ESA Lunar Exploration Activities

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  - Lunar Exploration Architecture Study
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European Space Exploration Heritage

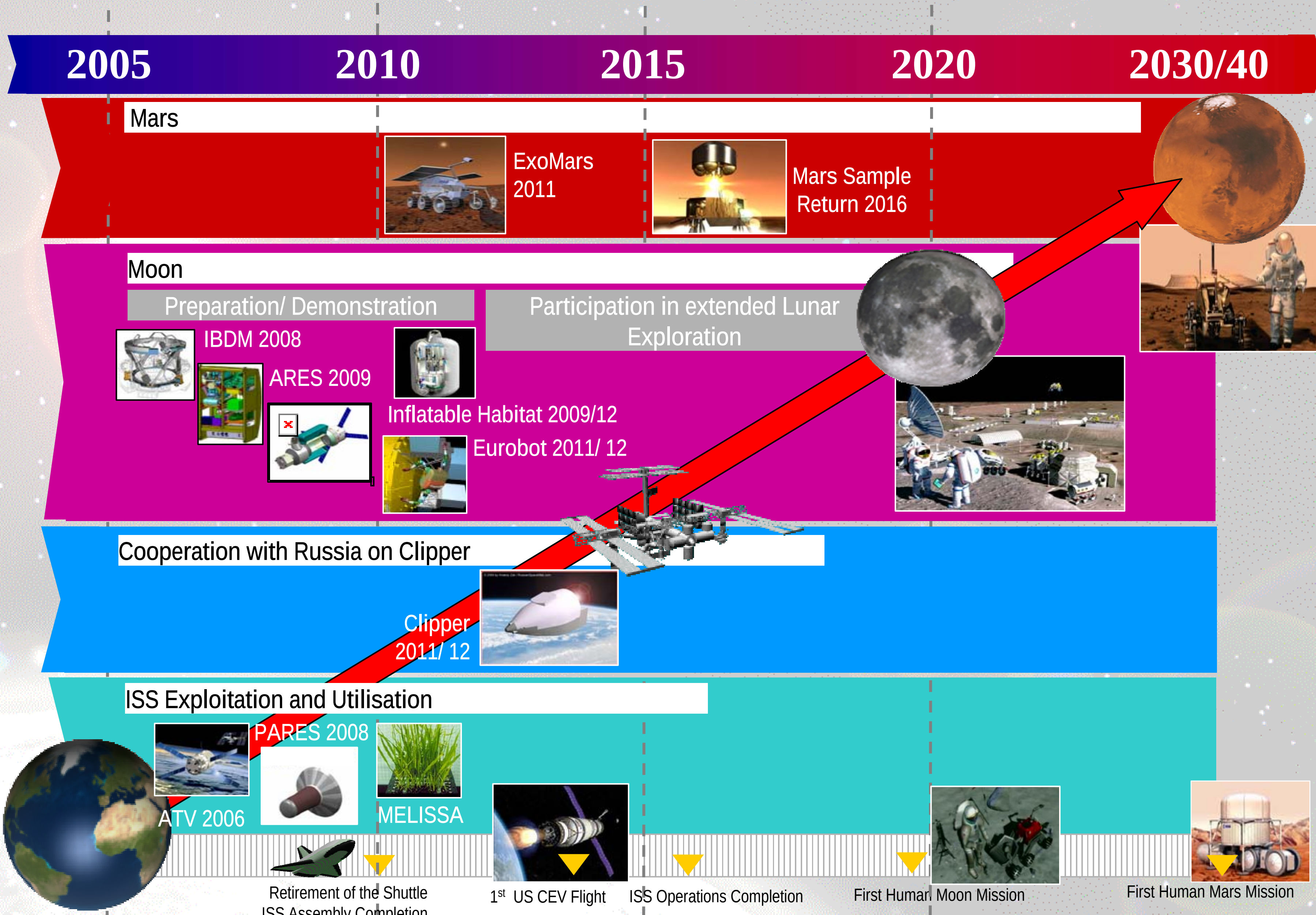
- ESA has been actively involved in space exploration for many years and is currently conducting several scientific missions in the Solar System
  - **SMART-1** is orbiting around the Moon
  - **Mars Express** is orbiting around Mars
  - Europe has successfully landed on Titan with the **Huygens** probe as part of the joint ESA/NASA mission Cassini-Huygens
  - Europe is on route to a comet encounter with **Rosetta**
  - **Venus Express** was launched on November 9 2005

- In addition, ESA is also planning the exploration of other solar system bodies
  - Mercury with **BepiColombo**, in cooperation with Japan

Aurora

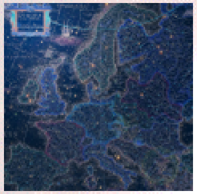
- ESA Member States have agreed to consider Space Exploration as one of the ESA priorities for the future, with the underlying goal to
  - increase knowledge
  - foster innovation
  - strengthen the European identity
  - inspire the young generation

- Within the Aurora programme, ESA is elaborating on an extended missions roadmap for the robotic and human exploration
  - with Mars as its main objective
  - and the Moon an intermediate step



2005
2010
2015
2020
2030/40
Mars
ExoMars 2011
Mars Sample Return 2016
Moon
Preparation/ Demonstration
Participation in extended Lunar Exploration
IBDM 2008
ARES 2009
Inflatable Habitat 2009/12
Eurobot 2011/ 12
Cooperation with Russia on Clipper
Clipper 2011/ 12
ISS Exploitation and Utilisation
PARES 2008
ATV 2006
MELISSA
Retirement of the Shuttle
ISS Assembly Completion
1st US CEV Flight
ISS Operations Completion
First Human Moon Mission
First Human Mars Mission

Four Cornerstones

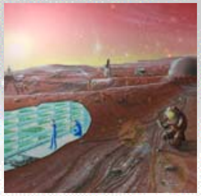


"Europeans in space"

– allowing Europe to be a significant Partner for Exploration by assuring a European access to enabling technologies, the presence of European culture in future space endeavours, the enhancement of European integration, the creation of European pride around an inspiring and ambitious cooperative project;

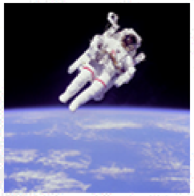
"History and fate of life in the Universe"

– understanding the origins and evolution of life on Earth and the search for extraterrestrial life in the Solar System, and beyond;



"Sustainable human life in space"

– the development of enabling technologies to support life and protect health, to access energy, manage environmental risks and exploit local resources; and



"Sharing the space adventure and benefits"

– communicating the excitement of human space flight and exploration and sharing the resulting benefits, with the general public.

Exploration Core Programme

- Exploration Roadmaps, Scenarios and Associated Architecture Studies
  - These activities will enable Europe to determine its objectives, interests and priorities in participating in a meaningful way in the global inspirational space exploration adventure, through the identification of further missions and mission elements

- Mars Sample Return (MSR) Enabling Technology Developments
  - the goal of MSR is to bring back the first-ever sample of Martian soil
  - It has important implications for planetology, the study of the origin of the Solar system and the search for life on Mars.
  - MSR is also a major milestone on the road to exploration, as it has a mission profile representative of a subsequent human visit to Mars

Exploration Core Programme (cont.)

- General Exploration Enabling Technology Developments
  - flight demonstrations of selected enabling capabilities (robotics, habitation, etc.)
  - preparation of potential European contributions to the exploration of the Moon
  - Regenerative Life Support System ARES
  - Rendezvous and Docking Demonstration

- Awareness Activities
  - engagement of European citizens in space exploration
  - inspiring generations of youth and students through involvement of universities in the elaboration of future exploration missions

Exploration Missions

- The next European led robotic exploration mission to Mars is the **ExoMars** mission to be launched in 2011

- Main scientific objectives
  - Search for traces of past and present life
  - Characterise Martian geochemistry and water distribution
  - Improve the knowledge on Martian's environment and geophysics
  - Identify surface hazards to future human missions

- Main technology objectives
  - Safe Entry, Descent and Landing of a large size payload
  - Surface mobility (Rover) and access to the subsurface (Drill)
  - Rover power generation using solar arrays
  - Forward Planetary Protection

ExoMars

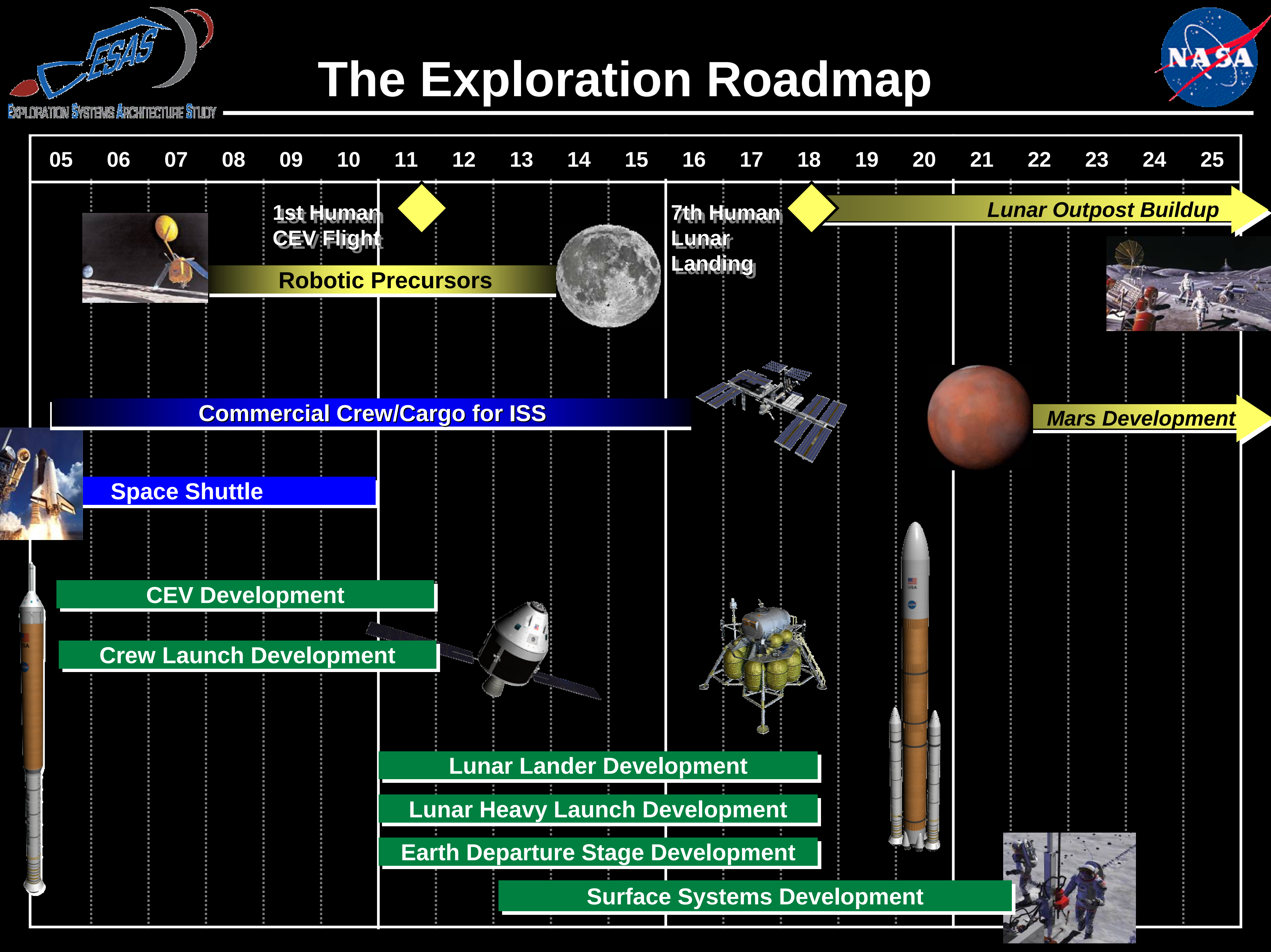
Clipper Preparatory Programme

- A preparatory programme of 2 years in order to:
  - Acquire human access to space capability for Europe
  - Maintain and enhance the European human spaceflight competences and capabilities in industry
  - Participate in the development, together with Russia and possibly Japan, of a crew transport system for LEO and exploration missions
  - Ensure compatibility with other exploration elements
  - Promote cooperation with Russia
- Identification of the system requirements and preliminary design of the elements and subsystems
- Prepare for a decision to participate in full development and operation programme

NASA Lunar Exploration Plans

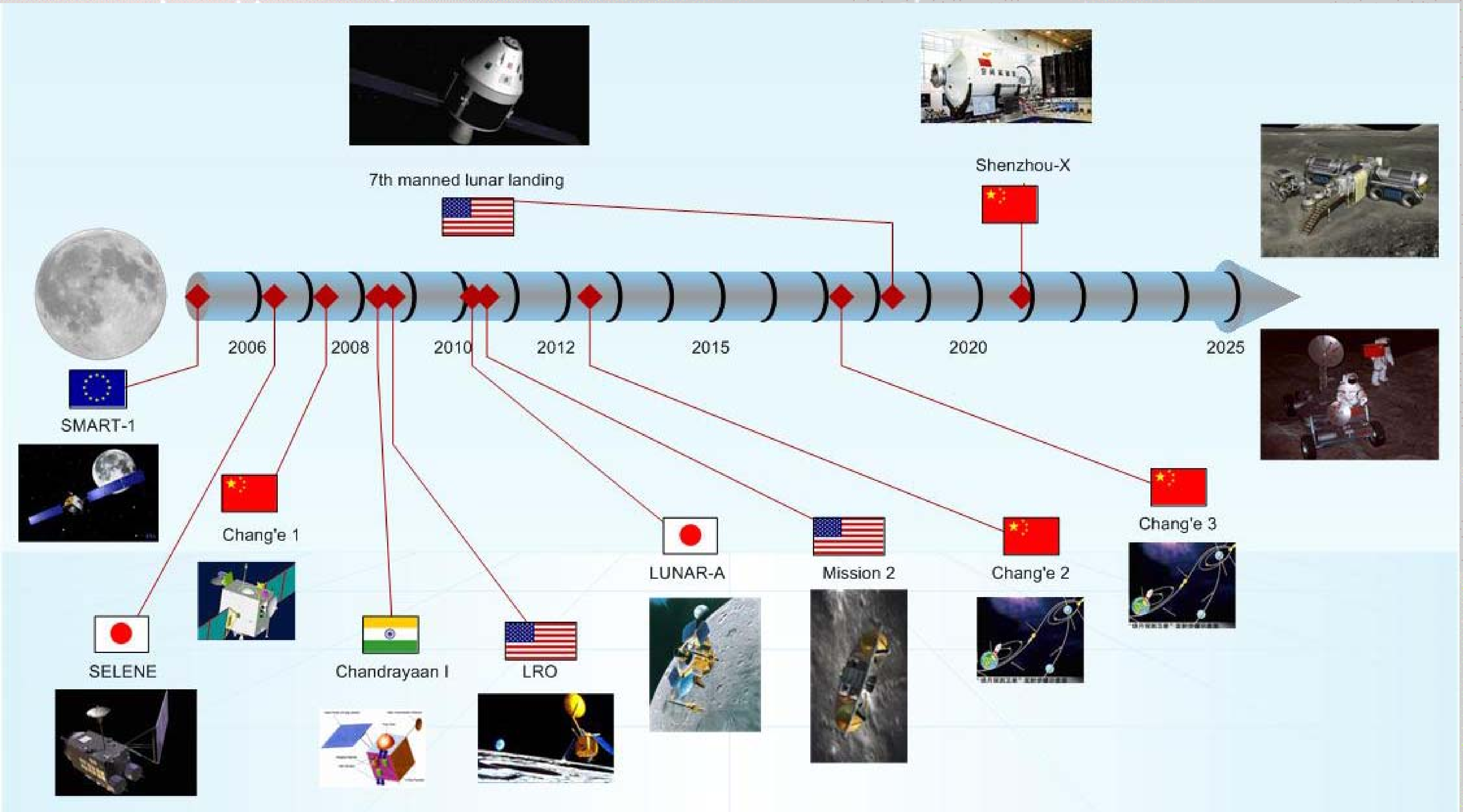
- ESA has been in dialogue with NASA since the Bush announcement of Lunar Exploration

- NASA has finalized the ESAS study which defines the exploration architecture for the transportation elements



Exploration Systems Architecture Study
The Exploration Roadmap
05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
1st Human CEV Flight
7th Human Lunar Landing
Lunar Outpost Buildup
Robotic Precursors
Commercial Crew/Cargo for ISS
Mars Development
Space Shuttle
CEV Development
Crew Launch Development
Lunar Lander Development
Lunar Heavy Launch Development
Earth Departure Stage Development
Surface Systems Development

International Plans for Robotic Exploration



Concurrent Design Facility

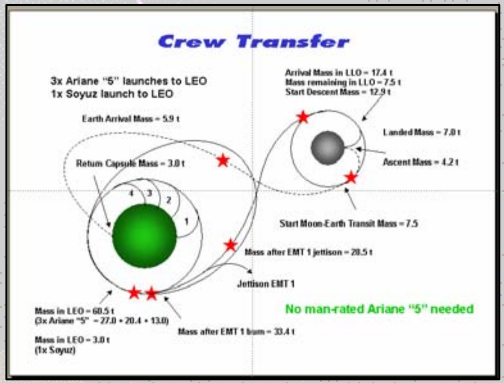
ESTEC CDF

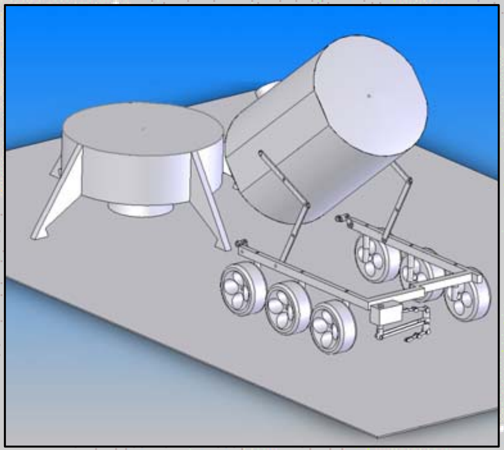
- ESA has performed several exploration mission studies using the ESTEC Concurrent Design Facility (CDF)

- The Concurrent Design Facility was established at ESTEC in November 1998 with the scope
  - to provide a mission design environment for the conceptual design of new space missions
  - a set up for the application of concurrent engineering principles
  - a more effective organisation of existing mission analysis
  - design tools and human resources and a generic approach to capture corporate knowledge for further reuse

Human Spaceflight Vision

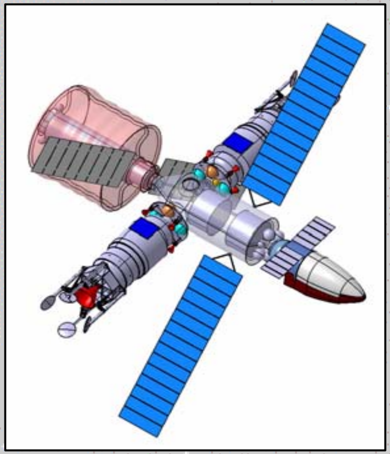
- Looked at the feasibility of building and operating a human tended lunar base using European technology and Ariane 5
- The main objectives were
  - to determine the number of launches required to launch and maintain such a base
  - perform trade-offs of propulsion system combinations (chemical and electrical)
  - determine ΔV requirements for all transfers
  - determine need of structure assembly in LEO
  - determine mission scenario and lunar base assembly strategy
  - determine the gross architecture and required infrastructure
  - identify technologies to be developed.
- A possible upgrade of the Ariane 5 launcher, capable of placing 27 tons into LEO was used for this study





Sustainable Lunar Exploration

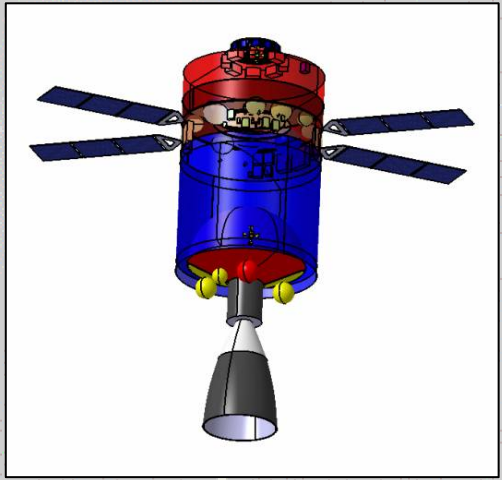
- The study, completed in December 2004, designed a set of spacecraft, which together describe an architecture, satisfying two main objectives:
  - To perform lunar mission(s) to demonstrate technologies and operations for future human Mars missions (e.g. long term habitation and surface operations)
  - and to perform sustainable lunar exploration, meaning building the capability for several short duration surface missions to any location on the Moon

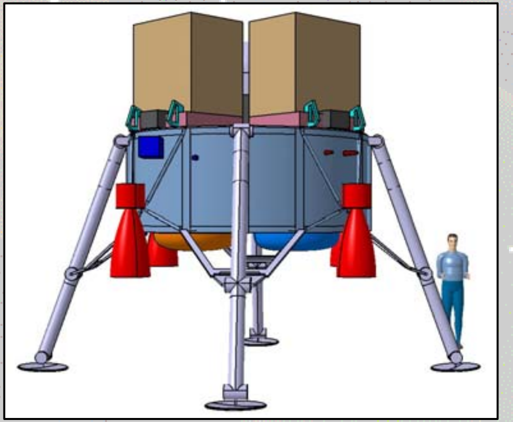


- The study defined an architecture allowing long duration habitation demonstration in orbit as well as excursion type missions to the lunar surface with up to 14 days surface duration with:
  - a habitable hub in LLO
  - several lunar landers can be attached

Lunar Exploration Cargo Transportation System

- The Lunar Exploration Cargo Transportation System CDF Study was finalised in June 2005
- It assessed a cargo transportation system for both lunar orbit and lunar surface applications
- Cargo can be pressurised and unpressurised
- Commonality between elements, as well as the European heritage from the ISS programme, has been pursued when advantageous
- For delivering cargo to the lunar hub, a dedicated system comprising a Propulsion Module, a Service Module and a Cargo Carrier can supply up to 1900 kg of payload to the Lunar Orbital Hub when launched by an Ariane 5 ES vehicle.
- For delivering cargo or other payloads to the lunar surface, a dedicated system comprising the same Propulsion Module and a Descent Module can supply up to 486 kg of payload to the lunar surface when launched by an Ariane 5 ES vehicle.





European Robotic Mission
Mission Objectives

- Provide Europe with a follow on mission to SMART-1 for lunar surface exploration
- Provide a European technology demonstration platform able to demonstrate technologies needed for future exploration missions e.g.:
  - ISRU technology and lunar material science
  - Surface and vertical mobility
  - Precision landing capability (within 500 m)
  - Mission and Surface Lander and Rover Ops
- Provide a scientific P/L platform for specific measurements needed for future lunar exploration
  - Radiation measurements and exposure experiments
  - Chemical composition measurements for assessment of Resources (minerals, ice, organics)
  - Life science precursor experiments
  - Lighting conditions

European Robotic Mission
Mission Requirements

- Mission timeframe
  - Start of C/D activities 2007-2008
  - Launch around 2012-2014
  - Survival/ Operation 3 month minimum, possible extension 6 months to 1 year
- Primary landing locations around possible “peak of eternal light” at South Pole or North Pole
  - Polar or near polar orbit or direct descent
  - Precision landing 500m
  - Rough terrain
- Investigation into dark crater areas of polar region looking for resources (water ice) for future use
- Target an “affordable mission”

European Robotic Mission
Mission Requirements

- Technology Demonstration
  - Lunar Transfer (propulsion, navigation, communication)
  - Soft accurate landing (navigation, variable thrust descent, airbags)
  - Propulsion Technology (LOX/Methane)
  - Surface Mobility for characterisation and in-situ sample analysis
  - ISRU technology precursor (perform resource extraction and processing)
  - Life Science package (detection of surface/subsurface cometary ice/organics, life science experiments (ECLSS precursor, plant ecosystem biology)
  - Drilling and subsurface core sampling
  - Remote sensing into craters
  - Science Objectives (geo physics package, sample collection for in-situ analysis, isotopic dating)
  - Resource localization and determination (for later ISRU: O2/H2 plus other elements)
  - Radiation Environment measurements
  - Planetary protection demonstration

European Robotic Mission
Main Study Trades

- Launcher trade and selection
- Mission analysis (transfers, descent (direct vs from orbit, coverage analysis)
- Propulsion Technology Selection
  - Electrical
  - Chemical
  - Solids
- Conceptual design for a Lunar polar lander
- Detailed Element Design (propulsion stage, descent stage)

European Robotic Mission
Main Study Trades

- Payload identification (including rover, accommodation, operations)
- Technology Readiness assessment
- Identify soft landing requirements for GNC Rover mobility concepts
- Power generation and thermal control (solar, nuclear, etc)
- Overall mission cost assessment

European Robotic Mission
Launcher Options

- Initial evaluation of most existing launchers
- Selection based on performance and cost

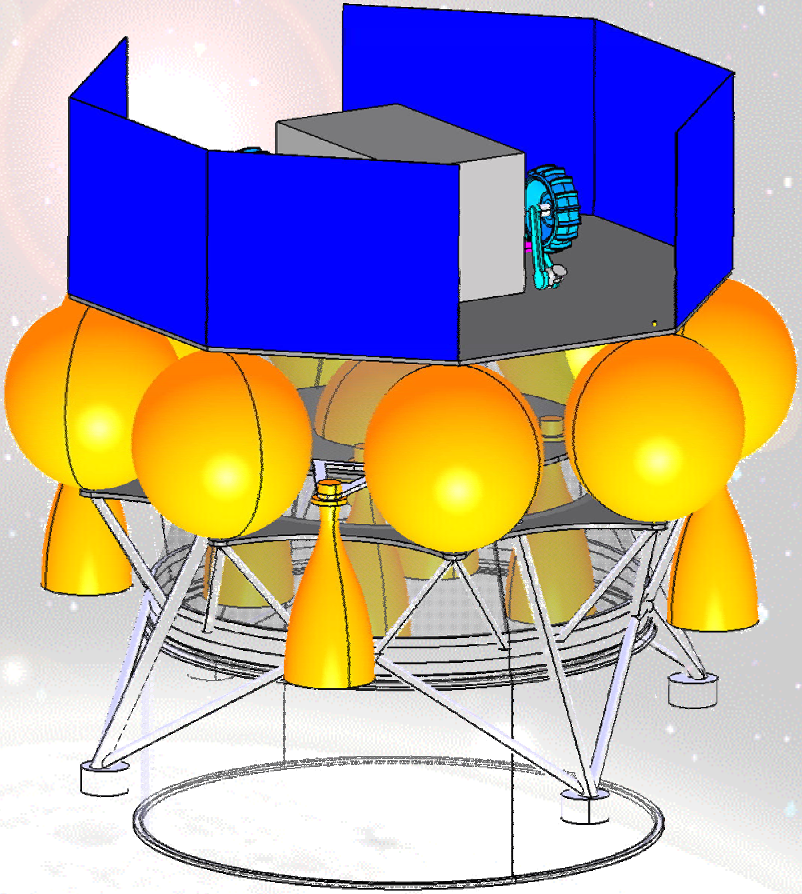
B/L

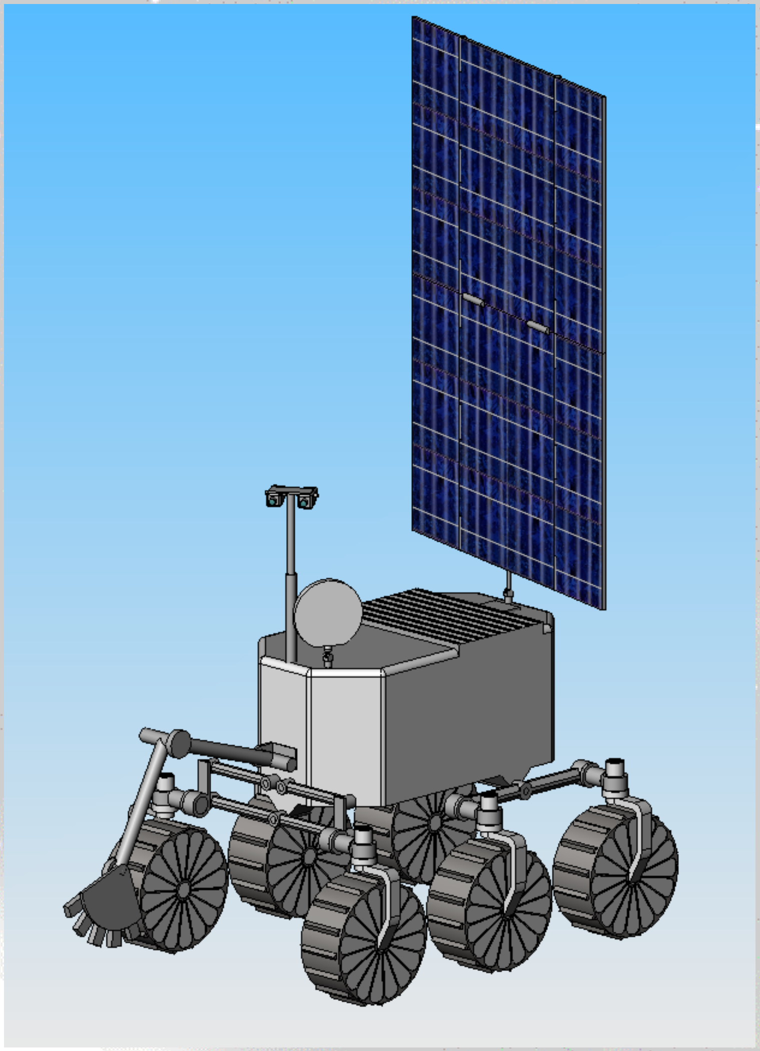
	Option 1	Option 2	Option 3	Option 4	Option 5
Launcher	Soyuz	Soyuz	Ariane 5	Soyuz	Soyuz
Strategy for launch	HEO	HEO	GTO	HEO	HEO
Staging in LLO	YES	YES	YES	YES	YES
Propulsion module?	YES	YES	YES	NO	NO
Altitude ejection for PM	10 km	10 km	10 km	N/A	N/A
Propulsion technology for PM	Bi-prop	Bi-prop	Bi-prop	Bi-prop	SEP
Propulsion technology for lander	Monoprop	Bi-prop	Bi-prop	Bi-prop	Bi-prop

European Robotic Mission
Selected Baseline

- Soyuz-Fregat launch from Kourou
  - Via optimized HEO
  - Launcher performance in HEO 3030 kg (with 115 kg of adaptor)
- Possibility to deliver 90 kg of scientific payload to the Moon’s surface
- Polar landing site achieved (eternal light/darkness)
- Technologies test and demonstration
- Lunar Science
- Affordable Mission

European Robotic Mission





European Robotic Mission Option

- Option with Ariane 5 shared launch (50%)
- Possible to deploy a payload mass of at least 200 kg on the lunar surface
- More costly mission
- More cost effective than Soyuz (M€/kg)

European Robotic Mission
P/L Options

- Overall payload mass is limited to around 180kg (With an Ariane 5 shared launch):
  - Lander Instruments => 4.4kg
    - Pan Cam
    - Descent imager
    - Permittivity
    - Susceptibility
  - Life Science/Environment => 8.6kg
    - ionizing Radiation
    - Dust suite
    - Environment
    - Melissa precursor (FEMME)
    - Plants on the Moon
    - Planetary protection
  - Deployable Geophysics Package => 9.6kg
    - Laser reflectometer
    - Seismometer
    - Geodesy and Laser
    - Heat flux
    - Magnetometer + boom
    - EF sensors

- 22.6kg of scientific payload on the lander
- 155kg for the regional rover and its payload (ca 20 kg)

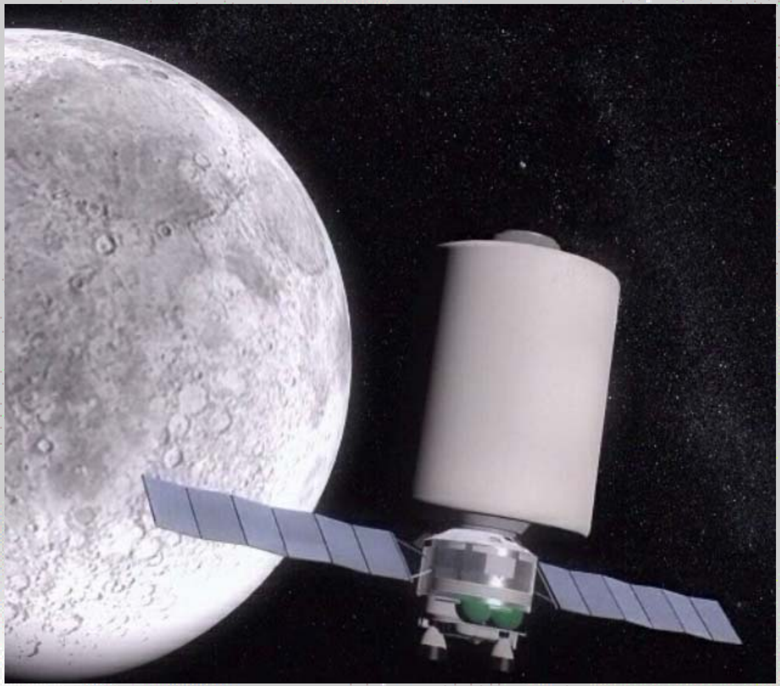
- A smaller P/L is being defined for the Baseline Soyuz option

Lunar Architecture Study

- Contribute to the consolidation of the European scenario for space exploration
- Analyze and define attractive and smart European contributions to the exploration of the Moon
- Logic:
  - Scenario Definition
  - Architecture Analysis
  - Building Block Definition & Evaluation
  - Contribution Scenarios
  - Development Plan

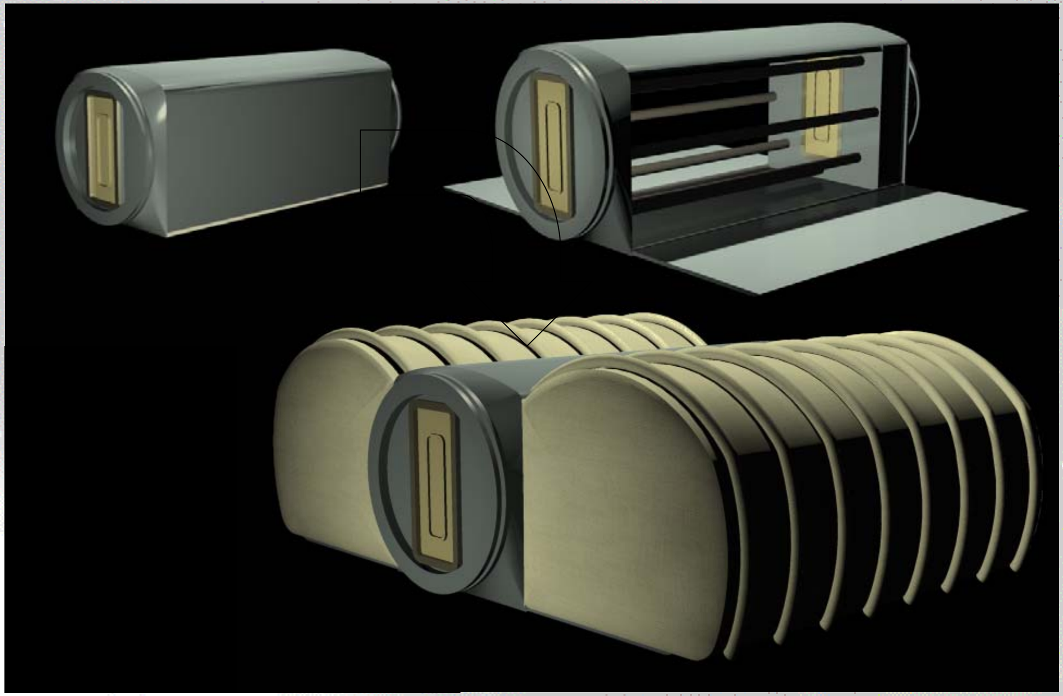
Inflatable Habitat SpaceHaven

- The SpaceHaven project is an ESA study which has defined a European habitation module based on
  - Inflatable technology for the main pressure shell
  - Regenerative technologies for life support functions
- The SpaceHaven will enable Europe to support humans in space, be it in Earth orbit in the near future, or in forthcoming planetary missions



SpaceHaven Lunar Application

- Ongoing Study as extension to main activity
  - Configuration Concepts
  - Structure and Mechanisms
  - Radiation Protection
  - Operations



Future Work

- Further define the European Lunar Exploration goals and missions roadmap
  - Involvement of stakeholders:
    - Scientific community
    - Industry
    - Public
    - Academia

- Define a possible first lander mission

- Define possible human contributions to International Lunar Exploration