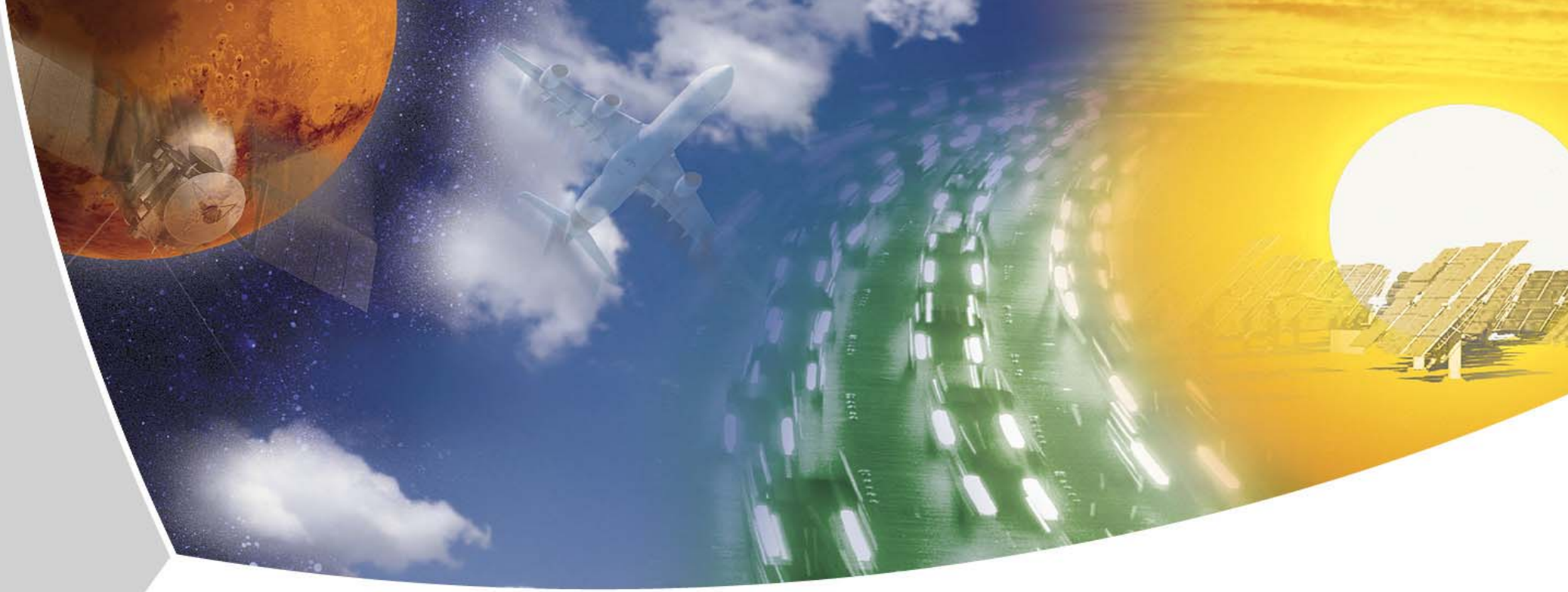


The Moon - stepping stone for Exploration of our Solar System

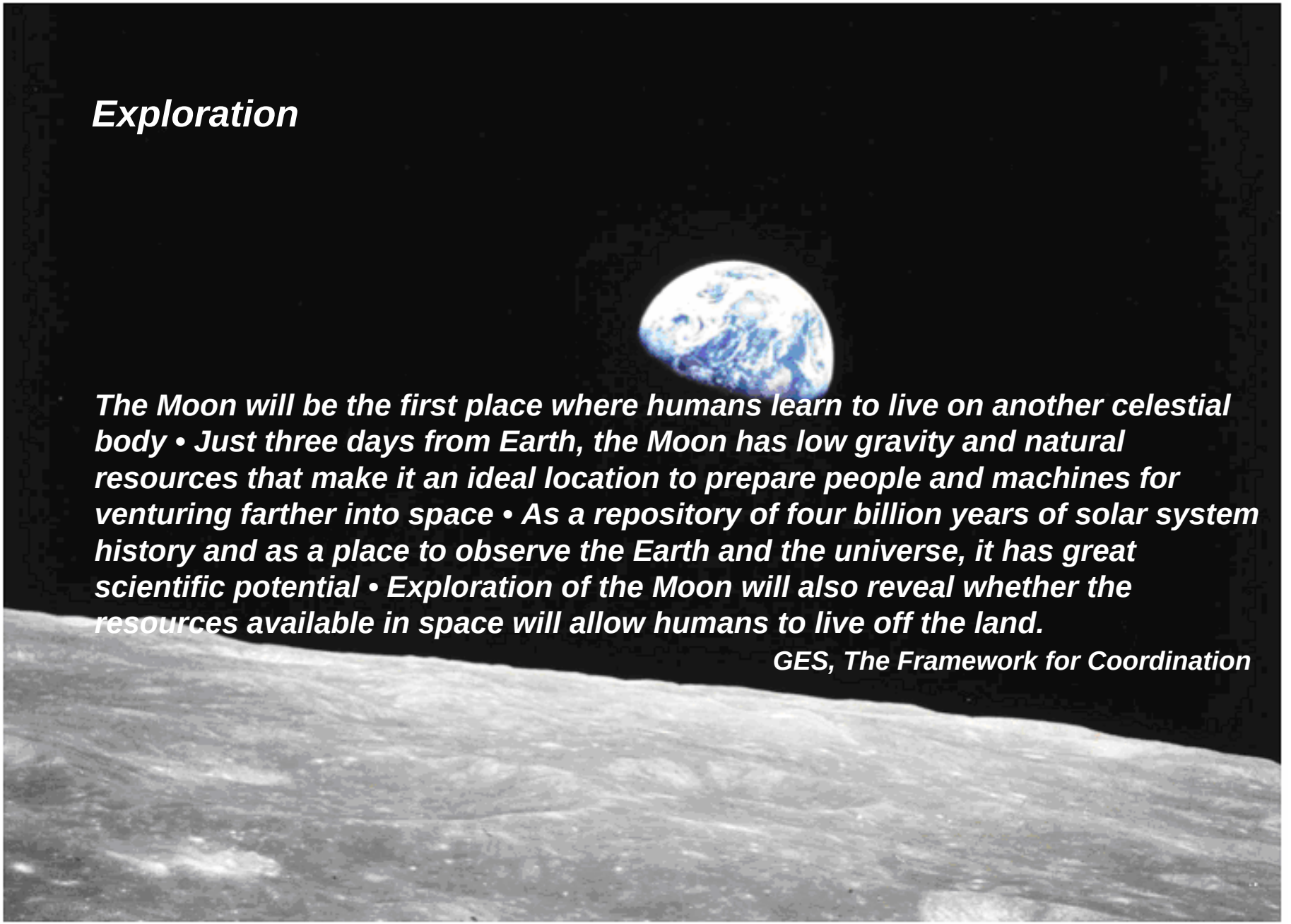
Norbert Henn
German Aerospace Center
Space Agency
Human Spaceflight, ISS and Exploration

9th international Lunar Exploration Working Group

Sorrento, Italy
22. – 26. Oct 2007

Deutsches Zentrum
DLR für Luft- und Raumfahrt e.V.

Exploration



The Moon will be the first place where humans learn to live on another celestial body • Just three days from Earth, the Moon has low gravity and natural resources that make it an ideal location to prepare people and machines for venturing farther into space • As a repository of four billion years of solar system history and as a place to observe the Earth and the universe, it has great scientific potential • Exploration of the Moon will also reveal whether the resources available in space will allow humans to live off the land.

GES, The Framework for Coordination

Exploration in Germany #1

- **The Global Exploration Strategy (GES) shows a strong and clear indication for the moon as a next step for human space flights after ISS**

- **Europe is actively involved in this global effort with participation of ESA and several national space agencies I, UK, F and D**

- **Global Exploration Strategy framework published in May; the International Space Exploration Coordination Group (ISECG) will be set up to continue these activities, ToR will be finalised in a meeting 6/7 November at the occasion of the Int. Space Expl. Conference (ISEC), Berlin 8/9 Nov., organized by ESA and DLR**

Exploration in Germany #2
Today / tomorrow

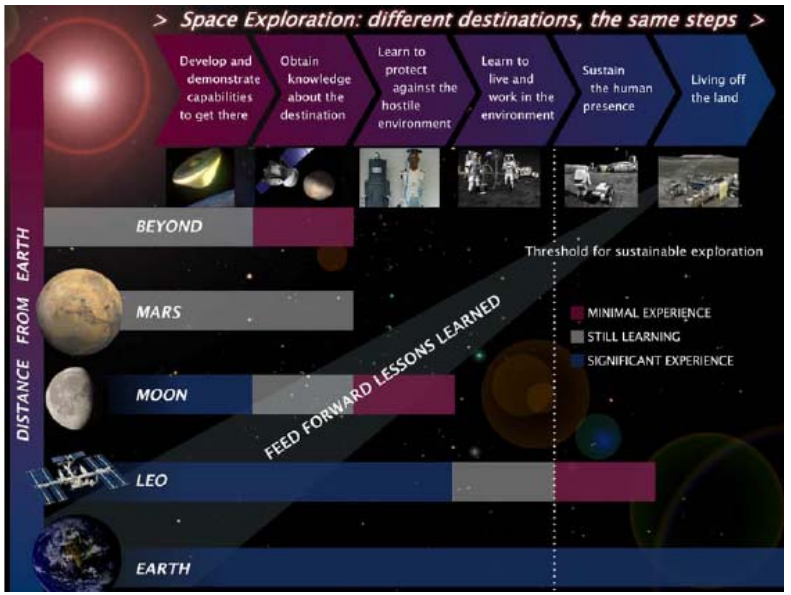
- ❑ **Germany participate in the ESA Aurora Programme: ExoMars, Core Programme**
- ❑ **National studies were initiated**
- ❑ **Germany supports the ISS as a test bed for exploration**
- ❑ **A National Exploration conference at 'Dresden' Nov. 2006 was held, arising the idea of a Lunar Exploration Orbiter (LEO)**

DLR's opinion

- **Moon - the next logical step, for demonstration of exploration technologies and manned activities beyond ISS**

National studies were initiated to answer related questions, e.g. what is

- **the scientific demand,**
- **the technological need for decades and the challenge of future missions,**
- **feasible.**

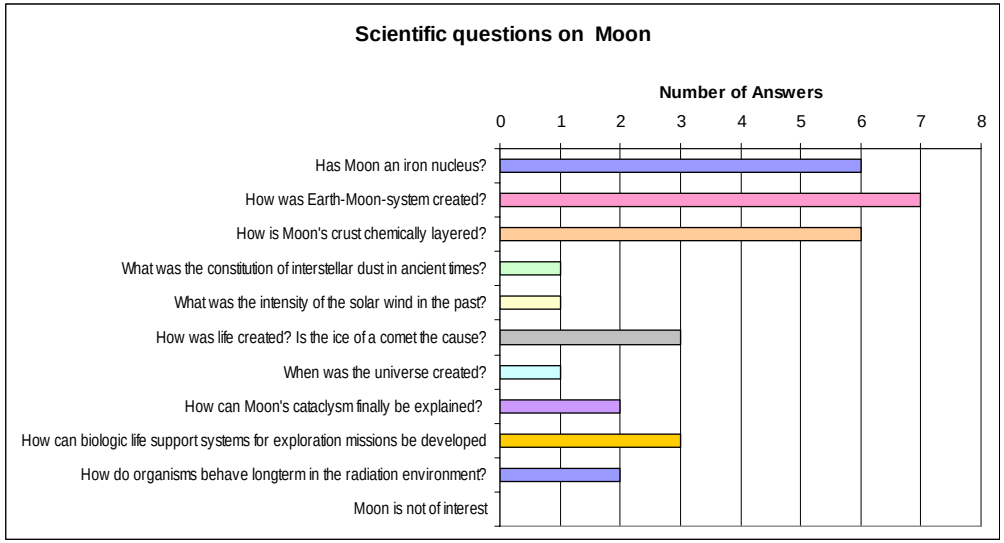


National Planning #1

Study „MonaLisa“, OHB, completed in May 07

- **What are the goal’s?**
- **What are potential missions?**
- **Where are the preferences?**

70 German expert scientists from various disciplines were interviewed with respect to mission objectives.



Main <u>scientific areas</u> (“mission’s”) were identified (no ranking):

- **Global lunar mapping with spatial resolution < 5m, incl. geo-chemistry analyses from orbit**
- **Global lunar gravity field mapping, especially on the lunar far side**
- **Determination of local/residual magnetic field (from orbit)**
- **Seismic probes and heat flux probes to analyze the inner construction of the Moon**
- **Astro-/ Exobiology**
- **In-situ-analyses of lunar samples at geo-physically interesting locations**
- **Lunar sample return from geo-physically interesting locations**

National Planning #2
MonaLisa, cont.

To identify the best mission to Moon from a German perspective, 6 criteria groups with 27 sub-criteria were established. Each potential mission was then weighted against each other according these criteria (Analytic Hierarchy Process, AHP).

Criteria groups

- **Scientific importance of the mission**
- **Key-systems and technologies**
- **Strategic / political importance**
- **Industry-political / economical importance**
- **Programmatic criteria**
- **Social and cultural consequences**

Sub-criteria, e.g.

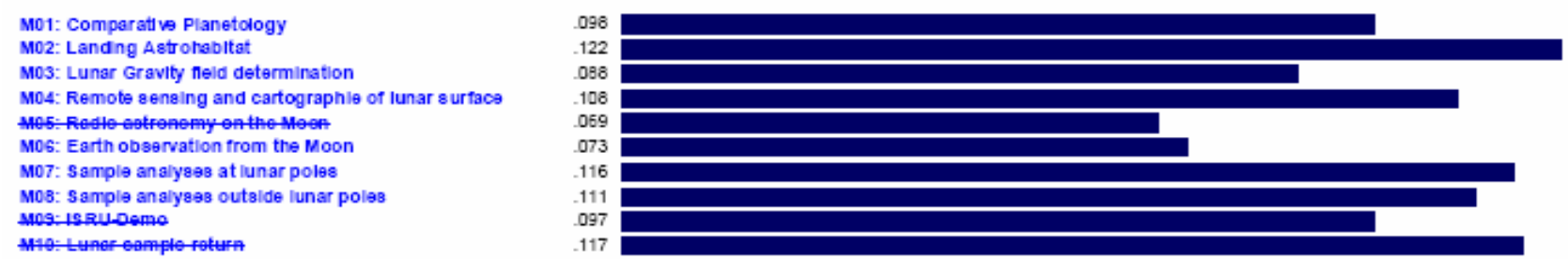
- **Overall importance of the scientific question**
- **Innovative character**
- **Complementary to other missions**
- **Cooperative potential**
- **No other efficient method available for achieving the scientific results**
- **etc.**

… resulting in ranked potential missions:

National Planning #3
MonaLisa, cont.

Missions as a result of the evaluation

- **Landing Astro-Habitat (M02)**
- **Exploration and analysis of lunar samples at and outside the poles (M07&M08)**



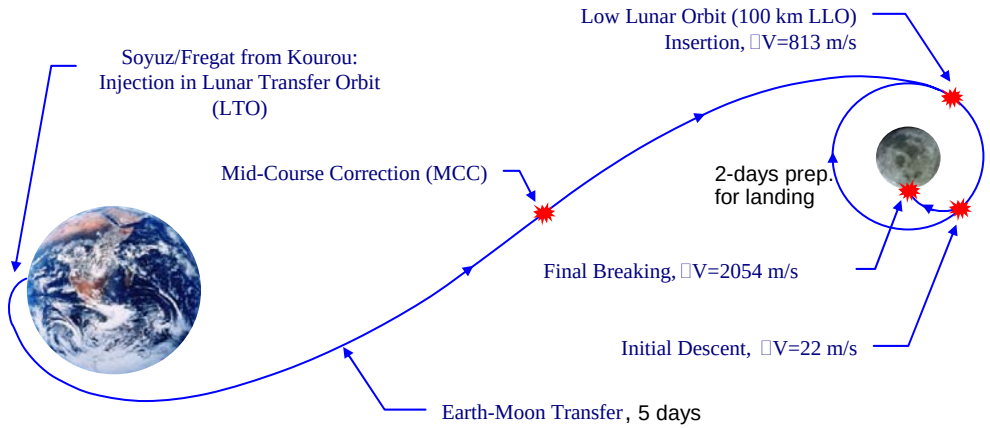
A remote sensing mission was not further studied because of the intended LEO mission.

Due to excessive overall cost and cost per year the missions M05 and M10 were not further examined.

Nevertheless, an ISRU Demo mission could also be considered (same P/L class and same energy requirement of an Astro-Habitat landing mission).

National Planning #4
MonaLisa, cont.

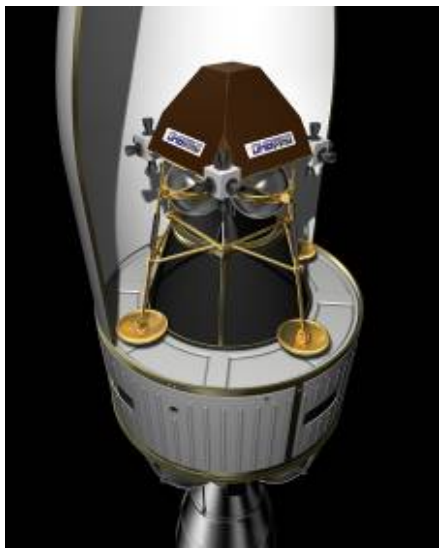
Mission design



Concept-design

one engine, 3.8 kN

cluster of nine 0.5 kN-engines (EAM)



Subsystem	Mass [kg]
Payload	127
Structure	204
Mechanisms	22
Propulsion	114
AOCS	83
Data-Handling	52
Power	43
Thermal	14
Communication	13
Drymass	670
System Margin	134
Drymass incl Syst Margin	804
Fuel	1,290
Launch Mass	2,094

Critical elements

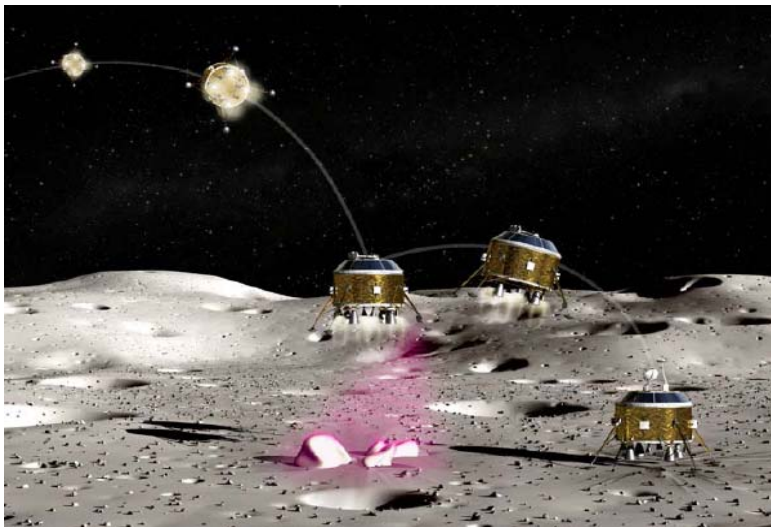
- **Propulsion system, e.g. the 4 kN-class This type is not available off-the shelf in Europe.**
- **Power generation system (for Astro-Hab/ quasi eternal light required); use of RHU/ RTG's in Europe not approved so far.**
- **Soft precision landing**

National Planning #5

Study ‘Lunar Application’, Astrium, nearly completed

Based on an utilisation planning with model payloads generic reference missions were elaborated:

- **Comparative Planetology Mission, alternatively a Radio Astronomy Mission**
- **Technology Demonstration Mission**
  - **Astro-Habitat, ISRU Demo**



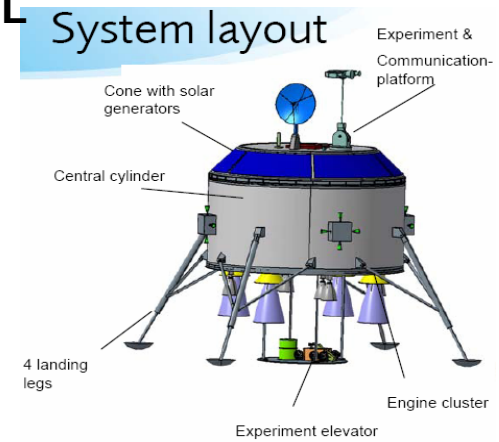
In particular the Lander/ missions were analysed with respect to

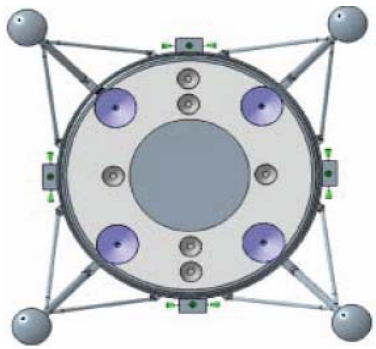
- **Definition and (preliminary) design**
- **Solutions for demonstrators**
- **Technology needs, key-technologies**

National Planning #6
Lunar Application, cont.

Due to P/L restrictions two mission concepts were studied, resulting in two Missions/ Lander Designs, Small (SLL) and a Future Lunar Lander (FLL)

SL
L





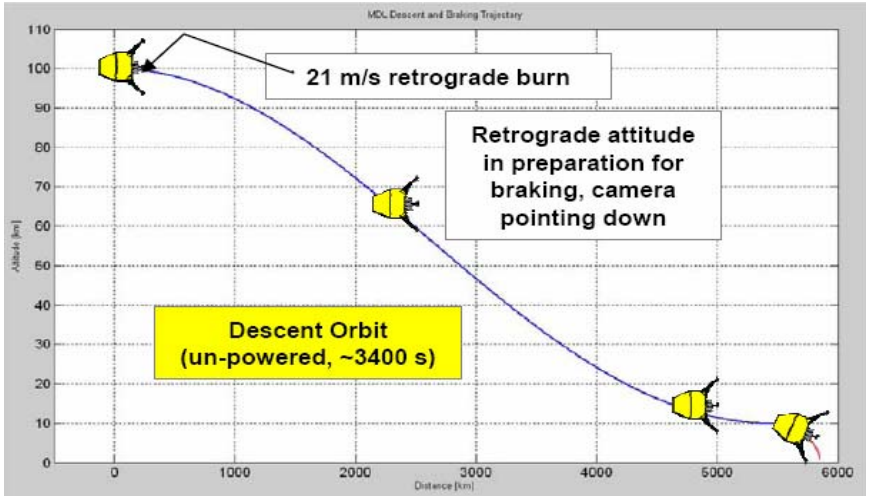
Propulsion subsystem

- **Unified propulsion subsystem concept (UPS)**
- **MON / MMH**
- **4 propellant tanks**
- **1300 kg fuel**
- **Engines :**
  - 4 x 500 N EAM (I_{SP} = 325 sec)
  - 6 x 280 N ATV RCS (I_{SP} = 287 sec)
  - 16 x 20 N RCS

Class	SLL	FLL
Launcher	Sojus-Fregat	AR 5 ECA
Trajectory	LTO/ GTO	LTO
Launch mass	2150/ 3230 kg	7800 kg
P/L moon	150 (200) kg	1500 kg
Application	Science mid mobility	Science high mobility infrastructure / logistic sample return

The FLL may be not considered for near term application so far, but nevertheless it will be of great interest in terms of build up moon infrastructures in a partnership.

National Planning #7
Lunar Application, cont.



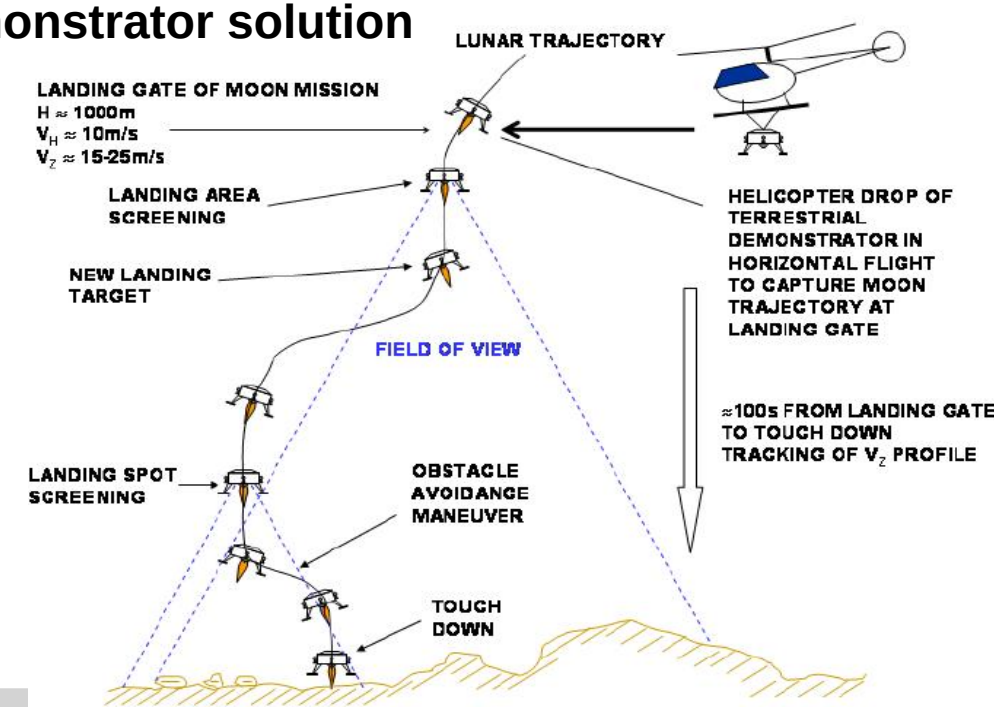
Navigation/ Soft precision landing, e.g.

- **Lunar transfer**
  3-5 days flight
  classic deep space navigation
- **<u>Approach and landing</u>**
  camera (CCD) and LIDAR (h< 1km) based for landmark-navigation
- **<u>Hazard and obstacle avoidance</u>**
  LIDAR based optic,
  fully autonomous for
  Day and night operation

Technology need

- **Propulsion concept still open**
  4 kN required for LOI
  Clustering of than available engines (EAM) not approved yet

Demonstrator solution



National Planning #8

Study 'scientific and robotic Lunar Mission', Kayser Threde, ongoing

Based on scientific requirements of the German science community and depending on mission assumptions (e.g. duration, stationary or 'network' P/L), the study will be refining the payload-view, concerning:

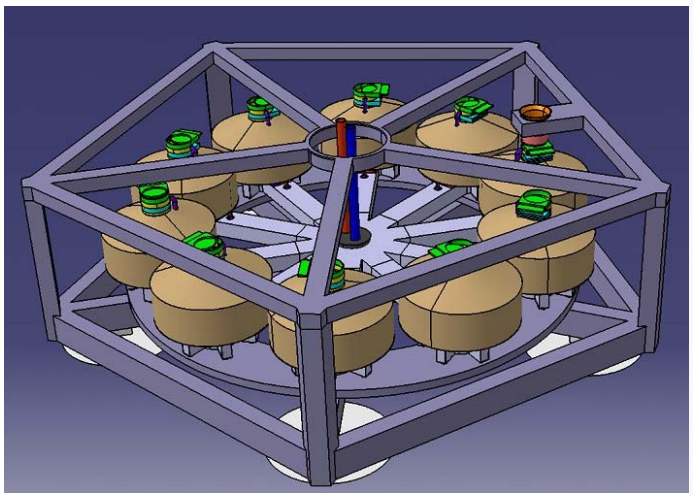
- **Stationary P/L (Instruments, ISRU equipment)**
- **Robotic elements and robotic P/L**

Considering, e.g. of the

- **<u>power need</u>, essential for longer mission duration (> 14 days), and the**
- **<u>mobility</u> (use of Rover) as a key factor to fulfil the 'network' requirement a …**

↪ Compromised Mission was assumed

- **Sojus Fregatt Launch (Small Lunar Lander)**
- **stationary P/L Lander package 30 kg**
- **ISRU 20 kg**
- **LIDAR 20 kg**
- **Mobile P/L 80 kg**



National Planning #9
Scientific and robotic Lunar Mission, cont.

Detailed P/L

VARIANT 1A++	Mission duration 14 days				
(minimised mission)	Landing area flexible				
Application	**Instrument**	**Mass [kg]**	**TRL**	**Lander [kg]**	**Rover [kg]**
Geology	Stereocamera	2,0	3	2,0	
	Microskopcamera (incl. Minispectrometer)	0,6	3		0,6
Geo-physic	RadMon	1,8	5	1,8	
Geochemistry	LIBS/Raman	2,0	3	2,0	
	APX	1,0	6		1,0
	Mössbauer	1,0	6		1,0
	INAA	10,0	0	10,0	
Mechanism	sampling & sample transport	TBD	0		TBD
SUM		**18,4**		**15,8**	**2,6**

Greater P/L packages, e.g. for longer missions and FLL (AR 5) will be assessed but not 'accommodated', due to the still open questions about RHU availability

National Planning #10
LEO – Lunar Explorations Orbiter

12 Instruments, 50 Scientists

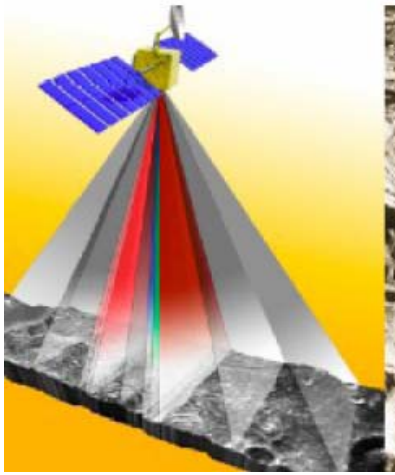
- **Planned launch date 2012**
- **4 years operational lifetime**

Scientific goals

- **surface composition**
- **surface ages**
- **mineralogy**
- **physical properties**
- **interior**
- **thermal history**
- **gravity field**
- **regolith structure**
- **magnetic field**

Planned Instrumentation

- **Camera systems - HRSC**
- **Imaging spectrometers UV-TIR**
- **µ-wave radiometer**
- **Sarsounder**
- **Accelerometer**
- **Subsatellite**
- **Particle detectors**
- **Dust detector**



Milestones

- **2 parallel industrial phase 0 studies (just finished)**
- **Announcement of experiment opportunity released Oct. 2007**
- **Peer review**
- **start of industrial phase A – study (early 2008)**
- **Mission Decision expected in spring 2008)**

National Planning #11

LEO – Lunar Explorations Orbiter, cont.

Mission planning and operations

For a low polar orbit as requested a special station keeping and consequently a bigger amount of propellant would be necessary.

➥ Partly polar, partly non-polar orbit (i=85°), inclination change to cover polar regions.

Feasibility of "frozen orbits" to be verified.

Multi-spectral mapping and global coverage lead to an enormous data rate that significantly exceeds that of the previous and upcoming Moon missions: 1,7Tbit/day.

Besides an appropriate sizing of the telecommunication and payload data handling system a careful assessment of the instrument operations timeline is mandatory, considering e.g. illumination conditions.

The goal of global coverage requires a strict scheduling of instrument operations including long term time lining and ad hoc observation of special targets of opportunity.

**Mission operations by the German Space Operations Centre (GSOC).
Ground station may be Weilheim close to GSOC, desirable to use a second ground station "down under". Alternatively a dedicated ground station could be instituted close to the equator in order to homogenise the duration of visibility periods.**

➲ Studies show good solutions for all technical problem areas.

DLR's Perspective

LEO: **decision for mission implementation early 2008 ➲ phase A project**

ESA/ NEXT: **German industry is prepared to make proposals for phase A soft precision lunar landing**

ISS: **to be used as testbed for exploration, e.g. life support systems**

Questions

- **Manned exploration missions beyond ISS (?), e.g. due to the proposed re-organisation of ESAs 'Exploration' (science, HSF)**
- **What is the German role *(?*), how will stimulate German preparatory activities potential mission opportunities**

↪ **Interesting discussions expected in the Berlin conference Nov. 8/9**

Thank you for listening!