Manned mission to Mars: Concept 2-4-2

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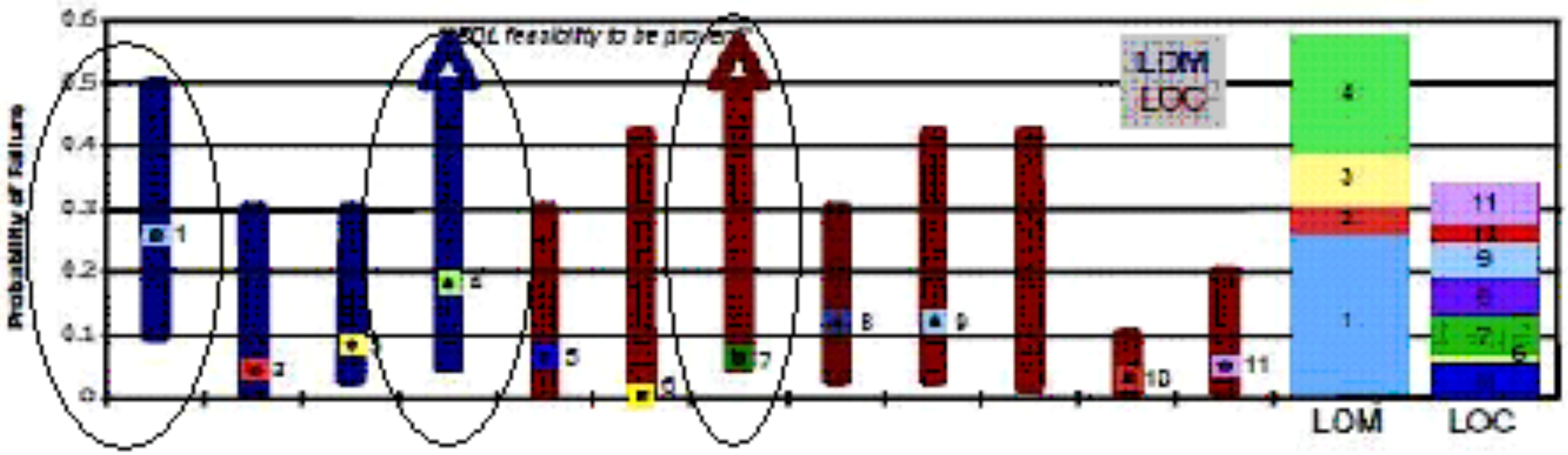
Introduction

DRA 5.0, risk assessment:



Launch and assembly

EDL cargo

EDL Habitat

Conclusion: Manned mission to Mars too risky?

How to reduce risks?

Main principles:

a) Reduce IMLEO

b) Reduce landed payload

c) Optimization !

Important variables:

- Number of astronauts: 1-6 ?
- ISRU:
  - O_2 ?
  - CH_4 and O_2 ?
  - H_2O, CH_4 and O_2 ?
- Direct return or Mars orbit rdv ?
- Number of landing vehicles ?

Let's start simple

1 astronaut ? => possible but risky

2 astronauts ? probably manageable.

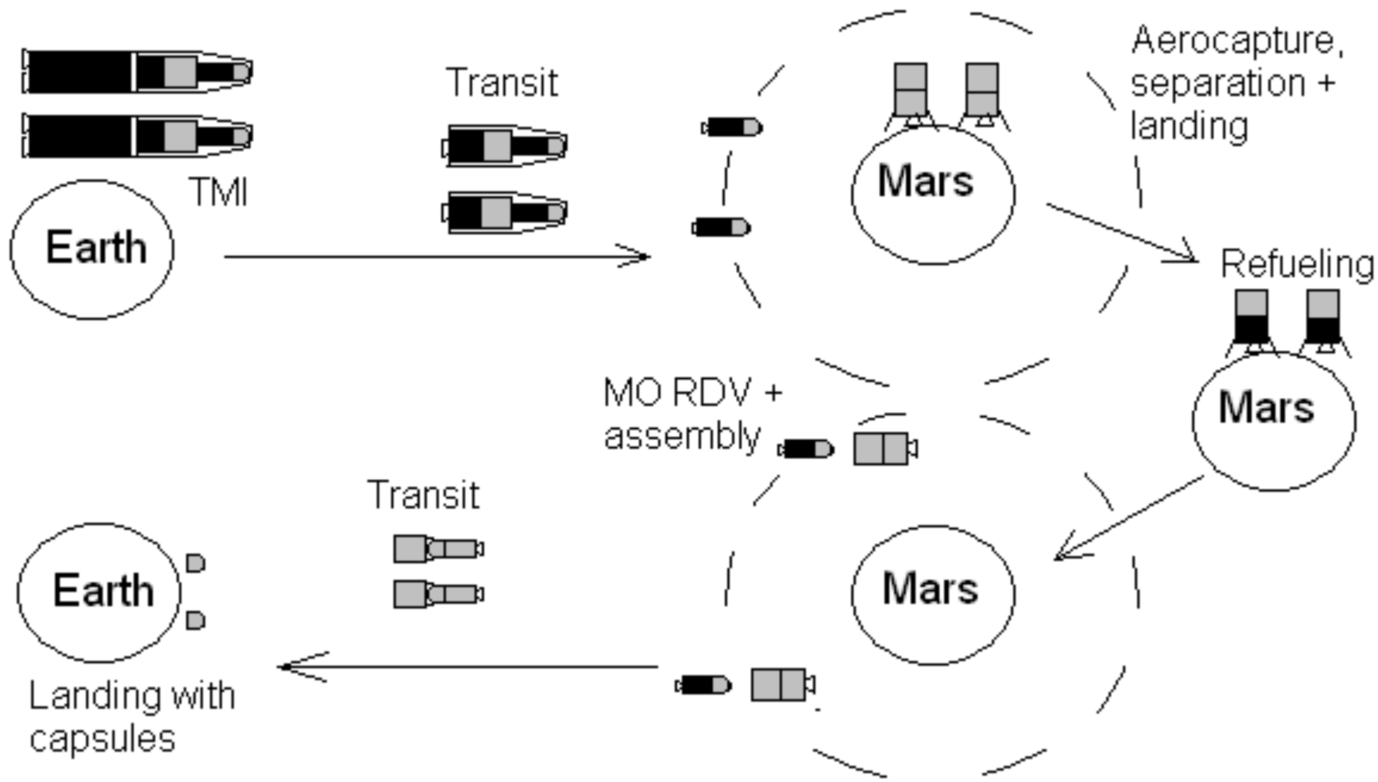
Remark:

NASA DRA 5.0, 2009: 6 astronauts a priori fixed. Number of crew identified as an important variable, but impact not examined.

ESA mission, 2004: same as NASA

=> 2-4-2 concept

2-4-2 basic concept



=> Optimization of Von Braun's original Mars scenario

Mass of the habitat before TEI, extrapolation from DRM 3.0

Subsystem	**Mass (kg) for 6 astronauts (DRM)**		Mass (kg) for 2 astronauts
Life Support System	4661		3000
Crew accommodations and consumables	12,058	} 4666	1555
Consumables jettisoned before TEI (it is stated in DRM that these consumables were needed in case the crew had to leave the surface before the expected date)	−7392		
EVA equipment	243		150
Comm/info management	320		320
Power prod. 30 kWe P.V.A.	3249		1000
Thermal control system	550		400
Structure	5500		3000
Science equipment (left on Mars for the new scenario)	600		0
Spares	1924		1000
Total without capsule and crew	**21,713**		**10,425**
Earth reentry capsule + crew and samples (also Mars ascent vehicle in DRM)	5329		3000
Total (kg)	**27,042**		**13,425**

=> payload / 2 !

Habitat designed for 2 or 4?

- Transshipment should be possible!
- Volume for a crew of 4? No, less comfort is acceptable if transshipment is exceptional
- Consumables for a crew of 4 to allow safe transshipments, but no margin acceptable
- Earth reentry capsule for a crew of 4? No, Earth reentry capsule for a crew of 2 + 250 kg of samples or for a crew of 4 + 50kg of samples

=> 2+2 < 4 !

ISRU

NASA DRA 5.0:

- Option minimizing payload on Mars:
  - Nothing from Earth
  - H_2O + CO_2 from Mars => CH_4+O_2
- Option chosen by NASA:
  - Bring CH_4 from Earth
  - CO_2 from Mars to produce O_2

NASA explanation:

  - too many uncertainties for automatic H_2O extraction
  - H_2 from Earth possible but complexity increases for small payload gains

Solution: Human presence on Mars for deployment and maintenance !!!

Powering ISRU

Cooper et al, Acta Astronautica, 2010:

- Solar panels (ultra light rollable blankets) better than nuclear reactor
- Solution for NASA: nuclear reactor

Reason: automatic deployment and automatic maintenance too complex

Human presence during propellant production

=> solar panels !!! (+ political advantage)

Estimation of payload for Mars landing

7 tons of payload left in Mars orbit (1) ← Mass at launch from Mars

500 days for a crew of 2 + 50% margins for 2 more ← Additional consumables mass

Habitable module (kg)	
Mass at launch from Mars	9200
Additional consumables mass	6200
Unpressurized rovers (from DRM3.0)	375
EVA suits and consumables (from DRM 3.0)	462
Science equipment	500
Subtotal	**16,737**
ISRU, chemical unit, LH_2 and solar arrays (kg)	
Excavation systems	3000
Water extraction systems	1100
Sabatier reactor and electrolysis unit	2810
Power systems	3850
Subtotal	**10,760**
Total payload Habitat + ISRU and power systems (tons)	**27.5**

Extraplation from values found in NASA DRA 5.0 report (1) — Excavation systems, Water extraction systems, Sabatier reactor and electrolysis unit

Extrapolation from Cooper et al, 2010 — Power systems

(1) See Jean Marc Salotti, Simplified Scenario for manned Mars mission, Acta Astronautica 69 (2011) 266–279 for more details.

Solutions for the Entry Descent and Landing problem

Reminder: EDL problem => reduce landed payload

Solutions?

1) Dedicated ERV in Mars orbit (MO) to reduce propellant production and ISRU mass
2) What is not needed on the surface should be left in Mars orbit => Propulsion system + Earth reentry capsule + return consumables in MO
3) Same propulsion system for descent and ascent
4) No dedicated capsule for ascent, same habitat can be used for round trip!

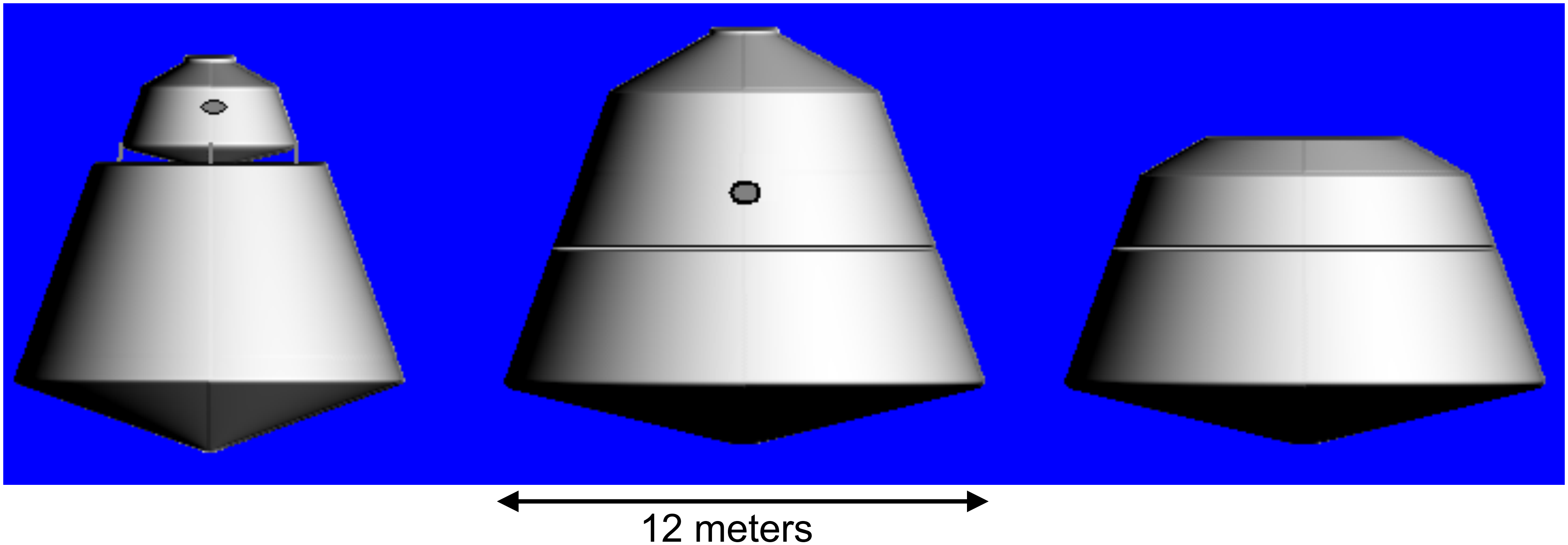
Ballistic coefficient < 153 kg/m^2 for standard landing ???

(Braun & Manning 2005)

Þ **1 lander with ISRU systems and consumables**

+ 1 lander for habitat

Payload for trans-Mars injection



ERP + Earth reentry capsule (ERC)
+ consumables
m=30 tons

Habitat lander
70° cone
m=33 tons
payload=14 tons
b<200 kg/m^2

Cargo lander
70° cone
m=33 tons
payload=12.5 tons
b<200 kg/m2

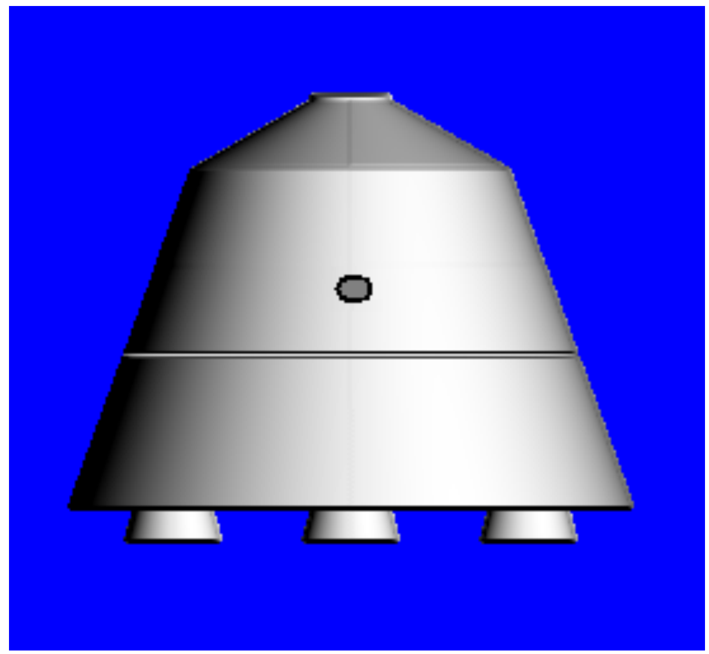
EDL simplifications[1]

Spacecraft 1: Habitat => 14 tons

Spacecraft 2: ISRU systems + 50% consumables => 14 tons

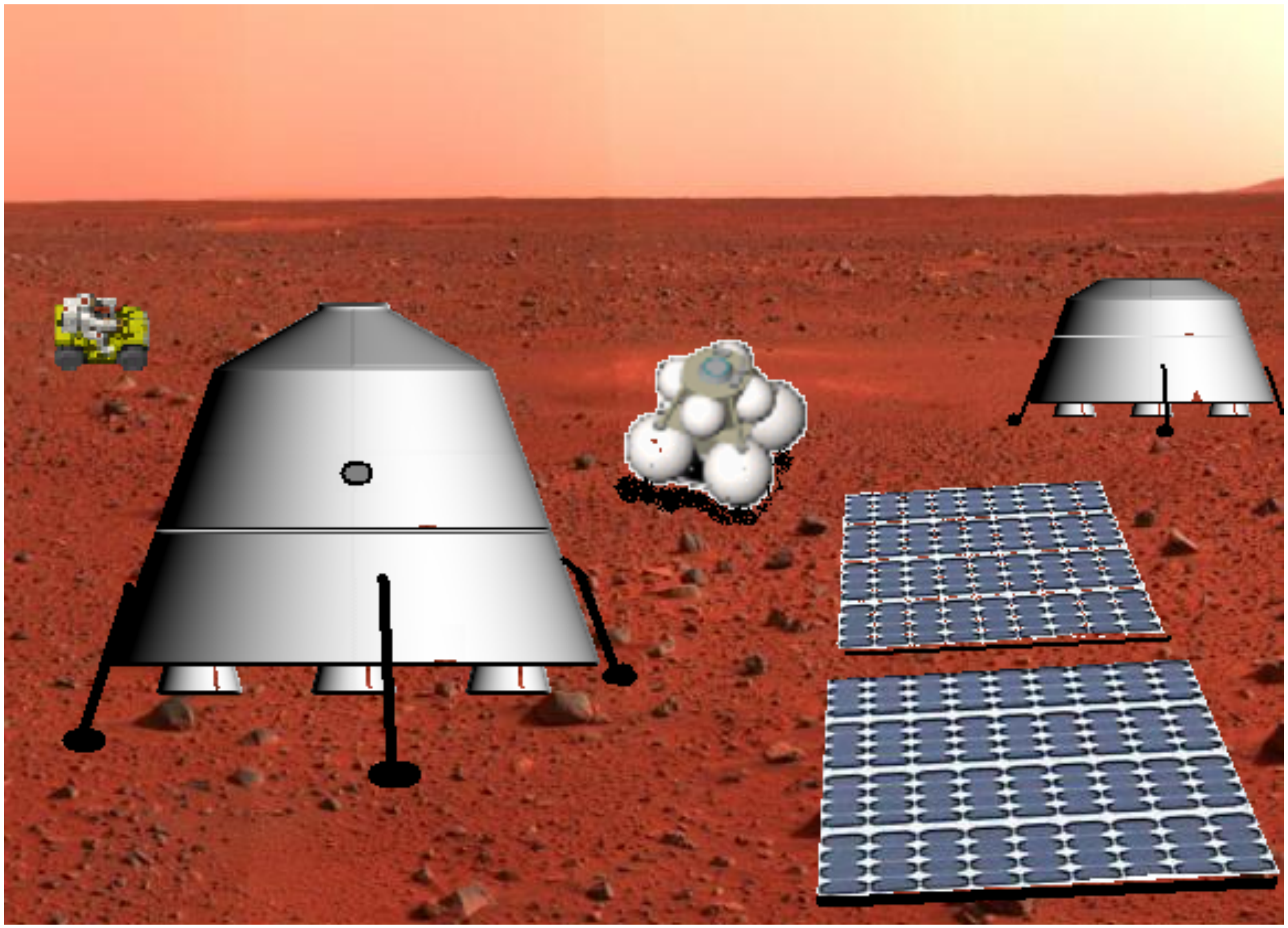
- Þ Same EDL systems for spacecraft1 and spacecraft2
- Þ Light landers
- Þ Lower ballistic coefficient
- Þ EDL simplifications:
- Dual use: aerocapture + EDL
- Simplified heat shield
- Simplified TPS
- Parachutes enabled

=> EDL risks highly reduced!

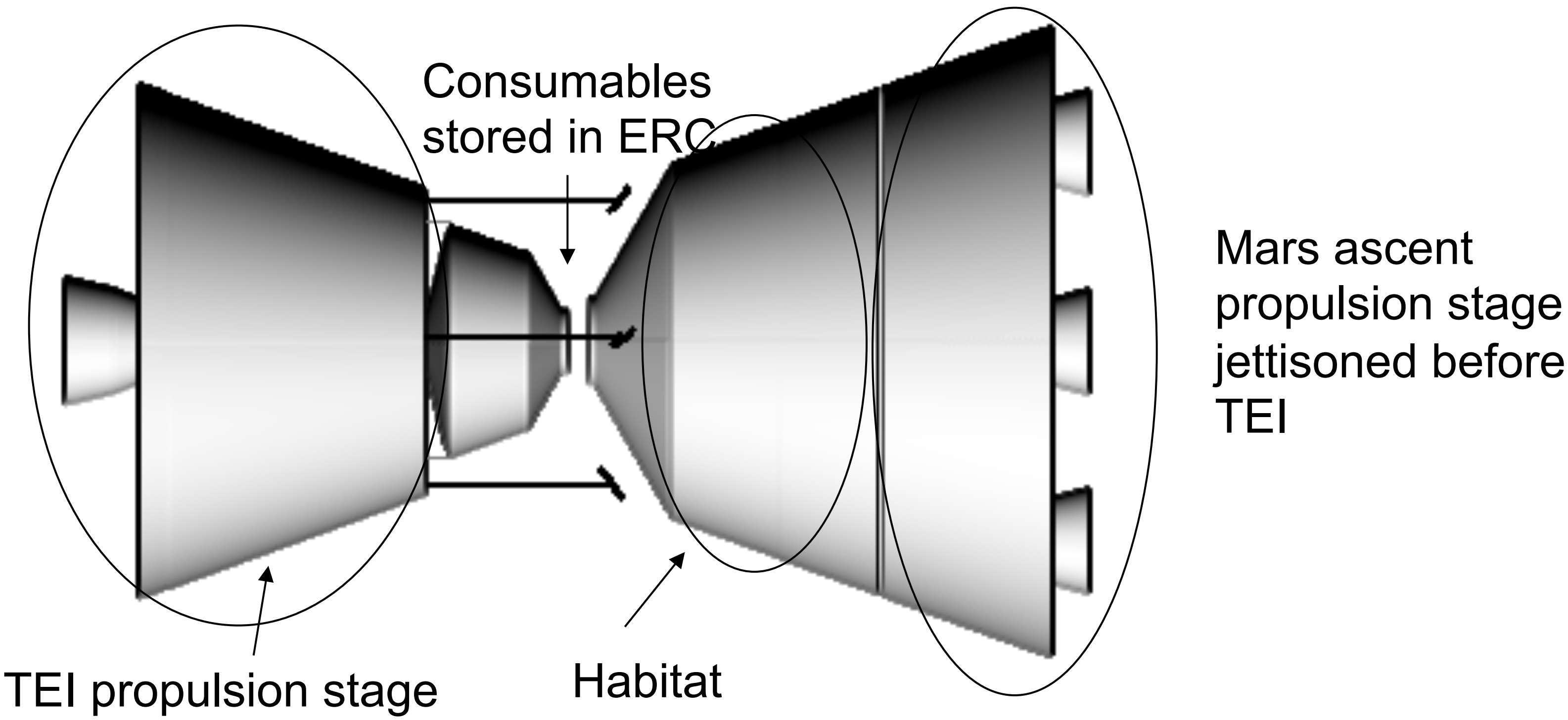


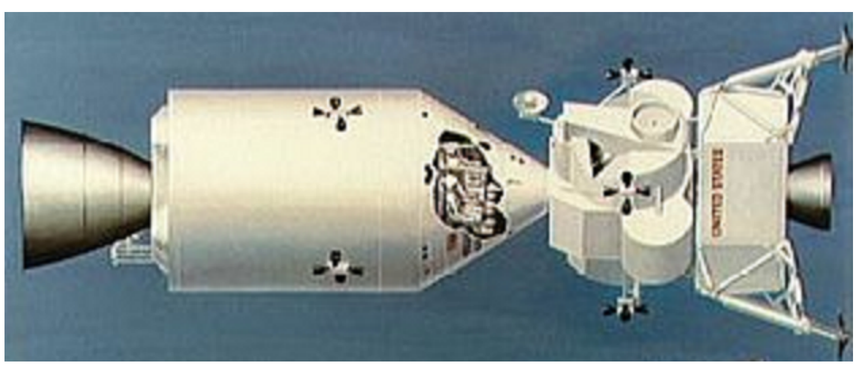
1: Improvement from Jean Marc Salotti, Simplified Scenario for manned Mars mission, Acta Astronautica 69 (2011) 266–279

Propellant production



Mars orbit rendez-vous





Apollo like lunar RDV

IMLEO estimation

Landers:

- Payload: 14 tons
- Propulsion system dry: 6 tons
- EDL systems + propellant: 13 tons

Total: 33 tons; 2 habitats + 2 ISRU = **4 landers = 132 tons**

ERV:

- Payload : 7 tons (capsule + consumables)
- Propulsion system wet: 14 tons
- Heat shield +TPS for aerocapture: 4 tons

Total: 25 tons; 2 ERV = 50 tons

Mass of propulsion stages to send 182 tons from LEO to Mars?

Tsiolkovsky equation, hypothesis: DV=3.6 km/s, 2 stages, dry mass / propellant mass = 12%, ISP=450s (1)

Þ **IMLEO = 493 tons**

(1) See Jean Marc Salotti, Simplified Scenario for manned Mars mission, Acta Astronautica 69 (2011) 266–279 for more details.

Risks in LEO

- **No LEO assembly required!**
- **6 spacecrafts directly sent to Mars!**
- **IMLEO for a single spacecraft: around 70 tons**
- **Unmanned spacecrafts can wait in LEO**

Þ **Low risks in LEO**

Other benefits:

Totally redundant

Transshipments possible during transit!

=> Apollo 13 problem manageable

Conclusion

2-4-2 concept:

- Risks minimized for EDL
- No assembly phase in LEO => risks minimized in LEO
- Transshipments possible => risks minimized during transit
- Human presence during propellant production => optimization of ISRU systems + no nuclear reactor

Programmatic issues:

- Small spacecrafts => big launchers, not huge launchers => Can be used for other missions
- spacecrafts of same size and mass => Same engines and EDL systems

Þ Reduced development costs

- Very few new technological developments => reduced development costs

Þ Mars in a decade might be possible.

- Next mission not necessarily at the same location