European Architecture for Lunar Exploration

LEAG – ICEUM - SRR
29 October 2008

O. Mongrad, J. Schlutz, B. Hufenbach
website: http://www.esa.int/explorationstrategy
Analysis Process and Products

International Coordination

1st Exploration Conference Orlando 2005
2nd Exploration Conference Rome 2006
3rd Exploration Conference Houston 2007
4th Exploration Conference Kyoto 2008

Human Spaceflight Vision Group 2003
Long-term Exploration Strategy 2005
Exploration Workshop Edinburgh 2007
Science Workshop Athens 2007
Humans in Outer Space Vienna 2007
International Exploration Conference Berlin 2008

The Global Exploration Strategy
A Framework for Coordination
May 2007

Stakeholder Consultations


Architecture Analysis

2003 2004 2005 2006 2007 2008

Strategy Development

The Future of European Space Exploration

European Objectives and Interests in Space Exploration

The ESA-NASA Comparative Architecture Assessment
### Scenario Studies and Stakeholder Consultations

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<tr>
<th>Science</th>
<th>Economy</th>
<th>Policy</th>
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<tr>
<td>Co-evolution of Life with its Planetary Environment</td>
<td>Applied Research in Space</td>
<td>European Ambition</td>
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<td>Lunar Observatories</td>
<td>Space Services</td>
<td>Lisbon Agenda</td>
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<td>Life Sciences</td>
<td>Entrepreneurial Activities</td>
<td>Global Partnership</td>
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<tr>
<td><strong>Robotic Missions</strong></td>
<td>• On-orbit Research</td>
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<td>• Risk mitigation for exploration</td>
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<tr>
<td><strong>Robotic Missions</strong></td>
<td>• Mapping</td>
<td>• Limited Life/Physical sciences research</td>
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<td></td>
<td>• Landing site preparation</td>
<td>• Capability demonstrations for sustained presence</td>
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<td>• ISRU demonstration</td>
<td>• Base construction</td>
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<td></td>
<td>• Lunar science</td>
<td>• Limited geological fieldwork</td>
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<td>• Sortie support tasks</td>
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<td></td>
<td></td>
<td>• Limited laboratory analysis</td>
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<tr>
<td><strong>Robotic Missions</strong></td>
<td>• Science</td>
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<td><strong>Mars Sample Return</strong></td>
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<td><strong>Extended Robotic Surface Operations</strong></td>
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<td><strong>Human Mars Mission</strong></td>
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</table>

**PHASE 1**
- Sustained Human Operations – Research
- Robotic Missions
- Mars Sample Return

**PHASE 2**
- Sustained Human Operations – Exploration
- Extended Robotic Surface Operations

**PHASE 3**
- Human Mars Mission

**PHASE 4**
- Sustained Human Operations – Exploitation
- Robotic Missions
- Mars Sample Return
- Extended Robotic Surface Operations
- Human Mars Mission
Phased Approach to Architecture Development

- **Mars**
  - Surface: ExoMars, Mars Sample Return, Human Mission to Mars
  - Orbit

- **Moon**
  - Surface: Lunar outpost/base operations
  - Orbit: ISS Extension, Man-tended station

- **Human access Launcher**
  - LEO capability
  - LLLO / Surface capability
  - Redundant lunar surface capability

**Phases**
- **Phase 1**
- **Phase 2**
- **Phase 3**
- **Phase 4**
Operations in Low Earth Orbit

- Development of crew transportation capability
  - Secure access to existing and future research infrastructure in LEO
  - Enable participation to human exploration
- ISS lifetime extension up to 2020 assumed for research continuation and exploration preparation
- Minimum configuration for research continuation post-ISS is a Man-Tended Free Flyer

Total mass 20540 kg
Support crew 2-3 for 15 days
Lifetime 10 years
Lunar Cargo Lander

- Use the full Ariane 5 performance capability
- Deliver payloads to any location on the lunar surface
- Perform soft precision landing (500m)
- Deploy payloads on lunar surface
- Provide resources to the P/L (power, comm’s etc)

Gross payload performance (A5 ECA) ~1.2 ton
Lunar Cargo Lander Mission Scenarios

- Technology demonstration and potential human landing preparation;
- Delivery of surface assets, be they stationary or with mobility, in order to support and accelerate the international lunar outpost build-up or for science and technology demonstration in sustained human operations.
- Provision of consumables for extended human surface exploration range and duration;
- Delivery of regular logistics to an international lunar base;
- (Automated lunar surface operations (e.g. ISRU) and exploration
Human Transportation – Scenario 1

**LEO Spaceport** (minimum configuration: 70 tons) for assembly, propellant management, refueling, power, safe haven in contingency situations
**LLO Staging Post** in polar quasi-circular frozen orbit (minimum configurations 28 tons) providing also crew rescue (anytime return, safe haven) and provision of power, attitude control, communications, refuelling to crew vehicle in LLO.
Transportation Infrastructure

- **Human-rated launcher**
  - > 13 tons payload

- **Crew Vehicle**
  - 13 tons

- **Cryo-Transfer Stage**
  - 24 and 50 tons

- **Crew Vehicle**
  - 13 tons

- **Heavy Lift Launcher**
  - 50 tons payload

- **LLO or LEO Staging Post**

- **Human-rated Lander**
  - 26 tons
## Lunar Surface Exploration Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Sortie (short)</th>
<th>Sortie (long)</th>
<th>Outpost</th>
<th>Lunar Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crew Number</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>4+</td>
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<tr>
<td>Duration</td>
<td>7-14 days</td>
<td>14-42 days</td>
<td>14-42 days</td>
<td>180 days</td>
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<tr>
<td>Characteristics</td>
<td>Apollo-like. One visit to a particular landing site.</td>
<td>Longer duration Apollo-like. Multiple visits to a region requiring high mobility.</td>
<td>Multiple visits to a region of high interest (e.g. science, telescope maintenance).</td>
<td>Permanent human presence at a lunar base.</td>
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</table>

### Surface Infrastructure

- **Habitat**
- **Mobility**
- **Power plant**
- **ISRU plant**
Lunar Surface Infrastructure

Pressurized rover
- 7600 kg
- Provide long-range mobility for human surface exploration

Mini-habitation module
- 6960 kg
- Support crew of two for short duration missions (14 days)

Lunar Base Modules
- 13 t each
- Support up to 4 astronauts to survive on Lunar Surface for extended stays (several months)

ISRU plant
- 1700 kg
- Provide O₂ from regolith

Utility vehicles
- 350 kg
- Terrain management vehicle
- 350 kg
- Tanker and services vehicle

Large solar power plant
- 1500 kg
- Provide power to outpost/base
Human Mars Mission Trade-Off

Number of ARES V Launchers:

- 21
- 17 – 19
- 11
- 7

IMLEO (metric tons)

<table>
<thead>
<tr>
<th>Study / Option</th>
<th>IMLEO (metric tons)</th>
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<tbody>
<tr>
<td>Chem.</td>
<td>1724</td>
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<tr>
<td>SEP</td>
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<td>CDF</td>
<td>1357</td>
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<tr>
<td>Advanced Chem.</td>
<td>530</td>
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<tr>
<td>NTP</td>
<td>308</td>
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Crew Flight
Cargo Flight 2
Cargo Flight 1

Mass (metric tons)

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<th>Study / Option</th>
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<tr>
<td>Chem.</td>
<td>83.5</td>
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<tr>
<td>CDF</td>
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<tr>
<td>Advanced Chem.</td>
<td>106</td>
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Landed P/L mass

ARCHITECTURE TRADE REPORT
Human Mars Mission Reference Architecture

- Pressurised Rover: 8 tons
- Transit Hab: 38 – 50 tons
- Surface Hab: 32 tons
- Nuclear Power Plant: 12 tons
- Ascent Vehicle: 30 tons
- Descent Vehicle: 24 tons
- Nuclear Transfer stage: 120 tons
- LEO Tug: 22 tons
- Payload Tug: 5.8 tons
- LEO Assembly station: 150 tons
High-level Findings

• Heavy-lift launcher with 50 tons payload capability enable human mission beyond LEO

• Human operations in Low Earth orbit of continued strategic interest beyond ISS programme

• Orbital infrastructure (a) enhance robustness of human exploration transportation architecture providing safe haven in contingency situation and services to the transportation system (assembly, maintenance, inspection, cryo-management, re-fueling, power) and (b) open opportunities for innovations in the transportation architecture

• Lunar surface architecture strongly depends on exploration scenario

• Interest in utilisation of Lunar ISRU for consumables (break-even in 2nd year of operations

• Advanced propulsion required for Human mission to Mars

• Moon-Mars synergies for advanced robotics, long-range exploration, long-term surface habitation, soft precision landing, surface operations, in-space operations, communications and navigations