT-TX<br>Solar Array |
| Platform including margin | W | 109 | 482 | 985 | 243 | 320 | 285 | 864 | 864 | 1027 |
| User I/F including margin | W | 0 | 0 | 0 | 6 | 6 | 6 | 6 | 185 | 185 |
| EXT User | W | 0 | 0 | 0 | 260 | 260 | 260 | 0 | 7700 | 7700 |
| TOT Power inclufding margi | W | 109 | 482 | 985 | 509 | 586 | 551 | 870 | 8749 | 8911 |

| ECSM - PeakPwr - Power Budget | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Power Source | | CRUISE-LANDING<br>LDE | DEPLOYMENT<br>Battery | COMM.<br>Solar Array | ECLIPSE-SURV<br>RFCS | ECLIPSE-TX<br>RFCS | ECLIPSE-SAROT<br>RFCS | DAYLIGHT-STANDBY<br>Solar Array | DAYLIGHT<br>Solar Array | DAYLIGHT-TX<br>Solar Array | PEAK-POWER<br>Solar Array / Battery |
| Platform including margin | W | 109 | 463 | 943 | 224 | 301 | 266 | 823 | 823 | 985 | 823 |
| User I/F including margin | W | 0 | 0 | 0 | 6 | 0 | 6 | 6 | 185 | 185 | 384 |
| EXT User | W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7700 | 7700 | 16000 |
| TOT Power inclufding margi | W | 109 | 463 | 943 | 230 | 301 | 272 | 829 | 8708 | 8870 | 17207 |

# MODEL PHYLOSOPY AND VERIFICATION APPROACH

## SW Validation Facility (SVF)

The SVF will provide a testbed to validate the OBSW without the real HW in the loop.

it will be composed of a Functional Model of the On-Board computer plus simulators of all the users coming from the platform and the payload.

## Avionics Test Bench (ATB)

The ATB will provide a testbed to validate by test the electrical design of the Spacecraft, its operational and functional interfaces, the system functions including on-board software, system database, and the constellation interconnection links.

The ATB will be representative of the flight units in terms of electrical and functional interface, and it will support the flight On Board SW.

The units integrated on ATB will be typically EM (Engineering Model) or FUMO (Functional Model)

## Structural Thermal Model (STM)

The STM will subject to a full mechanical and thermal qualification campaign to validate the mechanical analysis and to correlate the thermal model of the Spacecraft.

The STM will be "Flight-like" in terms of mechanical capabilities, and it will include STM of all platform and payload elements: structures, harness, and units

## Proto Flight Model (PFM)

In this proposed scenario, the structural model will be refurbished after the mechanical qualification and reconverted to become the proto-flight model (PFM).

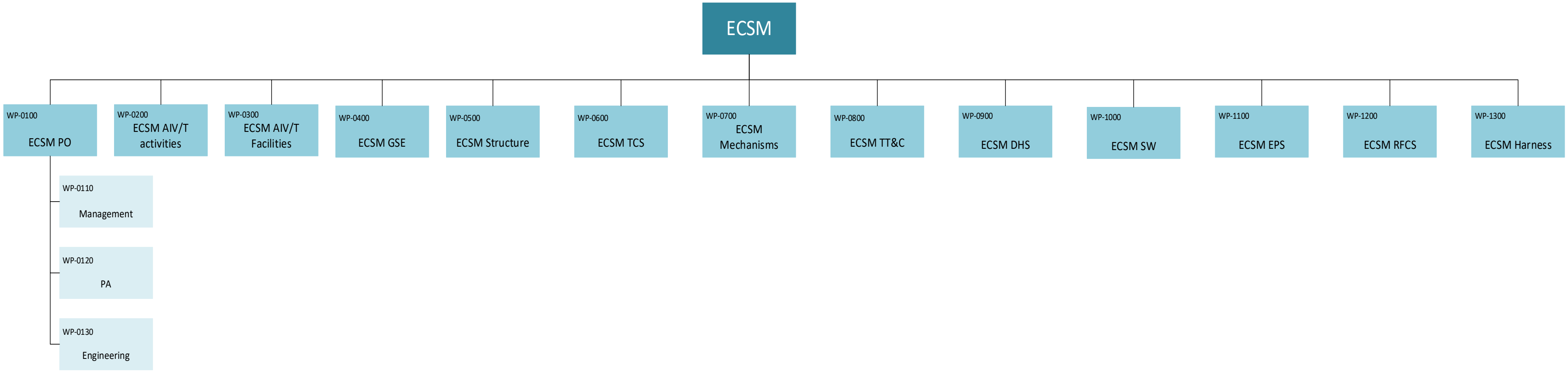
This solution was implemented for several satellite (e.g. GOCE), optimizing cost and schedule

# WORK BREAKDOWN STRUCTURE

**Compact Team focused to Prime activities**
Lean organization limiting the number of layers

**6 Subsystems**
- Electrical Power System
- RFCS
- Thermal Control System
- TT&C
- Structure
- Data Handling System

**The WBS is structured according to the Product Tree.**
This gives full visibility on the activities covered by Core.



# SCHEDULE

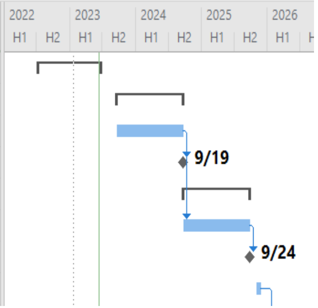
**The project phases occurring before the Industrial Implementation as supposed on the bases of other projects managed by TAS-I:**

- Start of Definition Phase (A/B1) in Sept 2023 (after formal Kick-off)
- Start of Implementation Phase (B2, C/D) in January 2026 (after CMIN25 and approval)

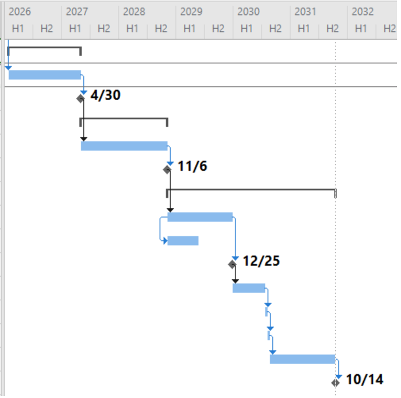
**The ECSM project is assumed to proceed through the following phases and reviews:**

- Phase A 12 months from KO to PRR
- Phase B1 12 months from PRR to SRR
- Q3&Q4 2025 Proposal preparation, CMIN25, negotiation, B2 KO preparation
- Phase B2 16 months from B2 KO to PDR
- Phase C 18 months from C/D KO to CDR
- Phase D 36 months including support to Qualification test campaign at RLS level
  - D1 one from CDR to ECSM Delivery (14 months)
  - D2 from QR to ECMS-FAR (16 months)
- Contingency 6 months
- Phase E Not requested

| Task Name | Duration | Start | Finish |
|---|---|---|---|
| **Phase 0** | **252 days** | **Thu 7/7/22** | **Fri 6/23/23** |
| **Phase A** | **264 days** | **Mon 9/18/23** | **Thu 9/19/24** |
| Phase A | 264 days | Mon 9/18/23 | Thu 9/19/24 |
| PRR | 0 days | Thu 9/19/24 | Thu 9/19/24 |
| **Phase B1** | **264 days** | **Fri 9/20/24** | **Wed 9/24/25** |
| Phase B1 | 264 days | Fri 9/20/24 | Wed 9/24/25 |
| SRR | 0 days | Wed 9/24/25 | Wed 9/24/25 |
| CMIN25 | 20 days | Mon 11/3/25 | Fri 11/28/25 |




| Task Name | Duration | Start | Finish |
|---|---|---|---|
| **Phase B2** | **330 days** | **Mon 1/26/26** | **Fri 4/30/27** |
| Phase B2 | 330 days | Mon 1/26/26 | Fri 4/30/27 |
| PDR | 0 days | Fri 4/30/27 | Fri 4/30/27 |
| **Phase C** | **396 days** | **Mon 5/3/27** | **Mon 11/6/28** |
| Phase C | 396 days | Mon 5/3/27 | Mon 11/6/28 |
| CDR | 0 days | Mon 11/6/28 | Mon 11/6/28 |
| **Phase D** | **766 days** | **Tue 11/7/28** | **Tue 10/14/31** |
| Phase D task-1 | 296 days | Tue 11/7/28 | Tue 12/25/29 |
| STM Ref. | 142 days | Tue 11/7/28 | Wed 5/23/29 |
| QR (Module CTS) | 0 days | Tue 12/25/29 | Tue 12/25/29 |
| Contingency | 150 days | Wed 12/26/29 | Tue 7/23/30 |
| ECSM shipment | 10 days | Wed 7/24/30 | Tue 8/6/30 |
| RLS integration | 10 days | Wed 8/7/30 | Tue 8/20/30 |
| Phase D task-2 | 300 days | Wed 8/21/30 | Tue 10/14/31 |
| FAR | 0 days | Tue 10/14/31 | Tue 10/14/31 |




# COMMERCIALIZATION

## Business Plan

The establishment of permanent human activities on the Moon is envisaged as a stepping stone for future space exploration and for the expansion of mankind in the solar system.

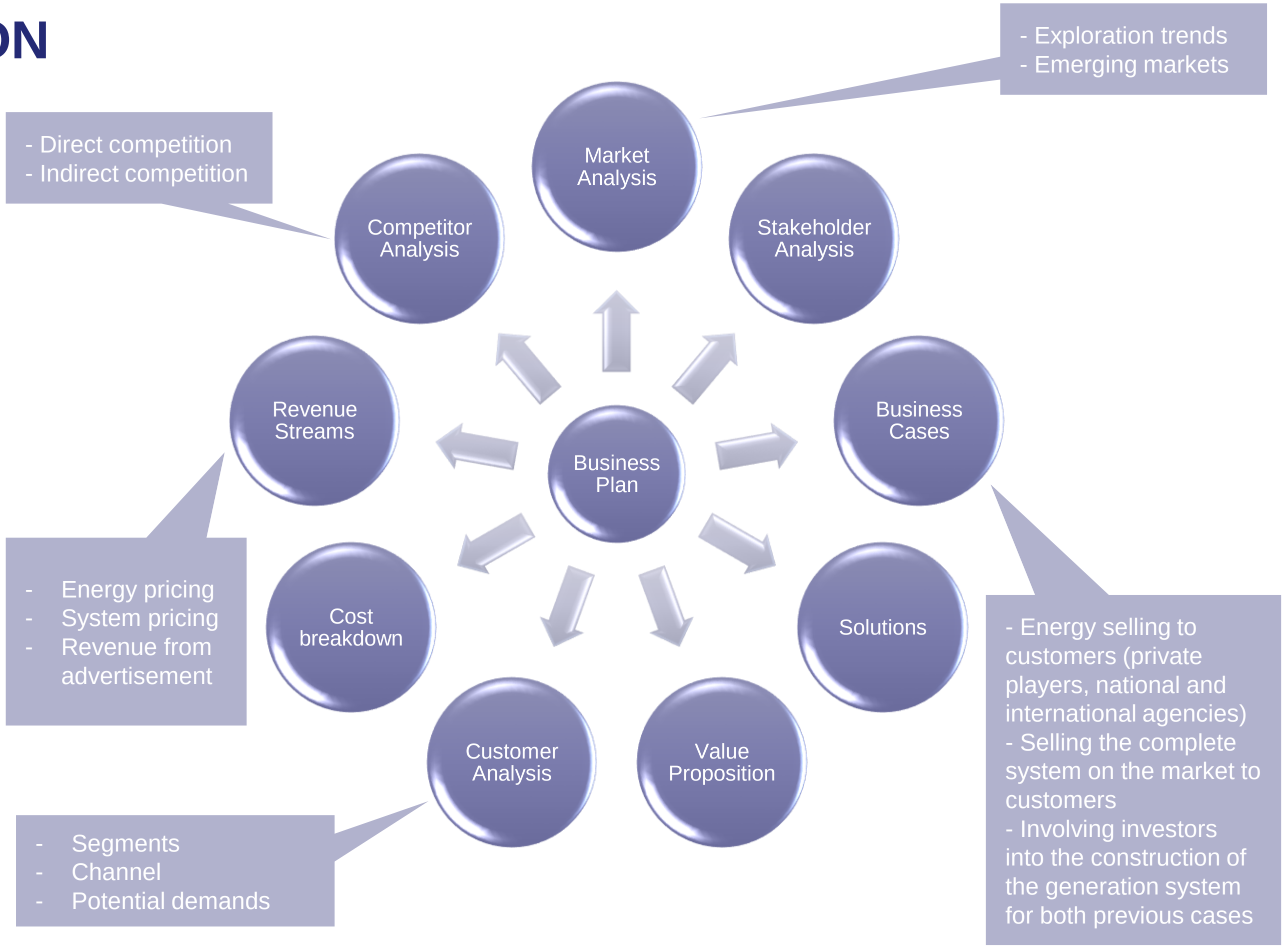
Besides the technical opportunity there is also an important business opportunity considering the different business models built around the following main features:

- Build, own, operate, and maintain the system and sell EV recharging services to customers (private players, national and international agencies)

- Build and sell the system, possibly along with O&M services, to customers

- Build and lease the system to customers (private players, national and international agencies)

All business models could be applied to ventures that involve, or do not involve, third party investors in their relative financial structures.



# LOG OF CHANGES AND APPROVAL

| Révisions | Log of change - Description | Date |
|---|---|---|
| 001 | First Issue | 27 June 2023 |
| | | |
| | | |
| | | |

| Actors | Approval - Name and role | Date |
|---|---|---|
| Written by | P. Morsaniga | 27 June 2023 |
| Verified by | G. Gervasio | 27 June 2023 |
| Approved by | P. Morsaniga | 27 June 2023 |