S2M2 Executive Summary Report

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1 S2M2 MISSION ARCHITECTURE AND CONOPS

An early phase mission architecture review and selection has been performed based on the input provided within the ESA-internal CDF study report. A potential implementation from industry's point of view has been assessed applying the strict design-to-cost philosophy by fostering strong reuse of an available OHB platform. Trade-offs have been performed for assessing a low cost mission profile targeting the programmatic constraints that were input to this study defined as follows:

- €125M industrial cost at completion (economic conditions 2022)
- Phase B2 kick-off in either Q2 2023 or Q2 2026
- Phase B2/ C/ D in ~4 years
- Launch between end of 2028 and 2033 (inclusive)

Exploration platforms differ significantly from platforms designed and configured for the application in an Earth orbit. The level of autonomy, the FDIR strategy and redundancy approach, the avionics, GNC and communication capabilities are discarding the small OHB Group platforms (SMART-1, Triton-X, InnoSat) designed for LEO applications for the implementation as Mars Communication Constellation spacecraft. In addition, also a severe performance gap with respect to the propulsion subsystem capabilities and delta-v capacity has been identified. Even when combining these platforms with a to-be-developed propulsion module for closing the performance gap identified for the propulsion subsystem capabilities, is still resulting in major modifications of the platforms in order to solve also the other issues. For the Mars Science Orbiter mission architecture candidate, instead, the OHB platform Hera has been identified as promising and feasible spacecraft. Therefore, the implementation of the Mars Communication Constellation is considered less feasible within the programmatic frame of this S2M2 program compared to the Hera-based Mars Science Orbiter mission architecture candidate. As outcome of the general mission architecture discussion and application of the Mars Science Orbiter, two different launch and transfer strategies have been derived. The S2M2 spacecraft, being a Mars Science Orbiter, will be launcher on Ariane 6.2 into GTO on top of the ASTRIS kick-stage which, after separation from the upper stage, will perform the manoeuvre for injecting the S2M2 spacecraft into a heliocentric Mars transfer orbit characterized by an orbital energy in the order of C_3 = ~10 km²/s². The direct launch into the heliocentric Mars transfer orbit by the launch segment still being the Ariane 6.2 has been kept as alternative option. After the cruise phase the S2M2 spacecraft will perform the Mars orbit injection manoeuvre with its own chemical propulsion means followed by a potential lowering of the apoares altitude in order to inject itself into the final elliptical target orbit. Within the final target orbit, the S2M2 spacecraft will nominally perform either data acquisition with the scientific payload pointing to Mars or payload data downlink with the body-mounted HGA pointing towards Earth. Exploiting the nature of the elliptical target orbit, the payload data downlink has been foreseen for the sequence in orbit when the S2M2 spacecraft is around apoares, see Figure 1–2. The baselined operational approach is such that the S2M2 spacecraft will be able to continuously perform data acquisition only except of the payload data downlink sequence around apoares. Preliminary link budget analyses revealed in the need for roughly 3.5 hours of data downlink for downloading 0.5 Gbit of data under worst case conditions respecting maximum distance between Mars and Earth. Taking into account roughly 30 min between data acquisition and payload data downlink for spacecraft attitude orientation (Mars vs. Earth pointing) the remaining time during one orbit will be available for data acquisition operations.

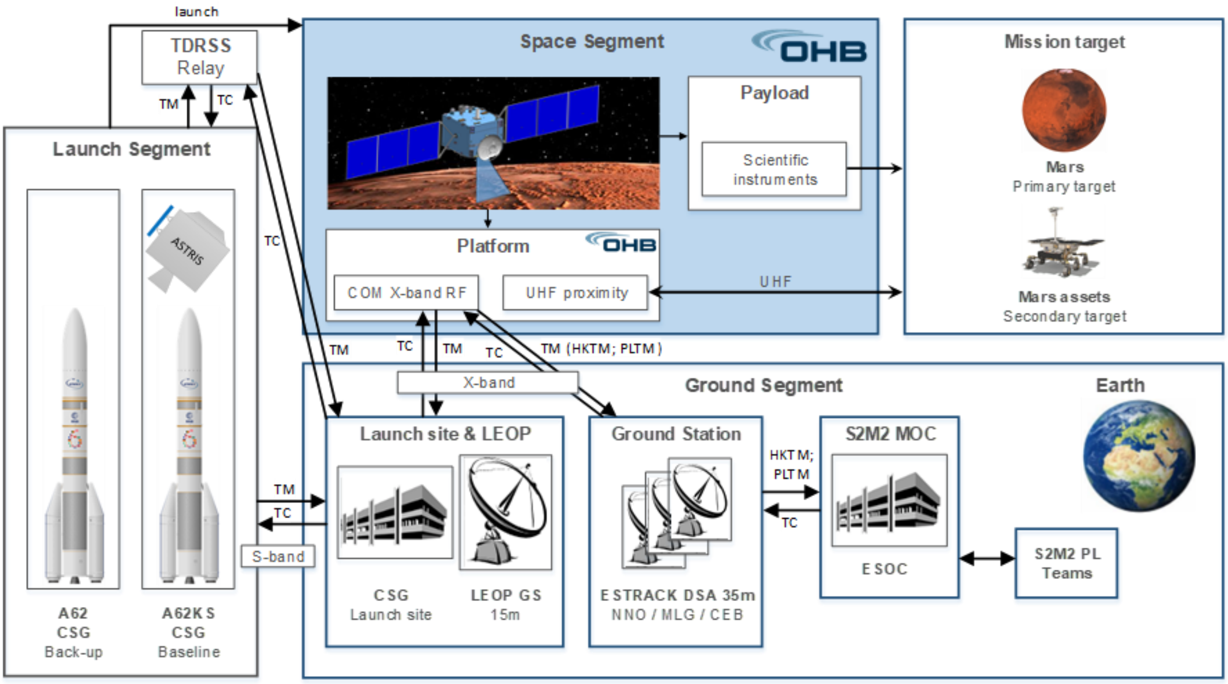

Figure 1–1: S2M2 mission architecture overview

The targeted baseline for the S2M2 mission has been preliminarily established for a launch within the first launch opportunity end of 2028. The corresponding science orbit will be an elliptical Sun-Synchronous orbit with a semi-major axis of roughly 9000 – 10000 km and an inclination of roughly 120°. The altitude of periares has been set to roughly 300 km. The orbital period of such orbit will be in the order of almost 8 hours and providing good coverage of Mars latitudes +/- 60 deg. It has to be highlighted that the selection of a science orbit within the current stage is only preliminary and subject to change within the next phase.

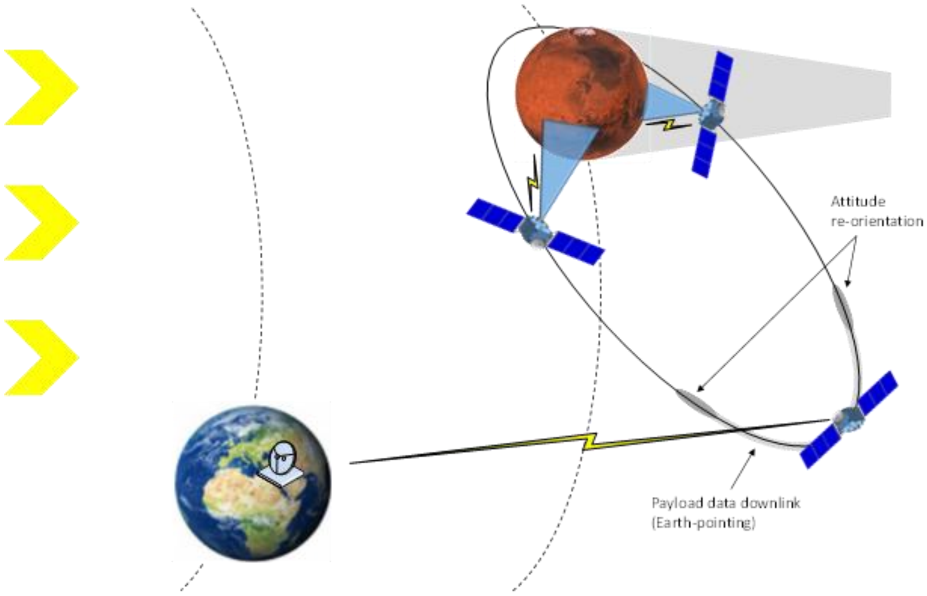

Figure 1–2: Science operation phase Concept of operation

Finally, a disposal manoeuvre has been included in the Concept of Operations which means an impulsive manoeuvre for increasing the periares altitude in order to reach a suitable orbit for assuring the fulfilment of associated planetary protection requirements. Within the disposal orbit, passivation of relevant subsystems as well as shutdown of the satellite will be performed completing the mission.

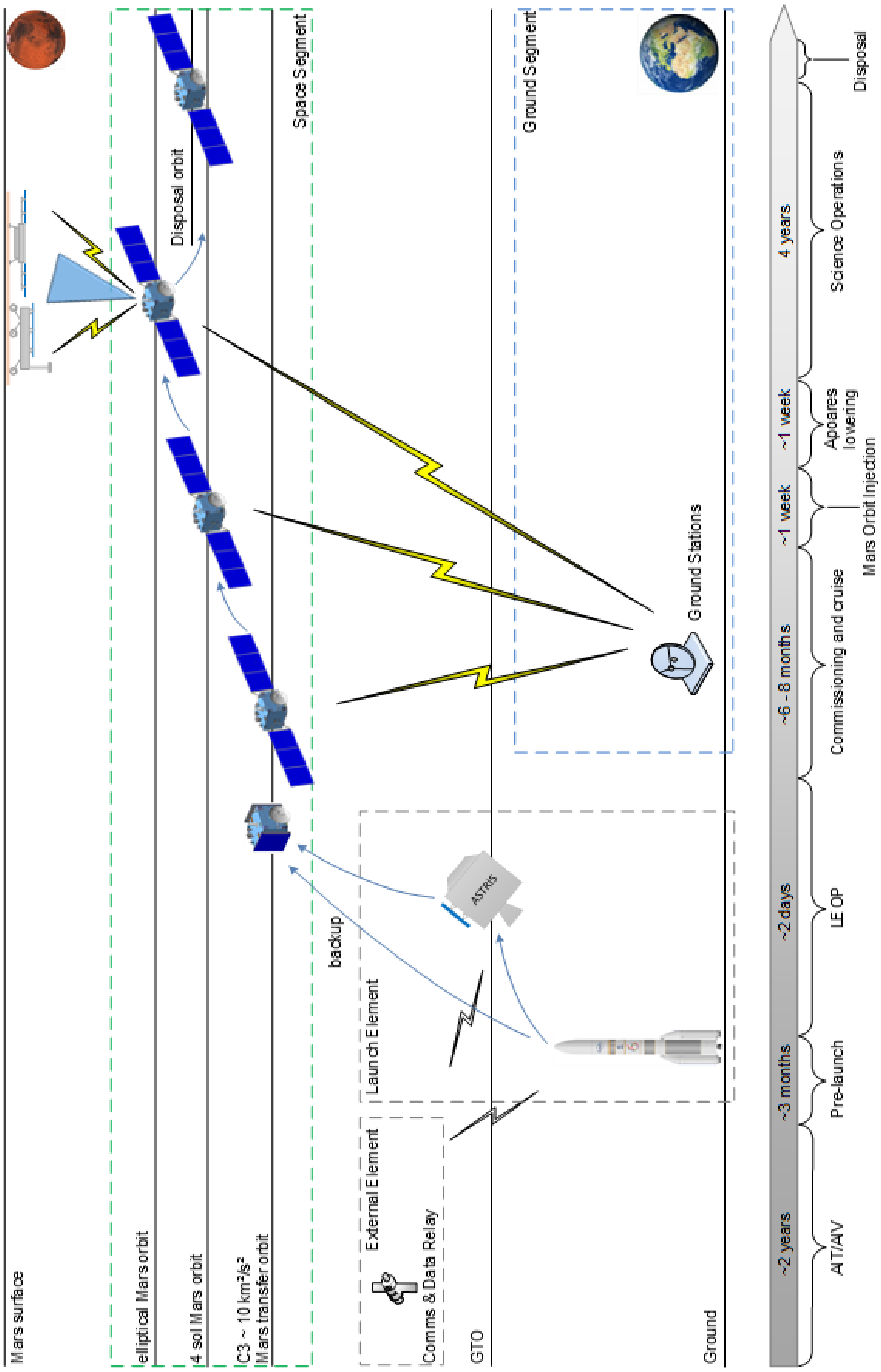

Figure 1–3: S2M2 consolidated Concept of Operations

2 S2M2 SPACECRAFT OVERVIEW

In this activity, the S2M2 spacecraft is proposed in two options differing in the tank selection. This optional tank modification is presented as potential performance growth of the S2M2 spacecraft due to enhanced propellant tank capacity. The final tank selection for the S2M2 spacecraft will be performed beginning of the next phase when payload requirements with respect to the orbit for science operation around Mars are available. Based on reuse of the same tank selection as the referenced Hera spacecraft, Option1 of the S2M2 spacecraft implements the 250 l tanks of the OST25 tank family. Option 2, instead, incorporates the tank modification to the 282 l tanks of the OST25 tank family.

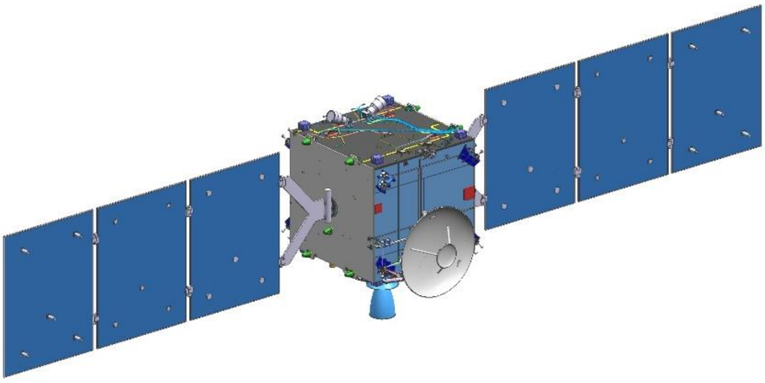

Figure 2–1: S2M2 spacecraft deployed solar arrays

The avionics architecture consists of an OBC, one Mass Memory Unit (MMU), two Remote Terminal units (RTUs), and all connected platform and payload units. The Propulsion RTU interfaces with the Chemical Propulsion Subsystem and allows the OBC to control it. The Platform RTU interfaces with the relevant platform units and provides also interfaces to a potential payload. The electrical design is based on a distributed architecture between the platform and payloads. One unregulated 28 V power bus has been foreseen for interfacing to all active satellite subsystems through the entire mission. Heater circuitry within the PCDU and units are provided to support the electrical architecture for the thermal control. The MTP architecture is based on a classical central structure (CFRP cylinder and aluminium cone) design. The central tube diameter is designed to fit to the propellant tanks while the cone establishes the 937 mm interface to the launch vehicle. The central structure is the main stiffness contributor and it provides the direct load path for the propellant tanks, the payload units on the top deck, and to the launcher interface ring. The launch loads are transferred directly to the central structure that accommodates the tanks inside. A passive thermal design has been foreseen for the spacecraft utilising radiator panels on the +/- Y panels (below the solar panels in stowed configuration) to reject the excessive heat in hot conditions. A more powerful main engine has been foreseen for S2M2 spacecraft implementation. The accommodation of the 400 N engine has been foreseen via the cone of the S2M2 spacecraft primary structure. In order to increase the delta-v performance of the chemical propulsion subsystem even further, also a potential implementation of larger tanks of the same tank family have been considered. The accommodation strategy of the propellant tanks inside the central tube has been kept the same, but the interfaces of the upper tank have to be shifted upwards to cope with the enlarged height of the lower tank. Consequently, also the top deck will have to be shifted upwards by roughly 160 mm. Due to this shift, also the central tube and the structural panels have to be modified and adapter to the increased height of the overall S2M2 spacecraft.

Table 2–1: S2M2 spacecraft overview

Spacecraft Design		
Payloads	Generic - up to 50 kg on top panel / 40 kg used in mass budget - 75 W used in power budget (also for eclipse) / growth potential possible	
Payload Support	Internal volume for payload units	
Dimensions	Stowed	2037 × 1992 ×2085 mm^3
	Deployed	2037 × 11512 × 2085 mm^3
Mass	Dry (w/ margin – 15%)	~729 kg (250 l version) ~740 kg (282 l version)
	Wet mass at launch	1227 kg (incl. He, 250 l version) 1302 kg (incl. He, 282 l version)
Delta-v	Propellant capacity - 95% filling ratio (max.) - 10% volume margin	237.5 l per prop. tank (250 l version) - 188 kg Fuel (MMH) / 308 kg Oxidizer (MON) 268 l per prop. tank (282 l version) - 212 kg Fuel (MMH) / 347 kg Oxidizer (MON)
Power	Max. mean consumption (incl. payload)	992 W data acquisition in eclipse 996 W data downlink in sunlight
Structure	1 × central tube assembly with launcher interface ring, cone and cylinder 4 × shear webs, 2 × closure panels, 2 × radiator panels, 1 × top deck, 1 × bottom deck, 2 × thruster support panels	
Propulsion	Bi-propellant pressurized system	
	Thrusters	1 × 400 N thruster 16 × 10 N thruster (RCT N+R) 6 × 10 N thruster (OCT N+R)
	Tanks	1×MON PMD tank (OST-25 250 l or 282 l) 1×MMH PMD tank (OST-25 250 l or 282 l) 1×Helium Vessel 50 l (MTA PVG50)
	He isolation	High pressure latch valves, 1 × pressure regulator
Communication	Frequency	X-band Earth communications UHF Proximity communications
	Antennas	2 × X-band LGA (omnidirectional), HGA (1m) 1 × UHF LGA
	RF Chain	2 × X-DST (N+R) 2 × TWTA (N+R) X-band 1 × UHF transceiver 1 × UHF amplifier
Data Handling	OBC	QinetiQ Proba Next
	RTU	Platform RTU internally redundant Propulsion RTU internally redundant
	MMU	NAND flash, 1 Tbit EOL capacity
GNC	Three-axis stabilized platform	
	Sensors	1N+1R × Star Tracker 6N+6R × Coarse Sun Sensors 1N+1R × gyro (no accelerometers)
	Actuators	4 × RW + RCTs
Thermal	passive: Radiators, black capton MLI interface fillers; active: heaters	
Power	Solar Array	2 × SADM, deployable, 1 × SADE
		2 wing, 3 panels / wing ,13 m^2, 3G30C cells
		MPPT
	Battery	8S24P SAFT VES16
	Bus	28 V unregulated

2.1 Payload characteristics

The accommodation strategy for the external payload units is shown in Figure 2–2 by an indicative orange payload envelope on the top deck. The general approach foresees nadir-pointing with the top deck normal vector towards Mars in line with the main spacecraft body axis. The envelope on the top deck available for external payload accommodation has been preliminarily assessed with 1550 x 600 x 500 (LxWxH), although in principle, the whole top deck can be used for payload unit accommodation respecting the structure performance.

RCT plume impingement as well as star tracker field of views have to be respected by the payload. Design measures have already been implemented for avoiding plume impingement on the payload. Depending on the final payload characteristics and the needed envelope for accommodation, a potential re-accommodation of the star tracker units could be assessed in the next phase of the S2M2 program in order to increase the envelope available for the payload.

An envelope for spacecraft internal payload electronic units has been preliminarily assessed with 0.7 m x 0.5 m x 0.3 m (LxWxH) although growth potential has also been identified if needed. Typical temperature limits for units mounted to this panel have been assessed with -15 – 55°C being the operational design temperature limits. For keeping the units within this temperature limit, only passive thermal control has been foreseen. However, also active thermal control can be implemented for guaranteeing to keep different thermal constraints of a potential payload electronic unit if needed.

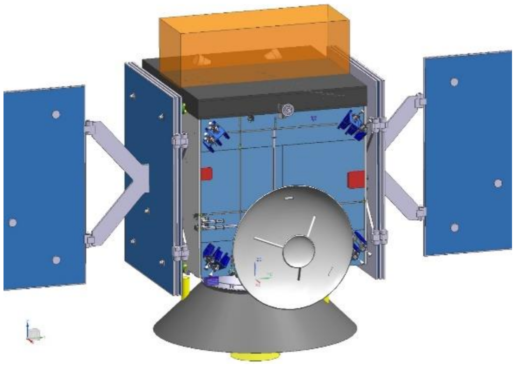

Figure 2–2: S2M2 payload indicative envelope

75 W of payload power have been generically assumed in the preliminary S2M2 power budget in sunlight as well as eclipse. An unregulated 28 V bus is foreseen for the S2M2 spacecraft. An additional regulated payload bus could be implemented if needed. Growth potential has been identified due to solar arrays EoL power output exceeding the spacecraft needs.

Heater power is provided to potential payload interfaces. The payload units are fully integrated into the platform without being thermally decoupled. Thermal control of the payload interfaces or even active control of the payload units can be performed by the S2M2 platform.

The physical architecture of the S2M2 spacecraft also incorporates several data interfaces to payload units consisting of several SpaceWire links, direct connections to the platform RTU via the main MIL-BUS 1553b as well as several serial RS422 UART interfaces.

In terms of pointing, the S2M2 performance has been preliminarily estimated to the payload interface. According to the preliminary performance estimate a preliminary APE < 0.1 deg (3 sigma) has been revealed.

Table 2–2: Preliminary payload characteristics key parameter overview

Payload parameter	Characteristics (TBC)
Outer envelope	1550 x 600 x 500 mm on CFRP top panel already available, (growth potential to be discussed next phase)
Inner envelope	700 x 500 x 300 mm on CFRP side panel, (growth potential to be discussed next phase)
Mass	Up to 50 kg (growth potential possible)
Power	Up to 75 W / unregulated 28 V (growth potential to be discussed in next phase)
Data interfaces	SpaceWire (3 OBC; 1 MMU link) / MIL-BUS 1553b / serial RS422 UART
Payload interface pointing	Currently APE < 0.1 deg (3 sigma)
Thermal	External payload: Thermal control of payload interfaces possible (growth potential possible) Internal payload: Typically -15 – 55 °C non-operating temperatures (growth potential possible)

3 S2M2 MISSION PERFORMANCE

Limiting the interplanetary transfer possibilities to cases without extra revolutions, low delta-v launch opportunities have been identified as shown in Figure 3–1.

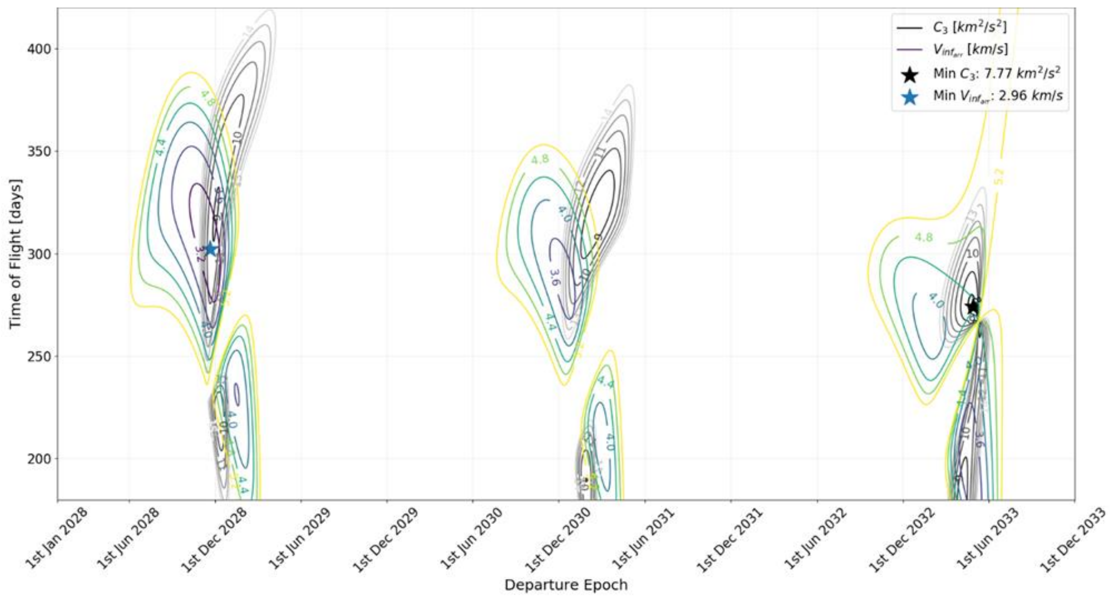

Figure 3–1: Porkchop plot showing the departure C_3 and arrival infinity velocity for the interplanetary cruise along the entire launch window

The lowest apoares altitude has been analysed for all options respecting also burn losses resulting from the S2M2 configuration, different launch opportunities as well as back-up strategies. Reference cases have been selected for further investigation based on eclipse and ground track assessments with the objective to provide a wide range of performance to a potential payload. Elliptical orbits with a maximum of 140 min eclipse will be considered for the system design. For the current S2M2 baseline, the second launch opportunity should be discarded due to the low mission performance. For the S2M2 option with 282 l tanks, the mission performance is increased compared to the baseline tank configuration. As a result, higher flexibility has been derived w.r.t. the science operation orbit characteristics that might be achieved.

The S2M2 baseline scenario has been defined including the kick-stage on top of the launch vehicle. The derived baseline delta-v budget has to be iterated within the next phase according to the consolidated S2M2 wet mass estimate. Compared to the S2M2 wet mass estimate as concluded within this activity only a minor impact on the delta-v budget as presented below is expected. Therefore, the resulting delta-v budgets for the three targeted launch opportunities are presented below as conclusion from mission analysis point of view within the current activity.

Table 3–1: S2M2 baseline (250 l tanks) preliminary delta-v budget

Manoeuvre	Final delta-v (m/s)		Engine
Kick-stage Dispersion Correction	40		AG S10
Interplanetary Navigation	10		AG S10
Mars Orbit Injection	2028+	1066.91	AG S400-15
	2030+	1423.52	
	2032+	1319.20	
Apoares Altitude Lowering	2028+	429.25	AG S400-15
	2030+	71.10	
	2032+	171.83	
Orbit Maintenance	11.31		AG S10
AOCS & Safe Mode Allocation	56.57		AG S10
Disposal	20		AG S10
SUM	**2028+**	**1634.04**	-
	2030+	**1632.49**	-
	2032+	**1628.91**	-

4 S2M2 PROGRAMMATIC APPROACH

The programmatic approach for the S2M2 spacecraft will be established in line with the strict design-to-cost approach applicable to this project. Driven by the reuse strategy of the HERA platform, the programmatic approach will be harmonized with the HERA project.

In this sense, the industrial strategy covering, for example, the industrial core team consortium and the procurement strategy has been based on HERA project in order to gain the most possible benefits from the reuse approach and to benefit from HERA heritage. As for HERA, Incorporating all subsystem responsibilities within a core team structure has been identified as beneficial measure for gaining cost savings by reducing overhead and additional AIT/V effort. Based on the programmatic assessment performed so far, OHB strongly recommends to adopt HERA geo-return distribution constraints for S2M2 in order to establish a low cost mission.

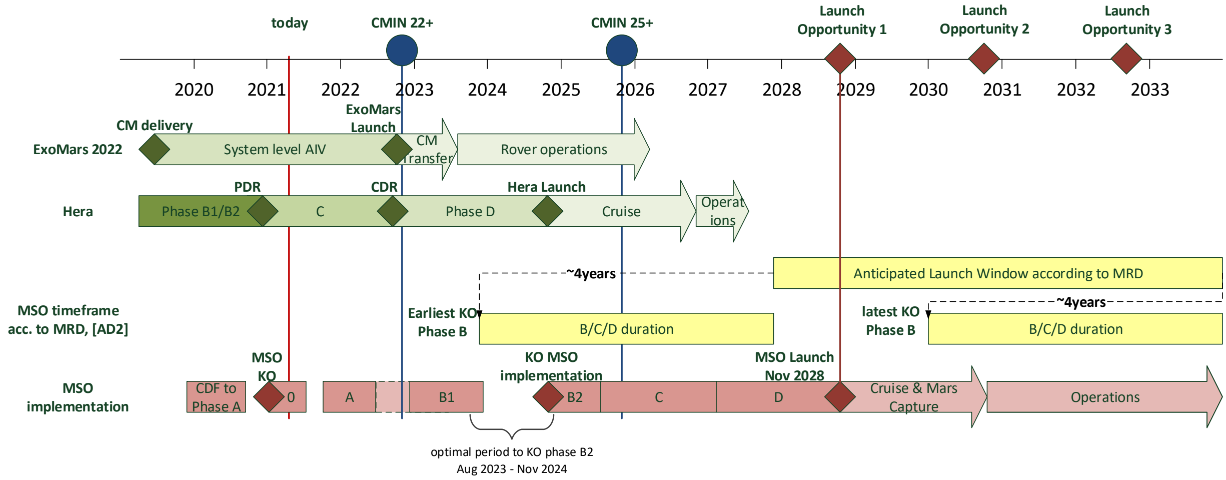

Figure 4–1: S2M2 preliminary schedule