Executive Summary

ESA

ESA-ESRIN, 16 January 2009

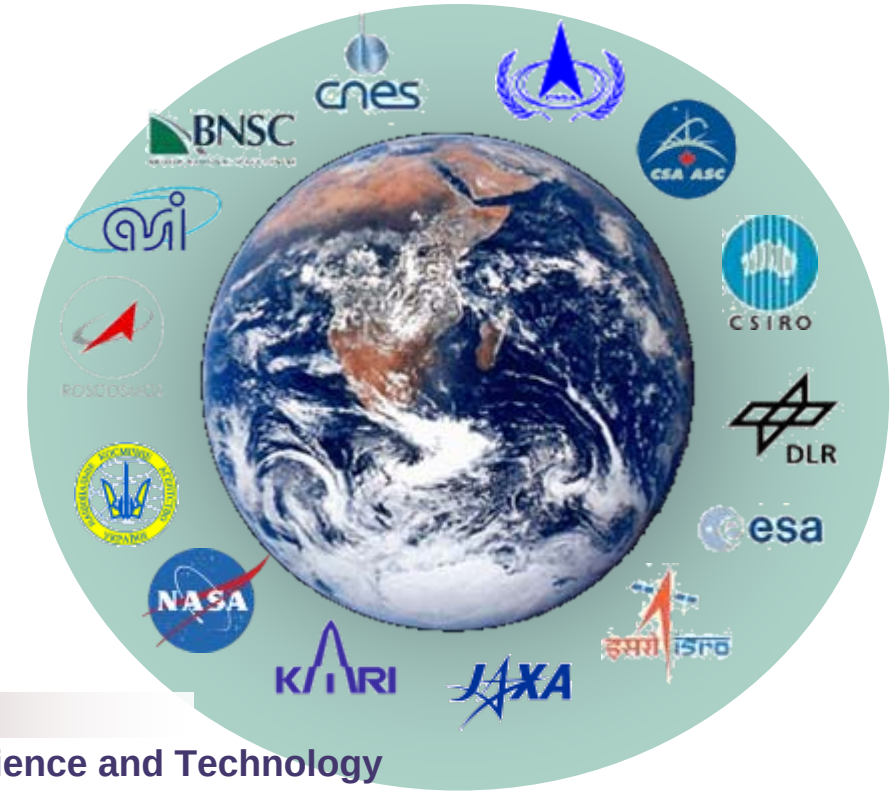
Motivation and Objectives

- **Develop integrated architecture for exploration of Earth-Moon-Mars space**
  - Responding to European exploration objectives
  - Being deployed gradually in phases in accordance with a clear logic
  - Including automated and human missions
  - Addressing operations in LEO, Moon and Mars exploration

  for

  - Understanding the architecture trade-space
  - Identifying synergies between automated and human missions and different exploration destinations
  - Preparing for international exploration scenario and architecture development activities
- **Identify and define areas of interest for Europe to contribute to international exploration missions and architectures**
- **Develop roadmap for focused long-term enabling research and development enabling human space exploration**

Strategic Framework



Theme 1

- New Knowledge in Science and Technology

Theme 2

- A Sustained Presence - Extending Human Frontiers

Theme 3

- Economic Expansion

Theme 4

- A Global Partnership

Theme 5

- Inspiration and Education

Analysis Process and Products

International Coordination

1st Exploration Conference Orlando
Spineto I
1st GES Montreal
Spineto II
2nd GES Rome
3rd GES Houston
2nd Exploration Conference Houston
4th GES Kyoto
Spineto III
ISECG Berlin
3rd Exploration Conference Denver
ISECG Montreal
ISECG Lunar WS1 Bremen
ISECG Lunar WS2 Cocoa Beach

2005 | 2006 | 2007 | 2008 | 2009

Stakeholder Consultations

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

2003 | 2005 | 2007 | 2007 | 2008

Architecture Analysis

Architecture Review
CDF
CDF
CDF
CDF
NASA-ESA
Architecture Review
NASA-ESA CAA Phase 1
CDF
CDF
Architecture Review
CDF
CDF
ESA-NASA CAA Phase 2
ESA-JAXA CAA Phase 1
Final Architecture Review

2007 | 2007 | 2008 | 2008 | 2009

Strategy Development

2003 | 2004 | 2005 | 2006 | 2007 | 2008

Past Work - Stakeholder Consultation

Main Results

- Underlying rationale and strategic cornerstones for European space exploration
- Identification of key stakeholder groups
- Assessment of broader innovation potential
- Assessment of specific opportunities for advancing fundamental science and applied research
- Assessment of new collaboration frameworks with the private sector, public sector organisations or regional entities
- Role of human exploration for further advancement of humanities (social sciences, philosophy, religious beliefs, culture, anthropology)

Relevance for Architecture Studies

- Development of high-level architecture requirements coherent with past stakeholder consultations

Past Work - Scenario Studies

Science-driven exploration scenario study

Final Report

Main Results

- Detailed assessment of political, scientific and economic drivers for space exploration
- Development of optional scenarios for European space exploration driven by scientific, policy or economic development objectives
- Development of European themes and objectives for space exploration
- Definition of exploration phases

Relevance for Architecture Studies

- Development of high-level architecture requirements based on scenario studies -> reference architecture shall enable implementation of identified European exploration scenarios

Past Architecture Studies

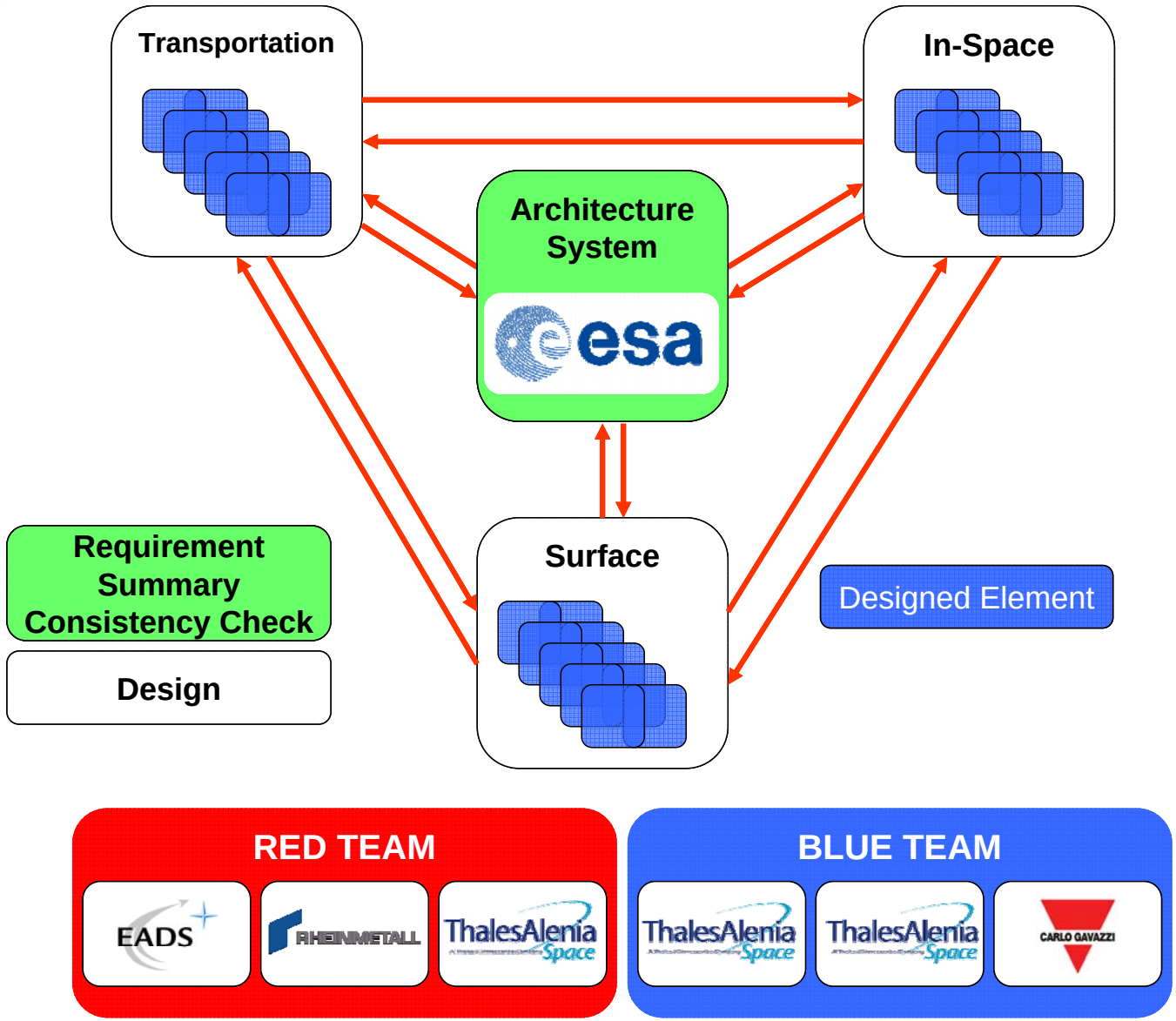
Main Results

- Analysis and definition of architecture elements/ segments including
  - Lunar surface outpost elements and transportation scenario
  - Lunar orbit and surface cargo transportation systems
  - Lunar orbital infrastructure supporting lunar surface excursions
  - Human mission to the Mars

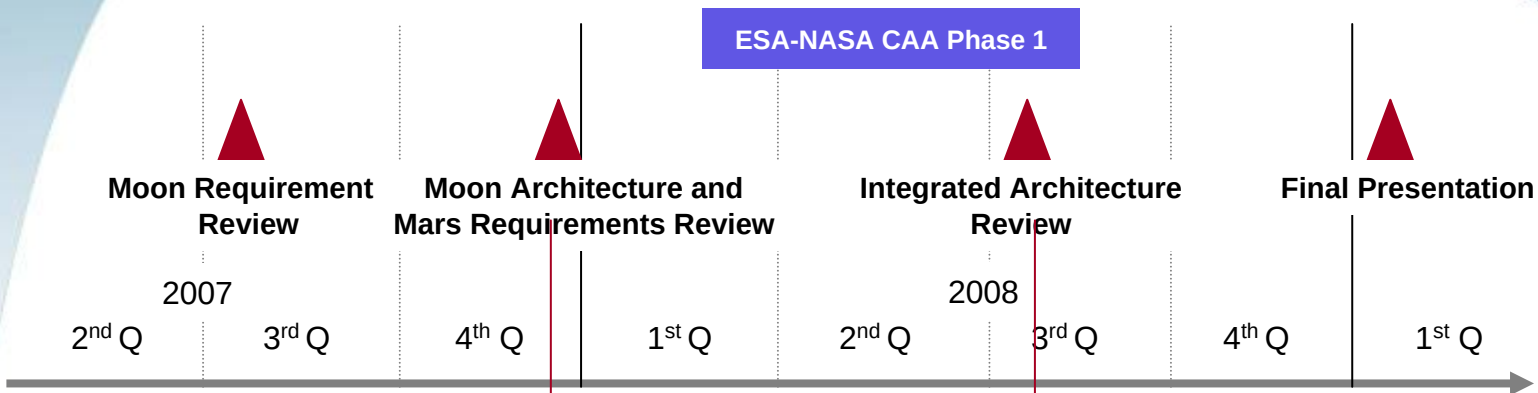
Relevance for Architecture Studies

- Findings of past element designs and trades used as point of departure

Architecture Study Process



Architecture Study Reviews



Elements Selected for Detailed Definition

Transportation

- Ariane 5 cargo lander (2 x)
- Large cargo lander
- Ascent stage
- Earth departure stage
- Shared Ariane 5 lander concepts

Surface

- Ariane 5 cargo lander payloads
  - ISRU demo
  - Deep driller
  - Hopper
- Pressurised rover (2 x)
- Mini-hab

In-space

- LLO/ EML 1 station (service module/ node)
- LEO assembly station
- LEO man-tended free flyer

Overview on deliverables

ESA

RD-1 Objectives
AD-1 High-level requirements

- transportation
- surface
- In-space

ESA-NASA

Coordinated Architecture Assessment

Industry

list of deliverables

D1 - Final Report
D2 - Exec Summary
D3 - Architecture Segment Specifications
D4 - Architecture Segment Design
D5 - Requirements for other Segments
D6 - Architecture Segment Elements Requirements
D7 - Contribution to Integrated European Reference Architecture
D8 - Plan for Definition of International Reference Architecture
D9 - Architecture Segment Element Design
D10 - European Priority Assessment
D11 - Integrated European Space Exploration Roadmap

ESA

Integrated architecture
Trade report
High level findings
CDF report

Key Findings – Reference Architecture

Transportation Architecture

- Human transportation architecture based on existing launch capabilities not feasible (minimum launcher size 50 tons)
- Interest of staging posts (robustness, contingency management, international mission integration, innovative concepts)
- Importance of dissimilar redundancies to enable new mission scenario (taxi lander versus sortie lander, large versus small logistic lander capability)

Surface Architecture

- An Lunar surface architecture strongly depends on exploration scenario.
- Interest in local resource utilisation for outpost operations
- Importance of robotic support systems and autonomous operations (human robotics partnership)

Mars Mission

- Requires advanced propulsion

Moon-Mars Synergies

- Advanced robotics, long-range exploration, long-term surface habitation, soft precision landing, surface operations and in-space operations, communications and navigations.

Key Findings - European Areas of Interest

Autonomy
Address European exploration objectives
Enable implementation of European led mission scenarios
Increase level of independence
Become a stronger partner in cooperative undertakings 1)
Sustainability
Identify and exploit Moon-Mars synergies
Assure robustness of programme against changes of international planning
Balance expenditures with projected budget
Enable implementation of new mission types to sustain public interest
Provide (dissimilar) international redundancy for essential capabilities
Innovation
Drive innovation for space and non-space
Enable commercialisation scenarios
Coherence
Build on past achievements
Assure coherence with other space domains
Cooperation
Ensure coherence with international planning
Create opportunities for cooperation with multiple Partners
Provide capabilities which make a real difference 2)
European Visibility
Ensure early presence of European Astronauts and systems on lunar surface

1) interdependence of Partners of future cooperative activities
2) enable new mission types, enhance crew safety, improve efficiency of operations

Key Findings - European Areas of Interest

Autonomy	
Address European exploration objectives	●
Enable implementation of European led mission scenarios	●
Increase level of independence	●
Become a stronger partner in cooperative undertakings 1)	●
Sustainability	
Identify and exploit Moon-Mars synergies	○
Assure robustness of programme against changes of international planning	●
Balance expenditures with projected budget	●
Enable implementation of new mission types to sustain public interest	●
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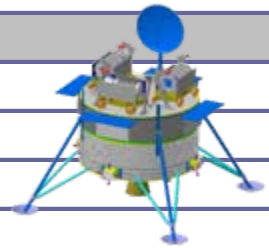
Key Findings - European Areas of Interest

Lunar Cargo Lander



Autonomy	
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1) interdependence of Partners of future cooperative activities
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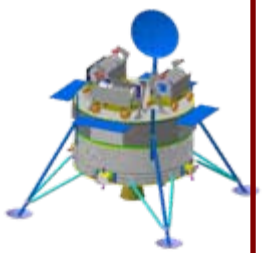
Key Findings – Enabling Capabilities

Enabling capabilities	Areas of interest
Advanced propulsion	Human access to LEO
Autonomous soft and precision landing	
In-situ resource utilisation	
Surface mobility	Logistic systems
Life support	
Advanced structures	
Autonomous operations	Supporting lunar outpost elements
Robotic aids	
Intelligent software	
Energy storage and distribution	Future human infrastructure
Cryo-management	
Docking and berthing systems	

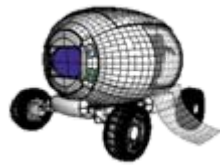
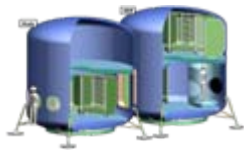
Possible European Role



Automated Lunar Exploration

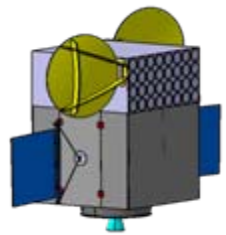


Logistic services

Enhanced automated services





Power Resources Com/ Nav

Capabilities for human in-space and surface habitation based on Columbus/ Nodes/ ARES/ MELISSA and human transportation based on ATV/ ARV/ Cargo Lander

Possible European Roadmap

Near - Term ***Medium-Term*** ***Long-Term***

2015 **2020** **2025** **2030**

Coordinated European **fundamental R&D programme** to advance enabling capabilities for sustained human exploration

Phase A to start in 2009

Participation in preparation missions for human lunar return with **lander and possibly orbiter** for surface mapping and advanced telecom demonstration

Phase A of surface systems to start in 2011

Participation in early international human missions with **lunar cargo lander and elements of power, ISRU and robotic systems**

Phase A of habitat capabilities to start in 2011

Participation in international lunar outpost operations with **habitat capabilities**, commercialisation of **logistics and communication services**

Participation in international redundant lunar human transportation architecture with **human access to space** and **staging post** capabilities

Delta B/C/D for CARV to start in 2015
Phase A for other architecture elements to start in 2011

Accomplishments

- European reference architecture (point of departure) jointly developed with key European stakeholder groups
- ESA studies served as precondition and strong motivator for bilateral (CAA with NASA and JAXA) and international (ISECG) architecture analysis activities
- Identification of lunar cargo landing system as key priority for early European contributions to international human mission to the Moon

http://www.esa.int/explorationstrategy