

SPACESHIP French contribution to lunar – long term Operations and surface navigation

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My Backgroung

- I&T manager, preparation operation as expert for Chemcam instrument for Curiosity (2012)
SEIS main instrument for Insight (2018)



- Tech demo manager on X-IFU main instrument of Athena satellite
- 2019 Project Manager for spaceship FR - innovation and application project for Exploration and Human Spaceflight
- 2028 …

What are Spaceships'?

Spaceships – Exploration Innovation across all 3 Destinations

What are the Spaceships ?

- Highly motivated **innovation teams** matched to their locations, partners and national agencies
- **Dynamic network** of collaborators across Europe, supporting and initiating low-TRL Exploration R&D with an emphasis on **practical demonstration and skunkworks** approach ('*innovate and implement under one roof*')
- Team members include visiting researchers, students, secondees from commercial entities, national agency staff as well as ESA staff

ExPeRT

E3P
Programmatic Position

'A fundamental element of ExPeRT are the Spaceships, initiatives that develop operational concepts and low TRL technologies…

…Spaceship projects are emphasized to be pragmatic, demonstration driven and innovative in their scope. Importantly, the initiative links with related activities within ESA and with varied stakeholders across Europe'

This in E3P P2 and to be continued in P3

Spaceship EAC – EAC, Cologne, Germany
- Human Spaceflight and Exploration Activities
- LUNA development

Spaceship ECSAT – ECSAT, Harwell, UK
- Analogue support projects
- Sample Curation related activities

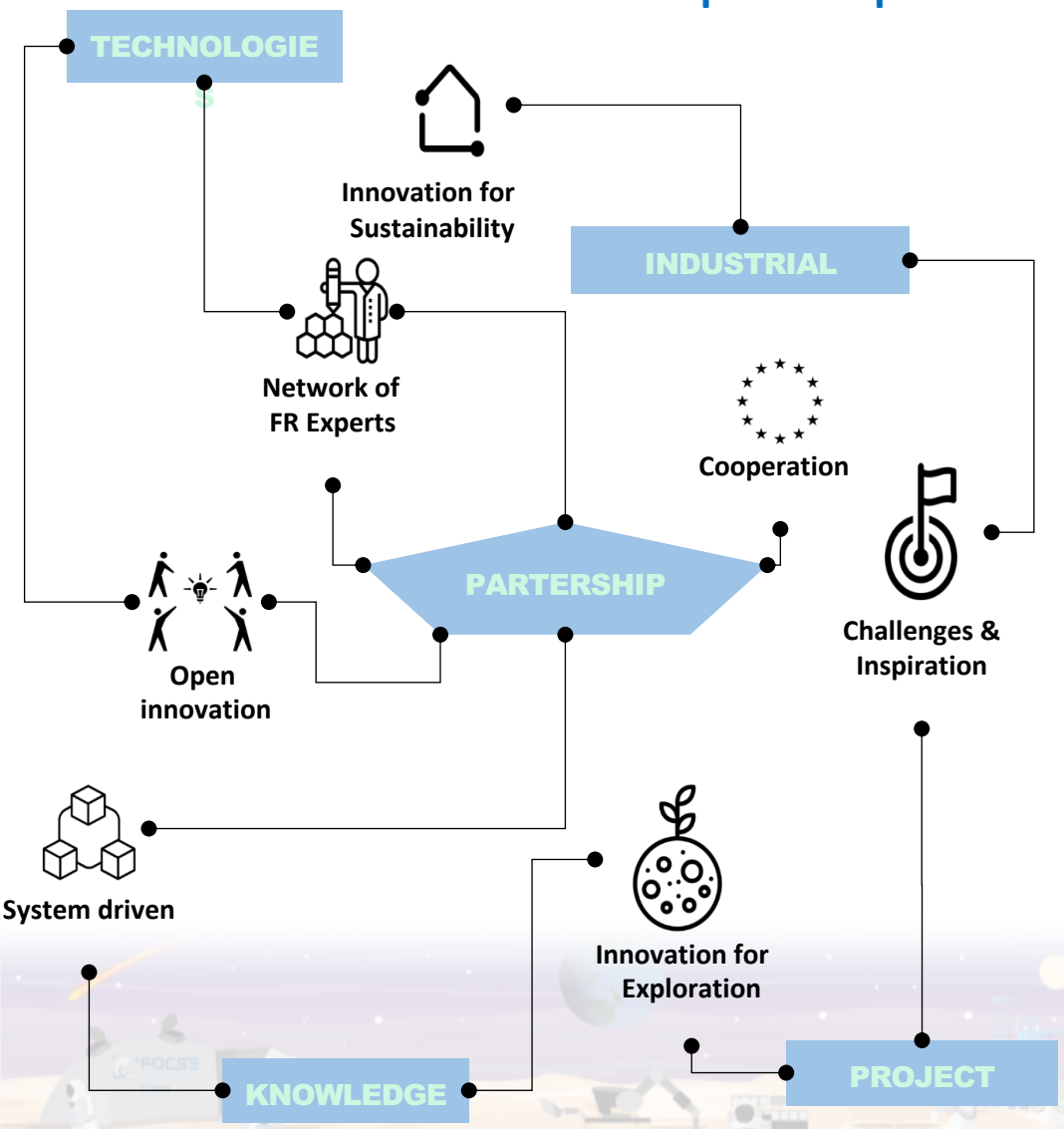
Spaceship France – CNES, Toulouse, France
- Currently developing domain areas
- Focused R&D activities with CNES & commercial partners

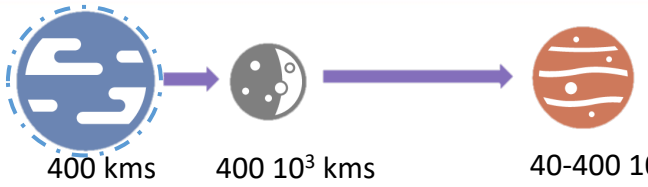
Thematic Areas
- Advanced Manufacturing
- Energy
- Off-World Living/Crew Health
- Disruptive Technology (AI, VR, Digital-Twin)
- Space Resources
- Robotics

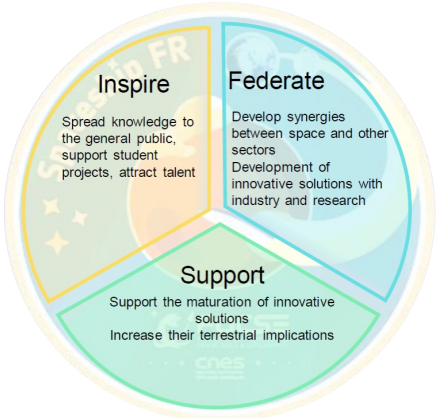
THE EUROPEAN SPACE AGENCY

CONTEXT

Scope for Exploration









GLOBAL EXPLORATION ROADMAP

PLANETARY OUTPOS

Digital & supervision

Habitat & protection
→Provide protection to the crew from extreme environment

Life Support System
→ Provide a habitable environment to ensure the crew's survival and satisfy its basic needs.

Crew Health & performances
→ Monitoring and maintain the crew members' physical & psychological health
→ improving its efficiency

Power generation and energy storage
→ Technologies retated to power generation,
→ Distribution and energy storage

Automation & robotics
→ Assist the crew operation through automation,
→ Help surface mobility and manipulation

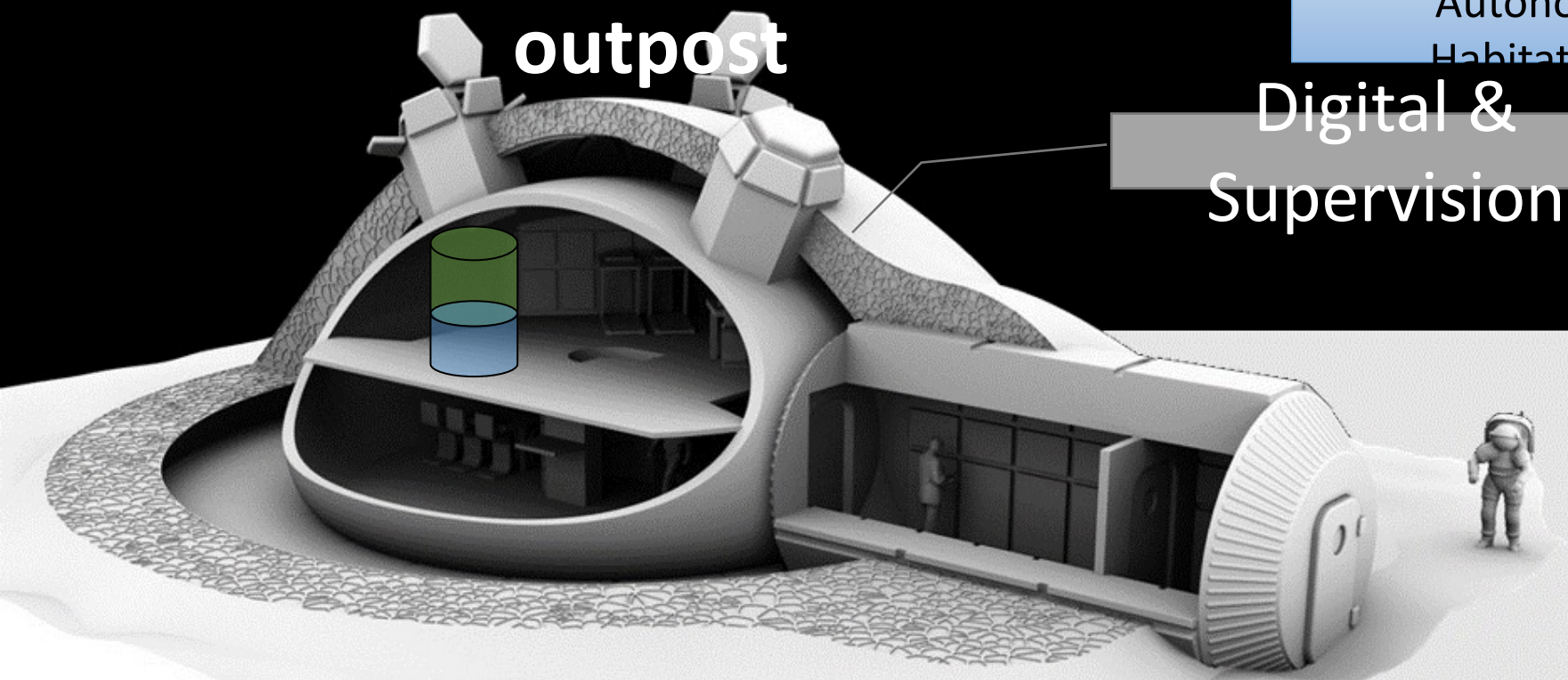
Autonomy & In-Situ Resources Utilization
→ Enable the utilization of resources from the outpost environment to support the mission sustainability

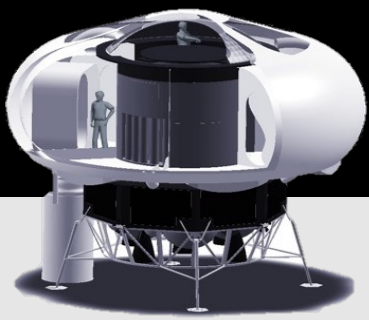
Key Drivers

Subsystems in the international outpost

Autonomous Habitat - LISE [1]

Digital & Supervision





Disruptive technology

Scalability

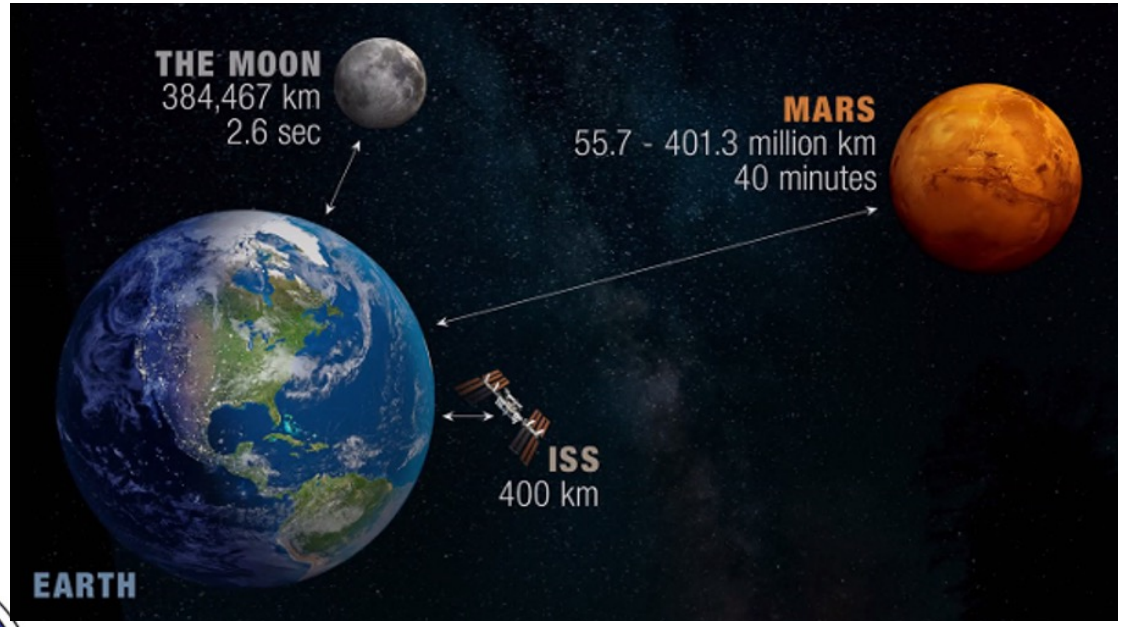
[1] Lunar Integrated Shelter for Exploration

Moon to Mars : New Space challenges for operational center

Distance to Earth

Unable to support Control Center in real time, Latency

→ An autonomous habitat and a digital assistant for the crew



Limited ressources

Water, air, food, **energy**

→ Recycling loop, resource monitoring

→ Autonomous management, sobriety and circularity, eco-design approach

Extreme Environment

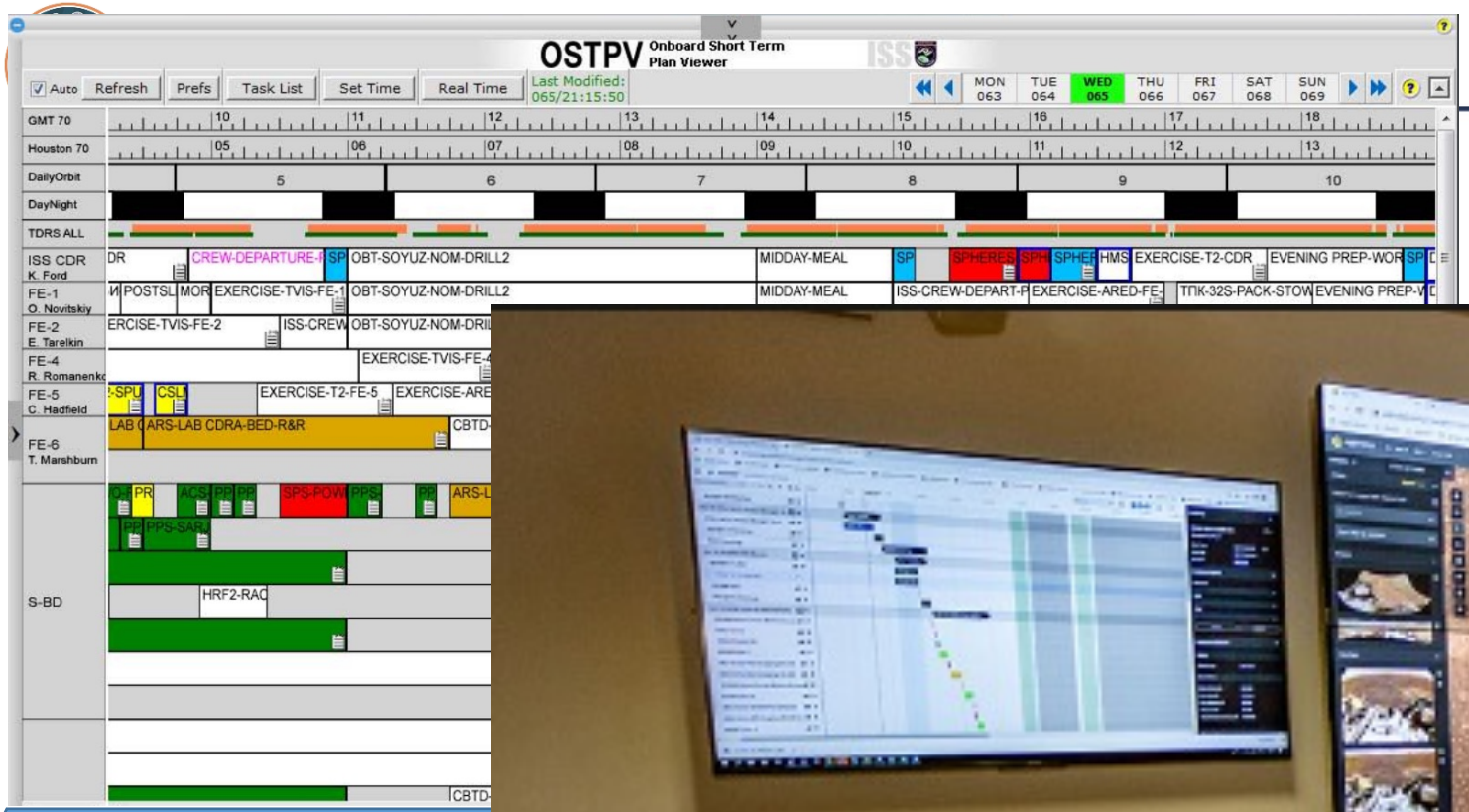
Mission duration increasing
Isolation, human factors, radiation, micrometeorites
→ An optimized and secure habitat
→ Reduce cognive load for astronauts

Interaction between all subsystems inside and outside the base

Supervision of the system via astronauts → Supervision of the system by the system

Currently : Operational center of ISS on the ground







Cocpit Interface for Perseverance Rover

Moon to Mars

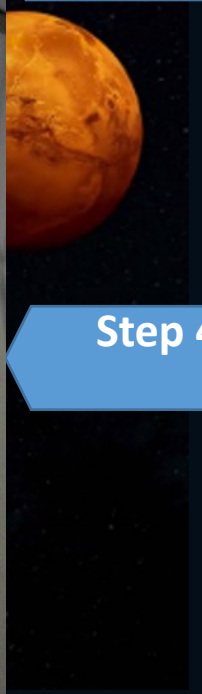
FOCSE
FRENCH OPERATIONS CENTER FOR SCIENCE & EXPLORATION
cnes



Step 1 : Miniturization

Step 2 : POC[1] on the Moon

Step 3 : preparing Mars



Step 4 : Mars International Outpost

[1] Proof of Concept

Moon to Mars : To imagine new Operational Paradigm

Scalability

System for evolution implementation
Learning by doing
Step by step implementation

Power generation and energy storage

→ Hibernated data center in accordance with Energy available in situ





Challenge for innovation

→ Provide a habitable environment to ensure the crew's survival



On board Human Machin Interaction

→ Need to be redesign for astronaut application

Automation, digital and supervision

→ Assist the crew operation through automation (AI DT XR)[1]

→ More Skills based for astronaut

Earth operational center

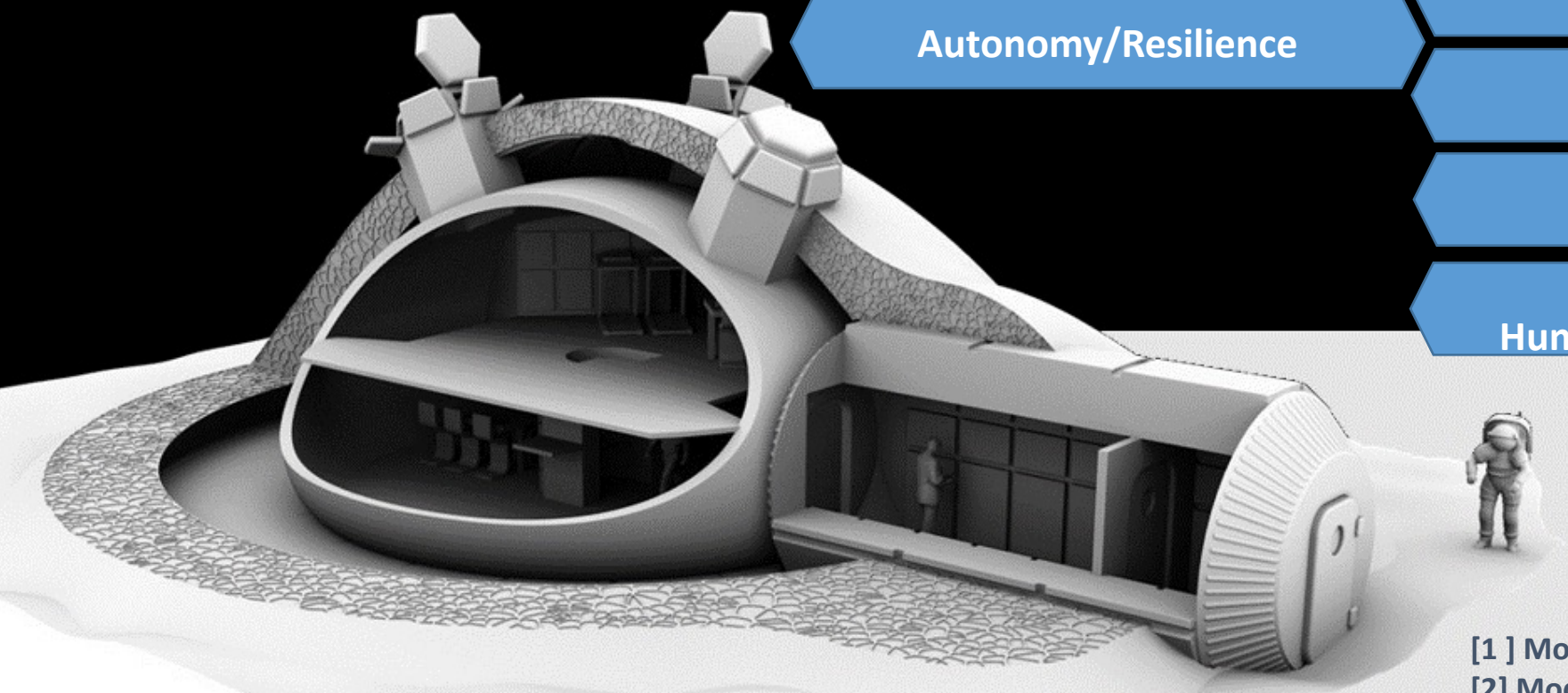
→New objectifs : anticipation & prevention for flight control team

New generation of deep space systems

[1] Artificial Intelligence Digital Twins Extended Reality

Most promising axis

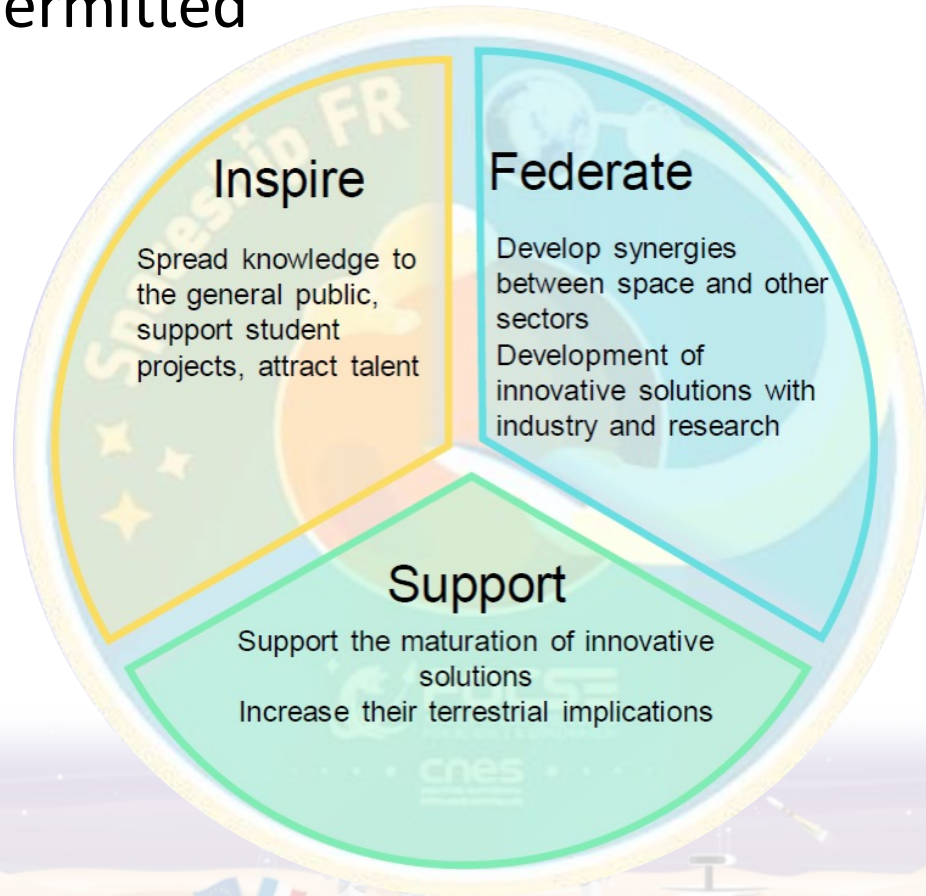
- Agility
- Supervision
- Mars Metaverse
- Machine learning
- Multi-modal control center
- Autonomy/Resilience
- Data protection
- Artificial intelligence
- Scalability
- Digital twin
- MBSE[1]/MBSA[2]
- HAT[3] Human ⇔ Machin Collaboration
- .....



[1] Model-based systems engineering
[2] Model Based Safety Assessment
[3] Human Autonomy teaming

Where we are, where we go…..

- Funny pilot project : Spaceship Fr *(est. 2020)*
- Limited budget/ smaller project
- Low TRL : find the way/ Light review process /risks is permitted
- Support from hierarchy
- Propose Internship/PhD…. for creativity
- Workshop with
  - space and non space industrial actors/ partners
  - Student /PhD
  - Operational team
- Roadmap in progress in coherency with ISECG[1]
- Light Validation process



[1] International Space Exploration Coordination Group

How and How to create innovation

Intern

Tech proposal
From innovative tiger team

Find
Ecosystem Partner

External

Tech proposal
Form communauty

Tech analysis



AI 4 U: Supervision & decision making for astronauts

Update could be performed during each spaceops

The objective of this CNES project is to propose ideas, concepts, technologies and the disruptive operation in order to contribute for the next challenging operation

[1] International Space Exploration Coordination Group
[2] Centre national d'études spatiales

Thank you very much for your attention



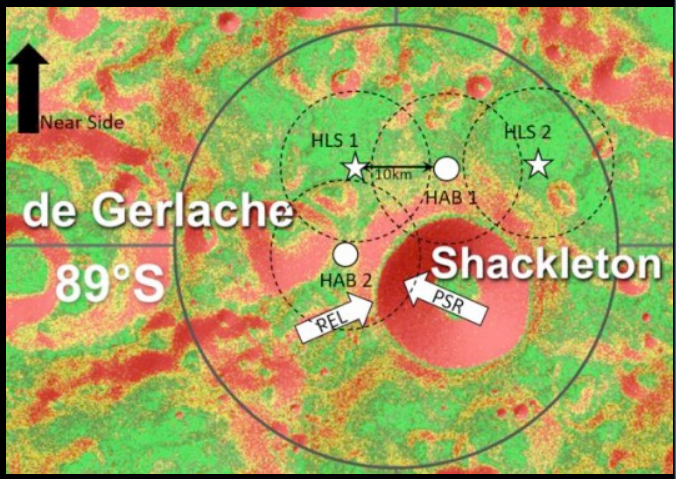
Lunar and Martian exploration, the next orbiting and surface missions at the Moon will feed forward to the first

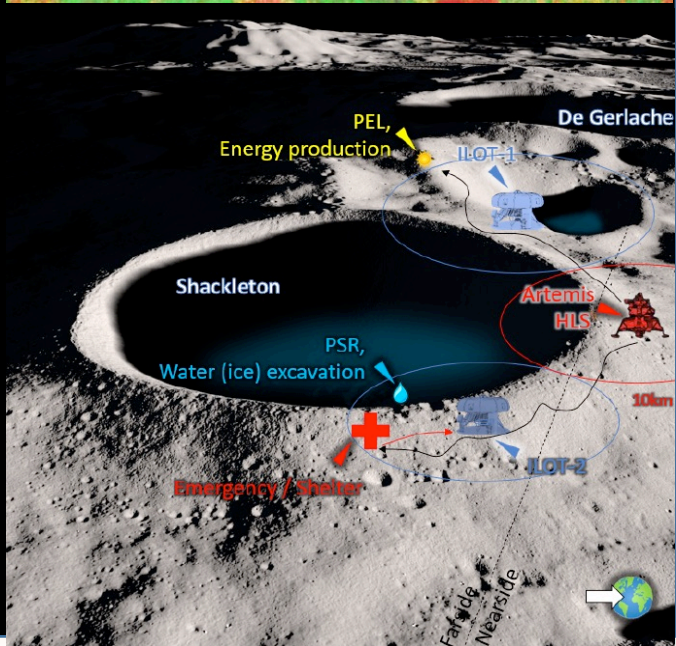
SPACESHIP FR RoadMap Priorities for next Operational Center

Artemis program marks a fundamental step for human spaceflight. All eyes are on the Moon: NASA has recently proposed a Lunar Orbital Platform Gateway (LOP-G or Gateway) concept as the basis for future space exploration. In this context, a lunar settlement has to considered as a critical building block to support either scientific and commercial exploration and exploitation of the Moon.

The design of such a complex, international and modular space base requires a dedicated framework of innovative methods and operational strategies. For example, some of the actual scientific and technical hurdles to be solved are:

- the modeling and management of interfaces
- the modeling of critical resource flows (water, oxygen, power, food, etc.) and of the information (IoT home automation supervision, smart house…)
- the non-quantitative constraints (e.g. legal, ethical, sustainable aspects, interior design, human factor, stressful environment ...) in a optimized architecture
- the autonomy, sobriety and circularity in particular for the identification and the modeling of the scenarios of failures (losses of communication links, depressurization, fire, period of strong solar activities...) in an eco-design approach, in an eco-design approach, such as the integration of Life-Cycle Analysis (LCA) methods.





This project will apply innovative systems engineering approaches combining MDO (Multi-disciplinary optimization), MBSE (Model Based Systems Engineering) and MBSA (Model Based Safety Assessment) so as to take into account safety and autonomy requirements in order to secure supervision and operations, to implement FDIR (Failure, Detection, Isolation and Reconfiguration) mechanisms and support diagnostic decisions of ground operators and crewmembers,

Preparing the next phase : Mars Exploration with Astronauts

SPACESHIP FR – Spin Off for industrial

Digital & Supervision

Habitat

- Inflatable structures: autonomous housing: deployment for intervention teams during natural disasters, area affected by epidemics (thanks to the medical lab), possibly later for individuals on unserviced land → ecological (solar energy, recycling water, economical in water and electricity use, etc ...)
- Home sensors and monitoring by connected and secure methods, implementation of home automation to reduce the carbon footprint.
- Safety and fire management improved and deployable in companies, public buildings and then in private homes (prevention system which alerts the user to a fire risk (monitoring), improved detection, non-destructive extinguishing (extinguisher based on the magneto-acoustic principle)

Life support

- Feed :
  - production in environments not suitable for agriculture: arctic zone (and antarctica), desert zones, mountainous zones, etc ... (the need is identified for example for the populations of northern Canada) production in urban areas,
  - improve plant yields with a controlled environment (sensors, nutrient management, etc.) without chemical input
  - Use of bioreactors in the food chain
- Recycle: reduction of consumable items that are currently discarded → reduction of carbon footprint
- Purify the air: VOC, Battery & Virus filtration in hospitals → Surgical units, public places and private homes thanks to miniaturization and good performance for controlled energy consumption
- Treat the water:
  - Reverse osmosis / membrane treatment to have consumable drinking water → reduce against "wat
  - Photolysis & catalysis: reduce / eliminate endocrine disruptors, POPs, … → Water trea etu
  - Urine treatments creation of fertilizer

Crew health and performance

- Monitoring patient heath by connected & secured methods in remote → more autonomy for patients
- Reduce the size and consumption of medical equipment,
- Have easily deployable medical equipment,
- Help with diagnoses via AI (specialist home doctor)
- Produce food with bioréactors

Automation & Robotics

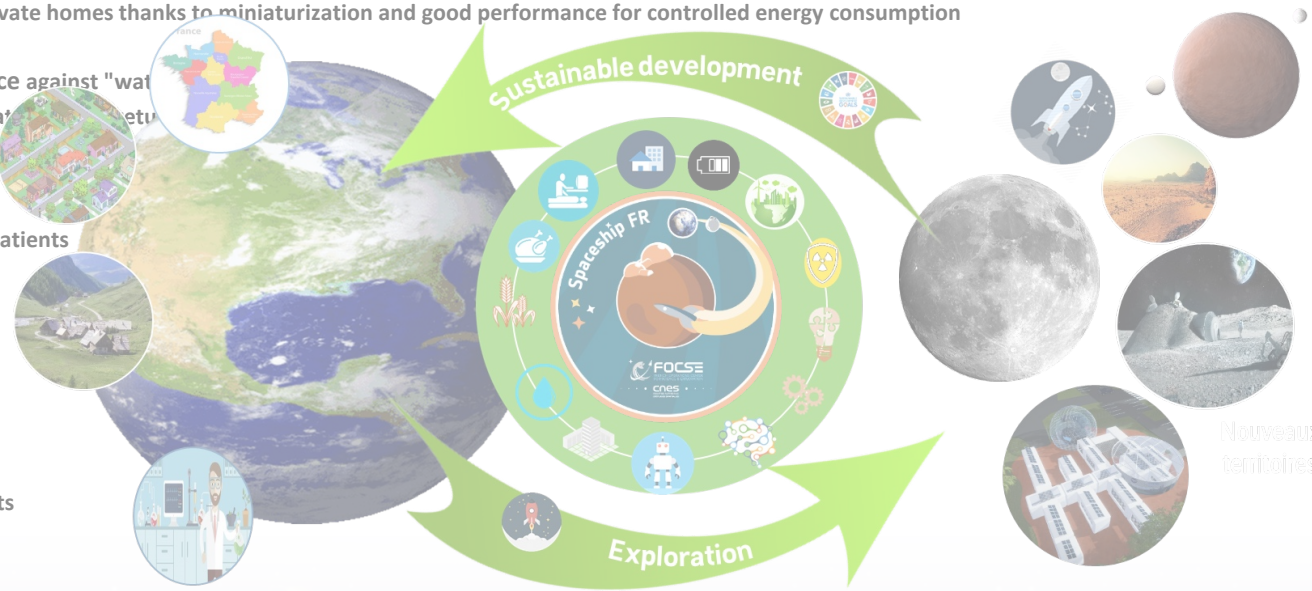
- Help with navigation, “follow me”, autonomous navigation with real-time decision-making.
- Robots assisting firefighters and rescue, demining teams, teams working in nuclear power plants

Autonomy & ISRU

- Recycle metals, plastics.
- Gases storage
- Recycle material by separating and recovering (mixed) elements from pieces of equipment → recycling and reuse of interesting materials for everyday devices (rare earths, silver, gold, etc.) rather than excavating them .

Energy

- Improve renewable energies and improve efficiencies (PhotoVoltaic Panel, Hydrogen, CH4, Baterry, etc.)

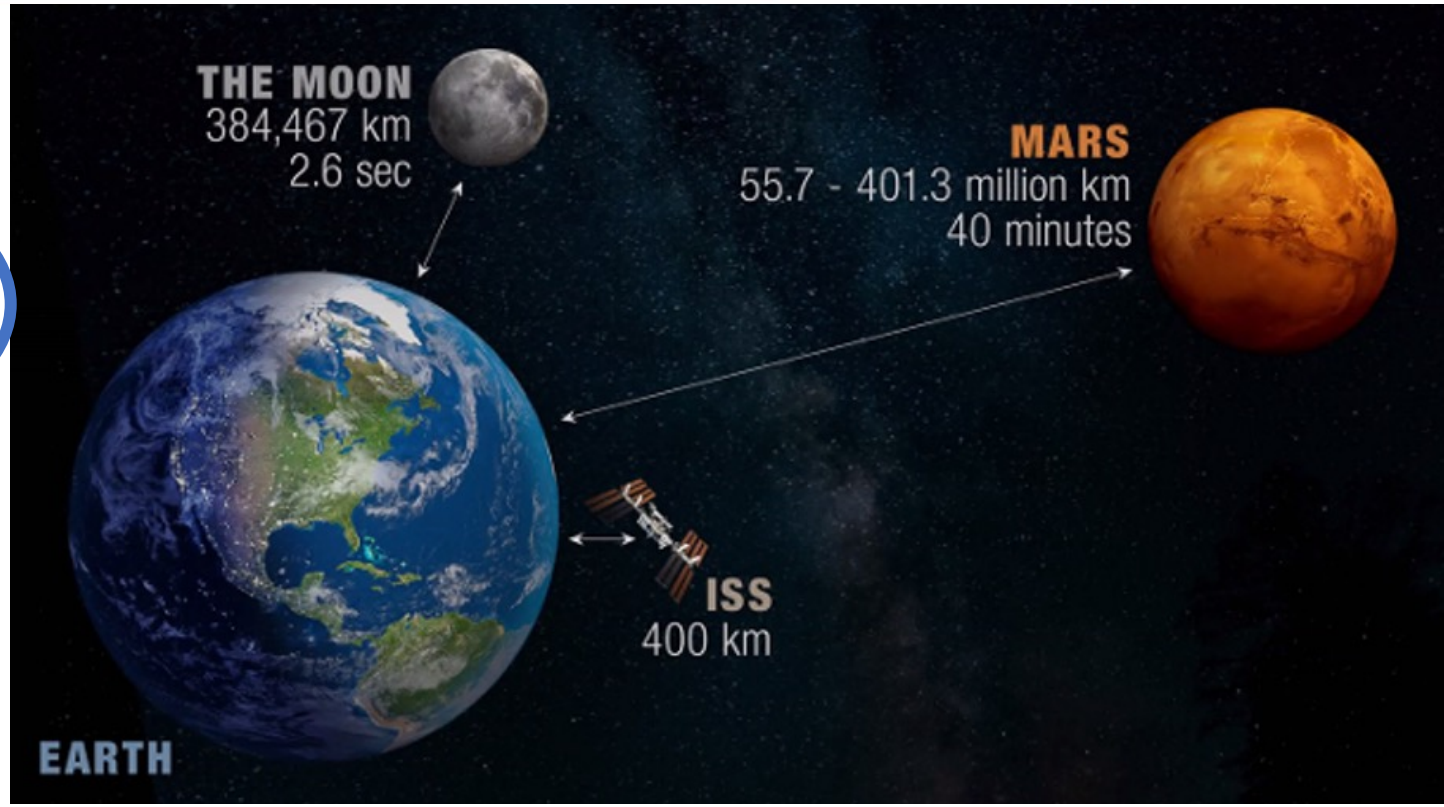


Vers La Lune et Mars : de nouveaux enjeux

Activités transverses

MDO
Multi
Disciplinary
Optimisation

LCA
Life
Cycle
Analysis





Spaceship : project pilot

MBSA
Model
Based Safety
Assessment