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AIM
(All In Moon)

MBSE Hackathon
2022

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Table of Content

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Introduction

- A robotic assistant assists human operations on lunar surface.
- Problem Statement: Create a system (Robotic Assessment) with capabilities to support the astronauts on lunar surface using MBSE approach (Arcadia method).
- Approach:
  - The given stakeholder needs, and operational scenarios were studied.
  - Use case scenarios were made to understand the capabilities of robotic assistant needed.
  - Design as per sequence of operations

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Rules followed throughout the project

The basic rule of ARCADIA- the **problem space** (Operational analysis & System analysis), the **solution space** (Logical architecture and Physical architecture) is implemented.

The **stakeholder and system requirements** are taken into consideration during the problem space.

The **architecture diagrams** are maintained with a **consistent layout.**

The **functions and functional chains** have been named according to Capella rules.

At least **three diagrams** are modelled in each phase to **ensure completeness**.

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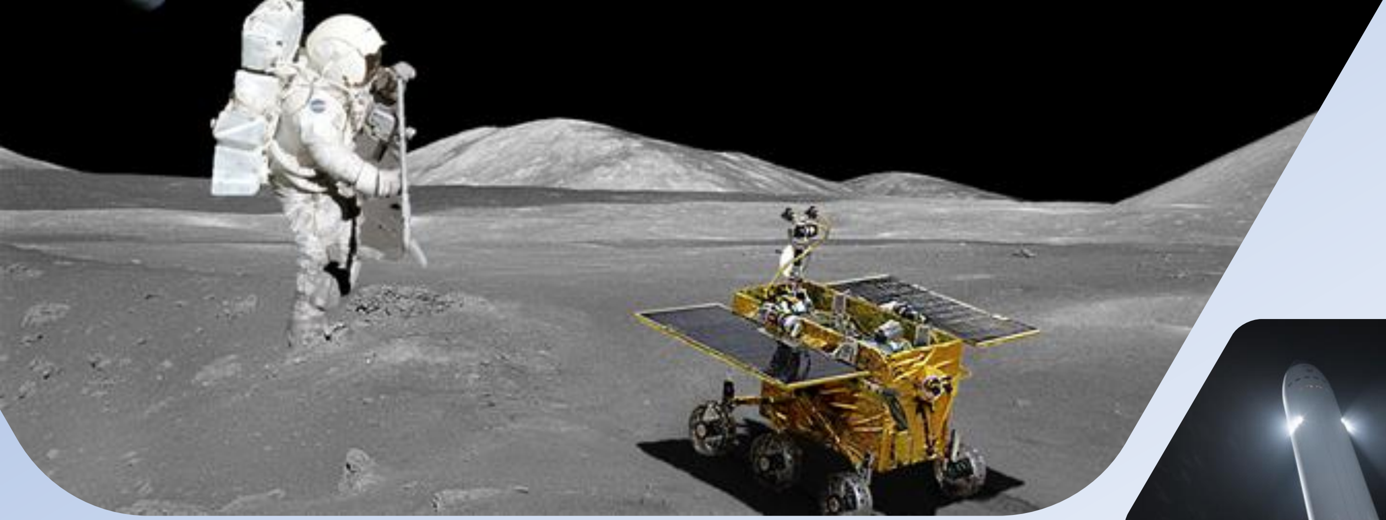
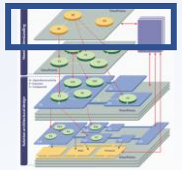


Operational Analysis



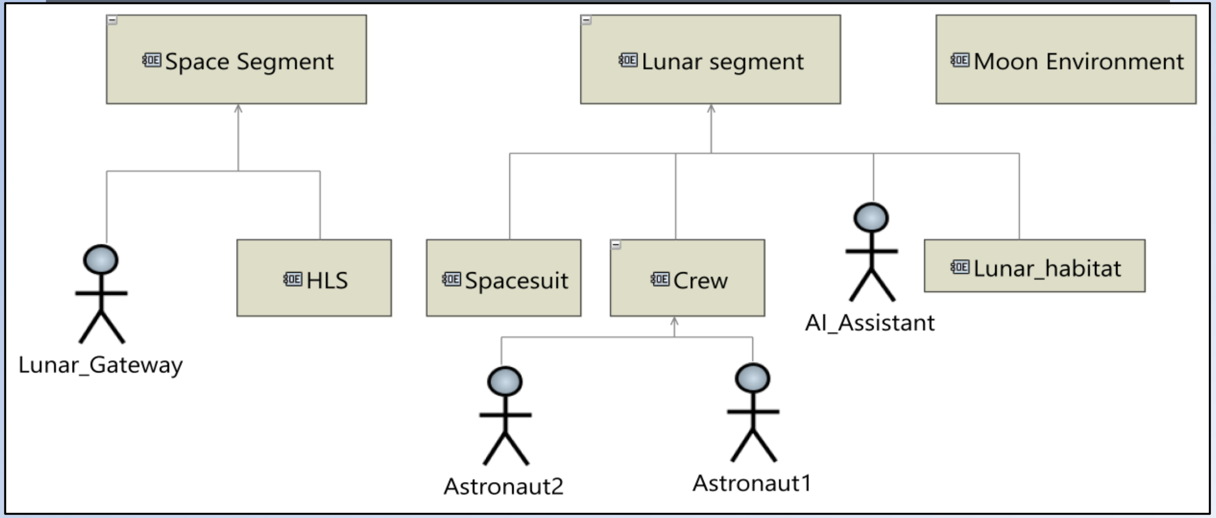
Assumptions

- The robot, moonlight constellation, Lunar gateway and the habitat are established in the Lunar environment. The upcoming human missions will be supported by these systems.

The story of our system

"The robot was eagerly waiting for its allies and after a long wait, a ***spaceship landed with astronauts****. To keep the astronauts safe, it dares to* ***explore alone and identifies the key spots*** *on the lunar surface for exploration. It then* ***supports the astronauts*** *in their investigations about the Lunar mysteries...."*

FIG. 1 - Actors and Entities



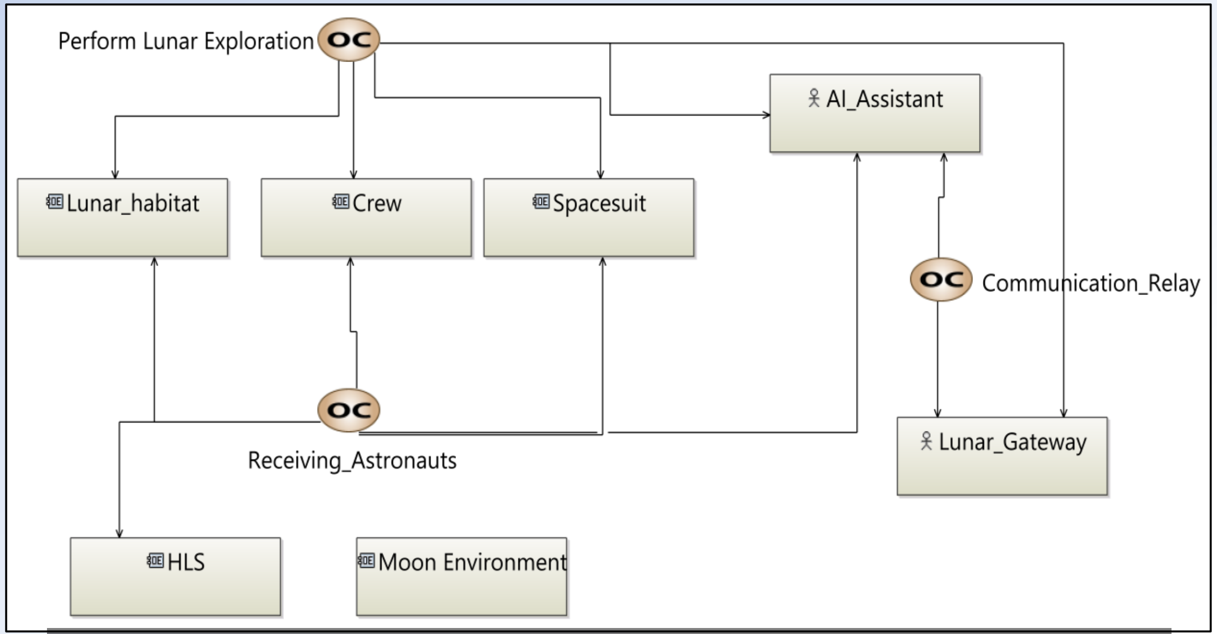


FIG. 2 - Operational Capabilities

Operational Analysis

Spaceship landed-

The capability identified is to guide the astronauts safely to Lunar habitat.

Explore alone and identifies the key spots-

The capability identified is that the rover to explore alone and share the data

Supports the astronauts-

The capability identified is that the rover should be accompany astronauts during exploration

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Operational Analysis: Exchange Scenarios

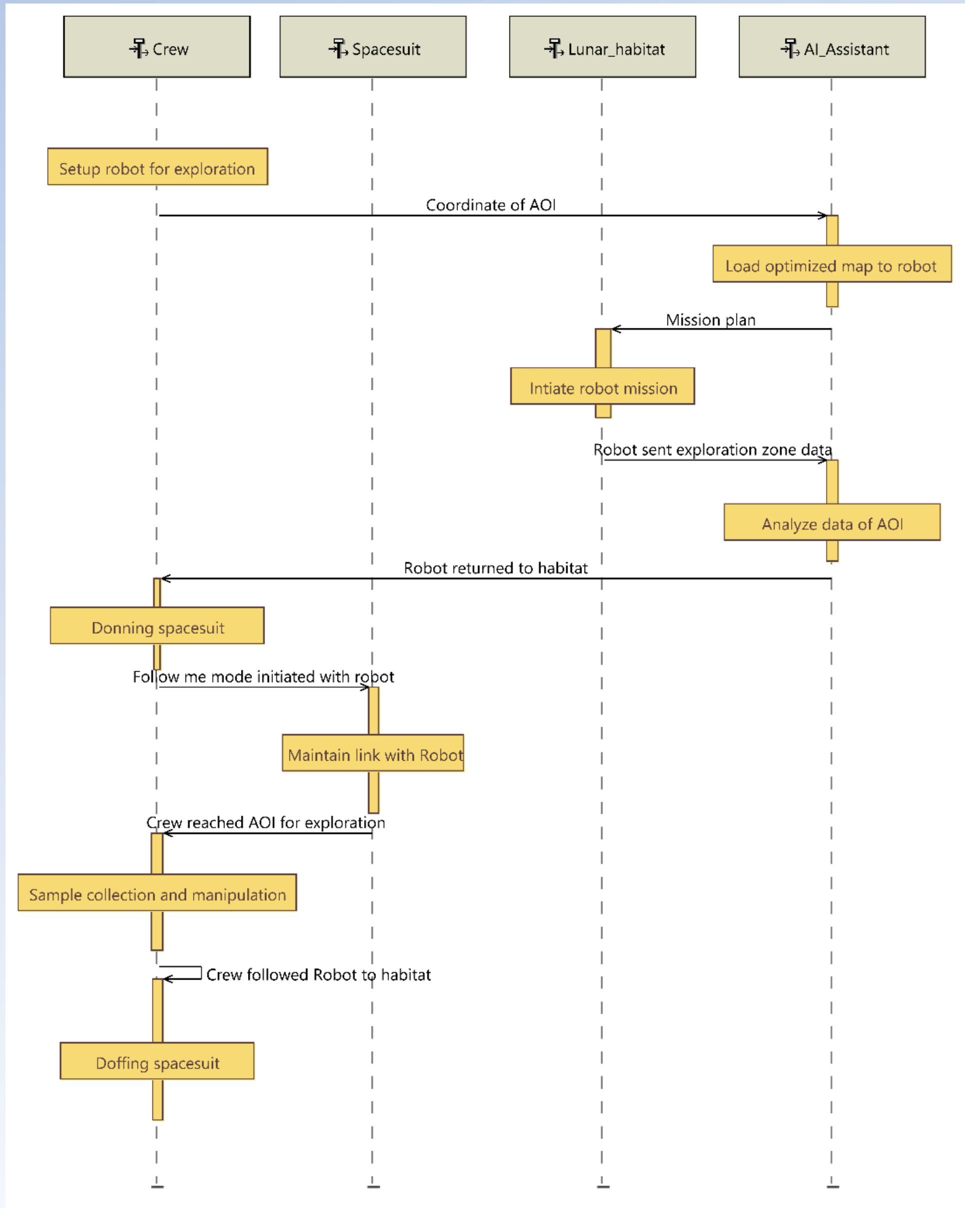


FIG. 3: Exchange Scenario of Exploration capability

The exchange scenarios models in operational analysis provides a sequence of events between various **entities** for each capability.

The Fig.3 is made to describe the overall view that will transpire when the capability- ***'Exploration'*** will be active.

The Interaction here is between *Crew, Spacesuit, Lunar Habitat and AI_assitant.*

The same was replicated for other operational capabilities.

Operational Analysis: Complete Architecture

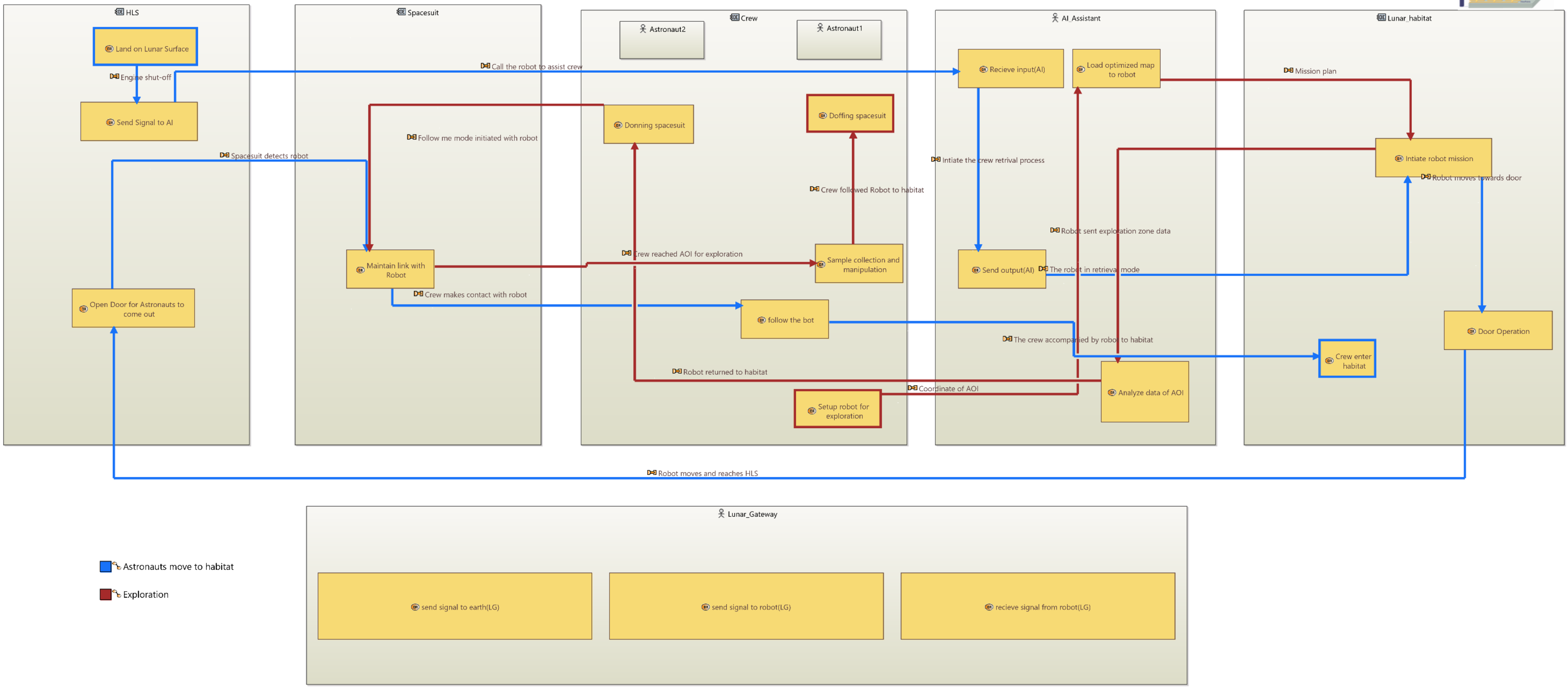


FIG. 4 - Operational Architecture

System Analysis

- The 3 main capabilities described earlier are decomposed in this step into 7 capabilities.
- Missions share common capabilities.

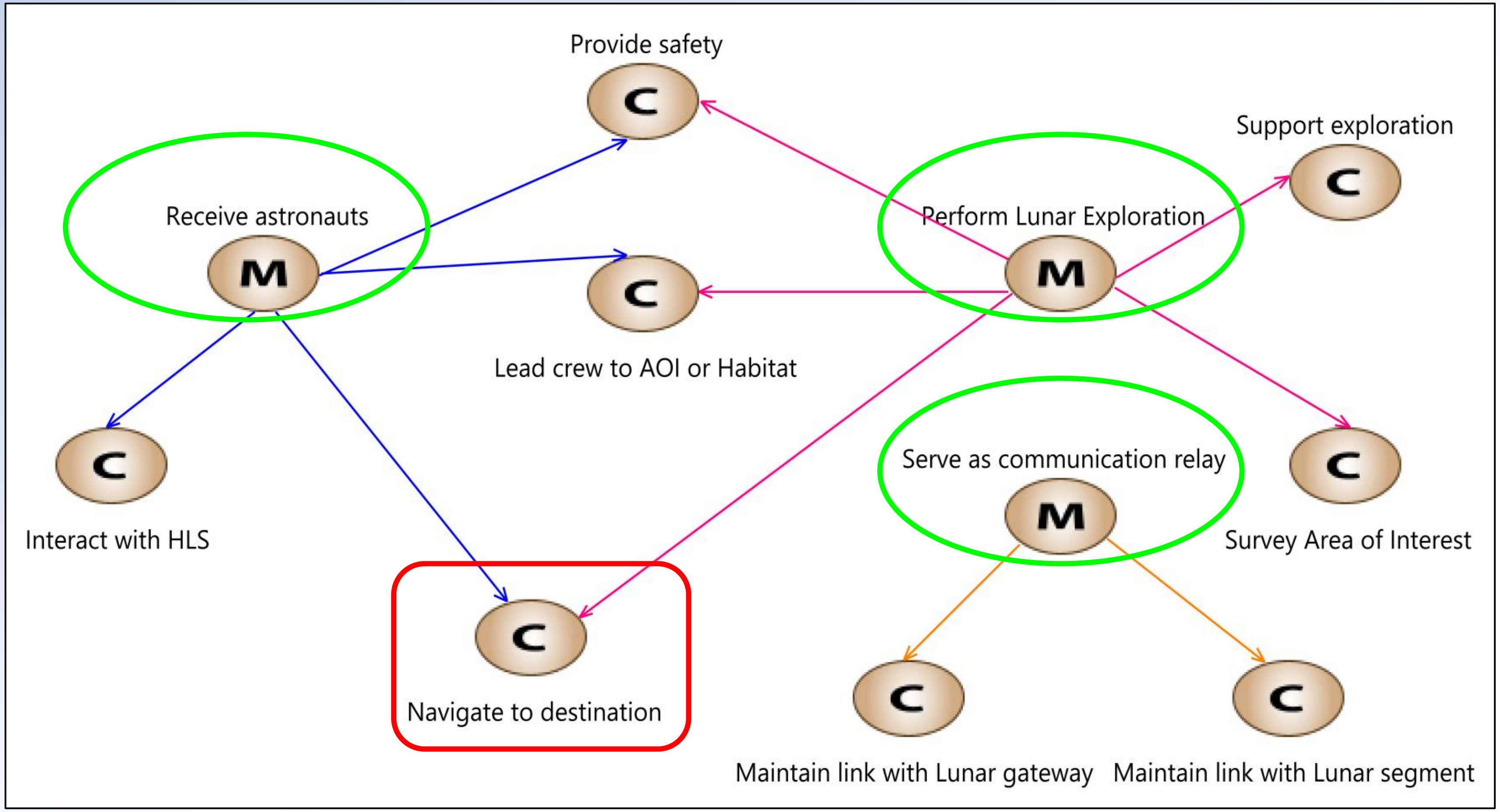
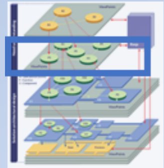


FIG. 5– Mission and associated capabilities

Example:

System Architecture of Navigation



- Navigation is responsible for the system to reach a designated destination
- The system interacts closely with the following:

1. *Crew*- Decides the destination to be searched.
2. *AI_assistant*- feeds the destination coordinates into the system.
3. *Lunar_habitat*- It physically makes it feasible for the rover to commence the mission.

The system (robot) itself avoids **obstacles** and navigates through the terrain.

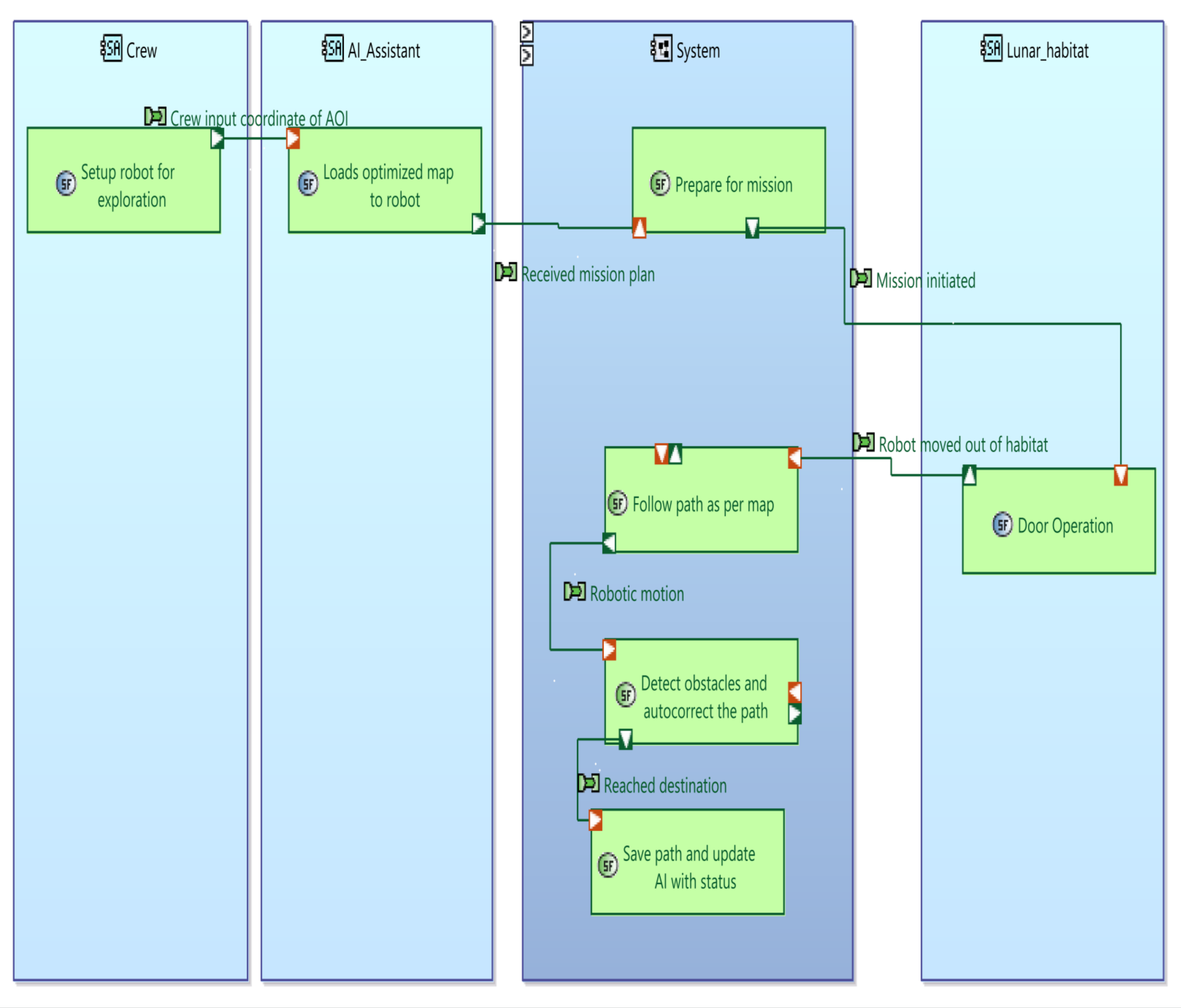


FIG. 7- System architecture for Navigation

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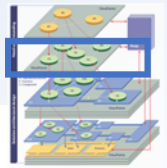
System analysis: Complete Architecture



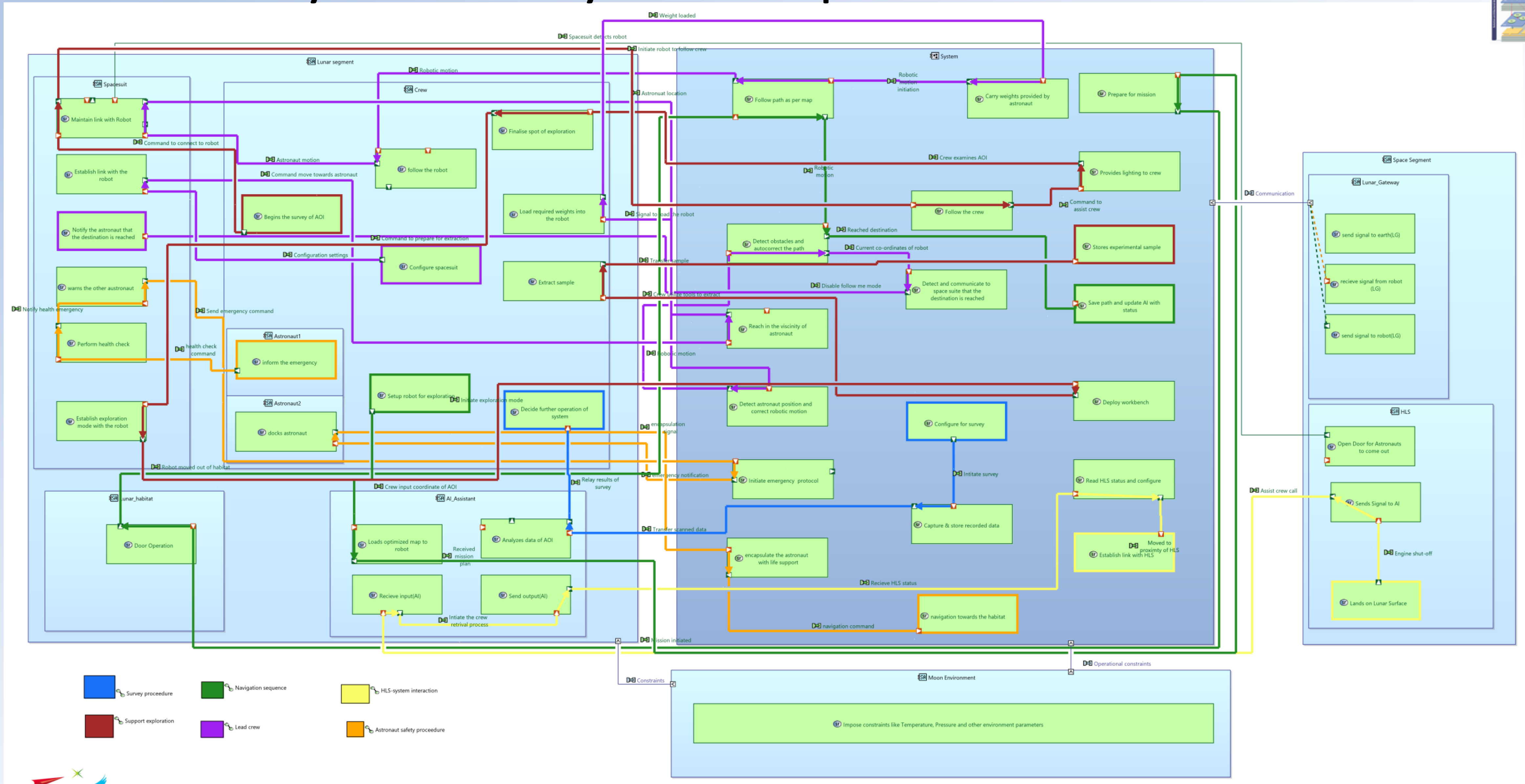


FIG. 8 – System Architecture view

Requirements Analysis

- The stakeholder requirements were derived from the needs given in the subject of hackathon.
- One stakeholder requirement corresponds to the constraints imposed by the lunar environment (STK-R8).
- These requirements were further broken down into the system requirements
- Constraints imposed by lunar environment were also elaborated on in the systems requirements.
- Traceability was established between the stakeholder and system requirements.
- These system requirements were allocated to the logical/behavioral components of the system during the logical architecture analysis.

Requirements analysis

Id	Stakeholder Requirement
STK-R1	The Robotic assistant shall carry heavloads
STK-R2	The Robotic assistant shall map the terrain
STK-R3	The Robotic assistant shall Support EVA exploration with a “follow-me” feature
STK-R4	The Robotic assistant shall serve as workbench to help in manipulation of samples, access of tools, and usage of instruments
STK-R5	The Robotic assistant shall carry an incapacitated astronaut
STK-R6	The Robotic assistant shall serve as a communication relay
STK-R7	The Robotic assistant shall provide light
STK-R8	The Robotic assistant shall function in the lunar environment

Refines

Satisfies

Id	System Requirement	Allocated logical component	Linked stakeholder requirement
SysR-1	The system shall carry weights upto 33N.	Structure	STK-R1
SysR-2	The system shall move over surfaces with slope of atmost 30 degrees	Drive unit, Navigation and	STK-R8
SysR-3	The system shall operate within the temperature range of 50K-400K	All components	STK-R8
SysR-4	The system shall protect itself from solar regolith.	All components	STK-R8
SysR-5	The system shall move over an obstacle of the size of 30cm atmost.	Drive unit, Navigation and	STK-R8
SysR-6	The system shall at all times have a battery level of (battery level needed for 14 days of eclipse+ 30% of the total battery level)	Power unit	STK-R8
SysR-7	The system shall move to and fro any exploration location provided by the astronaut atleast 20 km away from the lunar base.	Drive unit, Navigation and	STK-R2
SysR-8	The system shall communicate with the lunar base from atmost distance of 50km.	Communication	STK-R6
SysR-9	The system shall provide workbench of atleast 45x45 cm to facilitate sample manipulation.	Workbench	STK-R4
SysR-10	The system shall provide a platform with length of atleast 250cm for an average male astronaut to lie down on it.	Human safety unit	STK-R5
SysR-11	The system shall always have atleast 800 grams of auxillary oxygen supply.	Human safety unit	STK-R5
SysR-12	The system shall survey atleast 100m of radius around the survey point.	Surveillence unit	STK-R2
SysR-13	The system shall act as a communication relay between the lunar habitat and lunar gateway.	Communication	STK-R6
SysR-14	While in "follow me mode" the system shall maintain atmost 10m of distance with the astronaunt.	Surveillence unit,	STK-R3
SysR-15	The system shall detect its own position with respect to the defined destination while in motion.	Surveillence unit	STK-R2
SysR-16	The system shall detect the positions of target objects i.e, the astronaut and the HLS when needed.	Surveillence unit	STK-R2
SysR-17	The system shall detect obstacles of size 5cm atleast.	Surveillence unit	STK-R8
SysR-18	The system shall provide lighting to the entire workbench area for sample manipulation.	Lighting unit	STK-R7

Requirements analysis

STK-R5	The Robotic assistant shall carry an incapacitated astronaut

Refines

SysR-11	The system shall always have atleast 800 grams of auxillary oxygen supply.	Human safety unit	STK-R5

Logical Architecture

The scenarios derived from the system analysis are assigned with logical components.

In this stage, various system functions were broken down in terms of **how** they can be achieved by the model in different scenarios.

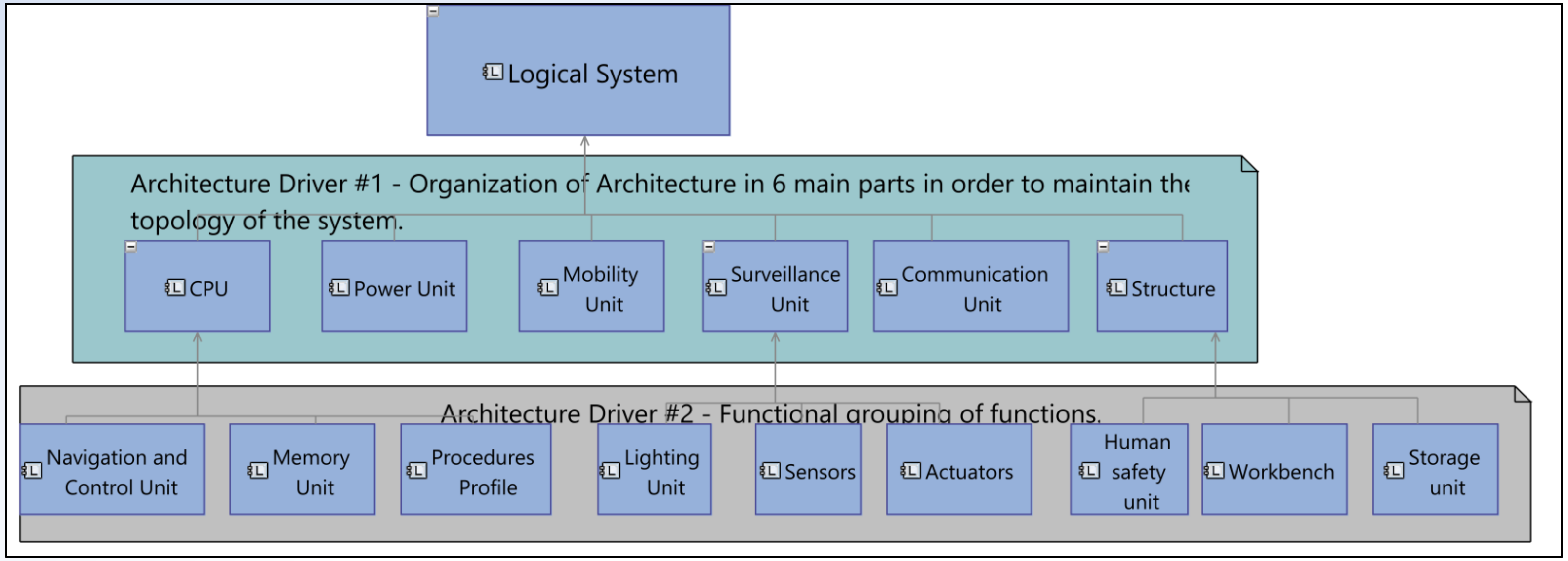
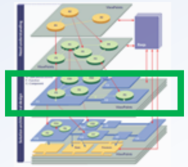


FIG.9 - Logical Component Breakdown Diagram

Logical Architecture of Navigation scenario



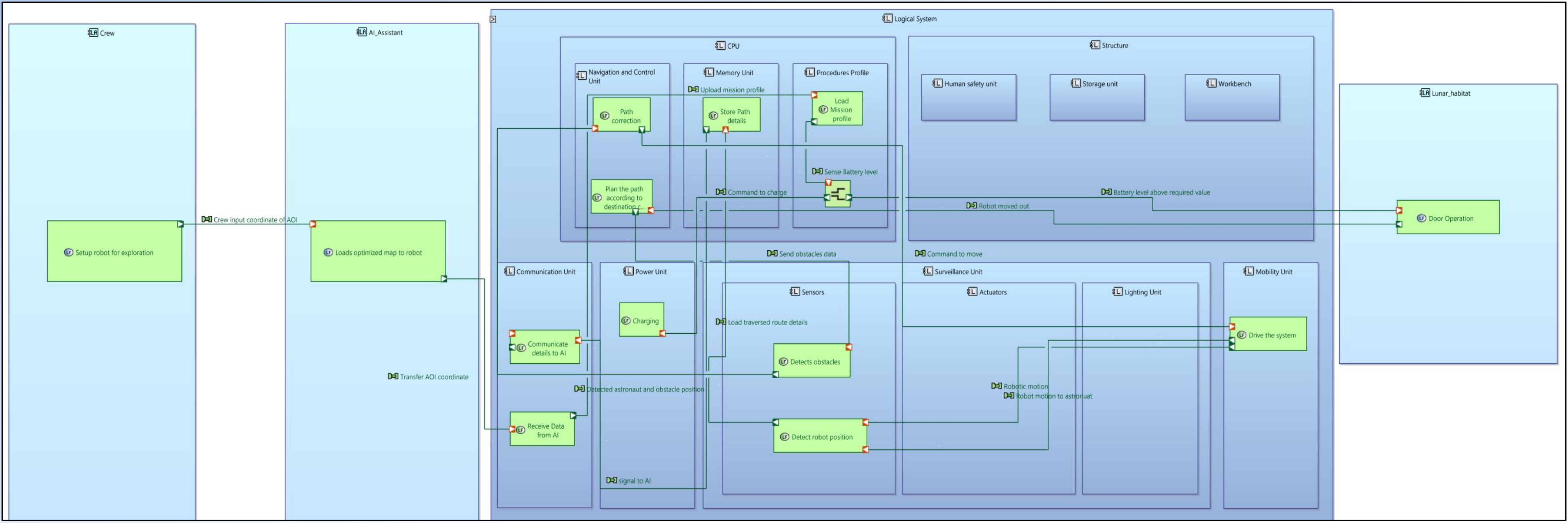
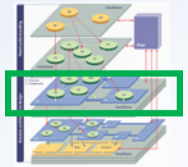


FIG. 10 - Logical Architecture view of Navigation

Complete Logical Architecture



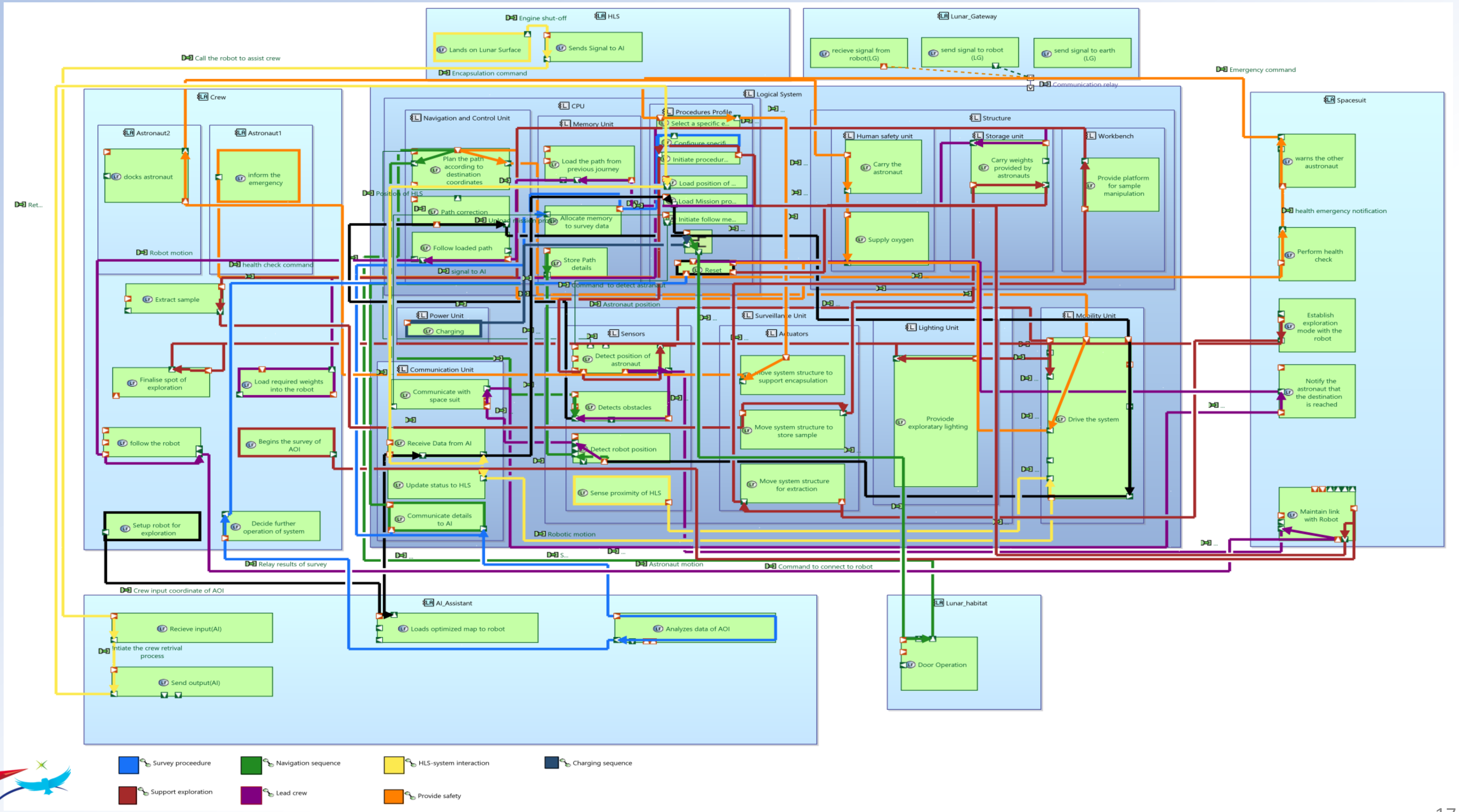


FIG. 11- Complete Logical Architecture

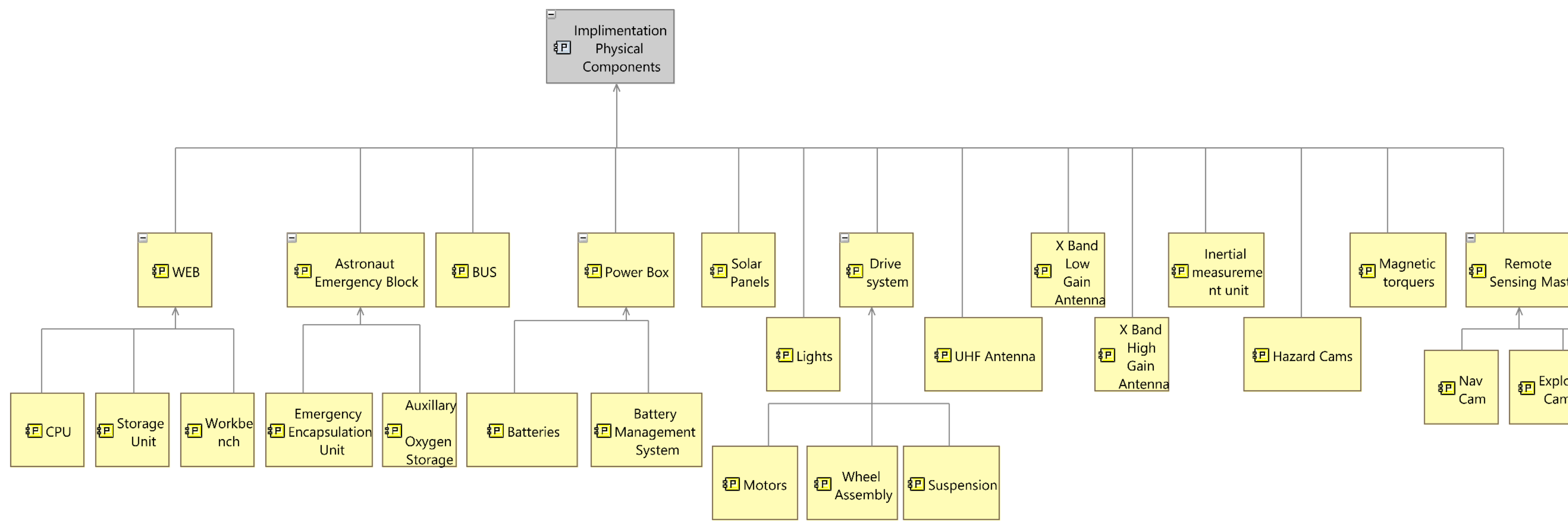


FIG. 12- Physical component breakdown

Physical Architecture

- Physical Analysis is performed with the same intent of logical architecture, except it defines the "final" architecture of the system to be developed.
- New Behavioral components and Implementational physical components are modelled.

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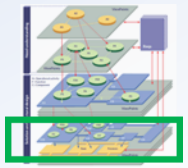
Physical Architecture – Build and Physical links



- The template of the logical architecture is utilized to have a consistency in the architecture diagrams.

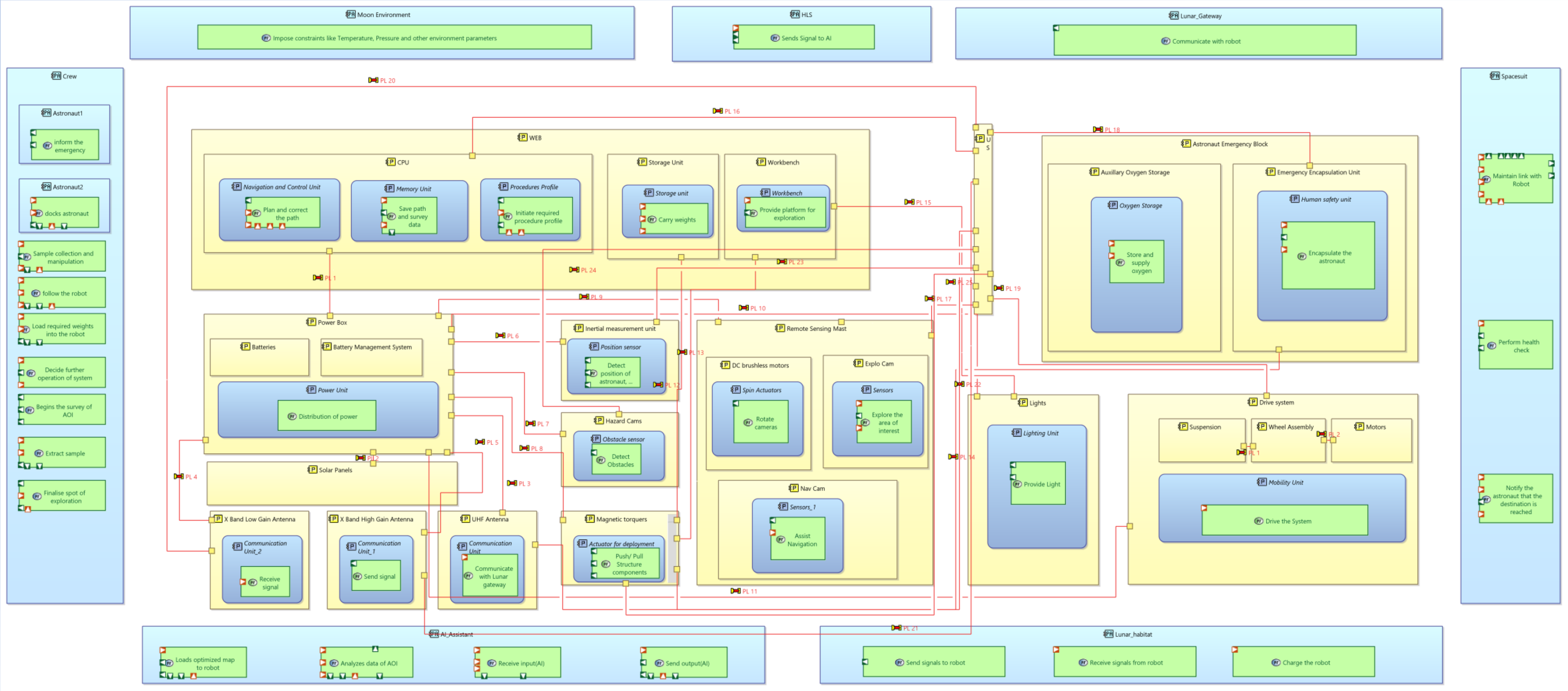


FIG. 13- Physical architecture with functions and physical links

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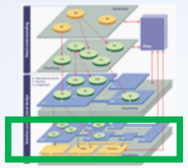
Complete Physical Architecture



- This diagram represents the physical links between all the implementation components and functional interactions between all the behavioral components of the system and the actors.

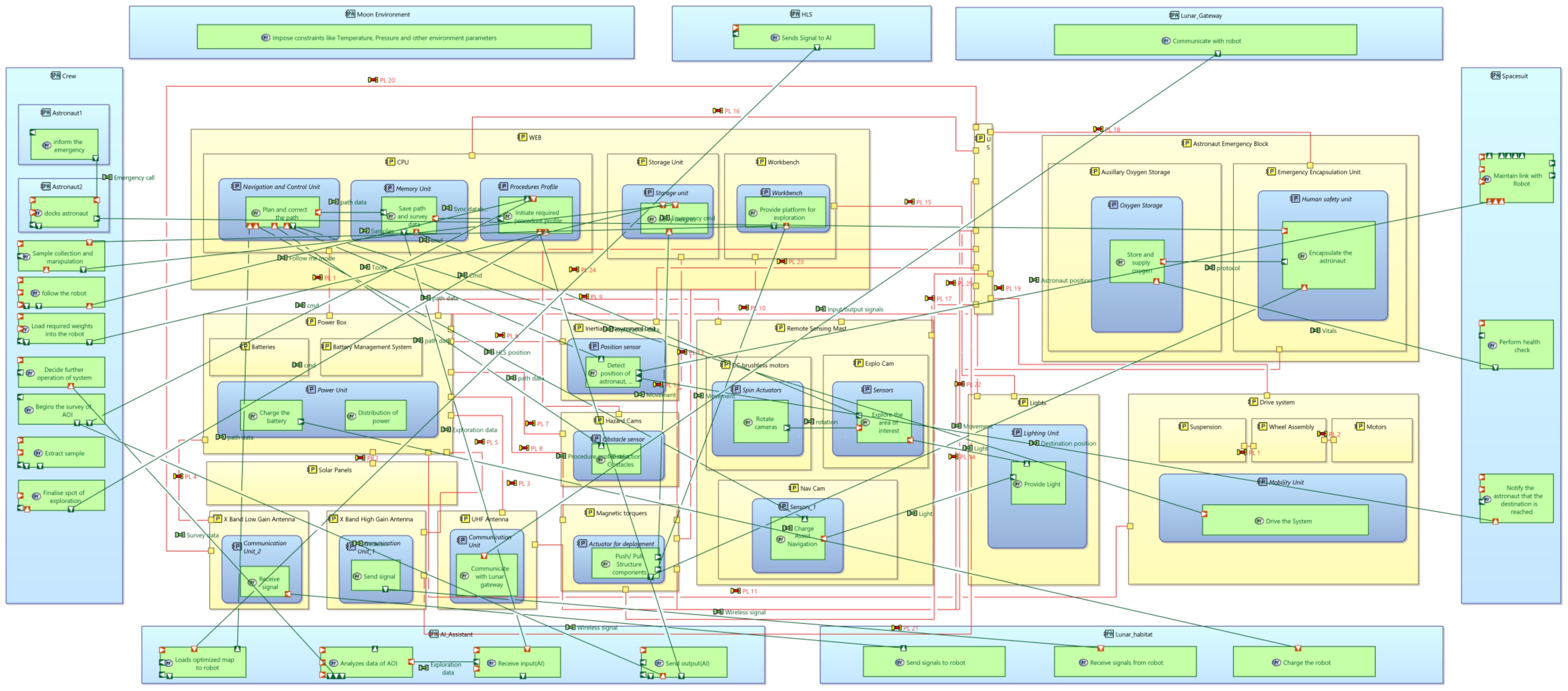


FIG. 14- Complete Physical Architecture

3D Model

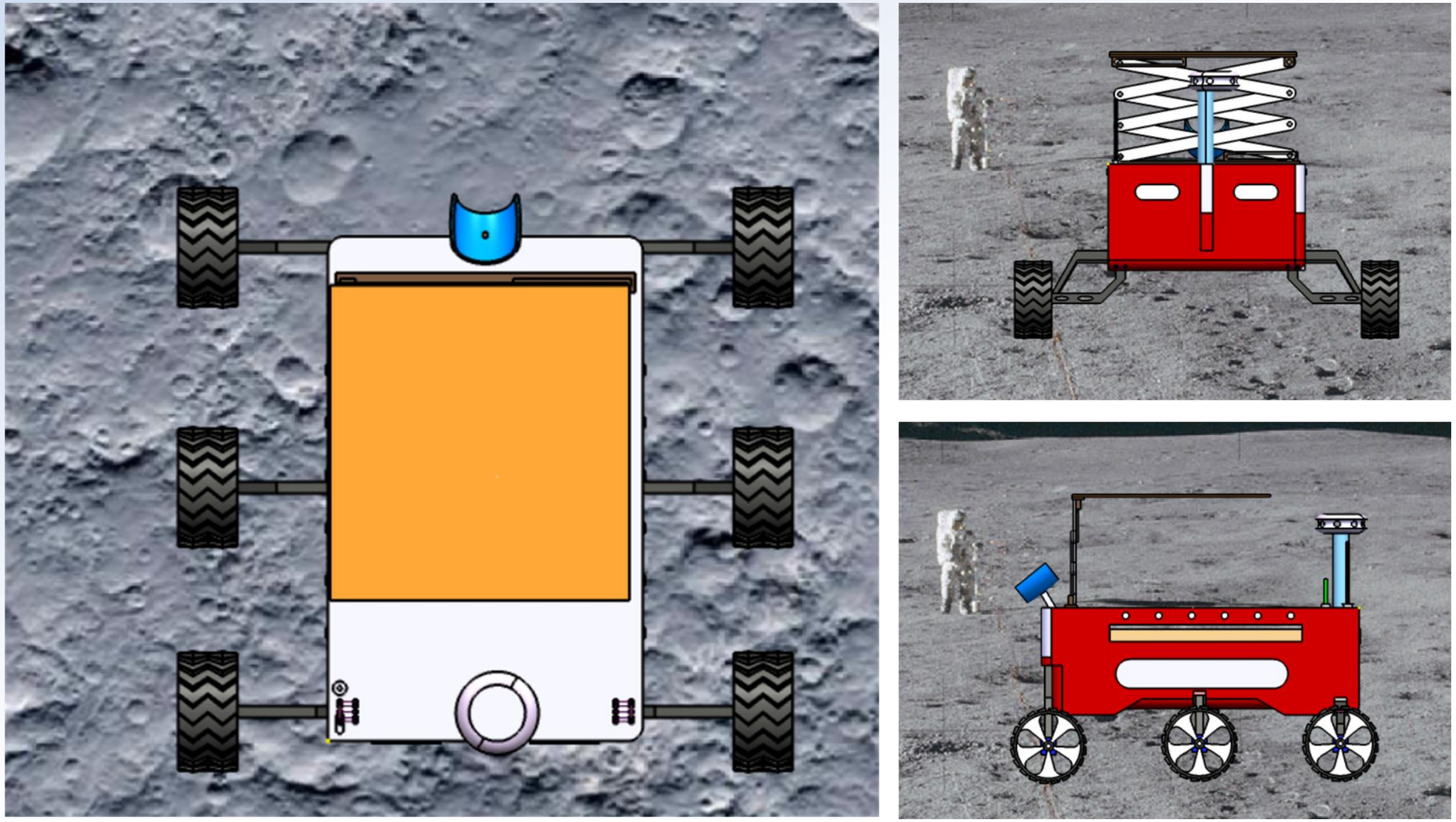


FIG. 15- 3D model of Robotic assistant

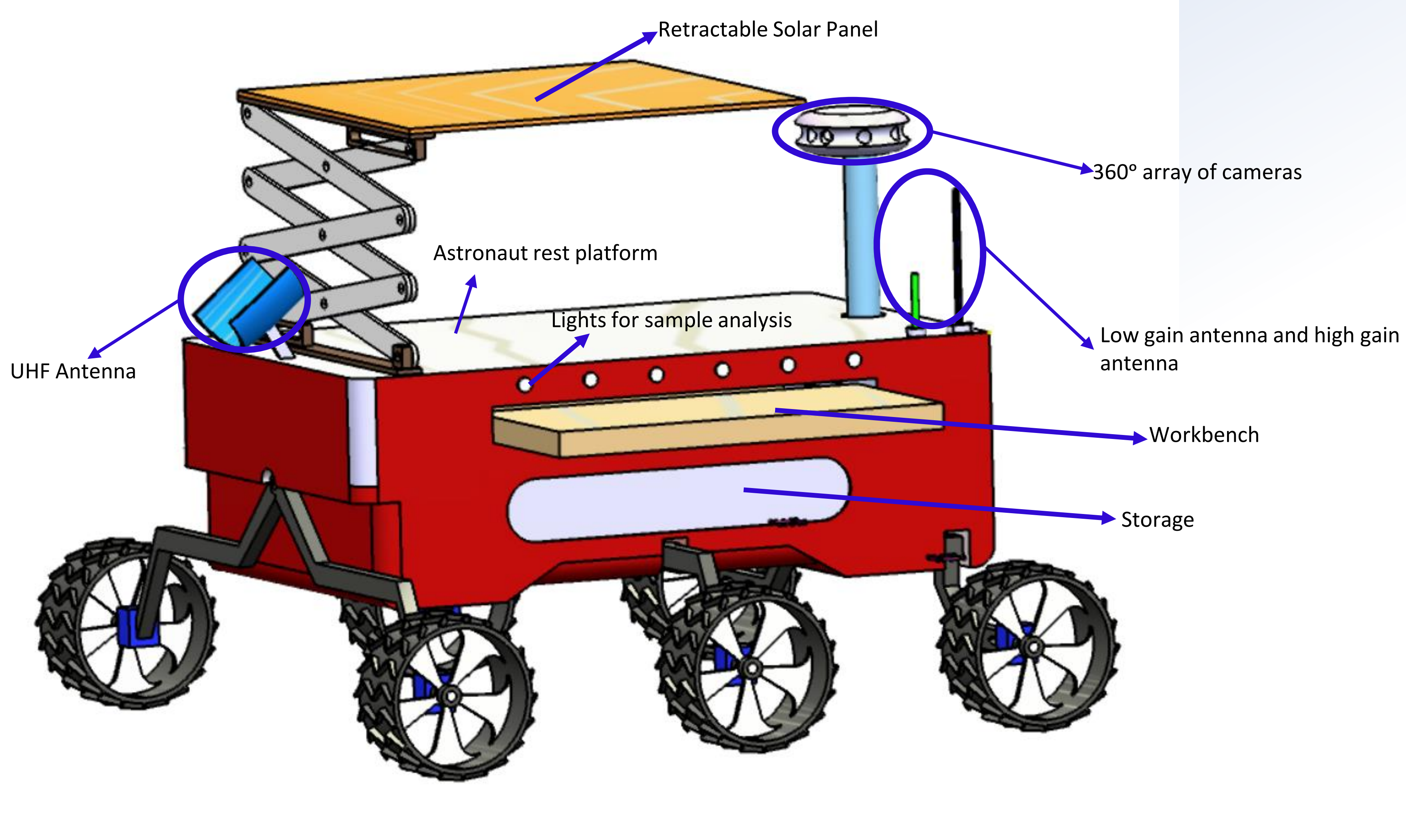


FIG. 16- Component description

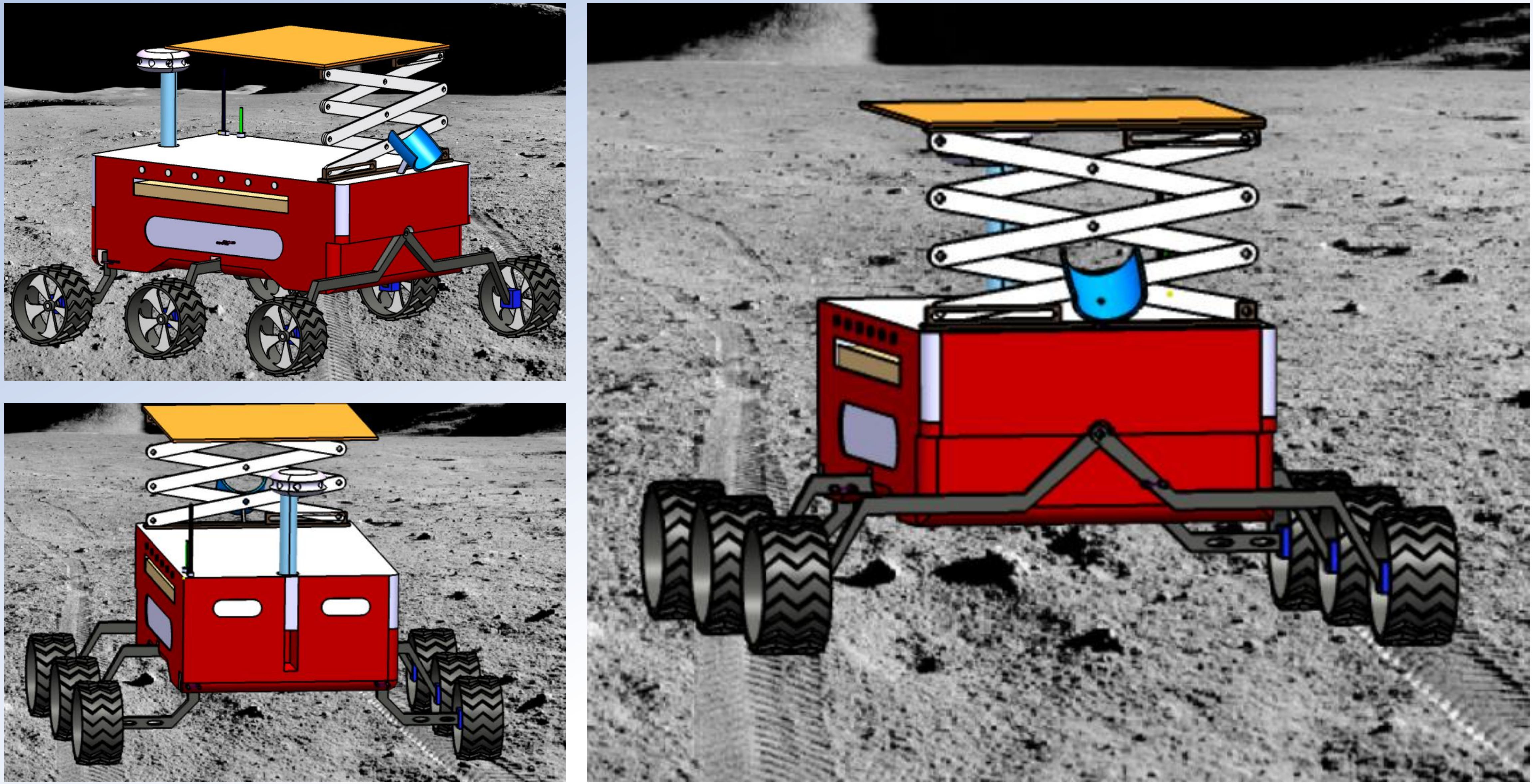


FIG. 17- Alternate views of model

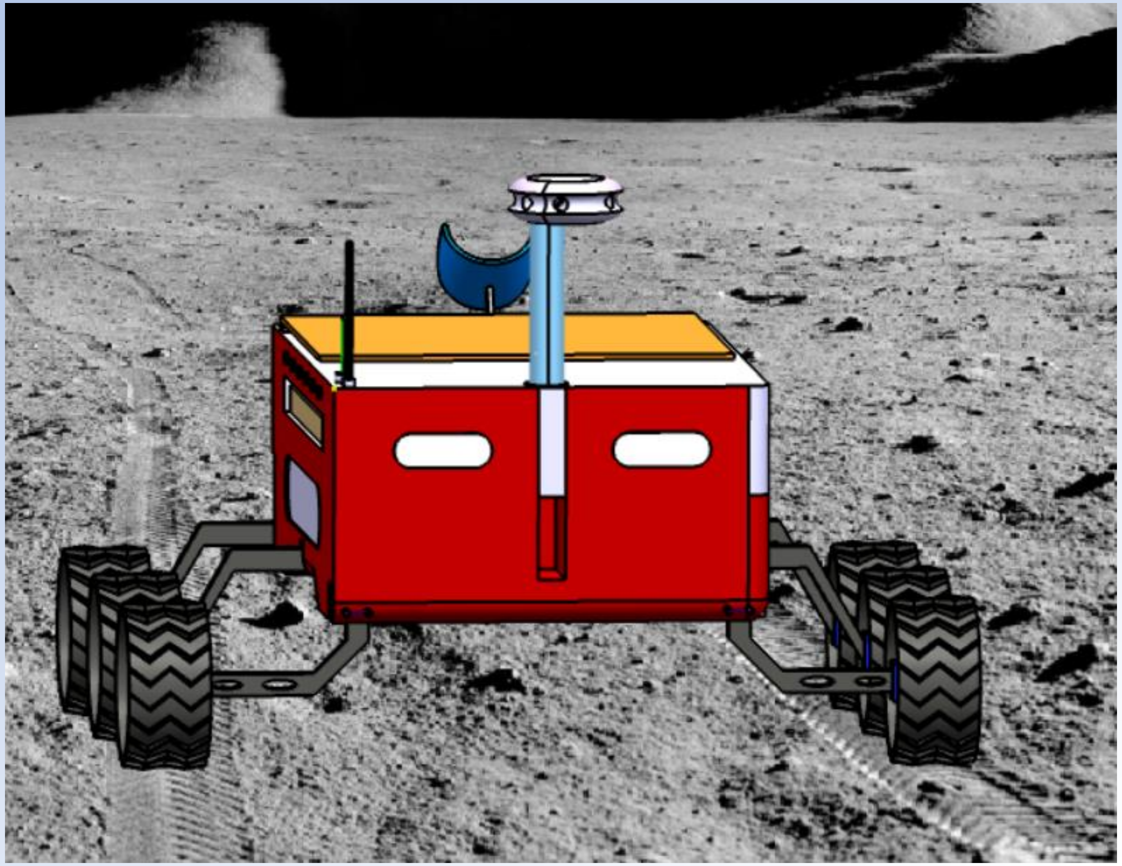


FIG. 18- Solar panel on robot body

Play video

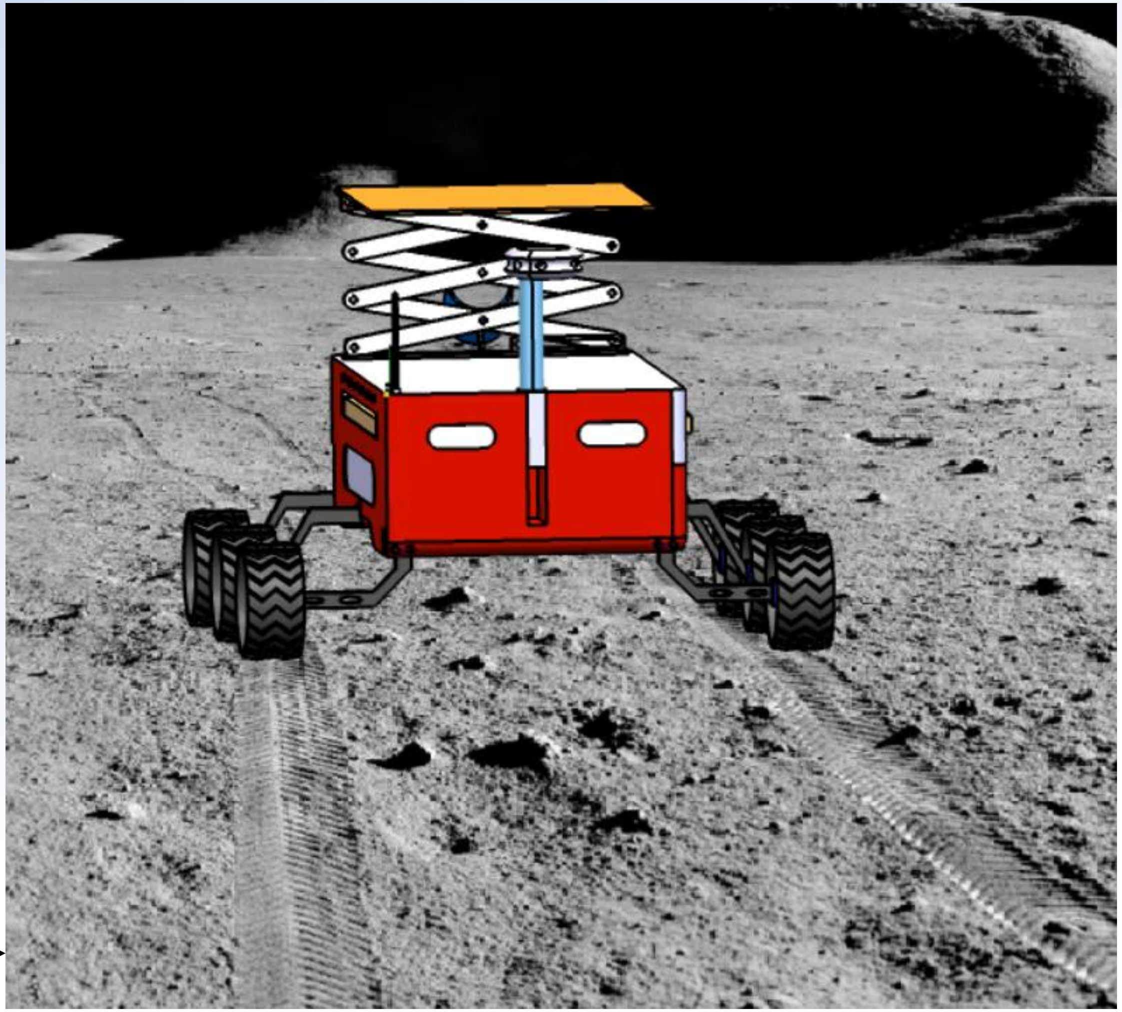


FIG. 19- Solar panel retracted when workbench deployed

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Conclusion

- A robotic assistant system was designed using model-based approach using following steps:
  - *Operational analysis* was performed to understand the mission of the system and involvement of actors and entities.
  - *System analysis* was performed to breakdown the mission of the system into capabilities and deduce what the system does to achieve these capabilities.
  - *Logical architecture* was performed to breakdown the system into logical elements and deduce how the system achieves these capabilities.
  - *Physical architecture* was performed to transform the logical elements into physical components and assign functions (needed to achieve the capabilities) and interactions to the physical components.
- The three capabilities of the system that we seek to meet are:

  (1) Receiving astronauts from HLS

  (2) Exploration of the lunar surface and

  (3) Serving as a relay for communication between the lunar habitat and the lunar gateway.

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Thank you!

Q & A