European Space Agency
human spaceflight

ESA Strategy for Human Exploration

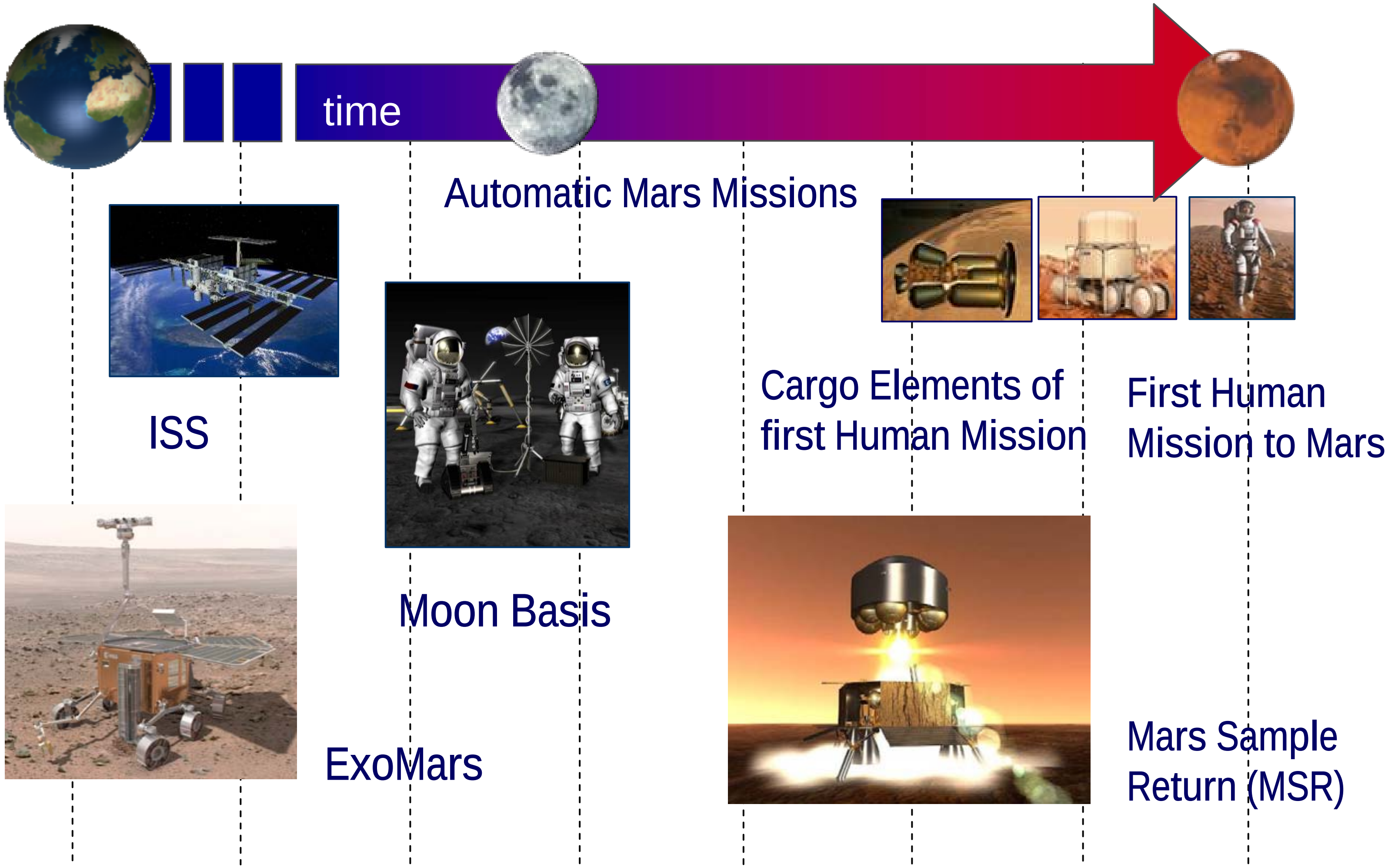
(Lunar Lander)

Schiaparelli and his Legacy
Torino, 21 October 2010

B. Gardini
D/HSF-E

Aurora Programme

ESA Programme (2001) for the human and robotic exploration of the Solar System



Lunar Lander

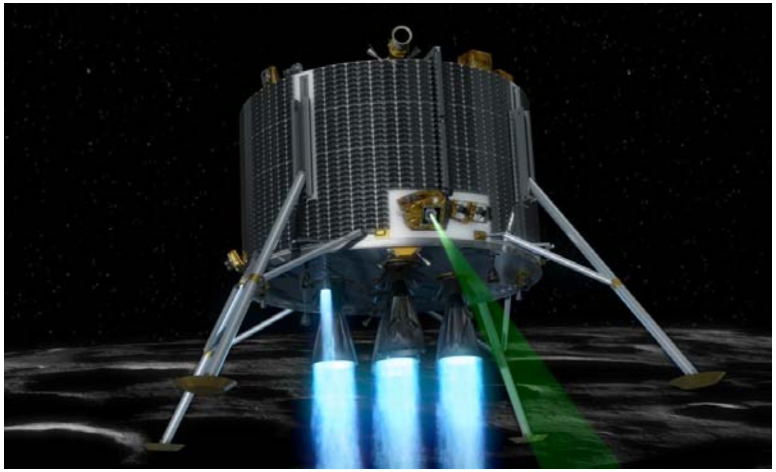
Lunar Lander Mission Objective

ENABLE SUSTAINABLE EXPLORATION

primary objective

opportunity for investigations

- **Soft Precision Landing with hazard avoidance**

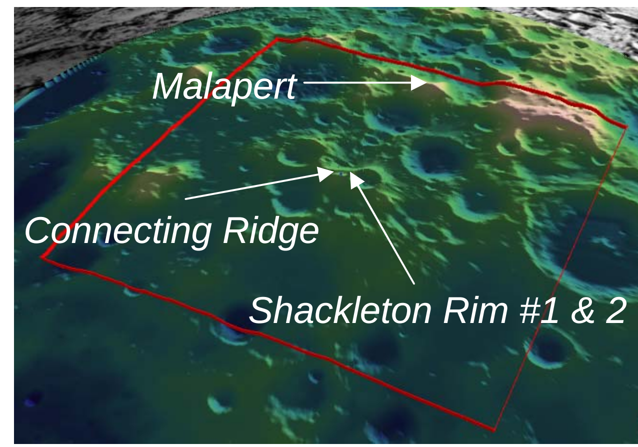


- **Crew health**
- **Habitation**
- **Resources**
- **Preparations for human activities**

Landing Site: South Pole

- Polar regions may experience extended periods of illumination (>14days)
- Critically dependent on the local topography in the polar regions: terrain requires very precise navigation and hazard avoidance
- JAXA's Kaguya orbiter surface mapping:
  - ~200m resolution in South Pole region
- 3 parallel analyses performed:
  - Illumination pattern: duration of light/dark
  - Earth communications availability
  - Physical extent of illuminated areas
- Several interesting locations found, but no 'peak of eternal light'

Courtesy of JAXA

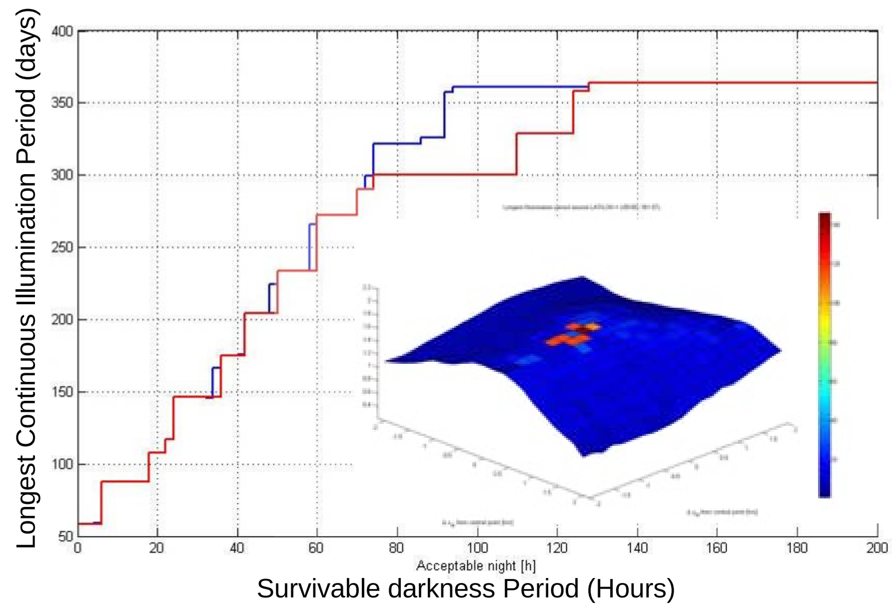


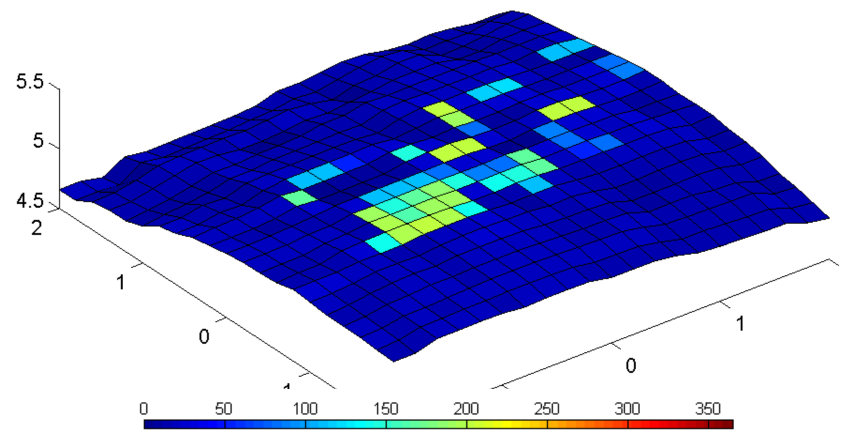
Courtesy of NASA

Topographic Analysis

- Various illumination patterns across the identified sites, strongly date dependent
- Enabling survival of short darkness periods:
  - Can significantly increase the effective illumination duration
  - Can lead to an enlargement of the effective landing areas
- Sites do exist which are illuminated for several months*; further analysis of new data will help confirm their size
- Analyses shall be repeated in Phase B1 using more accurate data coming in from NASA's Lunar Reconnaissance Orbiter (LRO)

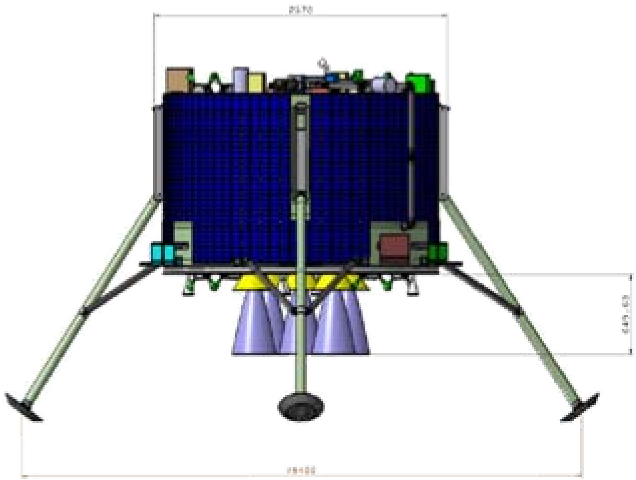
*given the capability to survive for short periods of darkness (up to 10's hours)





Example illumination map, Malapert, filtering out short nights of <55hrs

Technical Baseline Phase B1



Phase B1 Contract with Astrium ST (Bremen) initiated end July 2010:

- Single stage
- Propulsion: cluster of European engines (500N EAM & 220N ATV)
- Direct Communication To Earth
- Payload capability: ~60 kg total **(tbc in Phase B1),** including all instruments and the associated servicing equipment

Parallel Activities during Phase B1:

- Launcher performance analysis with Arianespace
- Payload definition studies (GSP funded)
- Consultancies about surface hazards analysis (G. Neukum, I. Crawford)

Launch & Transfer

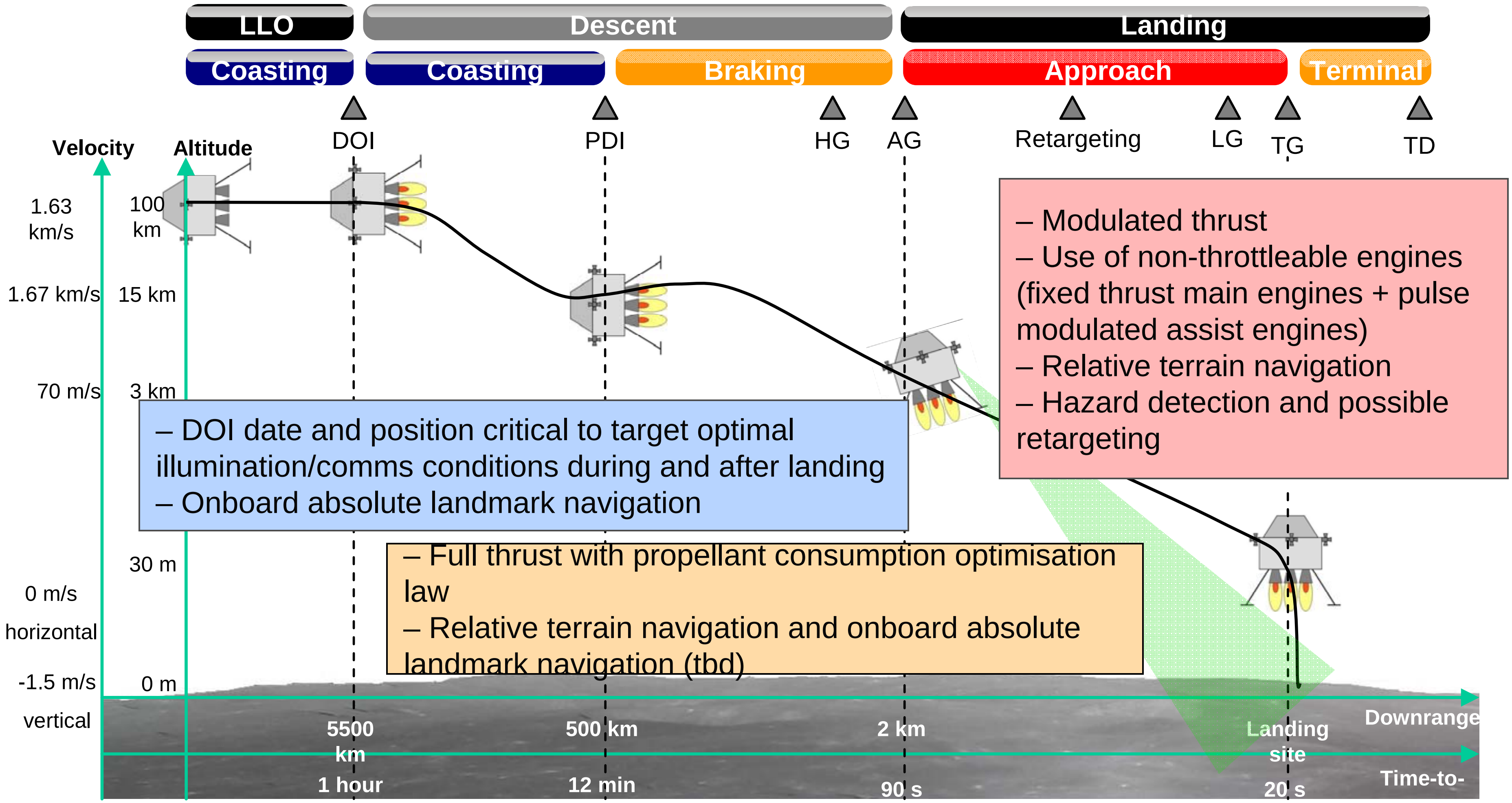
- Launcher: Soyuz 2-1b,with Fregat upper stage
- Launch site: CSG
- Launch period: every 2 weeks
- Launch window: 2 consecutive days
- Launch date: no later than 2018

⇨ main mission constraint from launcher: MASS

⇨ launch date compatible with favourable illumination/ comms period at the landing site

- Transfer via GTO or HEO:
  - Optimal solution under investigation in Phase B1
- Injection in LTO followed by insertion in LLO (typically 100 km altitude) performed by the spacecraft itself

Descent & Landing Profile



Note: the velocity, altitude, downrange, delta-V and time values are provided to give an order of magnitude

– Control of touchdown conditions, compatible with landing legs design
– Engines cut-off

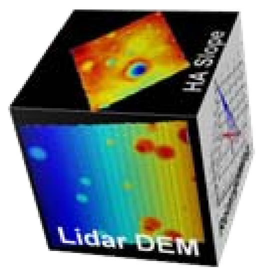
Soft and Precision Landing Technology

Technology activities developed since 2005 under ESA Aurora Core / TRP programmes and nationally funded R&D activities, are key building blocks in the mission development logic

TRN Sensors: Optical camera and Lidar

Optical Terrain Relative/Absolute+ Navigation

+: ANTARES



Reusable GNC and HDA Software

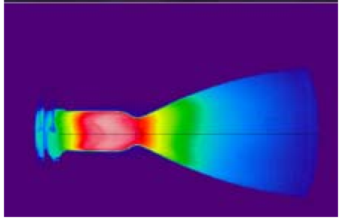
COTS Model-based Development & Validation Framework

Generic Avionics Platform

Terrestrial Dynamics Test Facilities

Industries across Europe are already developing the next generation of technologies needed to successfully land on the Lunar surface

Phase B1 Bread boarding Propulsion



- **Flow interaction test with water:** investigation of interactions and disturbances in the feed system
- **220N thruster hot firing test:** performance characterisation at 2.5 Hz command frequency (1 Hz qualified for ATV)
- **Pressure regulator test:** measurement of regulation accuracy at high mass flows

Phase B1 Bread boarding Navigation & HDA

- **Relative navigation and HDA demonstration test:** test with hardware-in-the-loop on the TRON dynamic test bench (DLR Bremen), with a representative Lunar surface model

- **Absolute navigation rapid prototype:** specification and implementation for systematic performance analyses

- **Absolute navigation demonstration test:** evaluation using the TRON indoor test facility

Payload Objectives and Definition

- Stepwise and transparent process put in place since 2009
- Request for information in March 2009:
  - 194 submissions received, demonstrating widespread interest across Europe and within both industry and academia

- Lunar Exploration Definition Team (external): defines objectives for a precursor mission to lunar exploration by humans
  - Supported by ESA technical experts and Topical Teams
  - Advised by Life Sciences and Physical Sciences Working Groups

Model Payload

Model payload (not selected payload)

- Total payload ~60 kg, including payload servicing s/s
- Derived from RFI responses and extensive definition process
- Consistent with mission constraints
- Input to mission system design
- Input to P/L development activities

	Heritage	Health	Habitation	Resources	Human Activities	Public Outreach	Mobility
Stereo panoramic imager	In development for other missions		High		Medium	High	
Arm camera	In development for other missions		High	Medium	High	High	Medium
Experiment in human radiation biology	Conceptual	High	Medium				
Radiation Monitor	Flight heritage	High	Medium				
Dust charge and trajectory sensor	In development for other missions	High	High		High		
Langmuir probes and booms	Flight heritage	High	High		High		
Radio antenna	Flight heritage		High		High		
Optical microscope	Flight heritage	High		High			
Atomic force microscope	Flight heritage	High		High			
Raman (LIBS?)	In development for other missions	High		Medium	Medium		
Dust chemical reactivity experiment	Has been subject to studies	High					
Volatiles analysis package	Flight heritage			High			
X-ray spectrometer / Raman optical head	Flight heritage	High		Medium	Medium		
Mobile Payload Experiment (MPE)							

Heritage	
Flight heritage	
In development for other missions	
Has been subject to studies	
Conceptual	

Priority	
High	
Medium	

Payload Definition Studies

- Objectives:
  - Improve instrument definition, interfaces and requirements (Phase 0/A)
  - Establish preliminary instrument package design
  - Identify opportunities for design and science optimisation: synergy, coordinated operations, commonality
  - Establish overall package development plan

Heritage	
Flight heritage	
In development for other missions	
Has been subject to studies	
Conceptual	

- 4 x Payload Definition Activities under GSP
- ITTs in preparation, release expected end October 2010
- Exchange of results between P/L studies and Phase B1 through Project

Cameras	Stereo panoramic imager
	Arm camera
Radiation and Effects Package	Experiment in human radiation biology
	Radiation Monitor
Dust Plasma Waves and Fields Package	Dust charge and trajectory sensor
	Langmuir probes and booms
	Radio antenna
Dust Chemistry and Microscopy Package	Optical microscope
	Atomic force microscope
	Raman (LIBS?)
Dust Toxicity	Dust chemical reactivity experiment
Volatiles	Volatiles analysis package
Optional Payloads	X-ray spectrometer / Raman optical head
Contribution In Kind	MPE

Payload Studies	
Planned ESA activities	abc
Activities planned outside of ESA	abc

1. Radiation package

Automated Microscope for the Examination of Radiation Effects

•Experiment concept from TT-IBER

•Radiation effects on human physiology

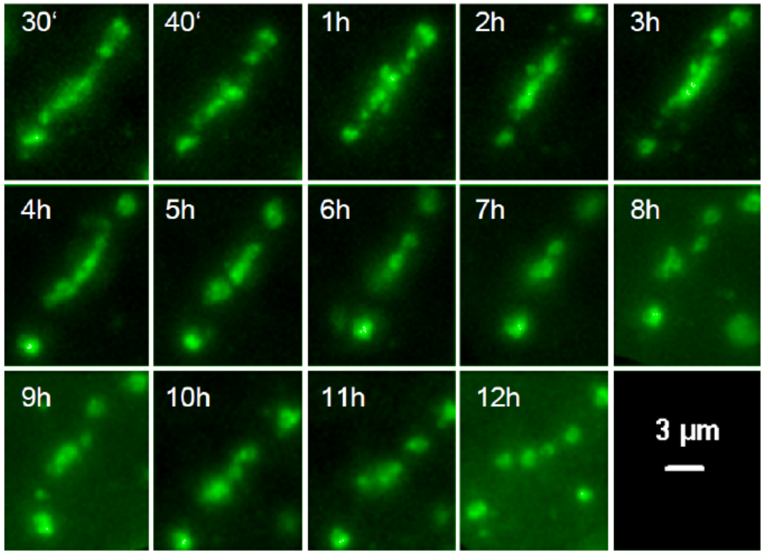
•DNA repair mechanisms

- •in human cells
- •following damage by HZE-GCR particles
- •in the Lunar environment

•Techniques applied in terrestrial studies

•Feasibility of lunar payload needs determining

•Potential application to other platforms for exploration preparation



From Jakob et al., Proc. Natl. Acad. Sci. USA, 2009

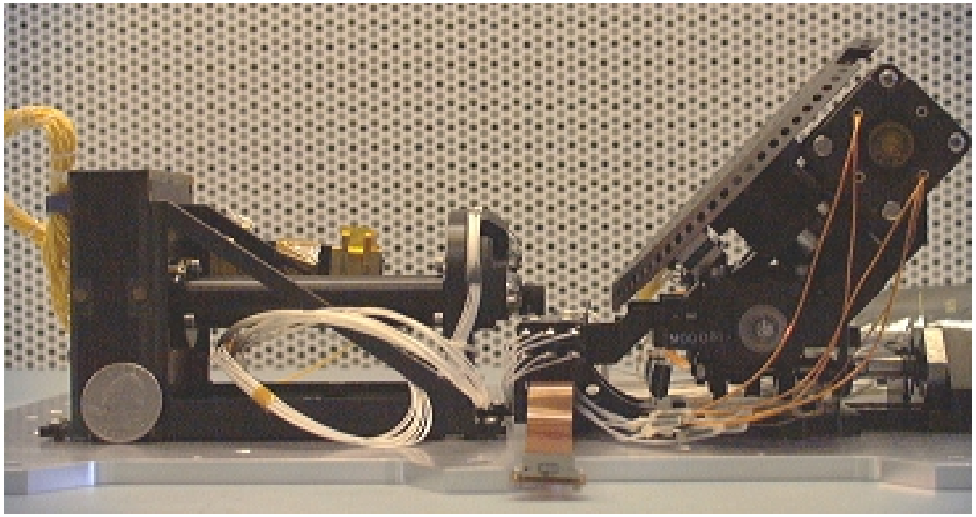
2. Lunar Dust Analysis Package

Lunar Dust Analysis Package

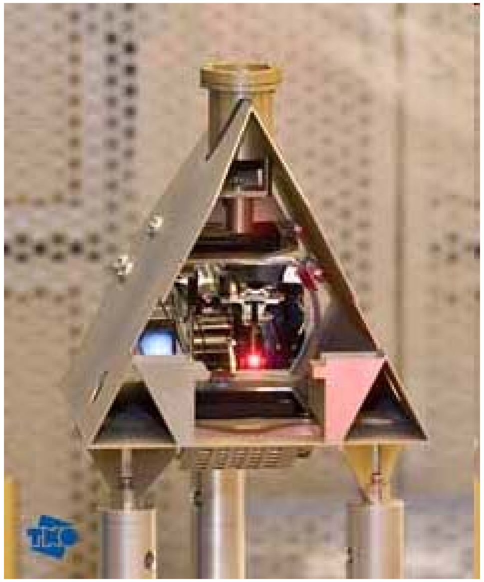
- Size distribution of dust ~10nm - 100µm
- Structure and morphology of grains
- Dust chemistry/mineralogy
- Dust elemental composition?
- OH group, H_2O

Potential Instruments for consideration

- Optical and Atomic Force Microscopes
    - E.g. Phoenix (MECA) / Beagle 2)
- Raman (+ LIBS?)
    - E.g. Heritage from Exomars



Phoenix MCA optical and Atomic force microscopes and sample stage.

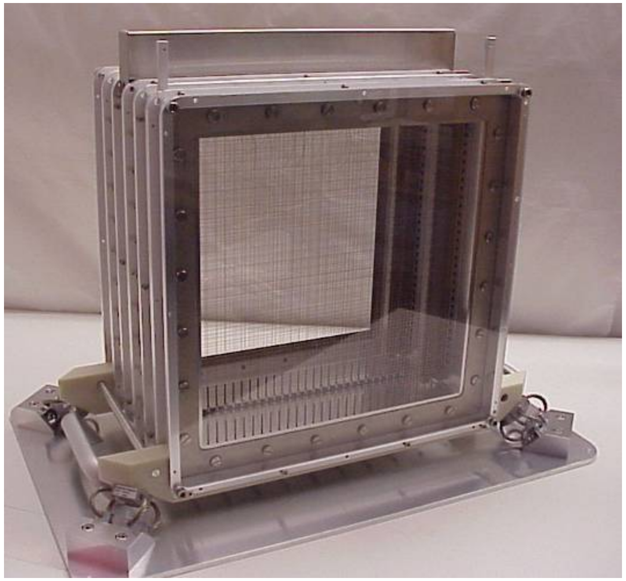


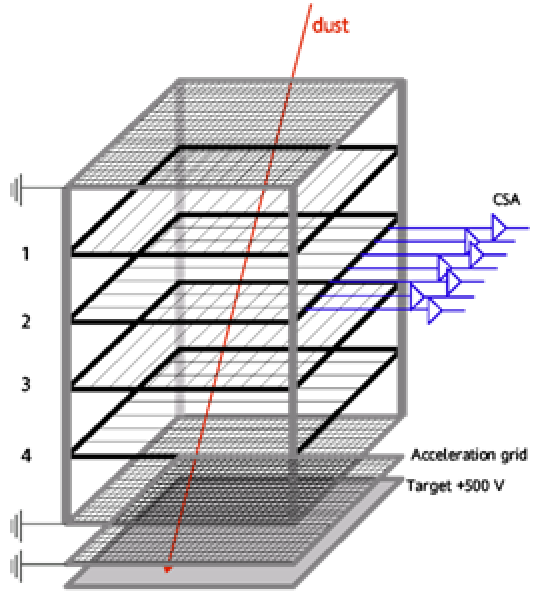
Raman-LIBS elegant breadboard spectrometer

3. Lunar Dust Environment and Plasma Package

Measurements

- •Dust motion, charge, size distribution, trajectory
- •Electric fields
- •Plasma temperature, density
- •Plasma EM properties
- •Medium - Long wavelength radio background





Potential Instruments for Consideration

- •Dust Charge and Trajectory sensor
- •Langmuir Probes (extensive heritage)
- •Broadband Radio Receiver (various heritage)

4. Lunar Volatile Resource Analysis Package

Measurements

Identify Solar Wind Implanted and other volatiles in the lunar regolith

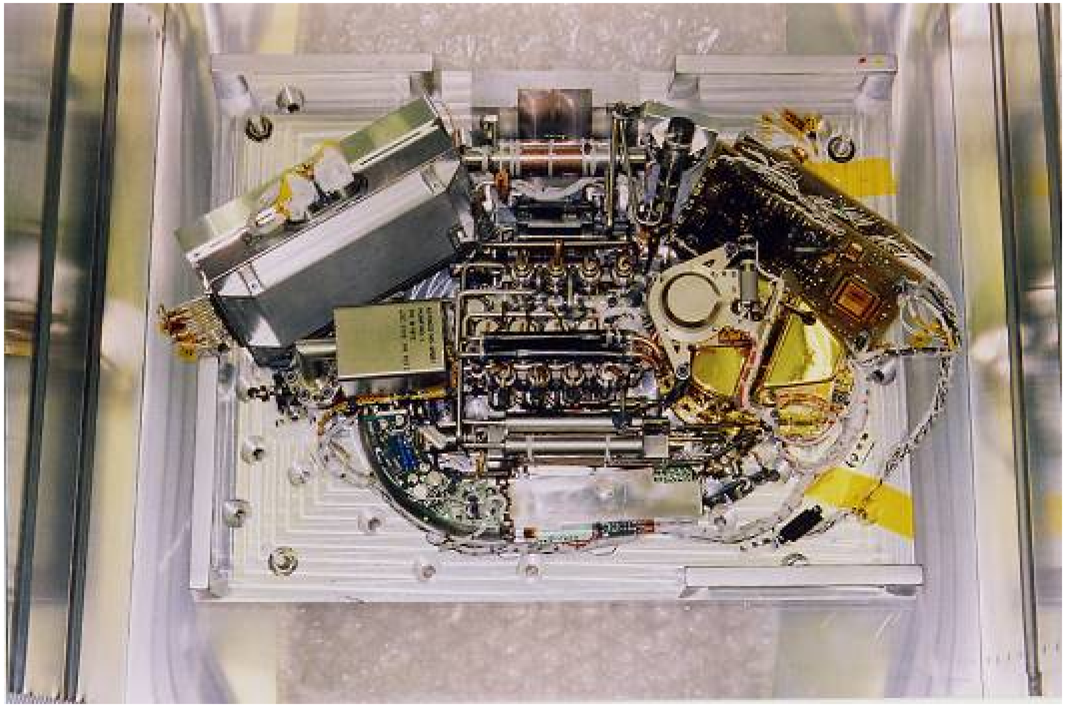
Extract volatiles from the lunar regolith as a potential resource

Observe exosphere species

Need to understand implications of surface contamination during landing

Potential Instruments for Consideration

•Mass spectrometer (heritage e.g. Beagle 2 GAP)



Beagle 2 GAP

Next Steps

- Increase support basis to the Lunar Lander Mission with contributions from ESA Member States other than D, P, Canada. Other 3 countries expected to join before end 2010.
- Payload definition studies (GSP) – ITTs to be issued in October 2010
- Preparation for Ministerial Conference 2012
- Preparation for Call for Proposals / Announcement of Opportunity for the Lunar Lander Payload Instruments

Conclusions

- Europe’s First Lunar Lander is a key step in preparing sustainable human exploration of the Moon and beyond
- The Lunar Lander will bring together the results of Europe’s technological investment and experience, particularly in landing, to achieve a first in lunar exploration: landing at the Moon’s south pole
- The Lunar Lander payload represents an important opportunity for the European research community

www.esa.int/esaHS/exploration