Mars Ice Access
Executive Summary Report

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1 INTRODUCTION

Mars Ice Access Mission is a key robotic precursor mission to future human exploration planning. It is part of ESA's Exploration Programme, named "Terrae Novae", encompassing all ESA's human and robotic activities related to the exploration and utilisation of Earth Orbit, Moon and Mars.

The "Mars Ice Access Mission Study" is a Pre-Phase A level study.

The objective of the study was to propose a preliminary design of a mission aiming to:

- Extract water-ice from Mars sub-surface down to a depth of 3 meters
- Demonstrate the capacity to produce a certain amount of consumables (Oxygen and Methane)

This study has taken place between September 2022 and September 2023.

The study has involved a consortium led by Airbus (in charge of Mission analyses, Carrier Module design and Lander platform design) and including:

- ArianeGroup (Entry Vehicle design),
- Leonardo (Drill Module design and Sample Processing and Distribution Module design)
- Open University (Demo Resource Utilisation Module design).

2 MISSION ANALYSIS OVERVIEW

This section provides a brief overview of the mission analysis work within this study.

The mission campaign is constituted by a baseline launch window of 21 days in 2033 and a back-up launch opportunity in 2035. The spacecraft is launched on Ariane62 EVO-Block2 version with a bi-boost escape strategy that is flexible towards the daily launch programme required (escape C3 and declination) to achieve the direct ballistic transfer to Mars at the earliest seasonal opportunity available to land (i.e. the end of the GDSS at Ls 330), such that the surface operations window is maximised.

The mission timeline is illustrated in Table 2-1 and Figure 2.1 for the baseline launch opportunity of 2033.

Mission phase	Associated dates	Comment
Launch and early operations	20/04/2033	Date corresponding to the opening of the launch window
Near-Earth commissioning	from 20/04/2033 to 27/04/2033	This phase will last typically one week
Transfer to Mars	from 27/04/2033 to 11/02/2034	Transfer type T2. The arrival to Mars corresponds to Ls 330° (end of the GDSS - Global Dust Storm Season)
Entry descent and landing	11/02/2034	This phase will last typically a few hours.
Surface commissioning	from 11/02/2034 to 11/03/2034	The lander commissioning will take 1 month typically (TBD)
Surface operations	from 11/03/2034 to 11/08/2034 and from 27/08/2034 to 30/01/2035	The end date of the surface operations corresponds to Ls 135° (beginning of RDSS - Regional Dust Storm Season). The surface operations will be interrupted during 17 days because of the occurrence of a solar conjunction.
Surface decommissioning	30/01/2035	End of the mission (start of the RDSS)

Table 2-1: Detailed mission timeline

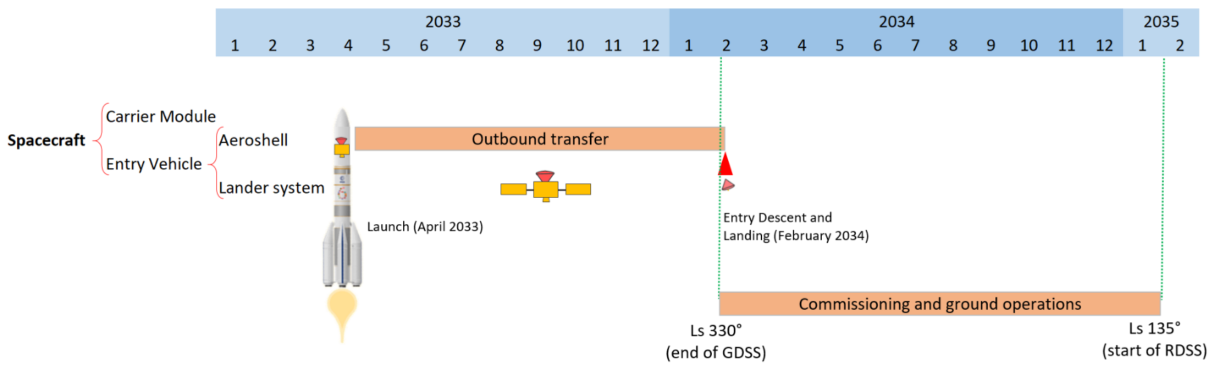

Figure 2.1. Mission timeline (overview)

3 BASELINE DESIGN

This chapter presents the selected baseline concept.

3.1 Carrier Module

Table 3-1 presents an overview of the Carrier Module baseline.

Mars Ice Acces Carrier Module Overview		
Mission	Mars Transfer	Direct Injection, No deep space manoeuvre
	Lifetime	Transfer phase only, then burn up after Entry Vehicle (EV) release
	Spin Up	Carrier-EV composite is spun up using Reaction Control System (RCS) prior to EV release.
Dimensions	L x w x h	1.7 x 1.7 x 1.0 m
Mass	Wet	690 kg (including 30% margin on dry mass)
	Dry	639 kg (including 30% margin)
Structure	Primary Structure	Proposed classical cone + shear walls structure aiming to ensure the launcher frequency constraints.
Propulsion	Thrusters	2 x 8 hydrazine thrusters, 20 N each
	Tanks	2 Hydrazine tanks (58 L) with membrane, 1 Helium tank (6.6L)
Comms	X-Band	Direct To Earth primary communications using 2 LGA (when close to Earth) and 1 MGA (when far from Earth) supports housekeeping TM/TC and Delta-DOR
AOCS	IMU	Inertial Measurement Unit function is provided by the Lander to avoid duplication of equipment
	Optical Sensors	1 Coarse Sun Sensor (internally redundant) Star Tracker: 2 optical heads in hot redundancy and the internally redunded electronic units
	RCS	Used for attitude control. See propulsion above.
Power	Solar Array	2 Small deployable / non rotating Solar Arrays totalling 1.6 m^2, thus providing 208W (when close to Mars).
	Battery	Makes use of Lander Battery and Power Conditioning and Distribution Unit to avoid duplication

Table 3-1: Carrier Module baseline

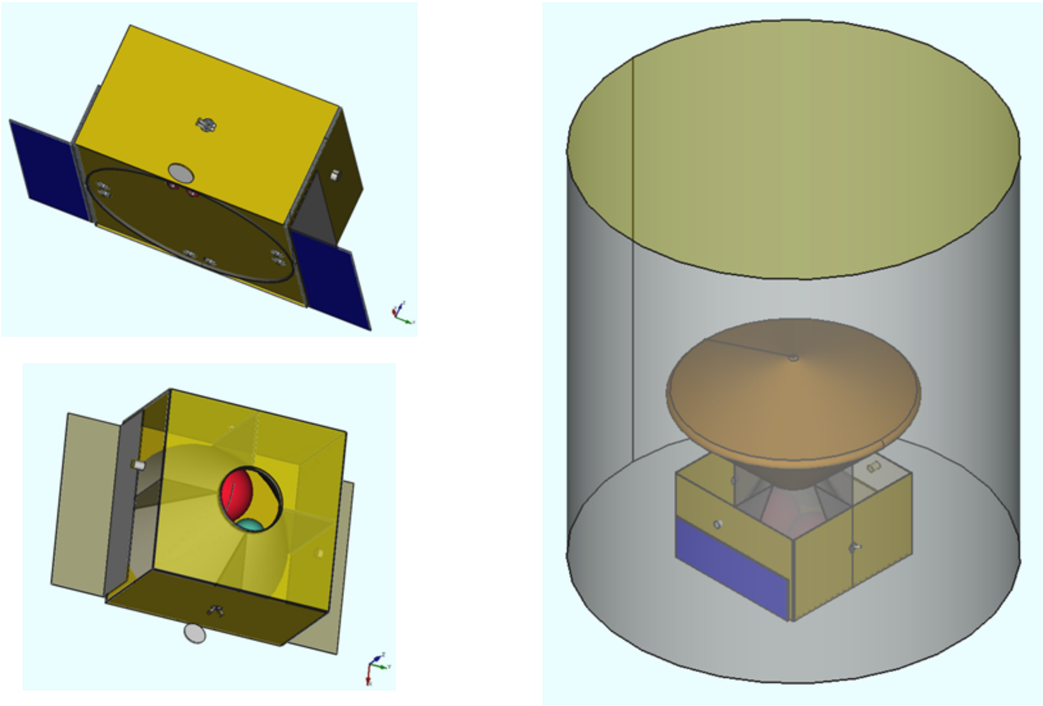

Figure 3-1 Carrier Overview

Left: Carrier Module in standalone

Right: Launch Configuration (Carrier Module and Entry Vehicle)

3.2 Entry Descent and Landing System

Table 3-2 presents an overview of the Entry Vehicle baseline.

Mars Ice Access Entry Vehicle Overview		
Dimensions	Form	Identical to ExoMars 2016
	Size	2.7m in diameter (scaled from ExoMars 2.4m)
Mass	Front Shield	147kg (including 30% system margin)
	Back Shell	275kg (including 30% system margin)
Material	Structure	CFRP (Carbon Fibre Reinforced Polymers) composite honeycomb shell structure
	Thermal Protection	ASTERM®
Structure	Ring Interface	600mm clamp band provides release interface to Carrier
	Back Shell	Back shell carries the weight of the Lander back to the Carrier interface with support from additional CFRP struts
Parachute	Packaging	Oblate cylinder as per MSPC study allowing greater internal volume
	Stage-1	Mortar-deployed first Pilot Chute: 2.4-m Disk-Gap-Band (DGB) – Huygens heritage Mach 2.1 deployment
	Stage-2	Drogue parachute deployed 2 seconds later: 15-m DGB (Huygens design) Decelerates to subsonic
Payload	Back Shell	Upward looking Entry Descent and Landing (EDL) camera captures parachute deployment Back Shell EMon captures temperature and pressure throughout EDL
	Front Shield	Front Shield EMon captures temperature and pressure throughout EDL

Table 3-2: Entry Vehicle baseline

Entry system

In order to accommodate the drill system, the front-shield diameter has been increased with respect to ExoMars 2016: for Mars Ice, the proposed diameter is 2.7 meters. The ballistic coefficient has thus been reduced, which helps enlarging the entry corridor.

Because no Deep Space Manoeuvre is performed by the Carrier during transfer, the ASTERM Thermal Protection material is selected to protect the front shield with low impact on global cost.

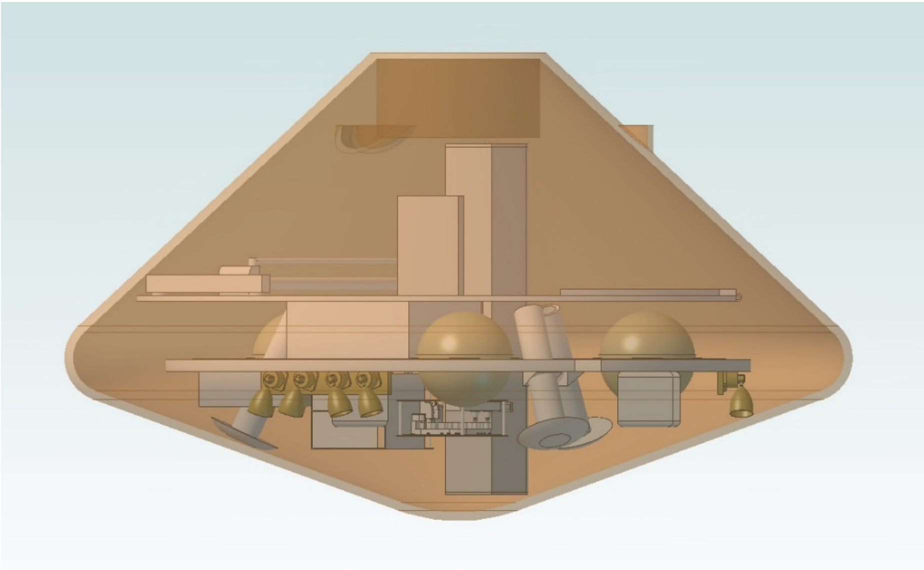

Figure 3-2 Lander Stowed in Aeroshell Side View

Telescopic Landing gear retracted, Pan Cam boom stowed, and Drill in flight position

Descent-parachute system

Re-use of ExoMars 2022 parachute system is proposed based on a 2-stages system including:

- A mortar-deployed 2.4-m DGB pilot chute,
- A 15-m diameter main chute enabling efficient verticalization of the trajectory during descent.

Figure 3-3: Parachute Deployment Sequence

3.3 Lander platform

The following Table 3-3 captures the key elements of the Lander platform.

Mars Ice Access Network Lander Overview		
Mission	Launch	Single Lander Launched with Carrier on one Ariane-64
	Mars Transfer	Direct Injection, No deep space manoeuvre
	Lifetime	Core Mission ~100 Sols up to 300 Sols
Payloads (CFI)	Primary	Ice Drill extracting core samples for analysis & ISRU demo
	Secondary	Met Package, Cameras, Ground Penetrating Radar, Payload of Opportunity
Dimensions	Stowed inside Aeroshell	Approximately 2.2m across x 1.2m tall (Drill casing)
	Deployed	Footprint ~2m diameter, Platform 0.7m above surface, Camera 2.1m above surface, total deployed ~2.2m x 2.8m x 3.1m tall
Mass	Wet Mass	553kg (incl. 30% system margin)
Primary Structure	2.2m diameter CFRP Honeycomb panel incorporating the Warm Electronics Box (WEB), and mounted directly to Landing gear and Propulsion system	
Payload Support	Centrally mounted drill mounts directly to main structure, with SPDM and SAM closely integrated below the main panel adjacent to the WEB	
Propulsion	Thrusters	3 groups of 4 x SCA 400N thrusters
	Tank	3 Monopropellant 18L Tanks with a single common pressurant tank
Lander Comms	Frequency	UHF Prox-1 to any available relays
	Antenna	2x low gain antennas
DHS	IABS	Fully Integrated Avionics Box System (IABS) encapsulating all electrical equipment which is practicable to bring inboard including data handling, mass memory, payload back-end, power management etc
GNC	IMU	1 x Astrix 1090A Inertial Measurement Unit with supplemental accelerometers
	Sun Sensor	CCD Sun Sensor to resolve Lander orientation
Thermal	Gas-gap warm enclosure houses all sensitive equipment	
	Primary electrical heating is supplemented by waste heat recovery from drill unit	
	1x Radiators of 0.15m^2 to dissipate excess heat during the warm case	
	2 x Loop Heat Pipes transfer heat to the radiators	

Mars Ice Access Network Lander Overview		
Power	Solar Array	1 x 3m^2 fixed body mounted array, and one rigid hinged deployable panel 1.5m^2 using Azurspace 3G30 cells with a single-shot dust clearing device.
	Battery	Single Li-Ion module of 1.7kWhr using Saft VL51-ES cells in a 9S configuration

Table 3-3: Lander platform baseline

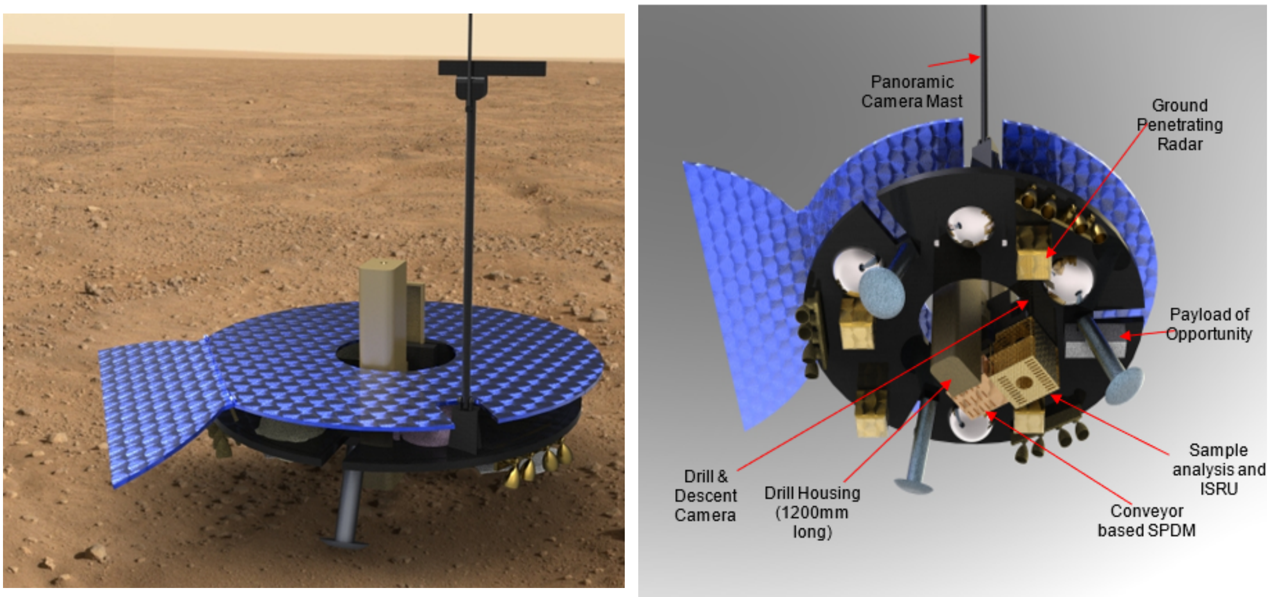

Figure 3-4: Lander Payload Configuration Overview Concept

3.4 Lander payload

3.4.1 Drill Module

The following Table 3-4 captures the key elements of the Drill Module baseline.

Drill Overview		
Architecture	Positioner	Rotation around the vertical axis to allow multiple holes Vertical translation mechanism in order to be compatible with the SPDM and allow delivery of sample
	Drill box	Multi-rod Drill Box based on ExoMars architecture: • 1 drill tip mechanism • 3 extension rods
	Storage	Stored vertically Hold Down Release Mechanism: in order to fix the Drill Box to the lander during launch and EDL
Dimensions	Drill box	1200-mm in vertical direction 190mm wide x 260mm deep
	Extension rods	740-mm-long, longer than ExoMars
	Drill tip	Core length: 30 mm Core diameter: 10 mm
Mass	Total	60 kg (including 20% Design Maturity Margin)

Table 3-4 Drill Baseline

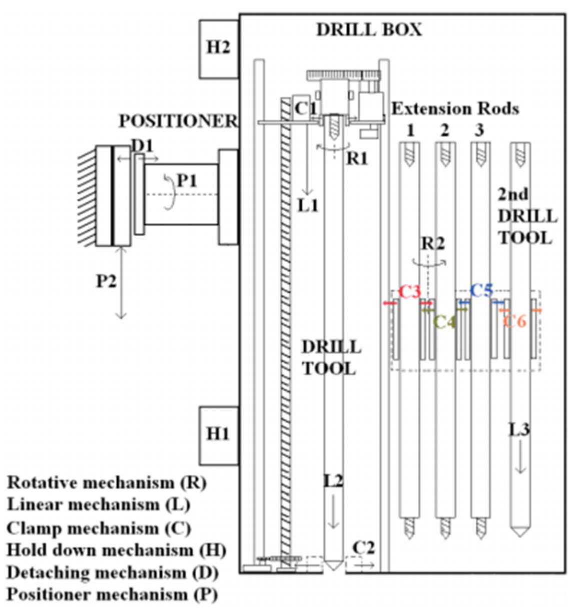

Figure 3.5. Proposed drill mechanism schematics

3.4.2 Sample Processing and Distribution Module (SPDM)

The following Table 3-5 captures the key elements of the SPDM baseline.

SPDM Overview		
Architecture	Sample receiving chamber	Drawer-type mechanism
	Sample processing chamber	Conveyor belt carrying 100 single-use containers equipped with Mutual Impedance Probes, Wet Chemistry Electrodes and heater electrodes
	Liquid reservoir	To store the water extracted from the different samples prior to being processed by the DRUM
	Blank dispensing system	Blank material stored within the SPDM in a gas cylinder
	Sample disposal system	Each individual container used to store sample residuals
Dimensions	Conveyor / SPDM box	275mm x 275 mm x 120 mm high
Mass	Total	13.8 kg (including Design Maturity Margin)

Table 3-5 SPDM Baseline

<u>Sample processing chamber</u>

Figure 3.6 shows the Sample processing chamber of the SPDM with the conveyor belt transporting the containers to the tapping station where they will be sealed prior to water extraction.

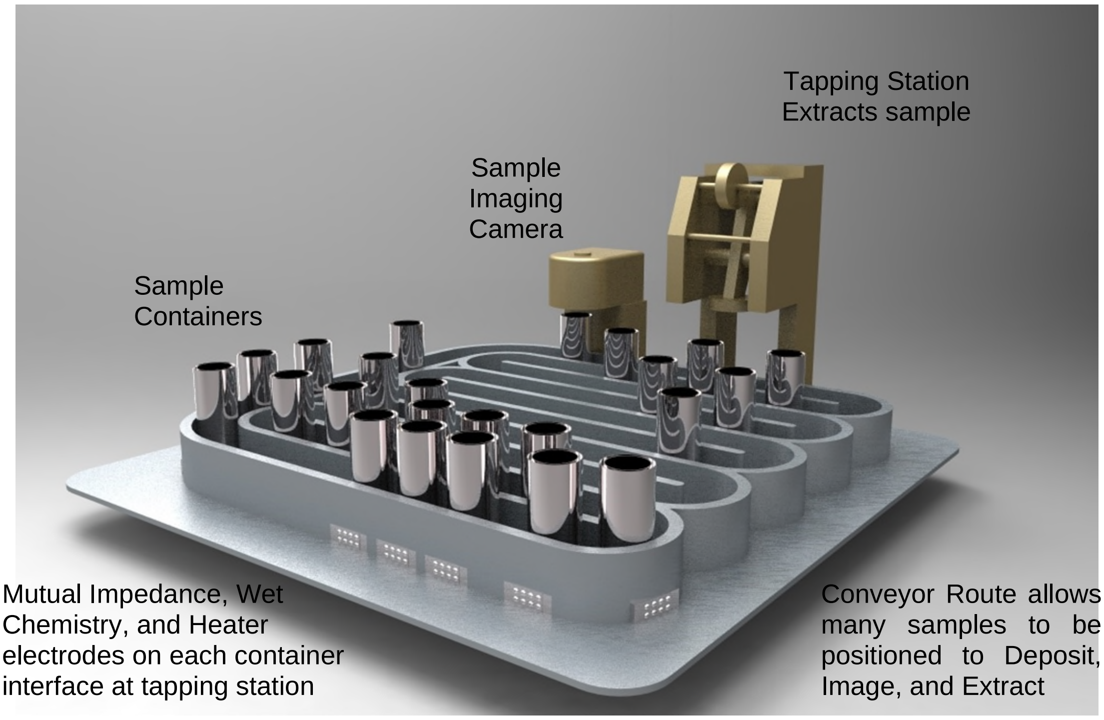

Figure 3.6. SPDM concept CAD – conveyor option (Baseline)

3.4.3 Demo Resource and Utilisation Module (DRUM)

The following Table 3-6 captures the key elements of the DRUM baseline.

DRUM Overview		
Architecture	Compressor	Scroll pump of the same dimensions and power as used for the MOXIE instrument
	Co-electrolysis module	Based on the design from the OxEon development activities following the SOXE cells used on Perseverance (5-cell stack baselined)
	Cooler	Cooling loop with appropriately-sized radiators to reduce the temperature of the syngas
	Methanation module	Based on a miniaturised version of the OxEon reactor prototype
Dimensions	Co-Electrolysis Cell & Mass Spectrometer	300x300x200 mm (below deck)
	Methanisation Reactor & Support Equipment	300x300x200 mm (above deck)
Mass	Total	21.8 kg (including Design Maturity Margin)

Table 3-6 DRUM Baseline

Figure 3.7 illustrates the In-Situ Resource Utilisation (ISRU) processes within the DRUM.

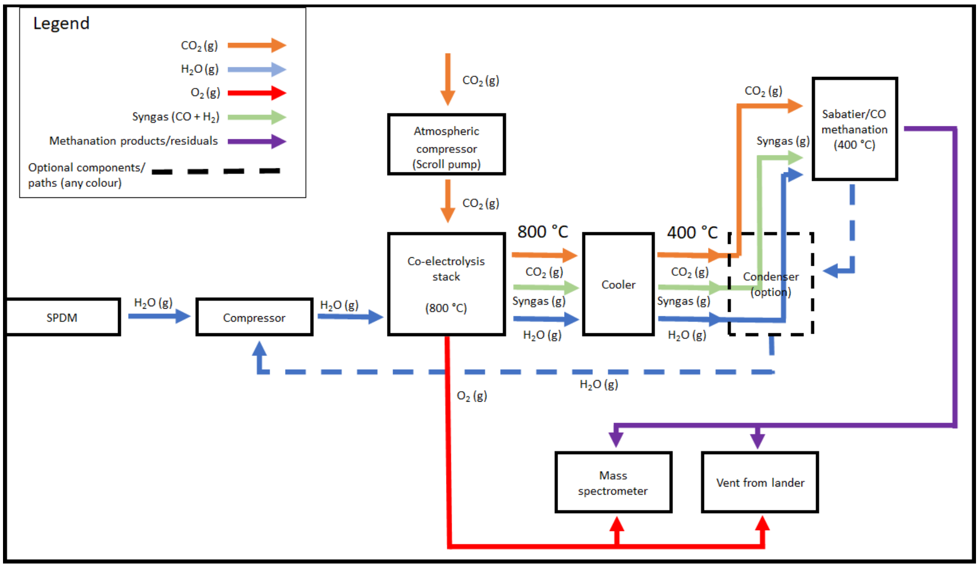

Figure 3.7. Baseline ISRU processes within the DRUM

4 CONCLUSION

Mars Ice Access is an ambitious programme. The pre-phase-A study has been a means to identify the critical elements of the mission.

A preliminary design of the space elements has been proposed but parallel to this, the pre-phase-A study has been a means to identify the critical elements of the mission and the robustness of the proposed baseline to potential evolutions of the different components (e.g. mass growth).

This study has outlined the conflicting situation between mission and science objectives (drilling depth, number of extracted samples, number and performance of production cycles) in a highly-constrained environment (risk of water-ice sublimation, high ice-fraction) on one hand and a design-to-cost approach on the other hand.

In further phases of the study it will certainly be necessary to develop some technical topics that have been overlooked so far but it will also be mandatory to review the mission objectives (and the associated requirements) if the mission cost is considered a driver.

DOCUMENT CHANGE DETAILS

ISSUE	CHANGE AUTHORITY	CLASS	RELEVANT INFORMATION/INSTRUCTIONS
1.0	-	-	Issue for MDR close-out: