Single Launch Mars Sample Return missions

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Introduction

INTRODUCTION

➔ Most Mars Sample Return scenarii involve two launches

- One with an orbiter
- One with a lander, providing a rocket with a sample storage container.
- The rocket performs a rendezvous with the orbiter, then the orbiter returns toward Earth.
- This type of mission is both costly (two launches) and risky (Mars orbit rendezvous), hence the interest of single launch.

➔ Single launch mission profiles

- Electric propulsion is a key enabler for single launch missions.
- Two options are presented :
- A short term mission with a rendezvous in Mars orbit,
- A more advanced mission with EP, Cryogenic propulsion, ZBO and a heavy lander with direct return toward Earth.

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Sample return using EP

SAMPLE RETURN USING EP

Mission profile :

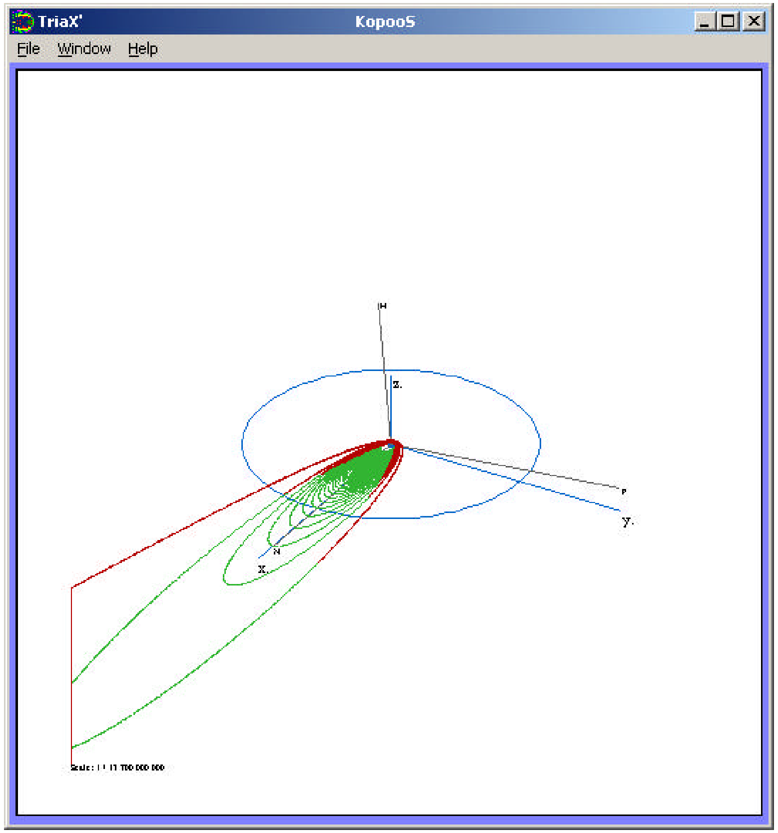
- Orbiter is separated from the main spacecraft (lander and MAV) after Mars orbit insertion, EP is used to circularize orbit,
- The orbiter waits for rendezvous with the MAV capsule,
- Then orbiter EP is used to increase orbit apoapsis and eventually inject orbiter into interplanetary orbit. EP is used to reach Mars – Earth transfer orbit.

SAMPLE RETURN USING EP

- **Launch mass 3905 kg (18% L/V mass margin)**
- **Includes EP orbiter + DM + MAV + Carrier**
- **EP orbiter wet mass: 625 kg**
- **. Total xenon used 354 kg, EP Orbiter S/C dry mass 271 kg**
- **Mission duration: 57.5 months (4.8 yrs)**
- **. Operational mission at Mars: 107 days**
- **. Descent to nominal orbit 690 days and return up to escape 396 days**
- **. Delayed transfers very well suited for dual (simultaneous) launch of electric low thrust and chemical vehicles**
- **1PPS®1350 operating at any time (2 for the required lifetime)**

Comments

- **. EP orbiter yields higher mass margins**
- **. Longer mission duration allows for significant reduction of**
- - ΔV needs (<10 km/s total) thanks to .multi-arcs. strategy
- - number of thrusters used simultaneously
- **. Comparison with SMART-1 brings confidence in present study**
- - SMART-1: launch mass 350 kg, dry w/o payload 255 kg, 1PPS®1350, ΔV ~4 km/s
- - EP orbiter: launch mass 625 kg, dry w/o payload 271 kg, 1PPS®1350, ΔV ~ 9.6 km/s
- **. Further analysis required to optimize heliocentric manoeuver**
- **This solution brings a strong motivation for further studies**



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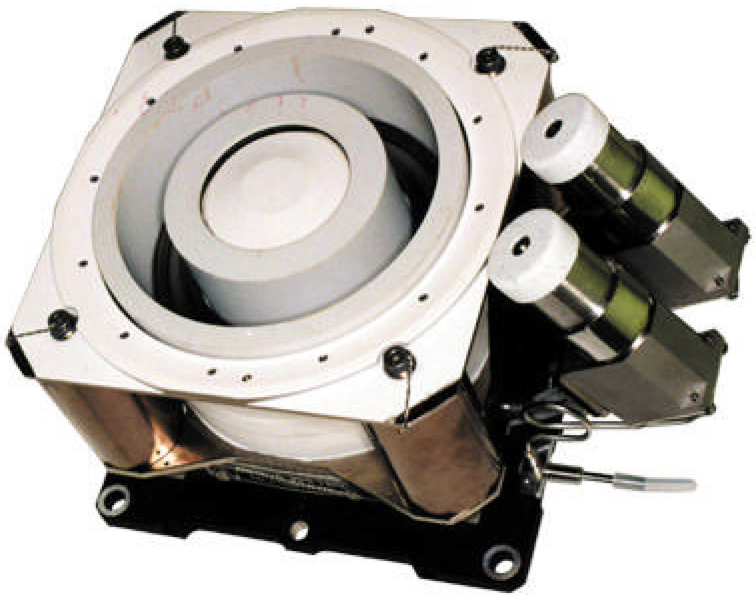
SAMPLE RETURN USING EP : PPS®1350

- Qualified for the Stentor application
- Flight-qualified on Smart-1
- Qualified for GEO Comsat
- missions, flight qualified on ALPHASAT :
- . > 10500 hrs of operations. > 7000 ON-OFF cycles (incl. 50 cold)
- Nominal operating point
- . 1500 W / 4,28 A / 350 V
- . 88 mN / 1650 s / 50% total eff.
- . 4,4 kg
- Variable power feature demonstrated on
- Smart-1
- . Can allow for cluster operations with
- thrust steering capability



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Direct sample return

DIRECT SAMPLE RETURN

- **Chemical only : The launcher provides an elliptical trajectory. A chemical propulsion module provides the ΔV for TMI, this module could be also used for MOI (Mars Orbit insertion) using Zero Boil Off for propellant storage.**

- **Chemical and HET: The launcher provides an elliptical orbit. Electric propulsion is used to raise the apogee in order to reduce the chemical ΔV required for TMI. The chemical propulsion module provides insertion into TMI.**

- **At Mars arrival, a chemical burn insures the capture in elliptical Mars orbit.**

- **EP can be used after insertion to decrease the aeroshell entry speed (lighter shield able to withstand higher ballistic coefficient)**

DIRECT SAMPLE RETURN

Mission profile :

- The combination of EP and Low Thust Cryogenic Propulsion (LTCP) is used to inject more than 9 tons toward Mars.
- ZBO is used during cruise to handle LOX /LH2 (LTCP) and LOX (MAV) during interplanetary cruise.
- At Mars arrival, LTCP is used to perform orbit insertion (+ EP braking option)
- LTCP provides deorbitation,
- The aeroshell protects MAV during entry,
- MAV lands with the first stage thrusters,
- The samples are loaded.
- MAV returns toward Earth,

DIRECT SAMPLE RETURN

- Initial orbit : ARIANE 5 ME GTO (300 x 36000 km) payload mass: 12000 kg

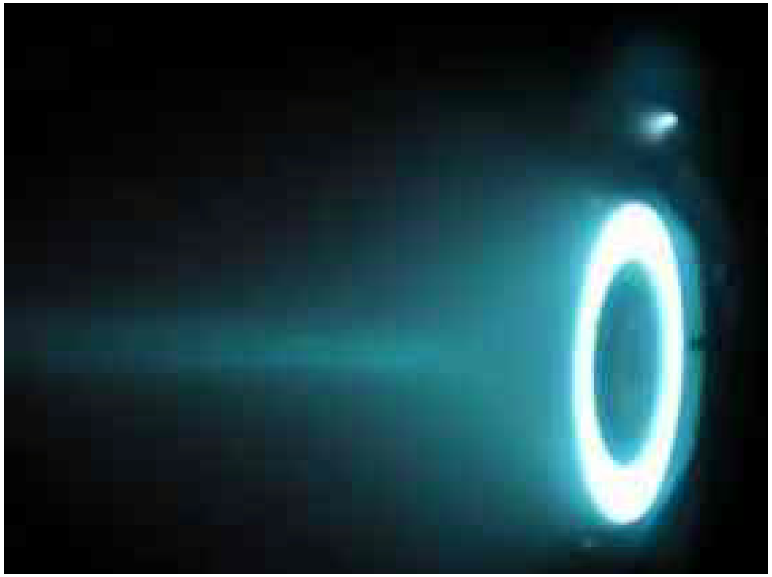
Propulsion system	Mars Orbit	Landed mass
Cryogenic (LCCP)	6601 kg	4800 kg
HET and Cryogenic	7175.2 kg	5210 kg
HET and bipropellant	6375 kg	4640 kg

DIRECT SAMPLE RETURN

Main characteristics of high power Hall Effect Thruster : PPS®5000

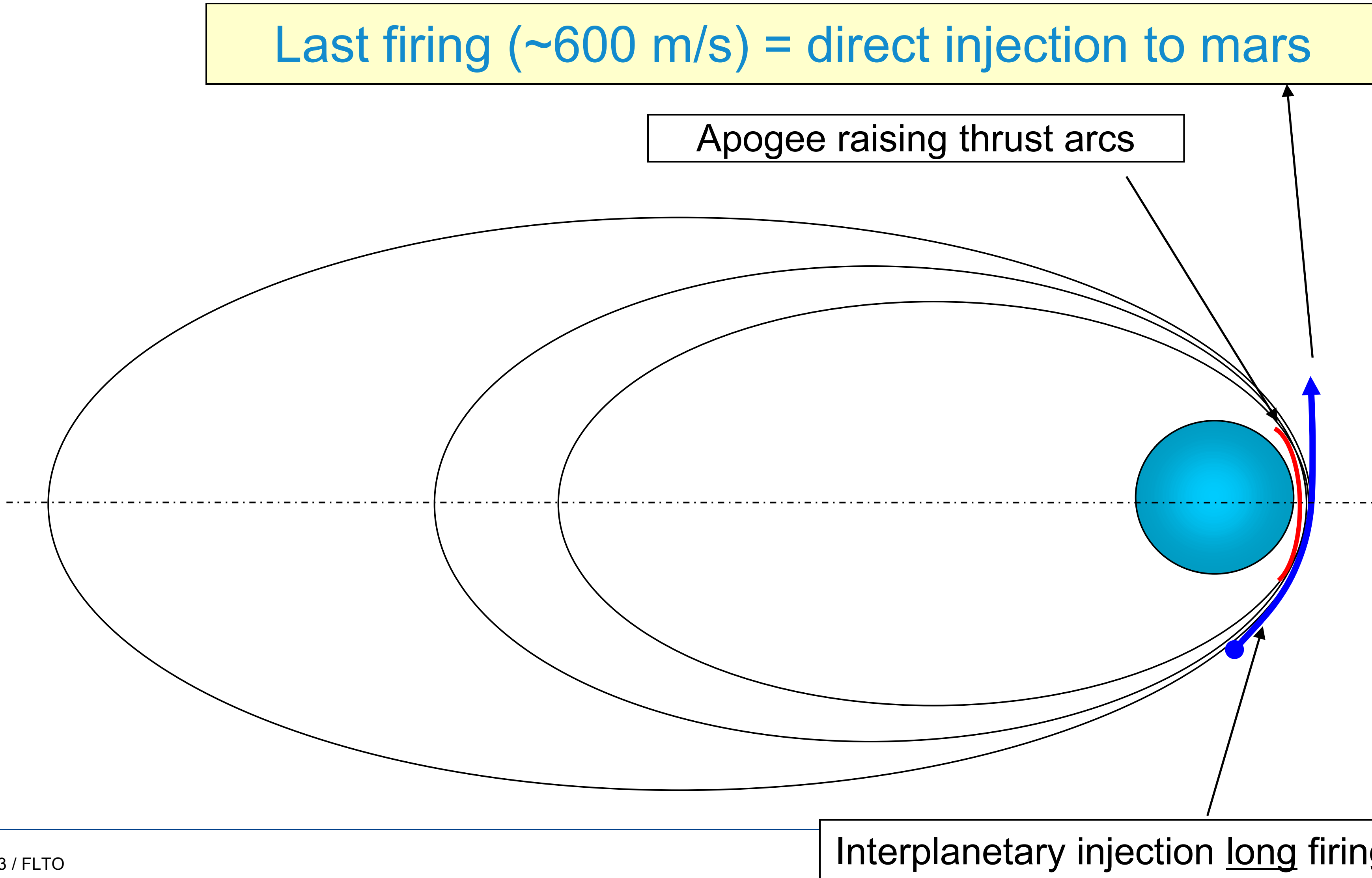
- **Over 1600 hrs of cumulated run time on**
- **PPS®X000 Technology Demonstrator**
- **Designed for dual-mode capability at 5 kW**
- . High thrust (300 mN / 1800 s)
- . High Isp (220 mN / 2200 s)

- **Continued activities on PPS®5000 design optimisation for same capability**
- . Technology consolidation
- . Simplification (*e.g.*, anode/gas distributor
- parts count decreased by 60% !)
- . Total mass decreased by 26% (to 10 kg)
- . Total coils power decreased by 37%
- Projected surface area decreased by 17%



PPS®5000 at 6.5 kW.

MISSIONS: DIRECT INJECTION TO MARS



MISSIONS: DIRECT INJECTION TO MARS

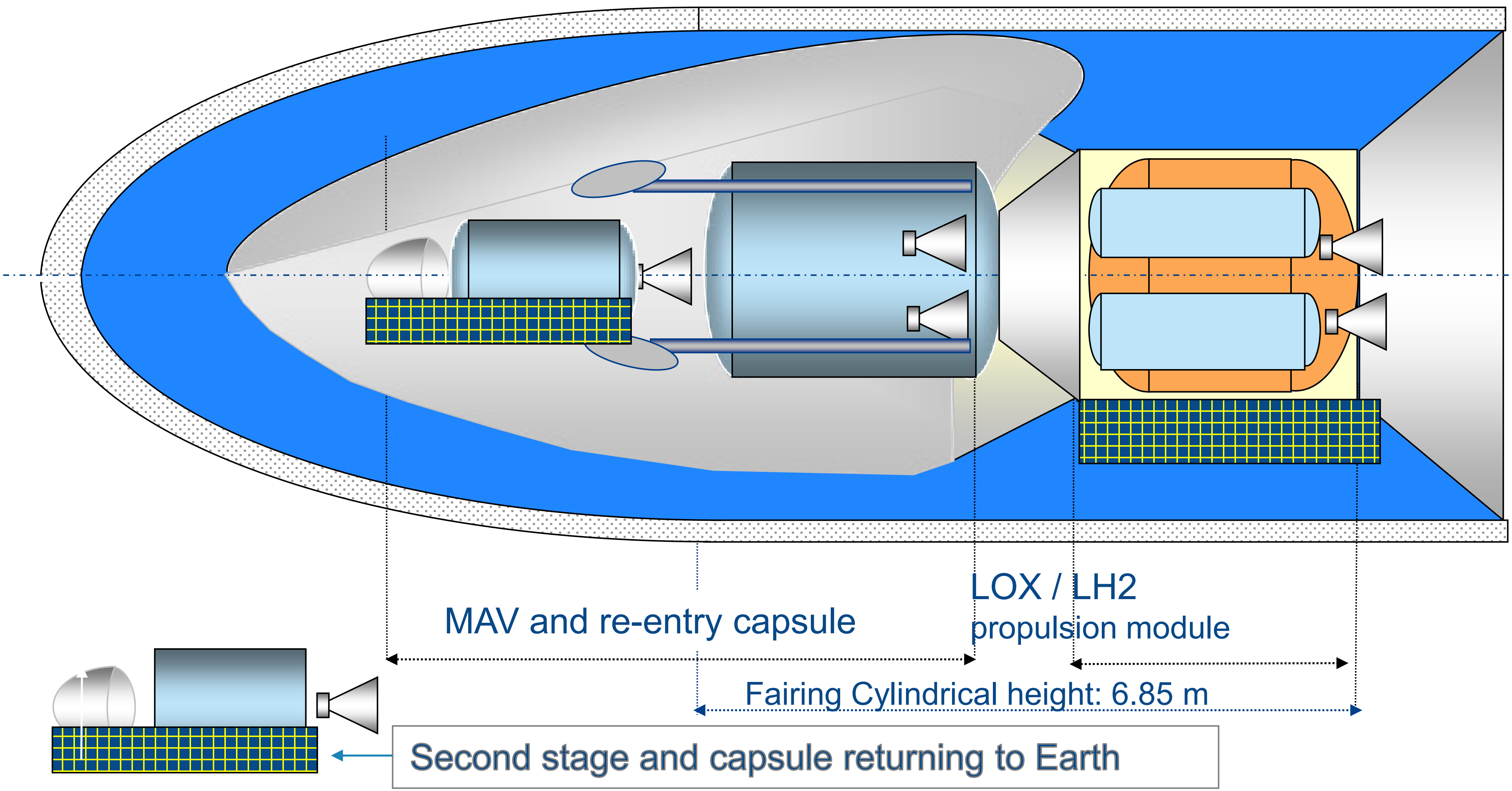
ARIANE 5 ECA:

- **Due to trajectory constraints (EPC re-entry over oceans), the direct injection to Mars provides a limited payload. Starting from a sub GTO orbit (initial mass : 9000 to 12000 kg), LTCP can inject 7000 kg toward Mars.**

ARIANE 5 ME:

- **The payload mass toward Mars is increased from 7500 kg (direct injection with ME and two VINCI engines firings) to 9200 kg (10 200 kg total mass including LTCP module).**

MISSIONS: DIRECT INJECTION TO MARS



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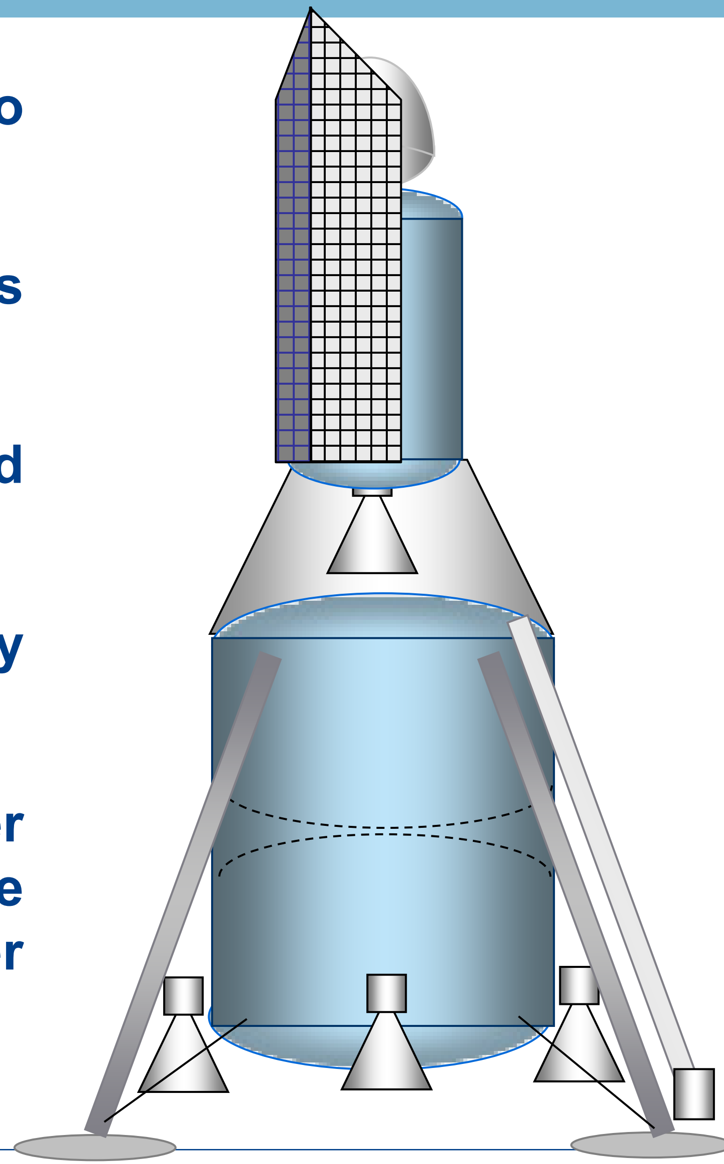
MISSIONS: DIRECT INJECTION TO MARS

- The Mars ascent vehicle includes two stages (LOX / Light HC). Isp : 360 s,
- The second stage is an autonomous spacecraft.
- The re-entry body is directly injected toward Earth.
- ZBO is used during the interplanetary cruise to prevent propellant evaporation.
- The stay on Mars should be short in order to limit propellant evaporation (the samples would be collected by a rover before MAV landing).



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Conclusion

CONCLUSION

- **Mission scenarii for baseline ESA Mars Sample Return are analyzed for possible benefit brought by Hall plasma thrusters**
- **EP on orbiter : Overall mission duration is 4.8 yrs (instead of 3 yrs) with Single Ariane 5 ESC-A launch (instead of 2)**
- **. Mission flexibility, Low power (1.5 or 3 kW at Mars)**
- **. Simple, robust and flight-proven hardware (derived from Smart-1).**
- **EP Low Thrust Cryogenic propulsion and ZBO combination : no need of orbiter : direct launch from Mars surface. Higher power EP (4 PPS®5000, 20 kW).**
- **More ambitious mission using ARIANE 5 ME and large aeroshell.**
- **HET and bipropellant combination is a simpler option with reduced payload.**