



Dutch Space



Human Mission to Moon

Final Architecture Review

Astrium-ST, J. Starke

ESA-ESRIN, 16 January 2009

Scenario Description

- Phase 1 lunar cargo / logistic missions
- Phase 2 manned missions to lunar vicinity and surface

Architecture Elements:

- Phase 1 elements based on existing or near future launchers (AR-5)
- Phase 2 elements based on improved launch capability



Mission 1: Cargo to Lunar Surface

Cargo/ logistic transport to Lunar surface injected by one Ariane 5

Mission 2: Cargo to Lunar Orbit

Cargo / logistic transport to Lunar orbit injected by one Ariane 5 or using two Ariane 5

Scenario 1: Assembly in LLO

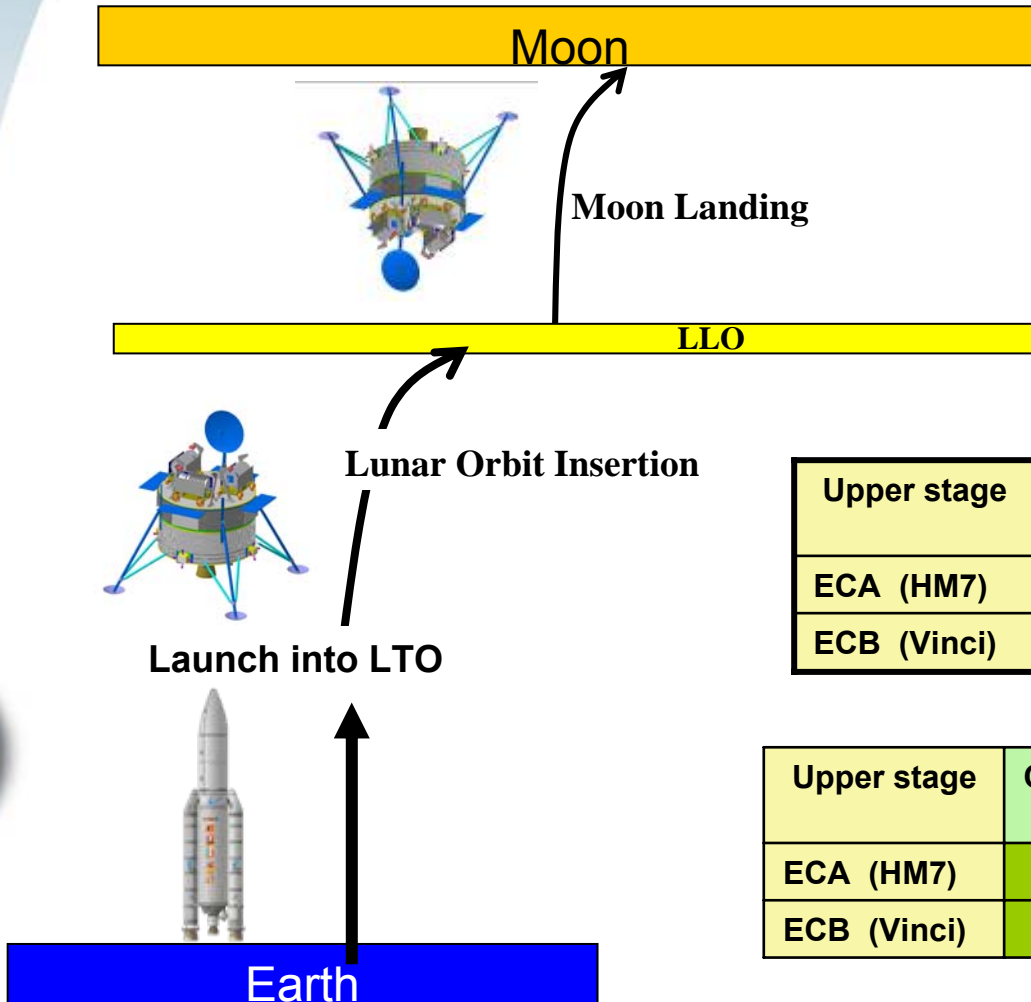
2 Assemblies in LEO of manned lunar mission, separate transfer of crew vehicle and lunar descent and ascent vehicle to LLO and transient of crew in LLO station

Scenario 2: Assembly in LEO

Assembly in LEO of the entire manned lunar mission system (comparable with Apollo scenario)



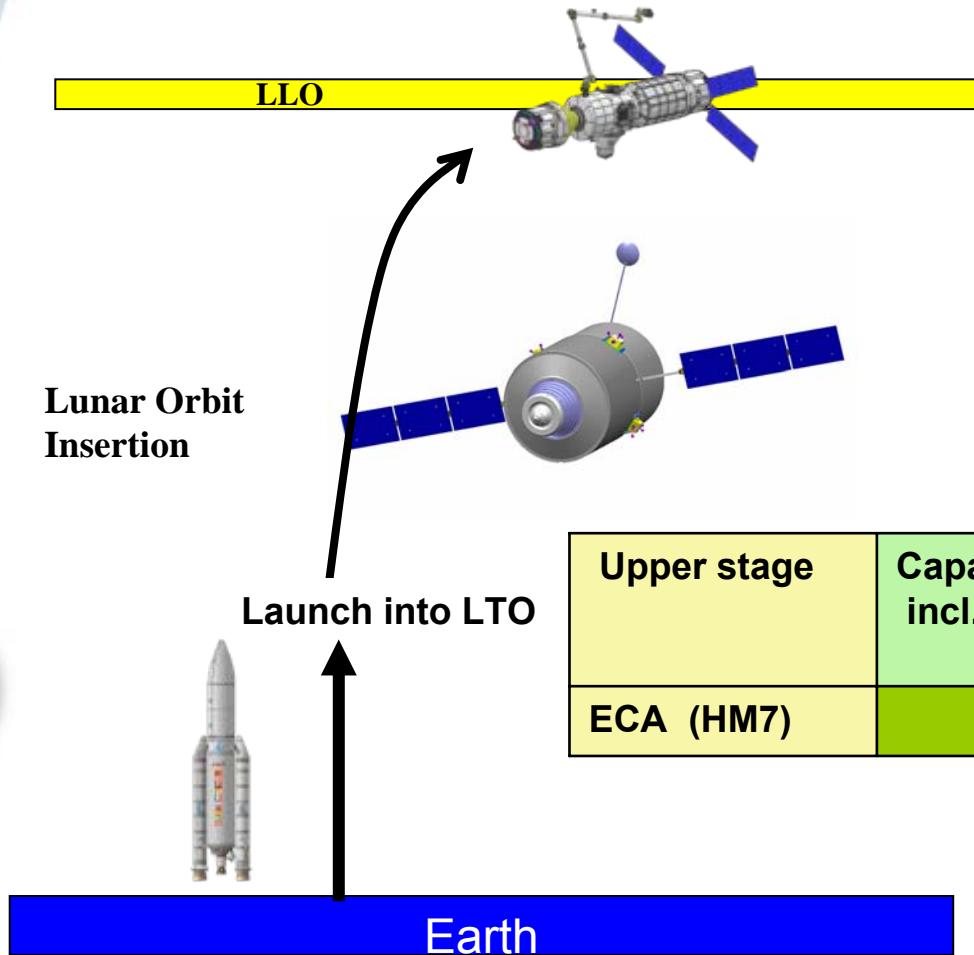
Cargo to Lunar Surface - Mission 1



Upper stage	Launch Capability [t]	Payload on Surface [t]
ECA (HM7)	7.8	1.2
ECB (Vinci)	9.7	1.7

Upper stage	Capability [t] incl. 5,24 deg	Capability [t] incl. 18 deg
ECA (HM7)	7.8	6.8
ECB (Vinci)	10.2	9.7

Pressurized logistics delivery to LLO

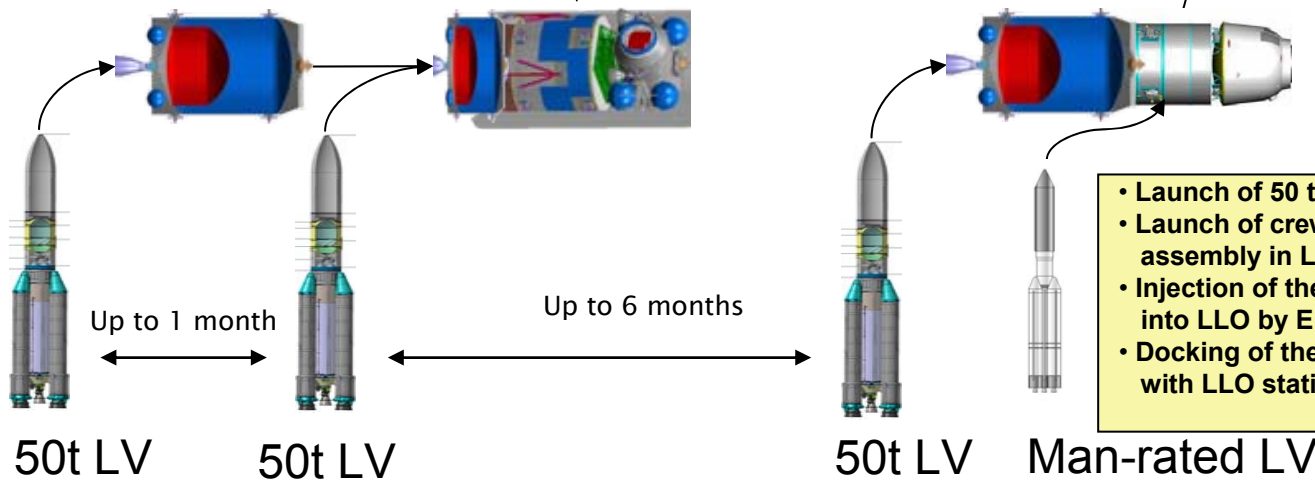
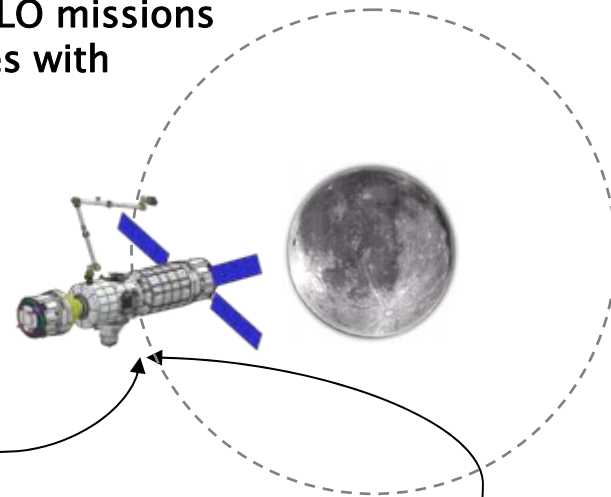


Upper stage	Capability [t] incl. 5,24 deg	Net P/L Capability [t] to Lunar Orbit
ECA (HM7)	7,8	2.1

Human transportation scenario 1

- Provide incremental access to LLO first, then to Lunar surface
- LLO Orbital infrastructure to support LLO missions and to provide cooperation opportunities with NASA architecture

- Launch of 50 t EDS (cryogenic system)
- Launch of combined payload + small transfer stage (cryo) and LEO assembly
- Injection into eccentric orbit
- Small transfer stage complements injection into TLI and LOI with cryo propellant
- Docking at the LLO station

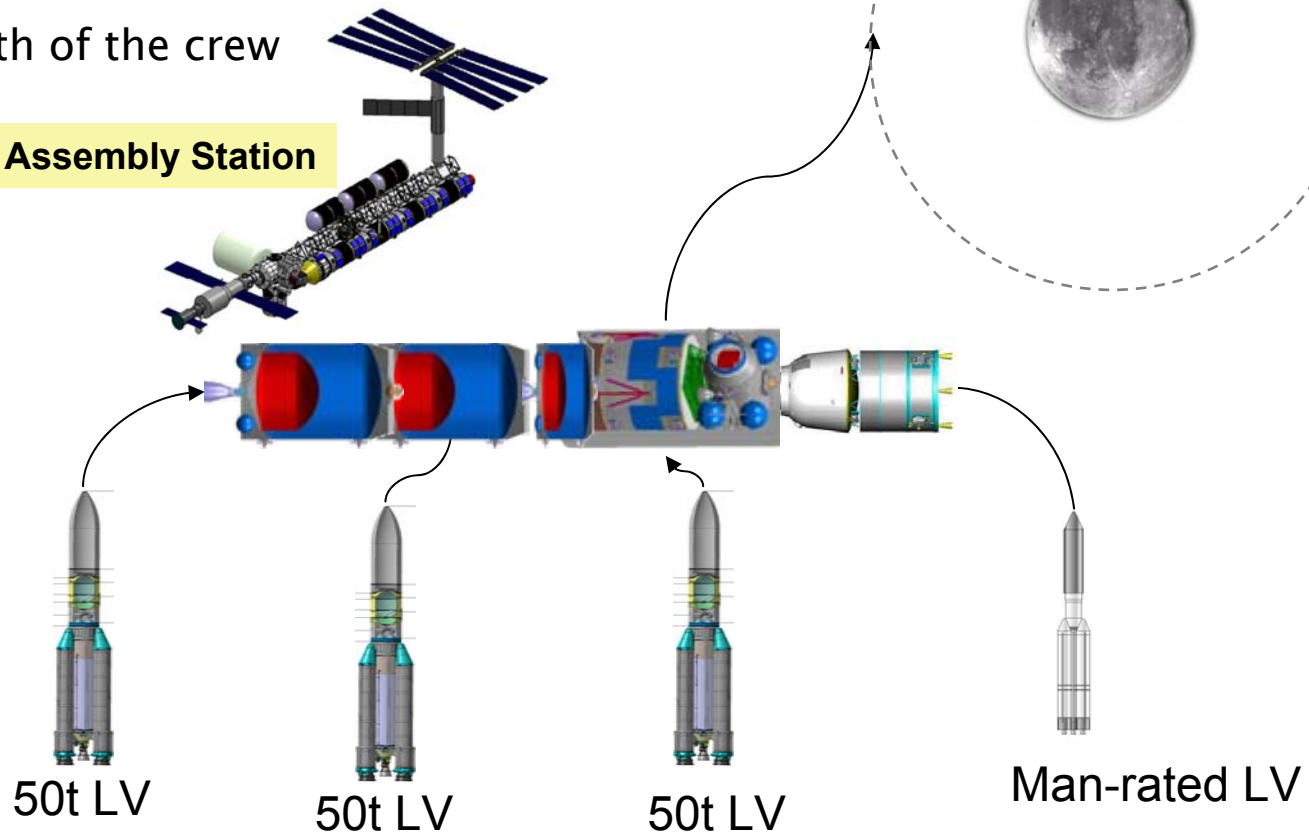


- Launch of 50 t EDS
- Launch of crew vehicle and assembly in LEO
- Injection of the crew vehicle into LLO by EDS
- Docking of the crew vehicle with LLO station

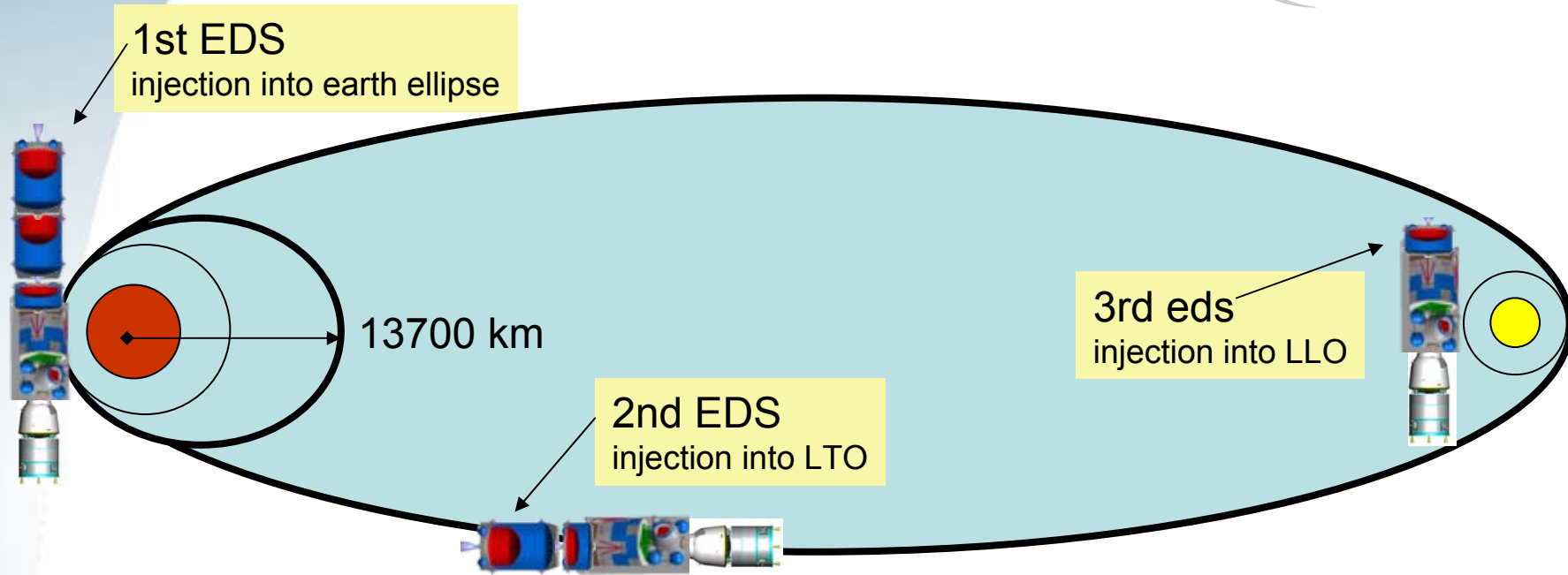
Human transportation scenario 2

- Provide assembly in LEO first, injection into LLO
- Separation in LLO and descent to Lunar surface
- Ascent to LLO and RvD with orbiting crew vehicle
- Transient of crew into the return vehicle and
- Return to earth of the crew

LEO Assembly Station



Transfer sequence for scenario 2



Hohmann transfer capability	TLI 3200 m/s	LOI 1000 m/s
ΔV per stage	1st 1250 m/s	
ΔV per stage	2nd 1950 m/s	
ΔV per stage		3rd 1000 m/s

Advantages of LLO transient of crew (scenario 1)

- Separate transport of crew and lunar descender and ascender to LLO
- Low number of RvD's in LEO per lunar transport (moderate waiting time in LEO, reduced boil off)
- Higher acceleration level per lunar transport (lower gravity losses)
- Scenario needs smaller infrastructure effort in LEO
- Scenario is more flexible because it allows also crew only to LLO or cargo to lunar surface



Transportation Elements:

- **Launchers**
- **Cargo Lander**
- **Crew transportation vehicle**
- **Manned descent and ascent stage**
- **Earth departure stage(s) (EDS)**
- **Service Modules**

Three overlapping spheres representing celestial bodies: the Earth (blue and white), the Moon (grey and white), and Mars (reddish-brown).

In-space architecture elements

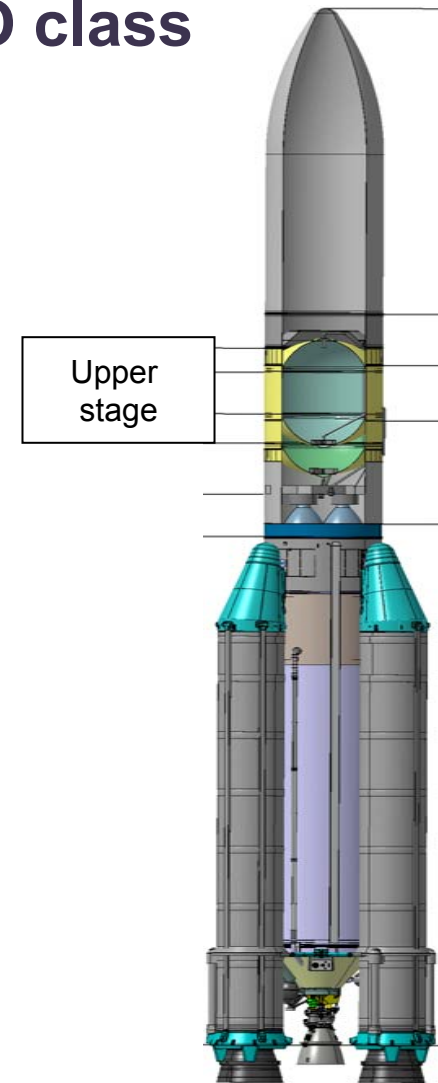
- **LEO and LLO infrastructure**

Launcher evolution to 50 t LEO class

- 6 boosters configuration
- 1 core stage
- Upper stage with 2 VINCI
- Overall length ~ 60 m



Vinci
Twin
chamber



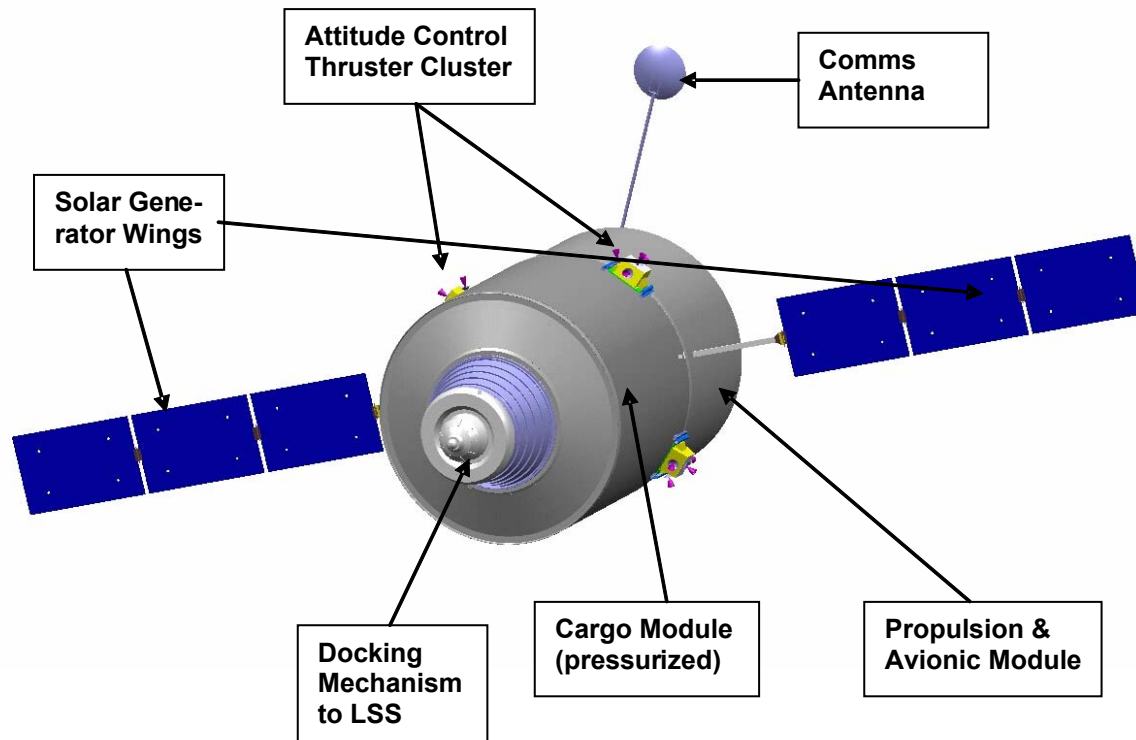
Upper
stage

Logistic transportation to LLO

payload	2100 kg
---------	---------

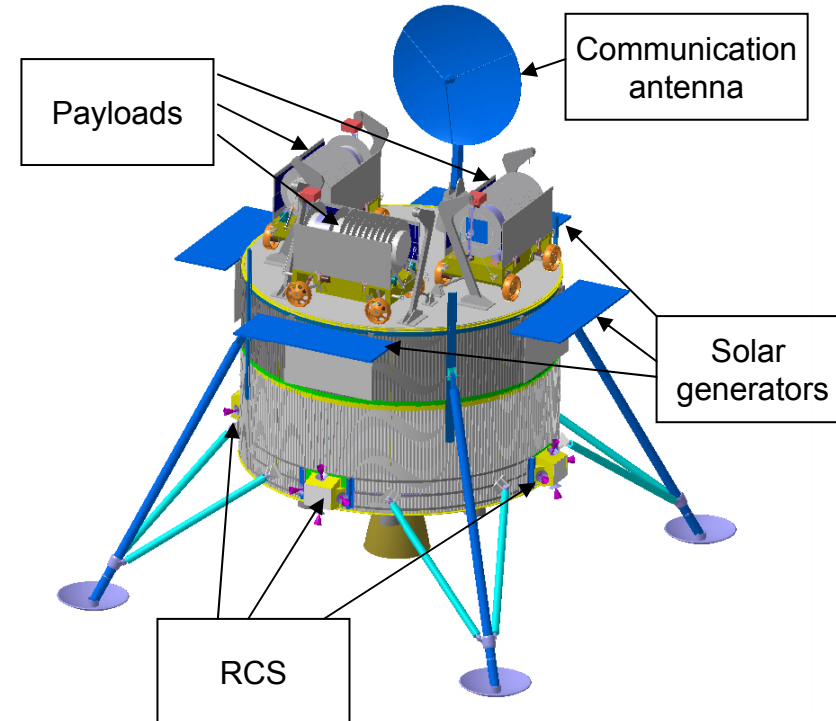
Dry mass	3240 kg
Isp	460 s
DV	1600 m/s
Propellant	2290 t
TOTAL MASS	7800 kg incl. adapter

Pressurized logistics Transporter



Cargo Lander

Payload	1750 kg
Dry mass	1680 kg
Isp	325 s
DV	2320 m/s
Propellant	6040 t
TOTAL MASS	9700 kg incl. adapter



Descent stage : 1 engine 12 kN (throttleable) or 3 engines of 4 kN constant thrust

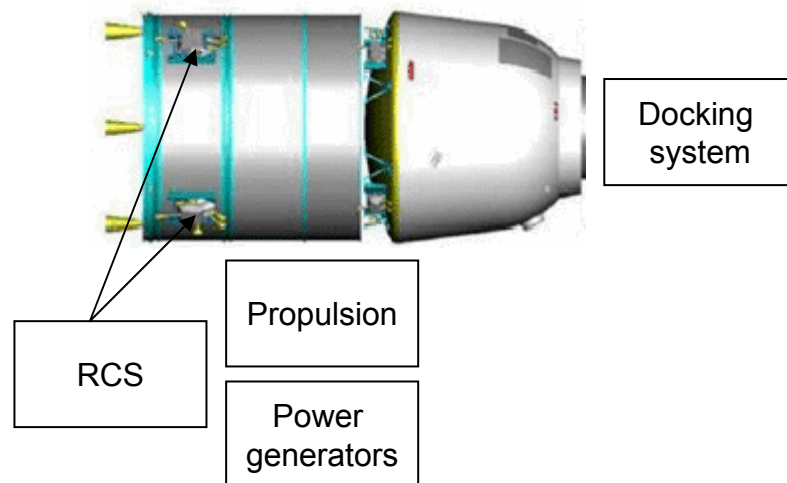
Crew transportation scenario to LLO

Crew transportation system (3 crew) baseline

7,5 t **Capsule**
5,5 t **Service module**
13 t **TOTAL**

50 t class for EDS transfer to LLO

Usable propellant	3 t
Isp	320 s
DV*	1380 m/s
Total (without adapter)	13 t



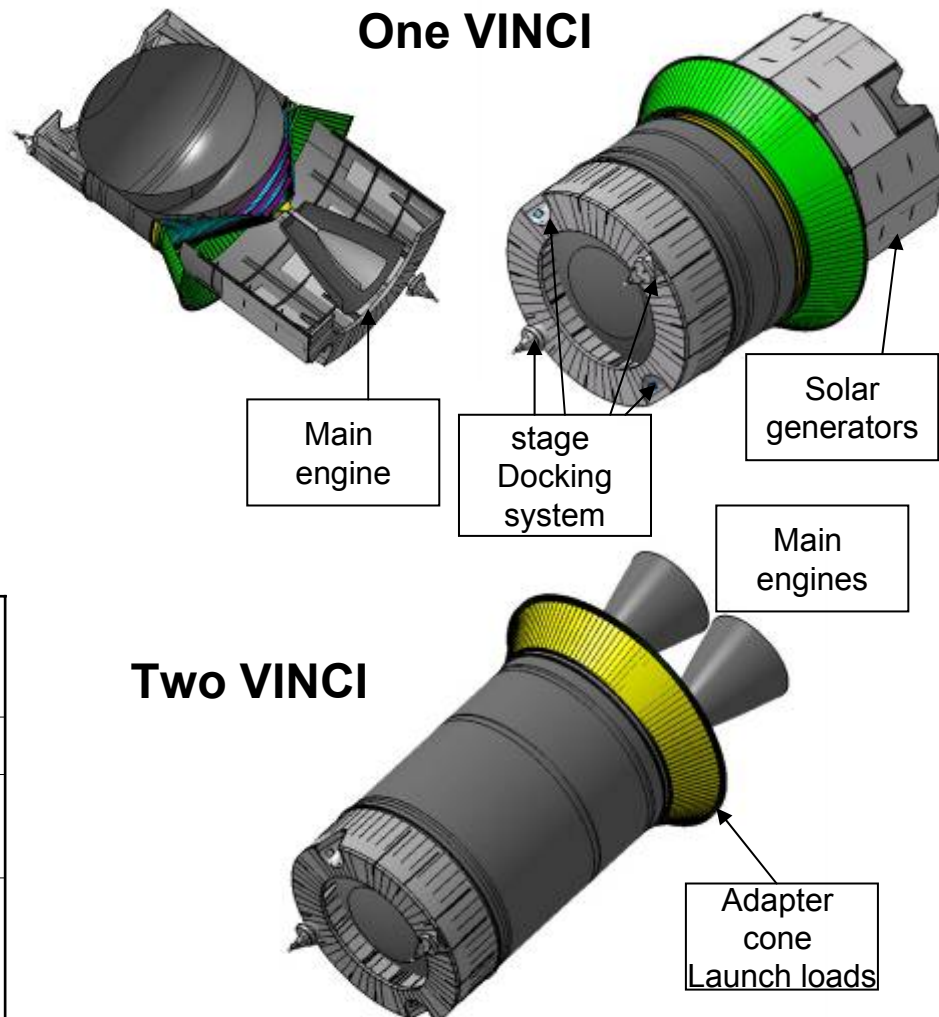
24 t EDS

Usable propellant	17.5 t
Isp	460 s
DV (P/L ≈ 26 t)	2030 m/s
Total (without adapter)	23,8 t

Total TEI + LOI: ΔV 4320 m/s

50 t EDS

Usable propellant	39 t
Isp	460 s
DV (P/L ≈ 50 t)	2290 m/s
Total (without adapter)	49 t



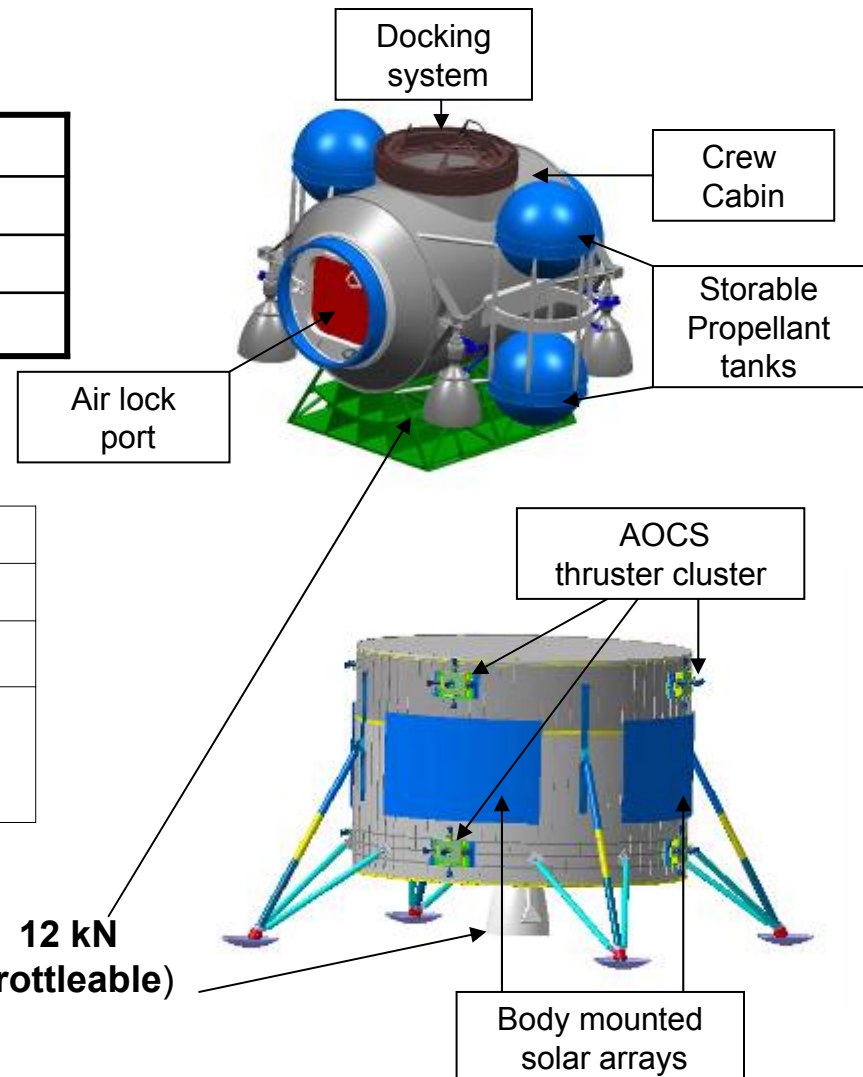
Human lander transportation scenario

Ascent stage

Dry mass	3615 kg
Isp	325 s
DV	2258 m/s
Total mass	7.5 t

Descent stage

Dry mass	4851 kg
Isp	325 s
DV	2260 m/s
Total w/o payload	18.7 t



Ascent stage
 Descent stage
 IBDM docking system

4 engines : **12 kN**
 1 engine. **70 kN (throttleable)**

Total stack to inject into LLO: 26.2 tonnes



Major Dimensions:

Launcher fairing diameter ~ 6 m

Diameter: 5.2 m (cylinder)

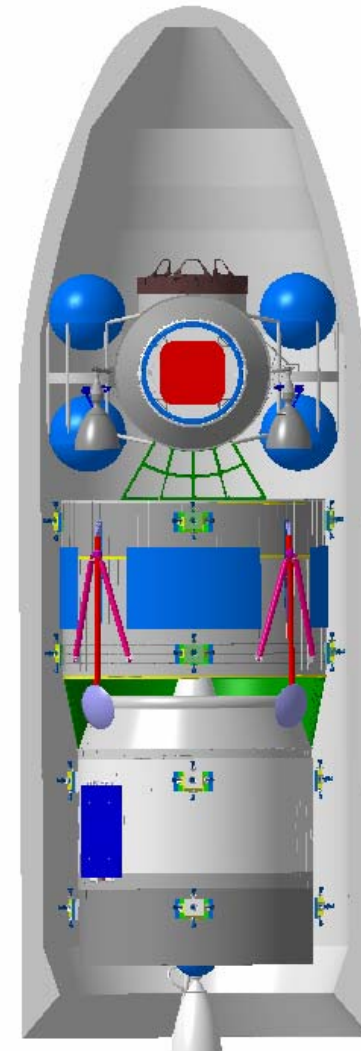
Height:

- Ascend stage: 4.4 m

- Descend stage: 4.6 m

- EDS 7,5 m

-Combined config. 16,5 m



Back up

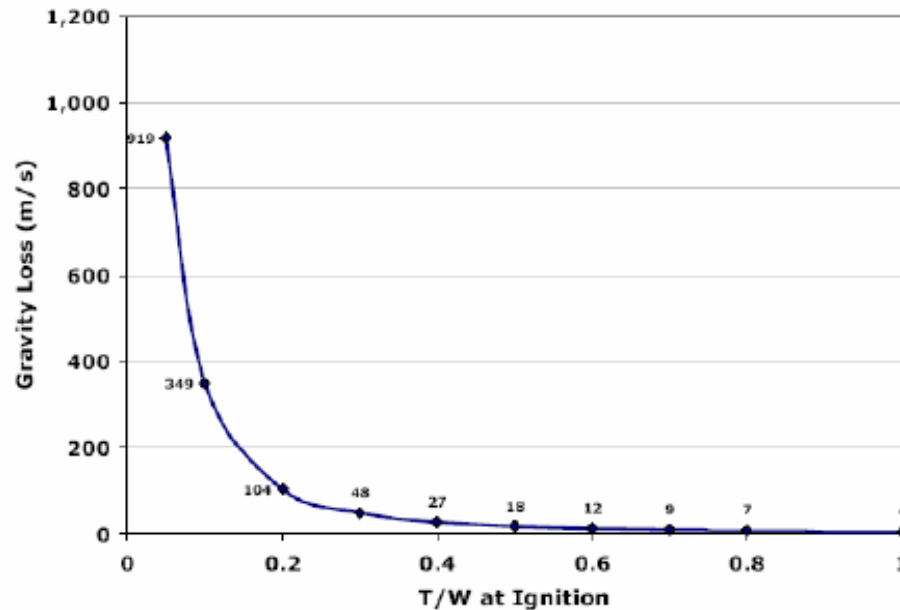


SC 1: 100 t initial mass (2 VINCI)

- ⇒ 0,37 g => additional $\Delta V \approx 30$ m/s
- ⇒ Number of lunar transfer orbits = 2
- ⇒ EDS burn time 8 min

SC 2: 163 t initial mass (2 VINCI)

- ⇒ 0,22 g => additional $\Delta V \approx 100$ m/s
- ⇒ Number of lunar transfer orbits = 2



Additional ΔV for TLI (3200 m/s) as function of the initial thrust to weight ratio or acceleration level [g]

1. boost: 300 x 7000 km 78,2 - 106 m/s losses
2. boost: 300 x 400000 km 143 m/s losses achieved orbit: 323000 km apogee

One boost approach 163 t with 80 t propellant

Target orbit : 300 km x 400000 km

Achievements with different thrust orientations (360 kN)

- Tangential thrust: 631 km x 170000 km; loss \approx 818 m/s
- Gravity turn: 540 km x 200000 km; loss \approx 880 m/s
- Inertial direction: 329 km x 153000 km; loss \approx 653 m/s



Scenario 3 summary

Launcher	Elements + RvD	Mass
2 x HL	EDS (50t) + Eds (24t) / Lunar sys	50 t 50 t
1. Mission	1 RvD LEO +1 RvD LLO	100 t
1 x HL + Man-rated launcher	EDS + CTV (CM +SM)	50 t 13 t
2. Mission	1 RvD LEO +1 RvD LLO	63 t
3 HL + 1 man-rated	4 RvD for transfer to LLO	163 t



Scenario 4 summary

Launcher	Elements + RvD	Mass
2x HL	EDS (50t) + EDS (50t) 1 RvD	50 t 50 t
1xHL	eds (24t) +Ascender / Descender 1 RvD	50 t
Man-rated	CTV + 1 RvD	13 t
3 HL + 1 man-rated	3 RvD to LLO	163 t

