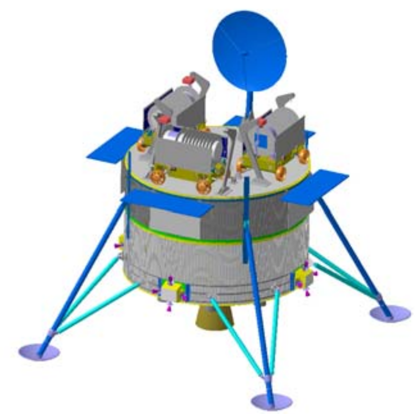
Lunar Lander

Final Presentation



EADS Astrium, Mr. B. Bischof

ESA-ESRIN, 16 January 2009

Overview:

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Shared Ariane 5 Lander

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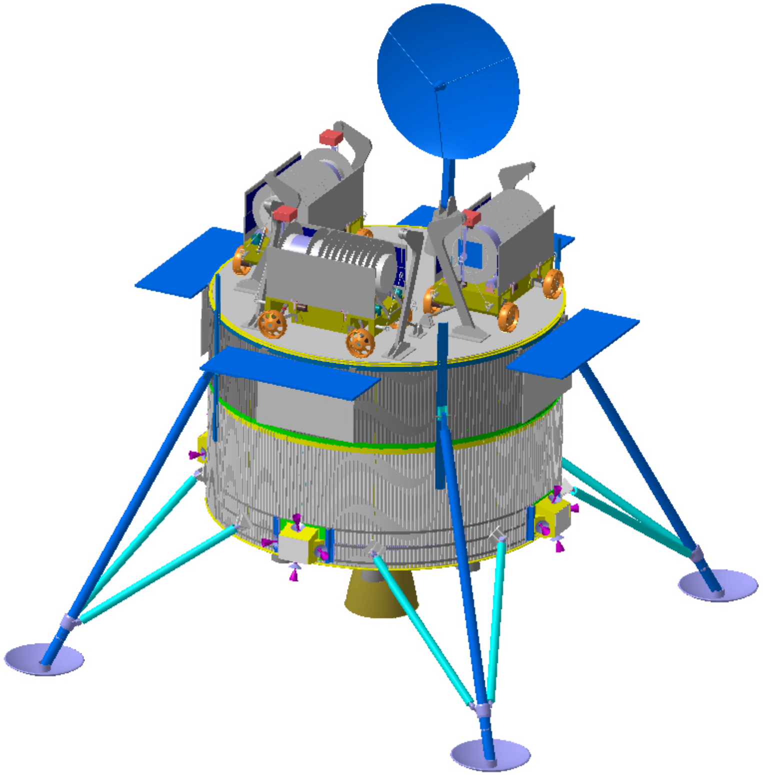
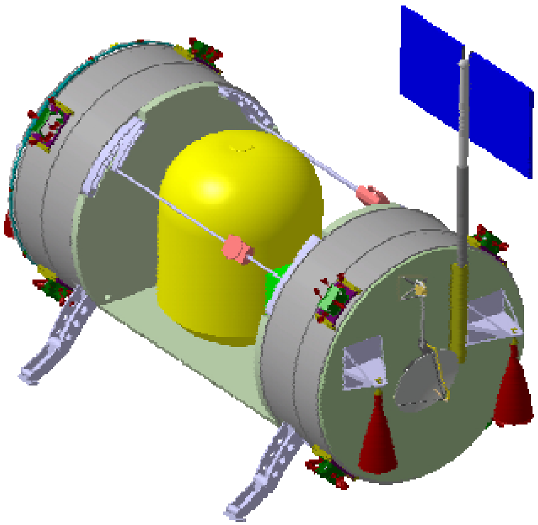


Lunar Lander

Two Concepts



- Ariane 5 ME launch with 9.4 t launch mass
- Payload mass: 1.3 t
- Easy unloading of payloads
- Unfavourable structural load path for launch and landing phase
- Two propulsion modules with more complexity and higher risk

- Ariane 5 ME launch with 9.4 t launch mass
- Payload mass: 1.7 t
- More complex payload unloading with robotic elements
- Optimum structure and propulsion concept
- More flexible payload integration and mass distribution for the launch phase

System Trades

Propulsion staging:

- Braking stage only for the LOI manoeuvre enables a small mass saving of descent and landing propellant
- Drawback: To achieve this potential mass saving, propellant line cut-off to avoid additional engines is required, which introduces additional risk
- Additional separation mechanism also increases the mission risk

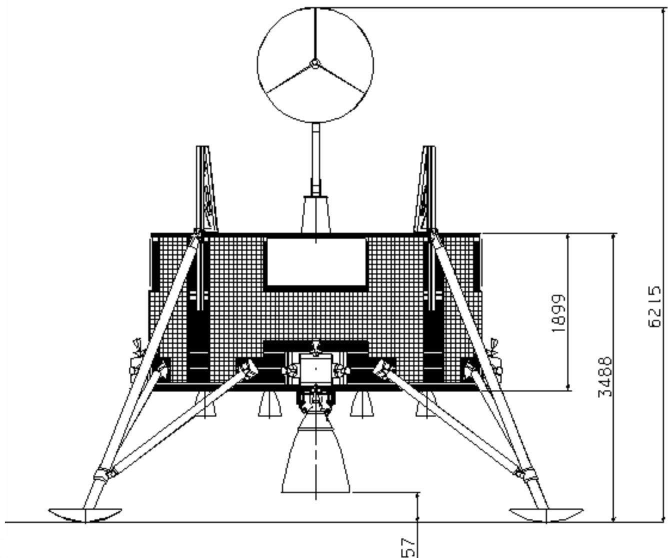
Cryogenic vs. Storable Propulsion System:

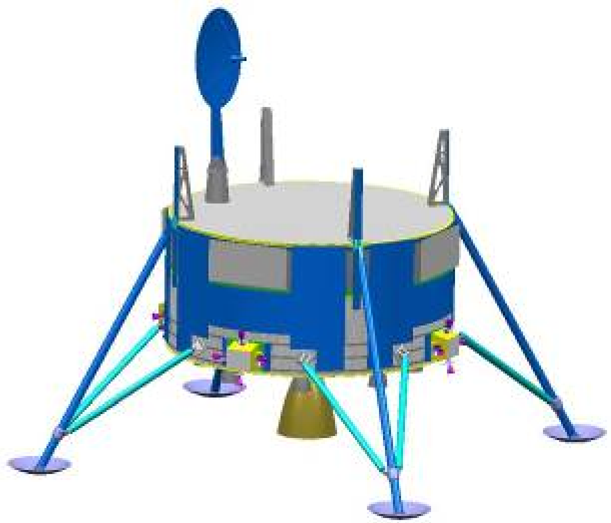
- Cryogenic propulsion allows propellant mass saving of about 1 t compared to storable propulsion
- Needed engines and tanks not available
- Needed boil-off reduction for 5 days is new technology with additional high cost and risk

Lunar Lander

Shared Ariane 5 Lunar Lander

The shared Ariane 5 lunar lander has mostly the same avionics as the larger, successor cargo lander and a similar configuration including structure S/S and propulsion with the same 3 Aerojet engines of 4 kN each or 12 kN engine (Version 5 with 3x4 kN engines)



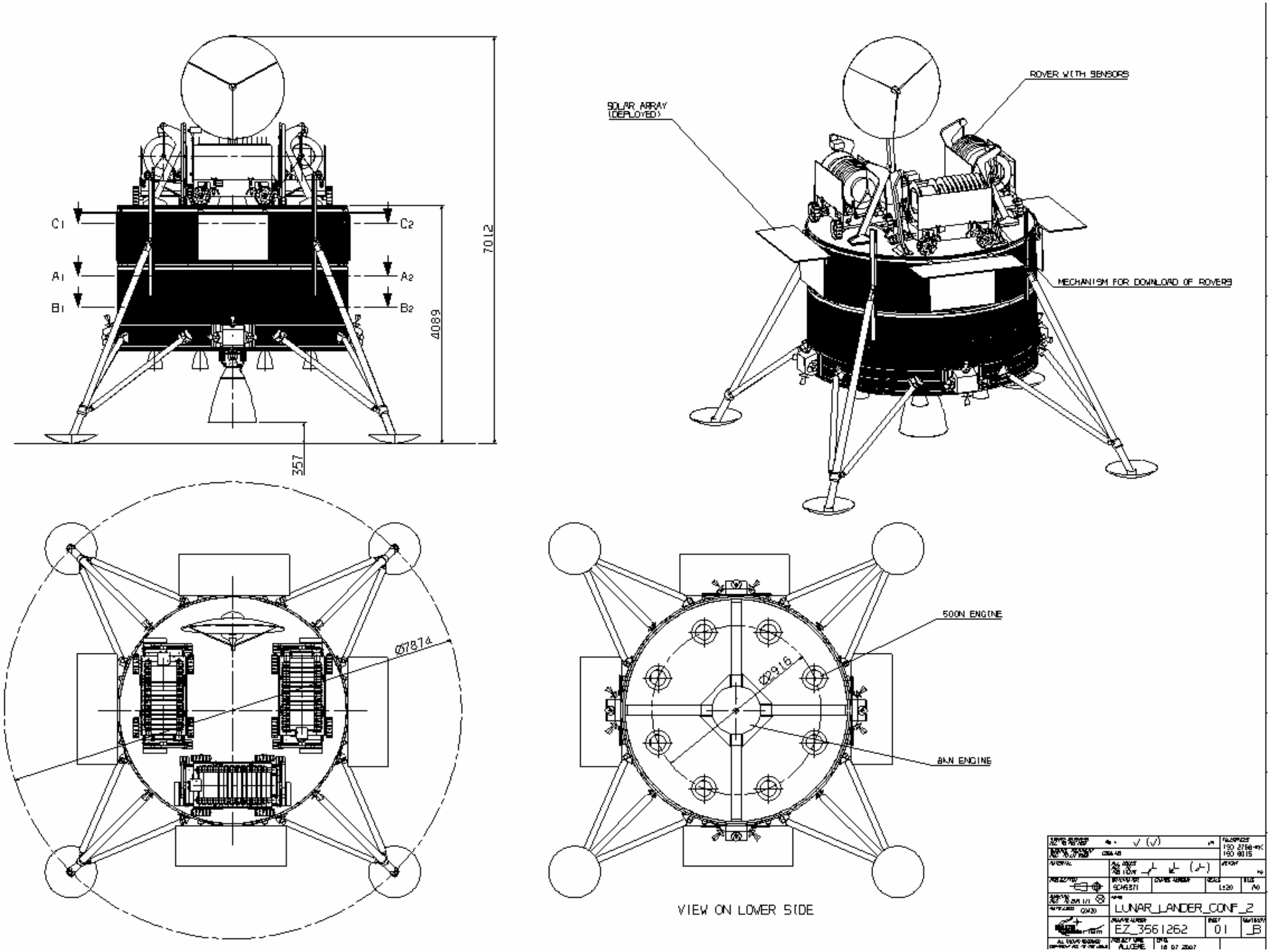


	Version 1, GTO	Version 2, GTO	Version 3, LTO	Version 4, GTO	Version 5, LTO with Orbiter
Launch Mass	6200	7200	4850	4200	7800
Dry Mass	1315	1352	1250	989	1280+1800(Orbiter)
Propellant Mass	4405	5148	3030	2796	4200
Payload Mass	280	500	370	215	320
Adapter Mass	200	200	200	200	200

Lander Design

- Direct injection by Ariane 5 ECA into LTO
- Low inclination transfer orbit with 2 injection opportunities per month
- Injection mass : 7.6 t
- LOI and descent and landing by the lander propulsion system
- Soft and precise landing with hazard avoidance manoeuvres
- Soft landing with <3 m/s vertical and < 1 m/s horizontal touch-down velocity
- Landing accuracy of about 500 m
- Use of RHU‘s for lunar night
- Large payload compartment on the lander upper platform for the 1.2 t payload mass
- Payload deployment by a crane system or a ramp for large rover unloading

Lander Design



Lunar Lander

Item / Ariane 5 Version	ECA [kg]	ME [kg]
Launcher capability	**7800**	**9700**
Adapter mass	180	190
BOL Mass in LTO	7620	9510
Used Propellant	4766	6000
Mass on Lunar Surface	**2854**	**3510**
Remnants + Pressurant	160	222
Dry Mass	2692	3288
Structure/Thermal	435	468
Propulsion	500	562
Avionics/Power	252	252
Development margin 20 %	237	256
Lunar Lander Subsystems	1422	1538
Payload	**1270**	**1750**

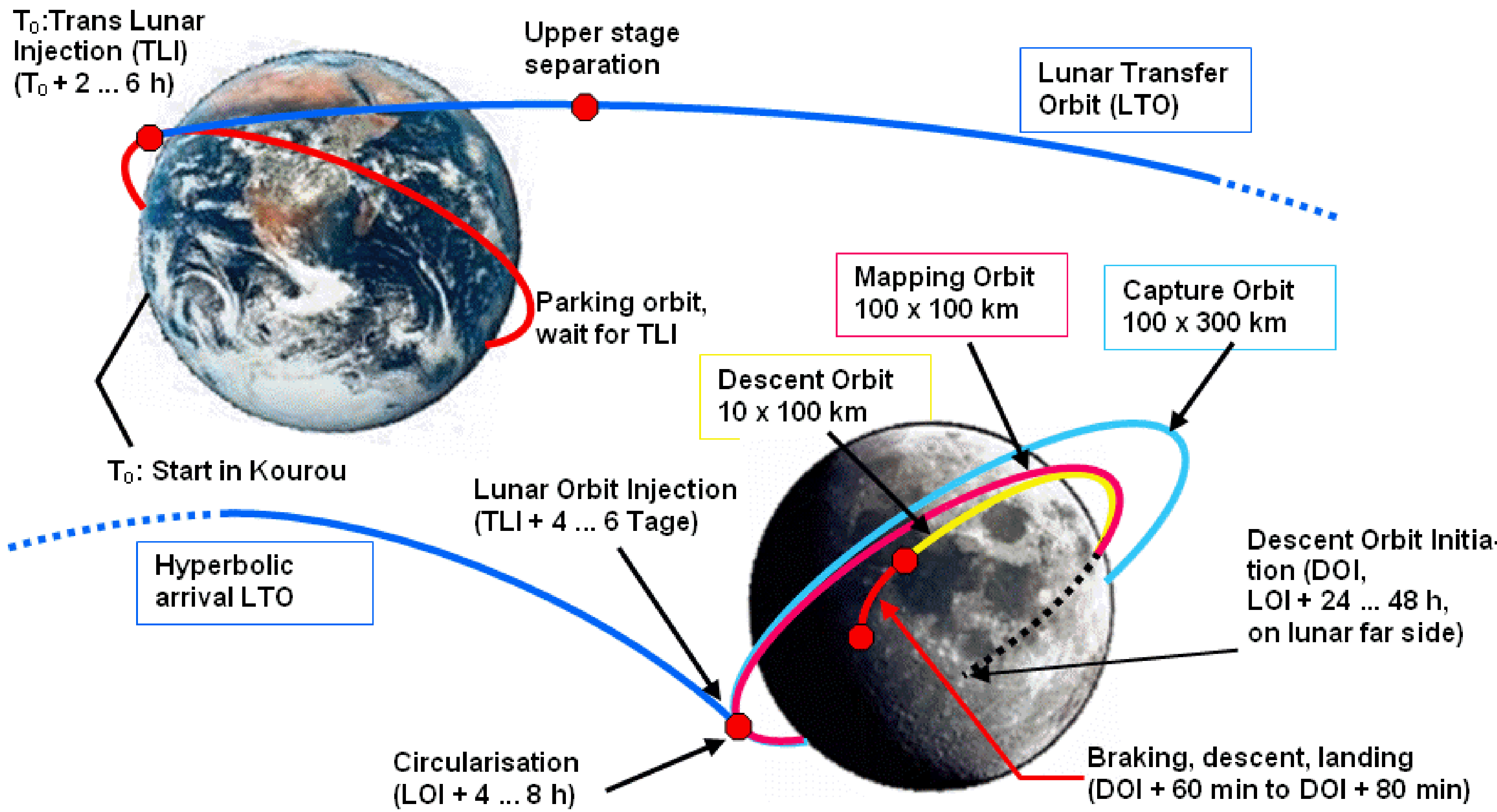
Mass Budgets for South Pole Mission

Component	Transfer	LLO/Sun	LLO/Eclip.	Descent	Landing	Lunar Day	Lunar Night
Phase Duration [h]	120	1.1	0.9	1.0	0.3	595	105
Subsystems	140	240	140	265	400	150	25
Payload	0	0	0	0	0	500	0
Battery Charge	10	164	0	0	0	6	0
Total demand	150	404	140	265	400	656	25
SG supply requirement	150	404	0	0	0	656	0
Energy by Battery [Wh]	0	0	126	265	120	0	2625

Power Budget for South Pole Mission

Mission Profile

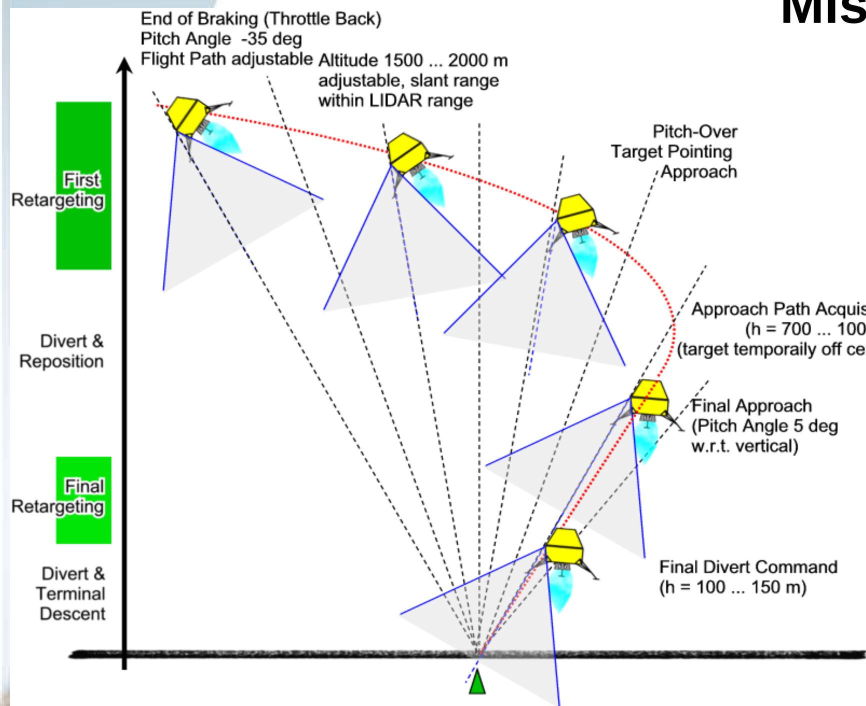
- **Direct translunar injection with Ariane 5 ECA: 7.8 t**
  (Two opportunities per month)
- **TLI from parking orbit with Ariane 5 ME: 9.7 t**



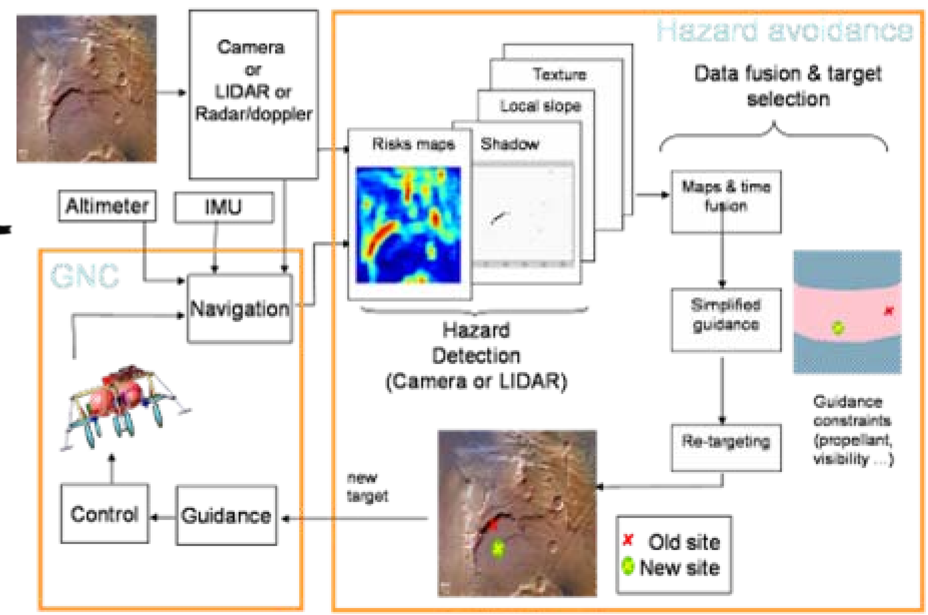
Lunar Lander

Mission Profile

Descent and landing profile

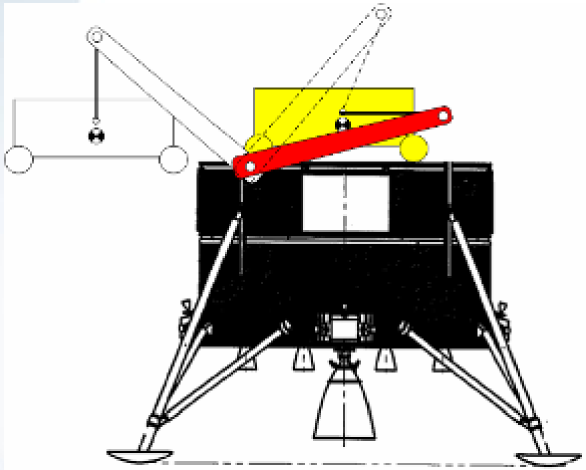


Hazard avoidance scheme



Payload Operation

Means to deploy large payloads:



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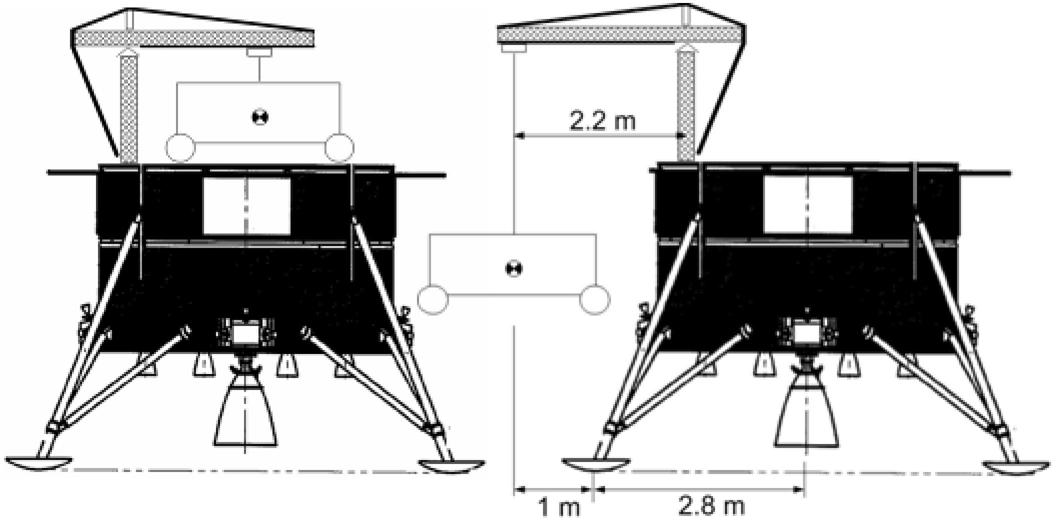
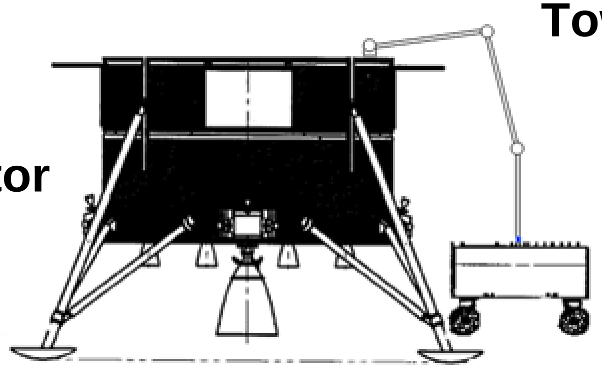
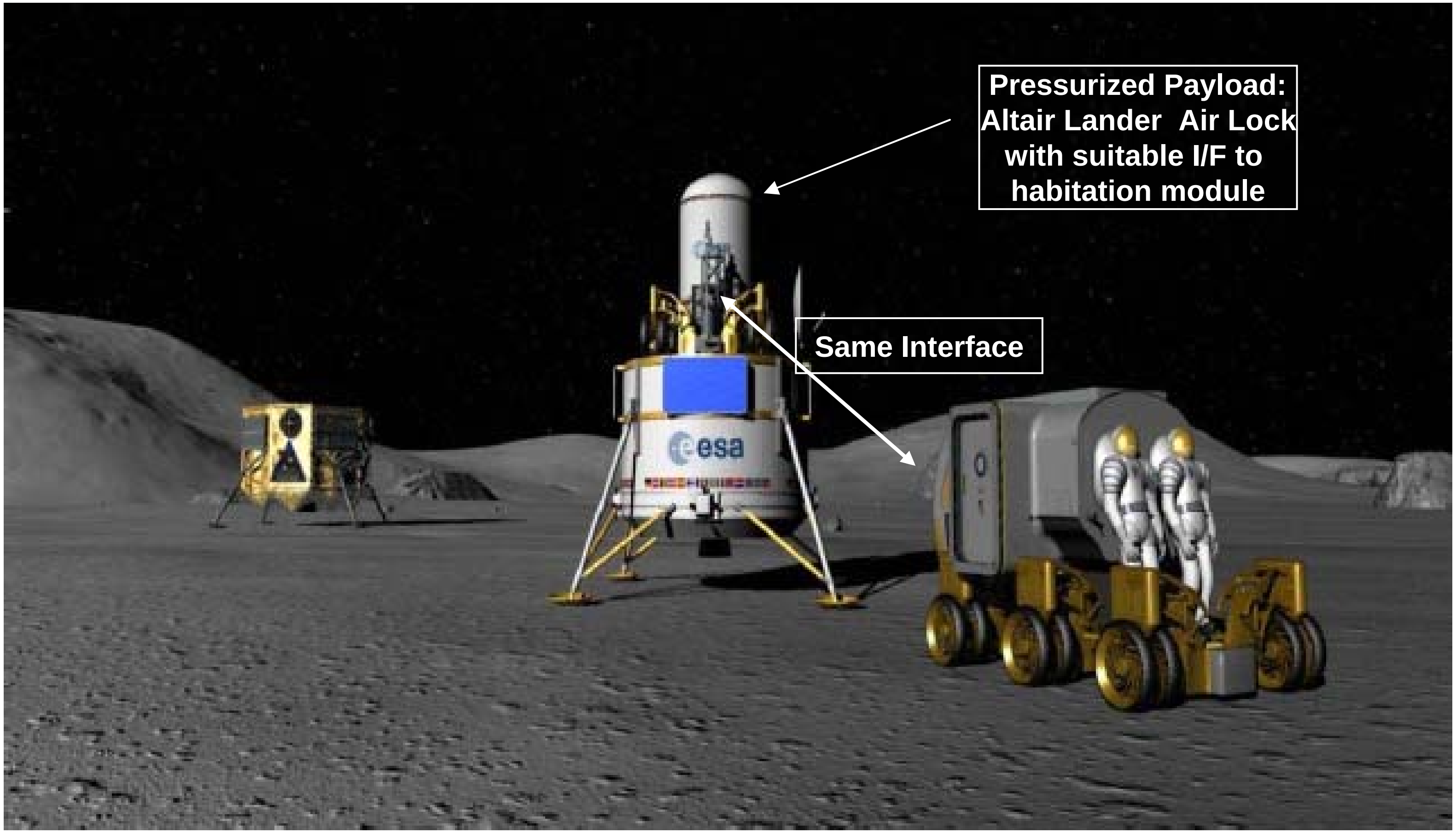


Tower crane

Multi-DOF manipulator



Payload Transportation



Logistic Support for Manned Missions (courtesy: NASA)

Propulsion subsystem

- **Storable bipropellant system with 2 tanks MON and 2 tanks MMH**

Manoeuvre	Needed Thrust level	Thruster Concept 1	Thruster Concept 2
LOI: 1-1.5 m/s²	9.5-14 kN	1x12kN+4x500N	3x4kN+4x500N
PDI: 2-3 m/s²	14-21kN	1x12kN+6x500N+8x280N	3x4kN+6x500N+8x280N
Landing: 1.4-2.3 m/s²	4.2-7kN	6x500N+8x280N	1x4kN+6x280N-2x4kN

- **A 12 kN engine for high-impulse manoeuvres (to be developed) in combination with 500 N and 280N engines needs 6 of 500N thrusters Concept 1)**
- **Alternative: Procurement of 3 x 4 kN (R-40B) engines from Aerojet used in STS OMS allows to use additionally only 6x 500N thrusters and 8x 280N thrusters (Concept 2) but would reduce the payload mass by 250 kg (lower specific impulse)**
- **A 12 kN throttleable engine would be the best solution but would need a large development effort**

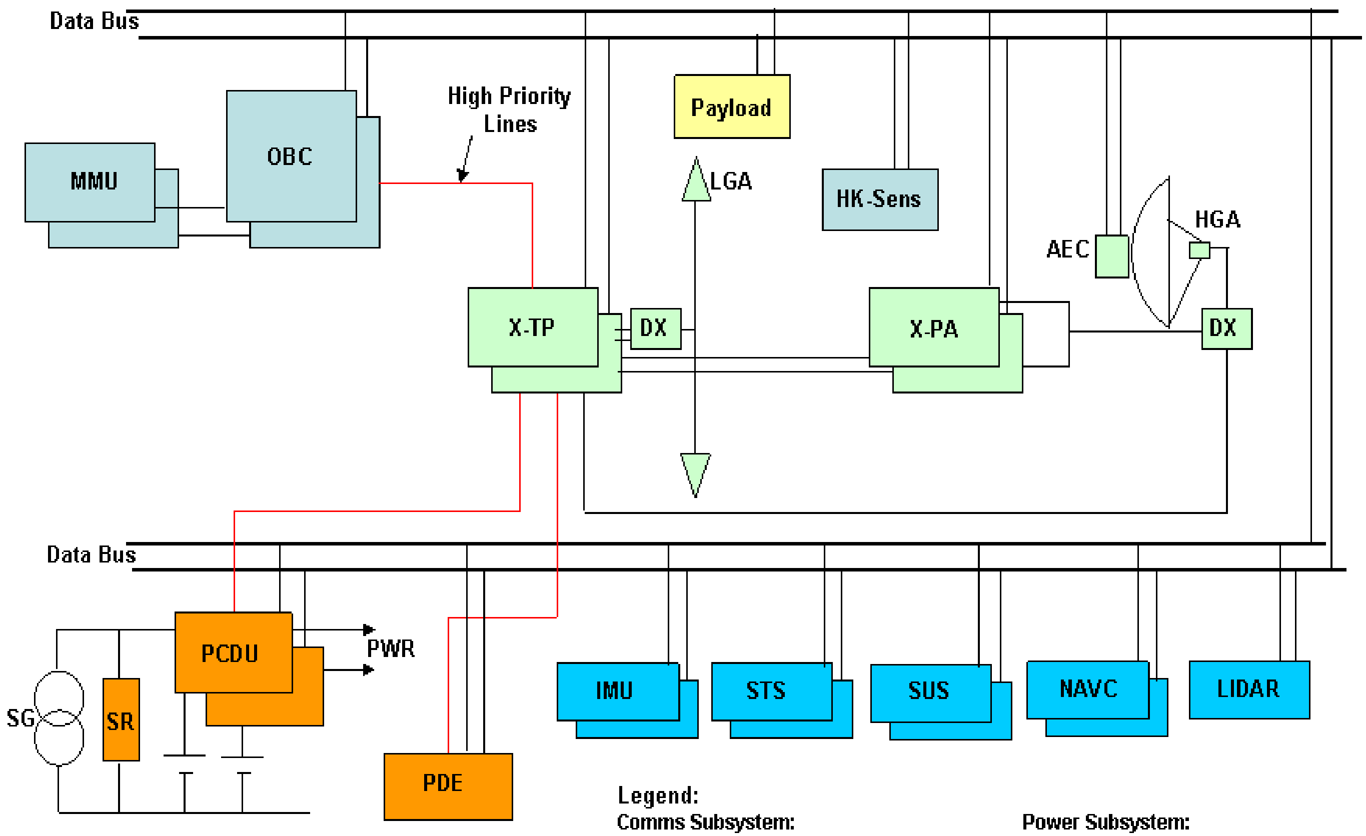
Aerojet R-40B

Thrust	4 kN
Isp	293 s
Inlet pressure range	10…28 bar
Mass	6,8 kg
Engine length	0,71 m
Nozzle Exit diameter	0,41 m

Astrium EAM

Thrust	500 N
Isp	325 s
Inlet pressure range	>15,5 bar
Mass	4,2 kg
Engine length	0,55 m
Nozzle Exit diameter	0,35 m

Avionic Diagram



Legend:

Comms Subsystem:

AEC	Azimuth/Elevation Control
DX	Diplexer
HGA	High Gain Antenna
LEOP-TP	Early Ops Transponder
LGA	Low Gain Antenna
X-PA	X-Band Power Amplifier
X-TP	X-Band Transponder

On-Board Data Handling:

MMU	Mass Memory Unit
OBC	On-Board Computer
HK-Sens	Housekeeping Sensorics

Power Subsystem:

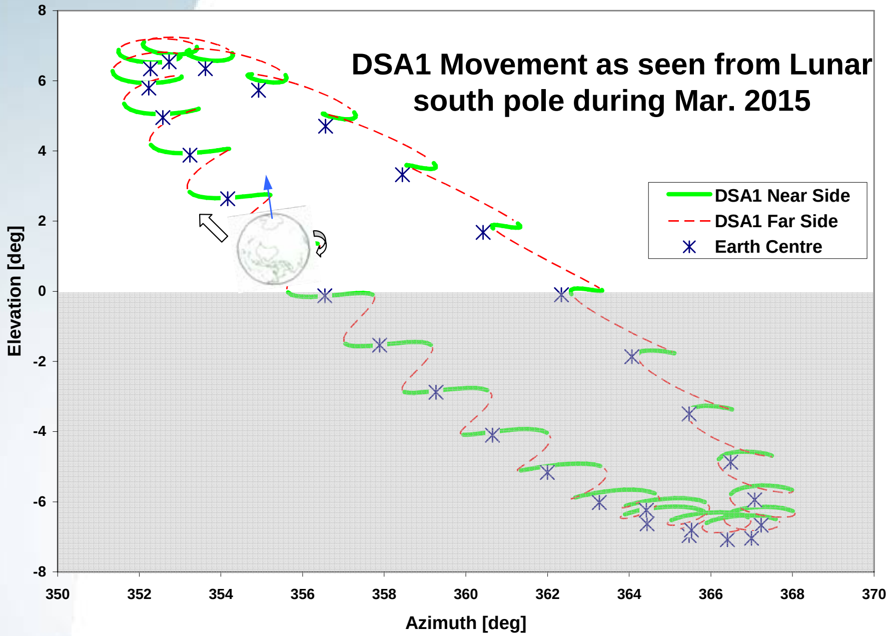
PCDU	Power Control & Distr. Unit
PDE	Propulsion Drive Electronics
PWR	Power Bus 1,2
SG	Solar Generator
SR	Shunt Regulator

Guidance, Navigation & Control:

IMU	Inertial Measurement Unit
NAVC	Navigation Camera
SAS	Sun Acquisition Sensor
STS	Star Sensor

Lunar Lander

Communication subsystem



The lander transmits directly to Earth using

- **Low gain antenna (LGA) during cruise, low lunar orbit and emergency**
- **High gain antenna (HGA) during descent, landing, and surface operations**
- **A downlink transmit rate of 2 Mbit/s has been assumed sufficient to download high quality pictures and medium quality video**
- **The link bit error rate (BER) is < 10-6 for the downlink and <10-7 for the uplink**
- **A Reed Salomon-Viterbi encoding modulation scheme has been adopted for downlink**
- **On the lander, a 0.3 m diameter dish antenna is proposed with steering capability**

Item	Unit mass [kg]	Mat. Margin [%]	Mass incl Marg. [kg]	No. off	Total [kg]
High Gain Antenna	3.5	20	4.2	1	4.2
Low Gain Antenna	0.1	20	0.12	6	0.72
X-Band Transponder	3	10	3.3	2	6.6
X-Band Power Amplifier	1.5	5	1.575	2	3.15
Diplexer	0.1	20	0.12	6	0.72
RF Cabling, Switches etc	2.5	0	2.5	1	2.5
Total					**17.9**

Power supply subsystem

Different solar illumination conditions lead to different requirements for the power generation and storage capability.

Two target landing areas can in principal be characterized:

Landing near the south pole

- **Landing place near the south pole (peak of eternal light) allows a body mounted solar generator**
- **The solar generator delivers (5 m² area) about 800 W**
- **After landing the Comms, Avionic, Thermal Control and Power S/S needs less than 300 W and allows about 500 W for any payload**
- **During lunar night about 6 days per month a battery provides power only for the subsystems**
- **Potential interfaces to other surface systems in vicinity of outpost**

Landing near the lunar equator

- **Landing at the sites near the lunar equator (e.g. far side) requires the capability to survive during the lunar night of about 14 days.**
- **The power storage capability limits drastically any operational activities during lunar night**
- **Deployable solar generator, battery and RHU's to survive lunar night**

EADS astrium

Thermal control subsystem

Different solar illumination conditions lead to different thermal environment

Two target landing areas can in principal be characterized:

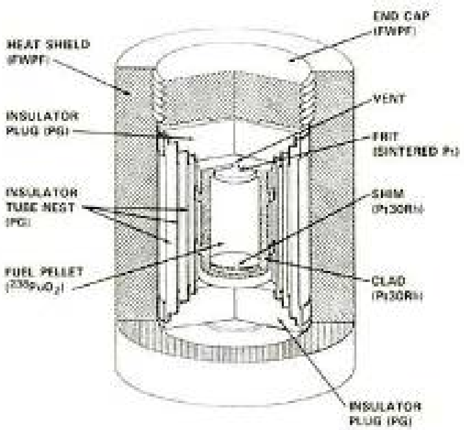
Landing near the south pole

- Lunar night duration of about 150 h with no payload activities
- Propulsion and GNC subsystems are switched-off
- Heating power for particular equipment in a special thermo-box by batteries or RHU’s

Landing near lunar equator

- Lunar night duration of about 14 days with no payload activities
- Propulsion and GNC subsystems are switched-off
- Heating power for particular equipment in a special thermo-box by RTG’s or RHU’s

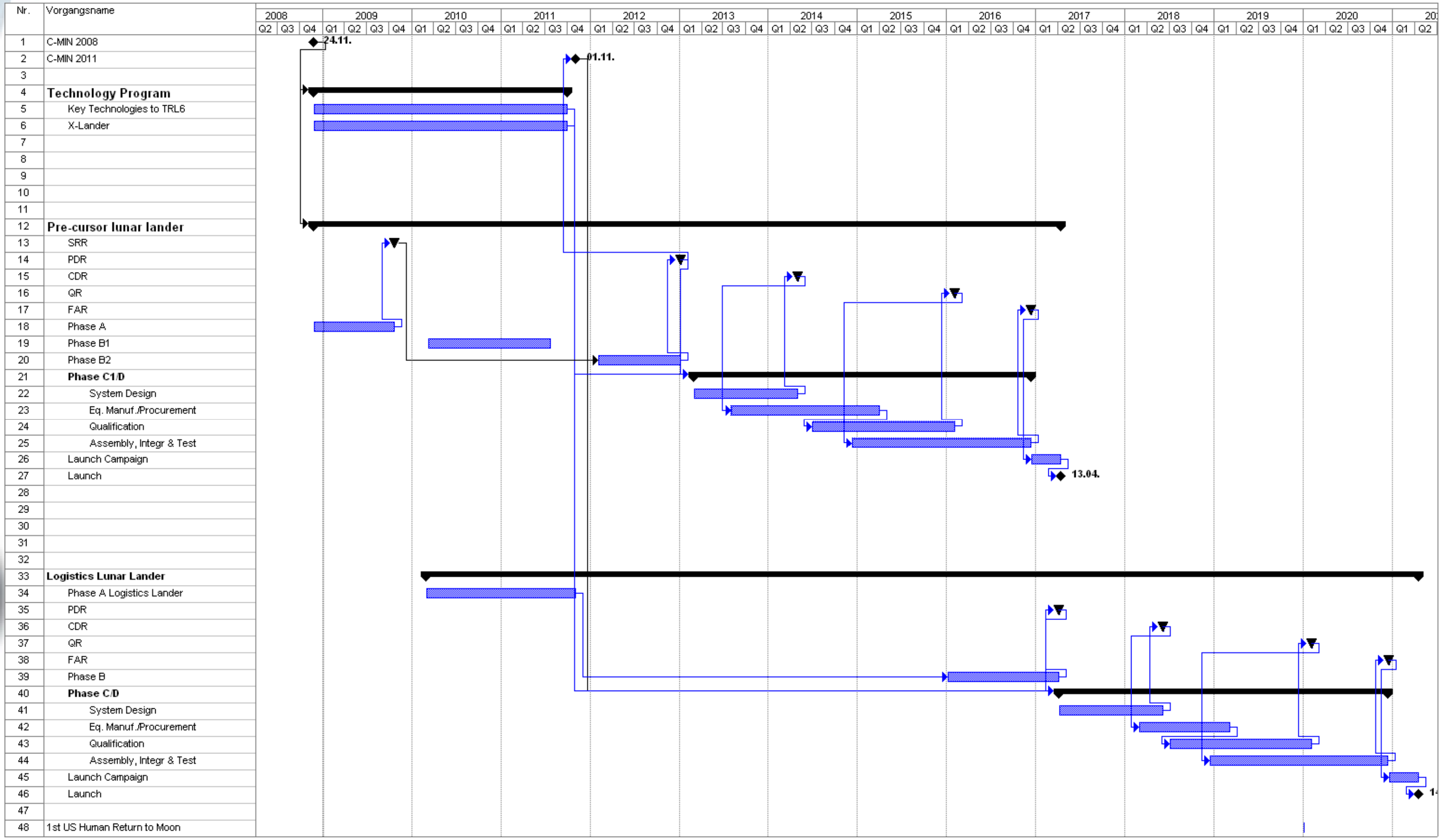
RHU
1 W heat performance
Mass: 40 gram
Length:32 mm
Diameter:26 mm



Development Plan

- Performance of a 3-year Technology Program (X-Lander)
- In parallel Phase A & B1 for a pre-cursor mission on base of a shared Ariane 5 lunar lander
- The shared Ariane 5 lunar lander has mostly same avionics as the successor cargo lander and similar configuration including structure S/S and propulsion with same 3 Aerojet engines of 4 kN each
- The shared Ariane 5 lunar lander has a lower total mass caused by lower payload mass, lower propulsion mass and some smaller components such as tanks and structure
- After a successful performed mission of the shared Ariane 5 lunar lander, the cargo lander needs only a small delta development

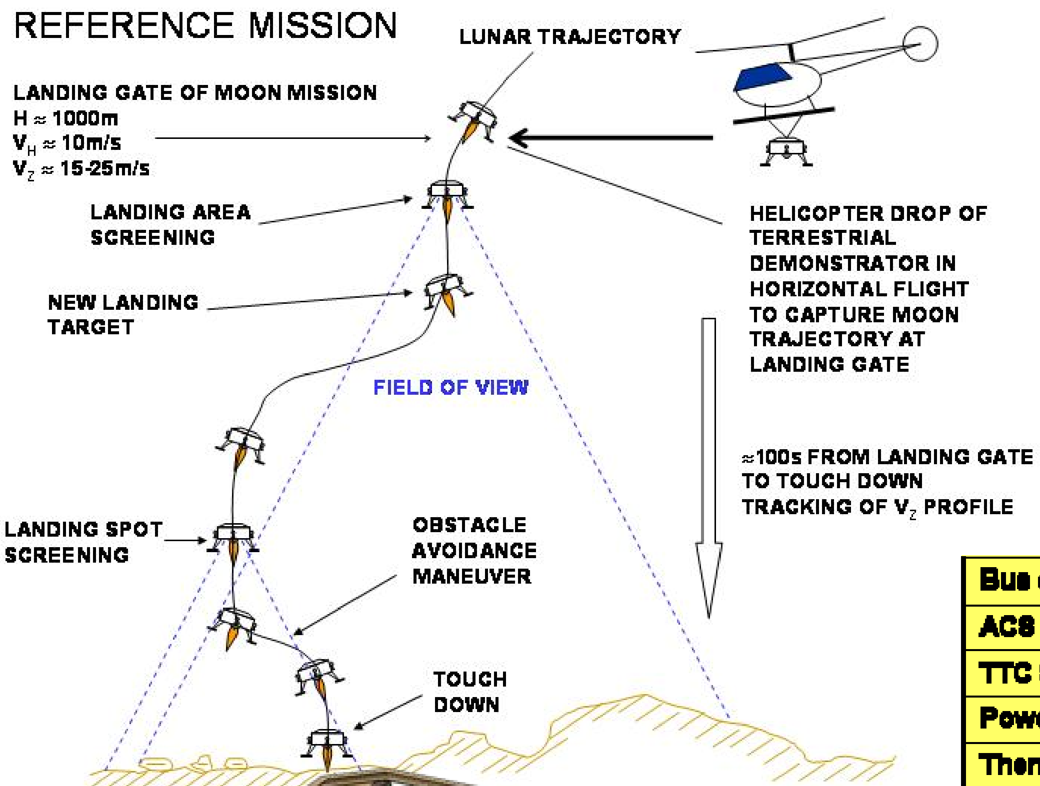
Development Plan

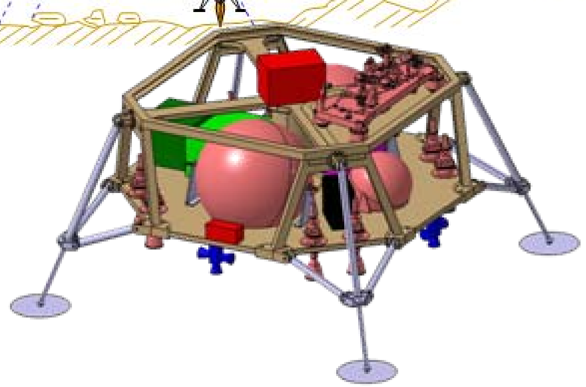


Lander Technology Test & Demonstration

	MAIT Models	today	Ph. C/D	Design Complexity
System AIT	1 STM, 1 EM, 1 PFM			New System-Level AIV
Flight SW	3 Versions: DM, EM and PFM			New Development
STR & Mech.	1 DM, 1 STM, 1 FM	TRL 5	TRL 5	Re-design, components and technology is available
P/L Platform Mech.	1 DM, 1 STM, 1 QM, 1 FM	TRL 3	TRL 5	Re-design, existing Spindle-Drive Actuators to be used
Landing Gear	1 DM, 4 STM, 1 QM, 4 FM, 2 SP (single Landing Gear Legs)	TRL 3	TRL 5	New Development
Propulsion S/S	2 EM, 1 FM	TRL 3	TRL 6	New S/S-Level AIV, existing Thrusters, Simple Modifications of components
Thrusters	1 EM Set, 1 FM Set, 1 SP each type	TRL 5	TRL 8	
SGS	1 EM, 4 FM	TRL 7	TRL 7	Re-design
EPDS	1 EM, 1 FM	TRL 8	TRL 8	Existing Batteries, Extensive Modification of PCDU
Harness	1 EM, 1 FM	TRL 8	TRL 8	New Design, but existing components
TCS incl. RHUs	1 STM, 1 FM	TRL 5	TRL 6	New Design, existing components
DHS	1 EM, 2 FM	TRL 8	TRL 8	Extensive Modification
Comms	1 DM (APM only), 1 EM, 2 FM X-band Antenna 1 FM only	TRL 8	TRL 8	Minor Modification
GNC	2 EM, 2 FM	TRL 5	TRL 6	New Development
LIDAR	1 DM, 1 EM, 1 QM, 1 FM	TRL 3	TRL 5	Extensive Modification

Lander Technology Test & Demonstration





- X-Lander as Testbed for soft & precise landing technology
- Development & Test of landing GNC sensors & S/W
- Development & Test of landing legs
- Development & Test of hazard avoidance manoeuvres
- 3 year programme to reduce the mission risk

Bus dry mass	[kg]	300,0
ACS dry mass	[kg]	40,0
TTC S/S mass	[kg]	0,5
Power system mass	[kg]	25,0
Thermal control mass	[kg]	20,0
Structures mass	[kg]	100,0
No. of thrusters	[-]	28,0
Pointing accuracy	[deg]	0,50
Pointing knowledge	[deg]	0,25
BOL power	[W]	50,0
Average power	[W]	270,0
EOL power	[W]	270,0

Conclusion

- A Lunar Logistic System operational by 2020 would be on-time to support crewed operations on lunar surface
- This would be a valuable European contribution for an international moon exploration architecture
- Development would focus on TRL 3 to 6 enhancement for landing gears, propulsion S/S and landing technology with LIDAR
- Sufficient thrust level would be provided by 3 Aerojet engines of 4 kN each
- The Lunar Lander development approach is based on a test & landing demonstrator for the last 2000 m performed on earth
- A pre-cursor mission until 2016 with a small payload to demonstrate the landing technology would reduce the development cost for the cargo lander but would enhance the total development cost for both