ESA's Exploration Programme and the Role of the Moon

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AURORA INTRODUCTION

EUROPEAN SPACE EXPLORATION PROGRAMME AURORA

- Initiated in 2001, based on consultations with scientific community – identified Mars and Moon as major exploration goals
- Aurora is based on:
  - Integrated stepwise approach combining robotic and human activity
  - Use of ISS, preparation on Moon, demonstration via robotic missions – working towards ultimate human exploration of Mars
  - Strong interaction with scientific community, industry and general public
- Aurora's context in Europe:
  - Ensure strong European contribution to the international effort on the exploration of the solar system

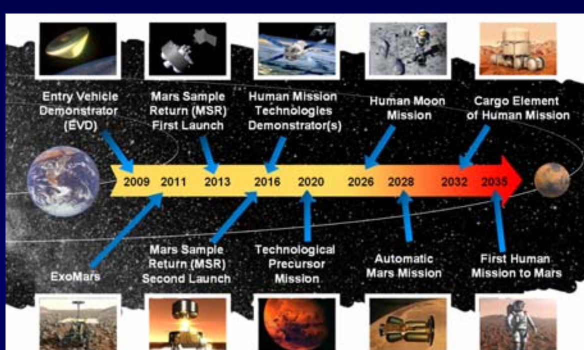




AURORA ELEMENTS

EUROPEAN SPACE EXPLORATION PROGRAMME
AURORA

- *2001 – 2005: Aurora Preparatory Programme*
  - Long term strategic planning and roadmapping → identification of key missions and capabilities to address European exploration objectives
  - Systems study of exploration mission options
  - Preliminary investigation of key exploration issues – human & robotic
  - Focussed development of required technologies
  - Maturation of near-term mission concepts



Initial Mission & Capability Roadmapping

Study and technology development for Mars Sample Return, Human Missions Aspects & Crew Transportation

ExoMars Mission Maturation and Development

Exploration Programme Proposal

ESA Ministerial Council 2005

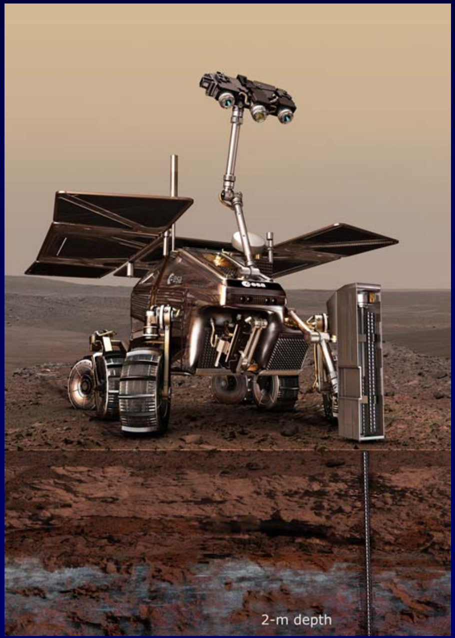
EXOMARS
Mission Objectives

SCIENCE OBJECTIVES:

- Search for traces of past and present life on Mars
- Characterise the water/geochemical environment as a function of depth in the shallow subsurface
- Study the surface environment and identify hazards to future human missions
- Investigate the planet's deep interior to better understand Mars's evolution and habitability

TECHNOLOGY OBJECTIVES:

- Develop and demonstrate European capability to land medium/large payloads on Mars
- Demonstrate high surface mobility and access to Martian subsurface
- Prepare technologies necessary for Mars Sample Return



EXOMARS
Mission Baseline

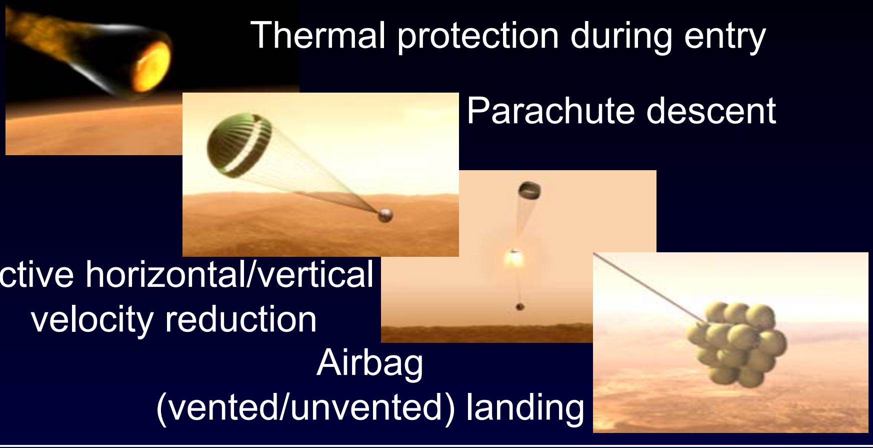
EUROPEAN SPACE EXPLORATION PROGRAMME
AURORA

Launch:	2011 (with back-up in 2013) – on Soyuz 2b from Kourou
Arrival:	2013, back-up 2015
S/C Composite:	Carrier, descent module, rover with geophysics package
Landing:	Ballistic entry from hyperbolic arrival trajectory – EDLS: heat-shield, parachutes, retro-rockets & airbags
Payload - Rover:	150 – 180 kg rover mass, ~10km rover mobility 6 wheel chassis selected Instrument package including Pasteur suite (8kg) Surface lifetime = 180 sols
Payload – GEP:	$\leq$ 20kg for Geophysics/Environment Package Instrument package including seismometer etc.(4-5kg) Surface lifetime $\geq$ 6 years (TBC)
Drill & SPDS:	Rover will be equipped with a sub-surface drill as well as a sample preparation and distribution system (SPDS) which will facilitate the analysis of surface & sub-surface samples by the on-board instruments

EXOMARS
Key Technologies

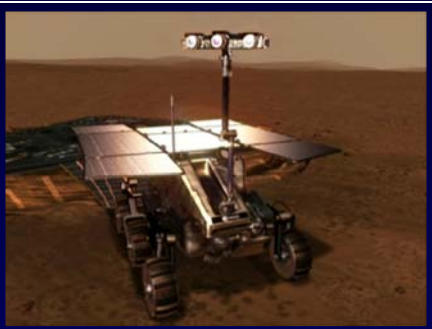
Entry Descent & Landing phase:

- represents one of the most technically challenging elements of the mission
- key opportunity for demonstration of critical technologies for the future
- development already begun, specifically on investigating a *vented* airbag concept



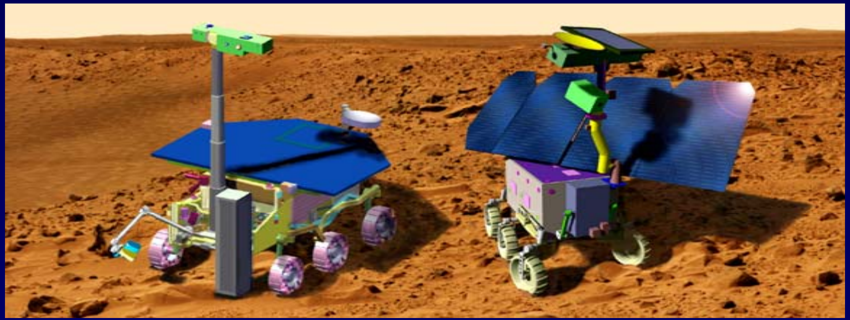
Rover:

- mobility capability is key to the mission science objectives
- platform must accommodate instruments, drill, mobility systems, power, thermal etc.
- communications delay demands a high level of autonomy in the rover’s ability to navigate and deal with potential problems



Power/Thermal:

- Low night-time temperatures on Mars place demands on thermal provision in order to ensure survival of sensitive components e.g: instruments
- Options to meet requirements include using large solar arrays to ensure electrical power for heaters, or the use of radioisotope power sources



RHU-based Rover (EADS Astrium) | Purely solar power-based Rover (MDA Robotics)

EXOMARS
Status & Outlook

EUROPEAN SPACE EXPLORATION PROGRAMME
AURORA

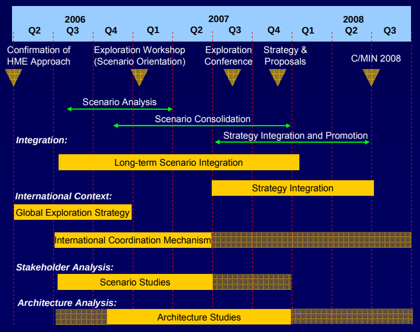
- After systems and technology work performed during Aurora Preparatory Phase, ExoMars has been approved, endorsed and funded during the Ministerial Council meeting of December 2005 receiving a broad base of support from delegations
- Phase B1 of the ExoMars project has been initiated, with Alcatel Alenia Space (I)
- Sub-contractor selection process to perform specific tasks within the project development has begun, e.g entry, descent and landing system,   rover
- Candidate instruments have been selected, and where necessary the instrument technologies are being advanced in preparation for integration in the mission

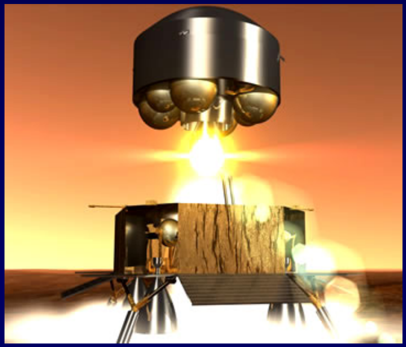
- Also under study is the *option* of using an Ariane-5 launch which could allow:
    - Inclusion of a Mars Orbiter to act as a dedicated European communications relay (as oppose to the baseline of using a NASA orbital relay), and which could accommodate Mars orbital science payloads

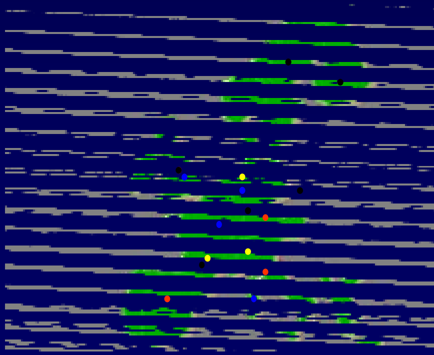
ExoMars with Orbiter

CORE PROGRAMME
Outline

- Approved by Ministerial Council of 2005 – for the duration 2006 – 2009
- Aims to continue the European development and preparation for participation to exploration
- Structured around 4 main elements:
  1. Exploration Roadmaps, Scenarios & Architectures
  2. Mars Sample Return Preparation
  3. General Exploration Technology & Preparation for Lunar Exploration
  4. Awareness







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- Next Ministerial Council of 2008 represents major milestone in progress of Core Programme
- Main goals of Core Programme:
  - To establish set of exploration mission options for decision at next MC-2008
  - To develop technologies in support of mission options
  - To pursue coordinated development strategy towards longer term capabilities
  - To establish foundations of possible future programme elements

Roadmaps, Scenarios & Architectures

ESA EUROPEAN SPACE EXPLORATION PROGRAMME AURORA

- Important to continue and build upon the roadmapping effort initiated in the Aurora Preparatory Phase, in order to ensure the Exploration Programme continues to match Europe's long term exploration objectives
- Also important to take into account, at strategy and planning level, the evolving international situation with regard to cooperation in space exploration
- Specific emphasis is placed upon:
  - Scenarios: Work on European long-term exploration scenario has already been initiated

    Envisaged to develop up to 6 scenario options responding to major drivers

    Scenarios will define over-arching long-term goals, implementation objectives, steps and decision points over time

    1st outline of scenario options to be ready for early 2007

Identified 'corner stones' driving scenario definition:

Europeans in Space	*Sustainable Human Life in Space*
Habitability & Life Beyond Earth	*Sharing the Space Adventure & Benefits*

Roadmaps, Scenarios & Architectures

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    1st outline of scenario options to be ready for early 2007
  - Architectures: Detailed architecture studies (x 6) will define different architecture configurations to enable implementation of emerging scenario options

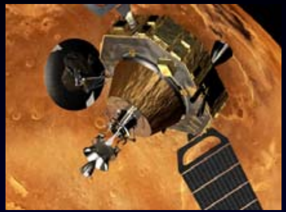
    Architecture options will be analysed and discussed in detail through 2007 with international partners

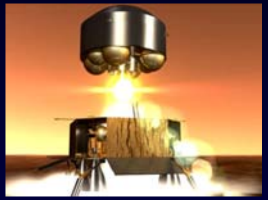
    Aim is to develop an *International Reference Architecture for Space Exploration*
- Stakeholder consultation with academia, industry and the public plays a strong role throughout the roadmapping process

MSR Preparation

- Represents next major step in Mars exploration in terms of:
  - achievement of long term science objectives, as identified by European, US and international science community
  - development of key enabling capabilities for future exploration including advanced robotic and possible human missions
- Envisioned in ~2020 timeframe, and internationally recognised as an opportunity for cooperation

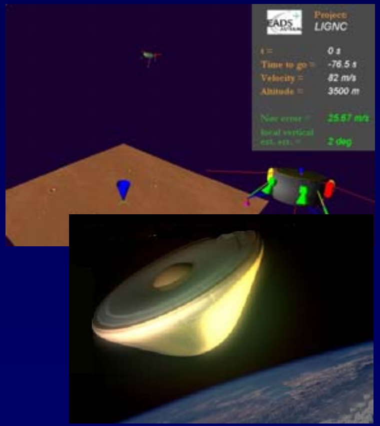
#1 MSR Orbiter with Earth Return Vehicle

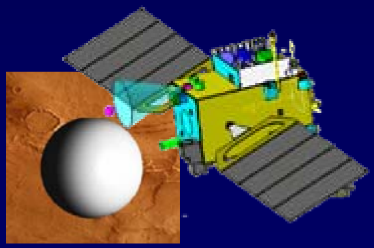


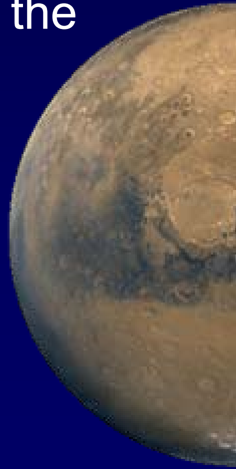


#2 MSR Lander with Mars Ascent Vehicle

- Past Aurora work, including 2 parallel industrial studies, defined ground-breaking mission architecture based on two launches
- Preliminary system & technology development work has begun to address the identified key enabling capabilities:
  - Soft-Precision Landing
  - Autonomous Rendezvous
  - Bio-containment
  - High Speed Earth Re-entry







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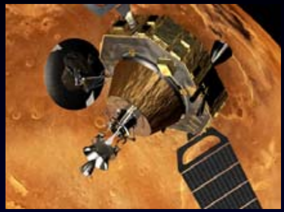
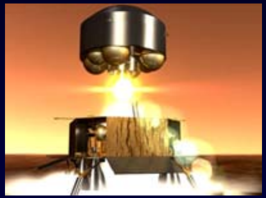
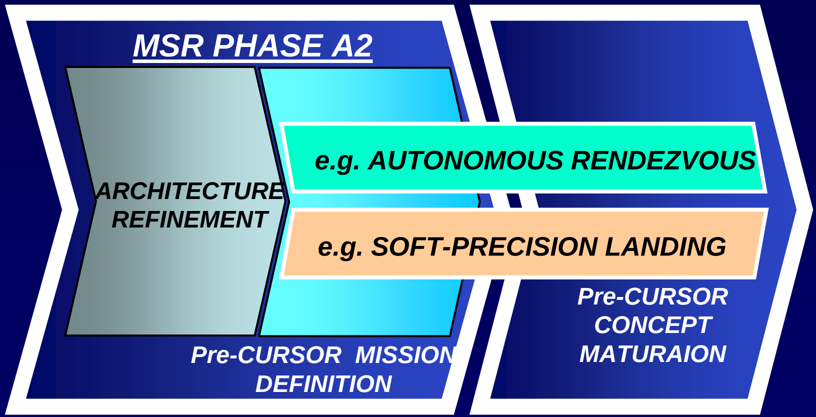




#2 MSR Lander with Mars Ascent Vehicle

- Further European development for MSR structured around ongoing Phase A2 system study
  - Refine MSR system architecture
  - Address new & open issues
  - Guide ongoing & planned technology development work in key areas,
  - Identify *PreCursor Mission Options*, for consideration in 2014/2015 timeframe, in preparation for Ministerial Council in 2008



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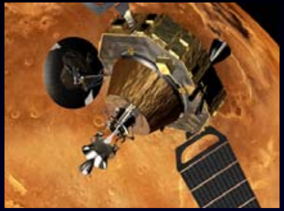
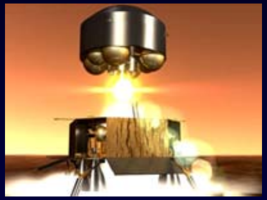




#2 MSR Lander with Mars Ascent Vehicle

- One of the Precursor Mission Studies will most probably focus on the demonstration of Soft Precision Landing on The Moon and may offer the possibility to accommodate a certain scientific payload (within a limited mass budget). A more detailed definition of the mission will be conducted first.

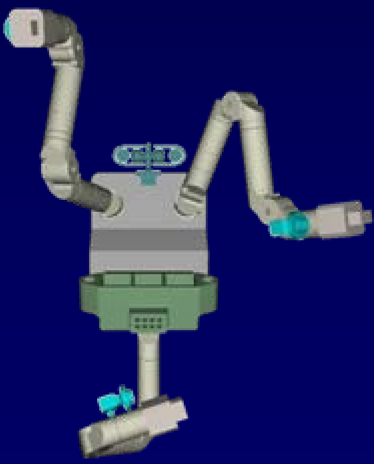
- For more information, please contact Gerhard Kminek at

Gerhard.Kminek@esa.int

General Exploration Technology & Preparation for Lunar Exploration

- Europe possesses strong heritage and experience in several technologies and capabilities specifically associated with human spaceflight
- Renewed NASA-led initiative to return humans to Moon by 2020 prompts action to coordinate potential European participation
- Require general coordination to ensure Europe's resources are targeted wisely to ensure strong role in future human space exploration of Moon and Mars

- Power: Assessment of medium-long term power provision aspects in human exploration architectures, e.g: solar/fuel-cell/nuclear power systems
- Robotic: Assistance Investigation into use and applications of robotic assistance technologies in future human exploration scenarios, e.g: Eurobot
- ISRU: Systems assessment of In-Situ Resource Utilisation (ISRU) technologies, the necessary technology developments and the elaboration of future European strategy



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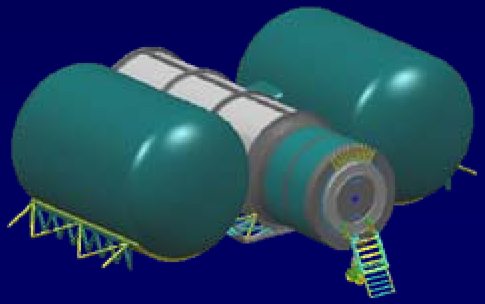
- Life Support: Development & demonstration of systems for near term applications, e.g.: ARES

  Further development & maturation of medium term LSS systems, e.g.: MELISSA
- Habitation: Continuation of preliminary development into inflatable habitation systems and technologies

  Use of ISS for future exploration preparation, e.g. via use of MPLM

  Refinement of system level understanding of habitation aspects, including requirements etc.



Awareness

- Of key importance to engage with public throughout exploration programme, in particular but not limited to:
  - School children
  - High-school pupils
  - University students
  - Academia

- Future approach will build upon the strong links developed during Preparatory Phase of Aurora and will include:
  - Development of education packs on exploration for school children
  - Running of interactive events and design competitions for students from high-schools up to universities
  - Creating opportunities to engage with the public on the issues raised by exploration

Crew Space Transportation System Development

- Crew Space Transportation is a key capability in overall human space exploration
- Europe has already gained some experience in critical technologies through programmes such as: Hermes, Atmospheric Re-Entry Demonstrator & ATV
- Current approach foresees potential European partnership with others in development of Crew Space Transportation Systems, e.g: Russia

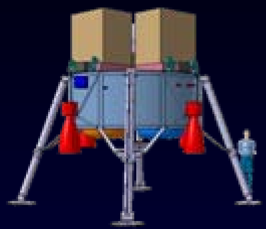
- ESA Council recently adopted resolution to carry out preliminary investigations to identify:
  - System requirements and concept consolidation
  - Preliminary system design
  - Design and bread-boarding
  - Cooperation framework and related arrangements
- Discussions are ongoing:
  - Establish international cooperation on the development of a CSTS
  - Establish internal European framework, based on existing experience & future priorities:
    - E.g. Rendezvous and docking via the International Berthing and Docking Mechanism (IBDM)

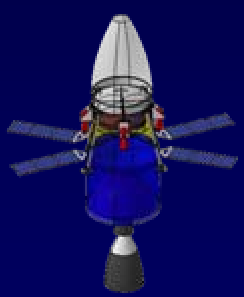
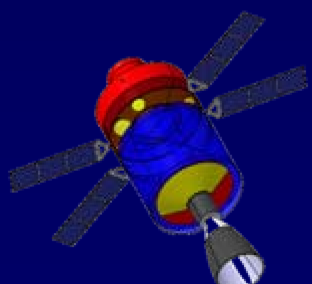
The European Lunar Robotic Mission Study Introduction

- The European Robotic Lunar Mission Study is the latest in a series of lunar exploration studies performed in the ESA Concurrent Design Facility (CDF)

- Previous studies include:
  - Human Spaceflight Vision (2003) addressed the build up of a manned lunar base using a possible evolution of the European Ariane 5 launcher
  - LES (2004) addressed Sustained Lunar Exploration and specifically long duration orbital flight (Mars transit simulation) and lunar surface time
  - LES-CTS (2005) addressed cargo transportation to a Low Lunar Orbit and to the Lunar Surface using current Ariane 5 capabilities

- This study builds on two previous studies undertaken by ESA, EuroMoon (1997) and LEDA (1995). Neither of the two previous studies were implemented. However, with the lunar terrain data now available from SMART-1 and the advancement in miniaturisation since the 1990’s , this type of mission should now be less costly and risky.



The European Lunar Robotic Mission Study Mission Objectives

EUROPEAN SPACE EXPLORATION PROGRAMME
AURORA

- Provide Europe with a follow on mission to SMART-1 for lunar surface exploration and identify possible ESA/European involvement in international lunar missions being planned (Chandrayaan-1, Selene, Lunar Reconnaissance Orbiter).
- Provide a European technology demonstration platform able to demonstrate several specific technologies needed for future lunar and Mars exploration missions (robotic and human)
  - Demonstrate ISRU technology and lunar material science
  - Demonstrate surface and vertical mobility
  - Demonstrate soft 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

The European Lunar Robotic Mission Study Mission Requirements

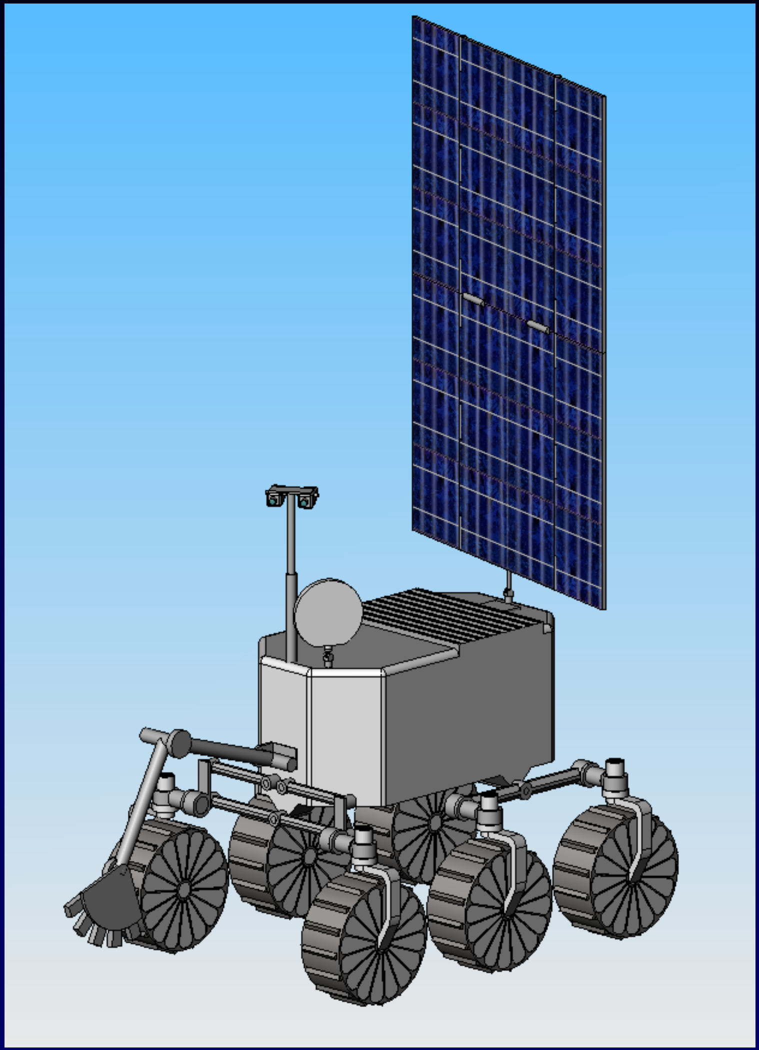
- Mission timeframe
  - Start of C/D activities 2007-2008
  - Launch around 2012-2014
  - Survival/ Operation 3 month minimum, possible extension 6 months to 1 year
- Primary landing location around possible peak of eternal light at South Pole (up to 80% in winter) or North Pole (data available from SMART-1 mission)
  - Polar or near polar orbit or direct descent
  - Precision landing 500m
  - Rough terrain
- Secondary landing site at proximity of North or South Pole Region during summer conditions
- Investigation into dark crater areas of polar region looking for resources (water ice) for future use
- Minimize cost

The European
Lunar Robotic Mission Study
Mission Requirements

- Technology Demonstration (with technologies identified for Mars exploration where possible)
  - 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
    - Low Risk: Around lander
    - High Risk: Travel down into dark crater
    - High Risk: Hopping to distant location and perform controlled 2nd descent
  - 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

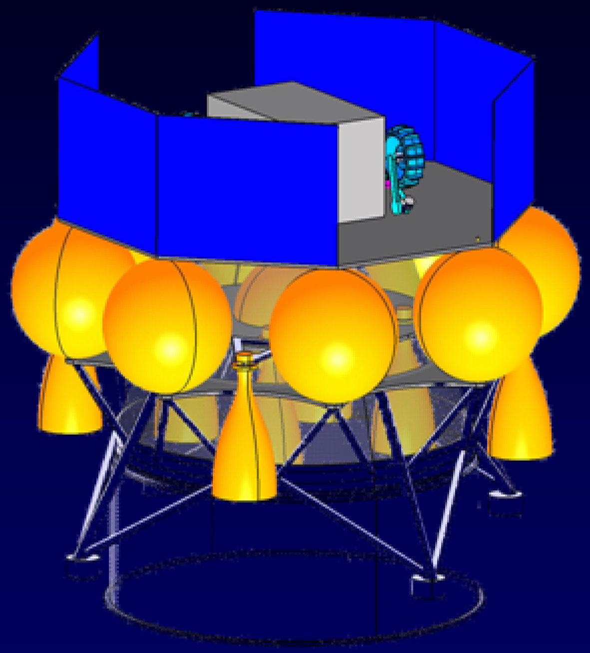
The European Lunar Robotic Mission Study Science and Payload

- 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 leaving 155kg for the regional rover and its payload which shall include means for ice detection, sample acquisition and analysis (Drill or mole)
- ISRU technology precursor (perform resource extraction and processing) was descoped from study



The European Lunar Robotic Mission Study Configuration

- The baseline design has the following features:
  - Launch by Soyuz Fregat from Kourou
  - Launcher payload capabilities 3030 kg
  - Single element design, without propulsion module or orbiter
  - 8 bi-prop thrusters 500 N, to perform injection in TLO, LLO, descent and braking phase
  - 4 of them used to perform soft landing in a Pulse Width Modulation mode
  - 8 off-the-shelf spherical tanks, polar mounted
  - Reaction Control System with off-the-shelf 10 N bi-prop thrusters
  - Cameras and LIDAR to perform landing site reconnaissance, obstacle avoidance
  - Direct communication link with Earth
  - 8 Vertical body mounted panels with regular octagonal shape



The European Lunar Robotic Mission Study Conclusions

- During the course of this study, five different system options for a European Lunar robotic mission to land on the North or South Pole have been studied
- Baseline option consists of one element, containing a bi-propellant system using eight thrusters giving the highest payload mass (about 200 kg) on the Moon when a Soyuz-ST launcher is used
- Other options studied included an Ariane 5 shared launch which leads to payload mass of more than 200 kg (depending on share)
- The use of electrical propulsion based on plasma thrusters does not give a significant increase in landed payload mass but increase travel time and risk
- Different scientific payload packages have been defined for the system options
- An assessment was done on the regional rover design and its surface operations
- Study indicates that a small robotic mission is well within the technical and financial means of Europe

CONCLUSIONS

- European Space Exploration Programme Aurora is progressing with the development of the ExoMars mission at the forefront
- Recently approved Aurora Core Programme is continuing the wider exploration effort in Europe through:
  - Further elaboration of long-term European strategy and priorities
  - Elaboration of candidate intermediate robotic mission options for possible approval in 2008
  - Pursuit of key enabling capabilities and technologies through future robotic and human missions, focussing on the preparation for Mars Sample Return and the potential involvement in a human return to the Moon
  - Involvement of academia, youth and the public at large

- Aurora continues to address potential future European priorities in space exploration such as cooperation on crew space transportation and the use of ISS in preparation for long duration human activity