The OWL Mission
Origin of **W**ater and **L**ife

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Abstract

Returning a sample from a small solar body will provide answers to many remaining questions about our Solar System and pose new technological challenges. This proposal represents a space mission that will visit and collect a sample from the Jupiter family comet 45P/Honda-Mrkos-Pajdušáková. The OWL mission (**O**rigin of **W**ater and **L**ife) aims to carry out a detailed study of the comet's composition and overall properties in order to determine the role of comets in the delivery of water and organic compounds to Earth.

1 Introduction

Space missions and ground based observations have helped us to achieve profound knowledge about the physical processes that shaped our universe. Still, we are seeking the answers to some of the most important scientific questions about the formation and evolution of our Solar System and its planets, as well as the existence of life on Earth. Answering these questions is therefore a main driver in the calls for missions of international space agencies.

Small Solar System bodies are assumed to be remnants of the early Solar System and carry the imprints of the primordial gas and dust disk. Asteroids and Comets do not only resemble the building blocks of planetesimals and consequently planets, but also shaped the evolution of the Earth by delivering water and minerals and maybe even the seeds of life to the early Earth. Subsequently they also caused occasional extinction events by impacts. Comets originate from the outer Solar System, where temperatures have stayed low enough, to preserve even the most volatile ingredients of the protostellar nebula. Detailed analysis of the comet's chemical composition can reveal important information about dynamical processes that shaped the early Solar System. For example, the Deuterium to Hydrogen (D/H) ratio found the different Solarsystem bodys is strongly linked to their distance to the sun at the time of their formation. While the more volatile, Hydrogen atom was removed easier in the warmer, e.g. closer to the sun, parts of the solar system. The D/H ratio is therefore supposed to be higher in bodies that formed closer to the sun. However, the D/H ratio in Oort Cloud object do not well fit into this picture. This leads to the assumption, that these objects must have migrated towards the outer Solar System after their formation. D/H ratio measurements of Jupiter-Family comets deliver diverse results, and demand for further and more detailed studies of the isotopical composition of these objects. Further, it has been shown (i.e.[3]) that comets, in particular, have a high diversity of organic compounds. However, the precise nature and origin of this organic compounds still need to be determined. This can only be achieved by heavy and advanced analysis devices, inconsistent with the S/C limitations, not only regarding mass and power. In order to precisely study the origin and nature of the comet's ingredients, a sample return mission is mandatory to perform comprehensive analysis on Earth. In situ measurements on the surface add important context information to measurements on Earth and ensure the evaluation of potential corruption of the samples during the travel back.

1.1 45P: a Jupiter family comet

The target body of the OWL mission was chosen as a trade-off between mission feasibility (inclination, orbital period) and scientific interest. As a Jupiter-family comet (JFC) 45P/Honda-Mrkos-Pajdušáková is thought to originate in the Kuiper Belt and was captured by gravitational influence of Jupiter. Short orbital period (<20 years), low inclination and high eccentricity characterize this comet family [12]. With a radius of 0.8 km, assuming a density of 0.5 g cm^{-3} and a spherical shape, we estimate the mass to be on the order of 10^{12} kg.

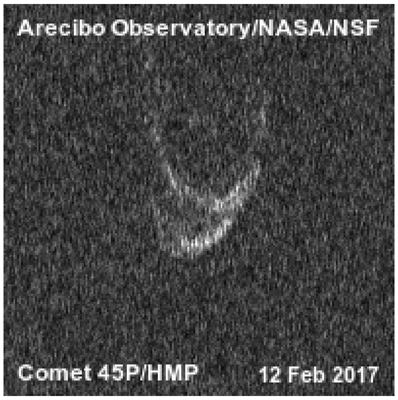

Figure 1: Delay-Doppler image of Comet 45P/HMP [1].

1.1.1 Previous Earth-based observations of 45P

45P was extensively observed by the Hubble Space Telescope with UBVRI photometry during a close encounter with the Earth in 1996 [8]. The data revealed an active area of 11% for the comet alongside a dust production rate of 1 kg/s. In February of 2017, The Arecibo radio observatory performed radar observations of 45P [1], revealing a fascinating shape with two apparent lobes (Fig. 1). These observations were also found a rotational period of 7.6 hours for 45P and the evidence for large grainsizes >2 cm in the coma [14].

Around the same time the Green Bank Telescope studied 45P with radio observations, revealing an estimated water mass loss rate of 2×10^{28} molecules per second, which translates to 600 kgs^{-1}, at an outflow velocity of 0.7-0.8 km/s [11].
Di Santi and et al. studied the composition of the comet with IR spectroscopy also in January of 2017, revealing strong CO and HCN depletion and an enriched CH3OH abundance whereas other species were largely consistent with previous values. This allows us to hypothesize a formation distance of approximately 20 AU based on the work of Brown and et al. [4].
Herschel observations revealed an upper limit of the D/H ratio consistent with that of the Earth [10], leading to the possibility that water may have been brought to Earth in primordial times by similar objects.

2 Science Interest

2.1 Science Questions

The mission aims to answer the following four science questions:

Q1: Could comets have delivered the building blocks for life to Earth?

Q2: Which specific comet populations could have been contributors to the delivery of water to Earth and to which extent?

Q3: What are the overall properties of the target body, a member of Jupiter type comet?

Q4: What can the comet's composition reveal about its origin and evolution in the early Solar System?

2.2 Science Objectives

SO1: The OWL mission shall characterize the organic material found on the surface and inside the comet. In order to do so, the inventory and abundances of organics and minerals shall be investigated. The spatial distribution of the organics and minerals on the comet and the correlation between them shall be determined. The origin and reactivity of the organic material shall be studied in order to explain the emergence of life on Earth. These objectives relates to the science questions Q1 and Q4.

SO2: The origin of water shall be examined by characterizing its isotopic composition and abundance. This shall help to answer Q2.

SO3: The comet's overall properties shall be investigated by determining its shape, rotation period and gravity field. Q3 shall be answered by these objectives.

The science objectives are summarized in Table 1.

2.3 Science Requirements

- Characterize the nature of organic molecules by measuring their IR absorption features from 2 - 20 μm

SO1: Comets as seeds of life	SO1.1: Comet composition	SO1.1.1: Organics	SO1.1.2.1: Inventory
			SO1.1.2.2: Abundances
		SO1.1.2: Minerals	SO1.1.1.1: Inventory
			SO1.1.1.2: Abundances
	SO1.2: Origin of organics	SO1.2.1: Spatial distribution on surface	
		SO1.2.2: Correlation with other materials	
		SO1.2.3: Reactivity	
	SO1.3: Life emergence	SO1.3.1: Biological reactivity	
SO2: Origin of water	SO2.1: Water abundance		
	SO2.2: Isotopic composition		
SO3: Comet properties	SO3.1: Shape		
	SO3.2: Rotation		
	SO3.3: Gravity field		

Table 1: Science objectives

- Characterize the nature of minerals by measuring their absorption features from 0.4 - 50 μm
- Study the surface of the comet with IR spectral imagery in the range of 1 - 3.6μm, high resolution imagery with a resolution of 0.1 mrad and IR microscopy in the range of 1 - 3.6μm, with a resolution of 20 μm
- Study the abundance of water on the comet by using mass spectrometry in the range of 18-22 amu
- Study the isotopic composition of water by IR spectrometry focusing on the absorption features at 1.4 μm (hydration) and 2.6μm (O-H)
- Study the shape and the rotational period by using high resolution imagery with a resolution of 0.1 mrad
- Study the gravity field of the comet in order to achieve Stokes' coefficients up to and including order and degree 2 [9]

2.4 Sample Requirements

Three sample containers shall be returned to the Earth. In total a mass of 150 g of the samples shall be obtained. For Earth based experiments a minimum of 18 g is needed. Including a margin of 100 % and a margin for destructive experiments, 72 g shall be probed. Additional 72 g will be stored for later use and 6 g will be distributed to possible cooperations.

3 Instrument Requirements and Payload

In the following the payload shall be described in more detail. Though, it is likely that the technology of the instruments will improve in the future we refer to heritage from already existing instruments. An overview of the payload is displayed in Table 3.

3.1 IR-hyperspectral imager

The infrared spectrometer onboard the main spacecraft shall determine the distribution of the organics and minerals on the surface of the nucleus and the correlation between them. In association with the High resolution camera it shall perform an overall mapping of the comet in order to gain the general physical properties of 45P and be able to select a suitable sampling and landing site. The suggested instrument could be a version of the NIRS4 / MacrOmega imaging spectrometer which is in development for the planned mission MMX (Martian Moons eXploration). It operates in a spectral range of 0.9 - 3.6 μm with a resolution of 2 nm at 1 μm - 25 nm at 3.6 μm [6] . The principle of the instrument is based on the MicrOmega spectrometer and has been modified as a hyper-spectral imager with spectroscopic function provided by an Acousto-optic tunable filter (AOTF).

Instrument	Instrument Requirement	Mass (kg)	Power (W)
IR-hyperspectral spectro-imager	Spatial res = 1 mrad Spectral range = 1 – 3.6 μm Spectral res = 2 nm at 1μm - 25 nm at 3.6 μm	6	20
IR-hyperspectral microscope	Spatial res = 20x20 μm^2 Spectral range = 0.99 – 3.65 μm Spectral res = 2 nm at 1μm - 25 nm at 3.6 μm	2	2 $\pm$ 0.5
High-resolution camera	Spatial res = 0.1 mrad (wide) Spatial res = 0.02 mrad (narrow) Spectral range = visible	20	50
Mass spectrometer	Mass range 2 - 535 amu Mass res $>10^{-2}$	15	30
Sampling mechanism	100 mm surface penetration, pre-cooled to <120 K quick enough to keep the sample frozen		
Sample chamber	Maintain temperature <120 K (cruise) and <140 K (brief peak during re-entry)		

Table 2: Instrument Requirements

3.2 IR-hyperspectral microscope

The infrared spectrometer onboard the OWLY lander will be used for the general determination of the nature of the solids on the nucleus surface. In particular it shall provide a detailed analysis of minerals inventory, abundances and the composition and structure of ices and dust. Furthermore, it shall characterize the organic compounds more precisely. As a suitable instrument, the MicrOmega near-IR hyperspectral microscope which is implemented within the MASCOT lander on Hayabusa 2. It is designed to observe in situ the texture and composition of surface material in a spectral range of 0.99 - 3.65 μm with a resolution of 2 nm at 1 μm - 25 nm at 3.6 μm [2].

3.3 High-resolution camera

The high-resolution camera shall perform an optical high resolution coverage of the nucleus and provide geologic context at a scale of 1 m. It shall characterize the size, shape and density of the comet and determine the its rotational properties. Besides, it shall monitor the nucleus activity and evolution and find a suitable sampling and landing site. Additionally, it is also is utilized for navigation purposes. The proposed instrument could be a simplified version of OSIRIS, the scientific camera system onboard the Rosetta spacecraft. OSIRIS operates with a resolution of 0.1 mrad for the wide angle camera and of 0.02 for the narrow angle camera [7].

3.4 Mass spectrometer

The mass spectrometer onboard the orbiter shall determine the elemental composition of the cometary sample particles and the isotopic composition of key elements such as H, C, Mg, Ca, Ti. Especially the most volatile or reactive compounds shall be measured to provide a starting condition of the sample as it is almost impossible to bring an undisturbed sample back to earth. Furthermore, it shall record changes in the chemical and isotopic composition that occur as functions of time and orbital position of the comet. Besides, it shall differentiate H2O, DHO, D2O and the mass enlargement due to oxygen isotopes in the outgassing of the target. The proposed instrument is the mass spectrometer implemented in SAM, the Sample Analysis at Mars onboard the Curiosity rover as part of the Mars Science Laboratory. It covers a range of 2 - 535 amu with a sensitivity of $> 10^{-2}$ cnts/sec [13].

4 Spacecraft Design

4.1 Structure

Structural architecture of the spacecraft is driven by accommodation of propellant tanks required to reach the target by electric propulsion. Central cylinder core is attached directly on the launcher interface ring ensuring exceptional longitudinal stiffness of the spacecraft. Four titanium propellant tanks with xenon for the ion thrusters are attached inside the central cylinder via full CFRP (carbon fiber reinforced polymer) rods. Argon tanks with gas supply for pressurization system and cooling system and hydrazine tanks for AOCS thrusters are located on the outer side of the central cylinder. Scientific and navigation instruments are attached on the walls inside the spacecraft. Earth return capsule is located axially with ion thrusters on the -Z side of the spacecraft. Manipulator arm and lander are located outside the spacecraft on +X wall. All walls of the structure are considered of sandwich panels (CFRP skins + aluminum honeycomb core) that has long spaceflight heritage and contribute to radiation shielding of the sensitive equipment.

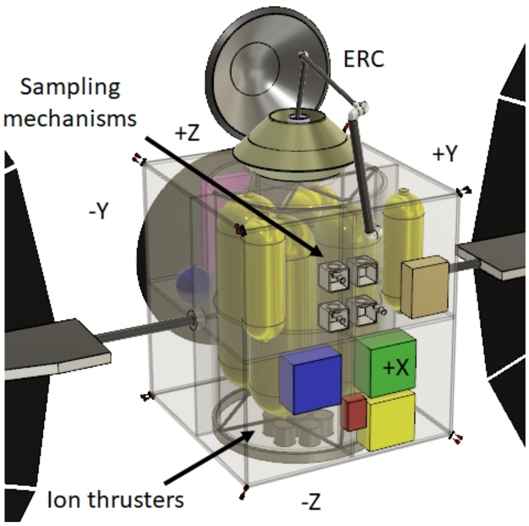

Figure 2: Spacecraft bus design

4.2 Mechanisms

There are four independent identical sampling mechanisms onboard of the main spacecraft. Nominal sampling strategy is retrieval of 3 samples + one sample for on-board investigation. In case of anomalies, there is enough redundancy in the sampling system. Sampling mechanism consists of a spring, trigger mechanism, coil mechanism, C-shaped spring tape and finally the sampling canister with shutter mechanism. Canister is accelerated by the spring to such energy that penetrates the fragile surface. When fully loaded by cometary matter, shutter mechanism is mechanically triggered and sample is secured in the canister. Electrically driven coil mechanism is then activated and canister is slowly winded back. During this operation, sampling canister shall be thermally decoupled and kept in shadow to keep the sample at original sampling temperature. When back at the spacecraft, the manipulator arm detaches the canister and transfer the canister into the ERC or on-board analyzer.

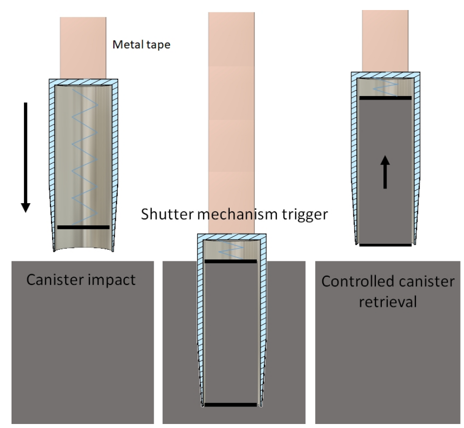

Figure 3: Sampling mechanism

4.3 Biocontainer and cryocooling system

Due to the risk of losing a part of the scientific value, it is necessary to develop a reliable Biocontainer located in the Earth Return Capsule to maintain temperatures below 120K for preserving the collected samples. Cryocooling is very energy-consuming, that is why equipping a spacecraft with such a system is a big challenge. Authors of the report have developed a cooling concept that can fulfill the set requirements in the future. The solution is based on the design of the Biocontainer-cryostat in a such way, to have the best possible thermal insulation and then cover the heat loads using passive cooling radiators with a thermal switch. To not limit maneuvering capabilities of the spacecraft it is planned to shift between radiators placed on different sides of the ship, according to the orientation towards the sun. In addition, it is proposed to support passive cooling with an active system based on 2 nitrogen stiriling cryocoolers (80K, 1.5W of total cooling power, 120W peak power supply), which cools down the volume of the Phase Change Material Chamber. Concept scheme is given in Figure 4. To

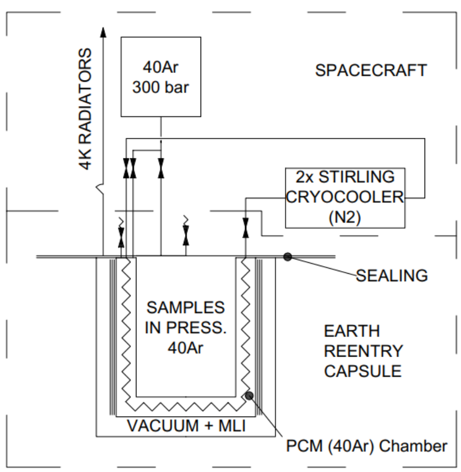

Figure 4: Scheme of the cryocooling system

prevent the samples from melting during the collection it was decided to hold mechanisms inside the S/C structure insulated with MLI to keep them cool. In addition, the collected samples will be slightly greater in mass than required, to account for some potential sublimation to whilst still meeting the scientific requirements. After the sample is placed in the BC,the BC will be pressurized with 40 Ar to increase the melting point of the material and protect against contamination in case of unsealing. During the flight the inner tank space is filled with PCM (40Ar) which condenses as the tank is filled.This will ensure proper thermal conditions and act as a heat accumulator during the return flight. Prior to the Re-entry procedure, the stored PCM will be solidified by the cryocooler, afterwards the valves between the Earth Reentry Capsule and the S/C need to be closed. Calculations shows that, heat accumulated in 0,5kg of PCM during melting, evaporating and heating up to 115K, should secure preserved samples against 5W heat loads for over an hour which covers time necessary for re-entry and seizing the capsule by mid-air collection.

4.4 Thermal Control

The outer body of the main space craft is coated with Kapton 20 layer MLI from Dupont, as was used on Rosetta. Radiators will also be required to keep the scientific equipment and other on board electronics at operational temperatures. The expected power for the thermal control system based on similar missions is critical item will be equipped with electrical heater.

4.5 Propulsion System

The main thruster proposed for the orbit transfer is the T6 xenon based ion engine developed by Quinetic. In order to complete the transfer orbit in the specified timeline, a thrust of 1N is necessary. For that, knowing that each thruster can provide 0.15 N of thrust and 4300 s of specific impulse for a power of 4.5 kW, 8 thrusters will be used for the mission (seven operational and one for redundancy). One Power Processing Unit (PPU) will be used for two thrusters. In addition it has been considered a high pressure regulatory system and a harness system. The propellant will be stored in a cluster of four Cobham tanks of approximately 0.75 m^3 each. To keep a constant pressure of 20 bar in the propellant tanks, they have been connected to a system of two argon tanks with a total volume of 0.27 m^3. The total weight budget of the subsystem has been estimated as 403 kg.

4.6 Attitude and Orbit Control System

The spacecraft shall be 3-axis stabilized in order to ensure a correct pointing during the duration of the mission. The suite of sensors is composed by three Autonomous Star Trackers AA-STR by Leonardo, and three FS Sun Sensors by MOOG, combined with an Inertial Measurement Unit ATA IMU by Aptec. Each Star Tracker a Field of View 20x20 degrees. The Sun Sensor has a Field of View of 128x128 degrees with an accuracy of 0.3 degrees. The IMU has a Bias Stability of 0.01 deg/h. Close operations will be performed with a combination, as Optical Navigation Camera system, of the star trackers as wide Field of View cameras and the high resolution camera included into the science payload. To determine the distance to the surface, a Laser Altimeter will be included. The actuators needed for monitor the attitude during the mission conform a cluster of four reaction wheels RW8 by Blue Canyon, a cluster of 12 Aerojet MR 103M hydrazine thrusters of 1N with 221s of specific impulse, and an AOCS Control Unit by MOOG. The hydrazine monopropellant has been chosen due to the technology readiness level of the technology and the relation thrust/specific impulse. The reaction wheels have a tetrahedral configuration, and provide a maximum torque of 0.11 Nm with an approx. angular momentum of 8 Nms. The propellant for the hydrazine tanks will be stored on four Cobham tanks of 0.113 m^3 each.

4.7 Reentry Capsule

The reentry capsule design is scaled based on Hayabusa to get a similar ballistic coefficient and therefore similar flight path. The larger design is required to house the biocontainer and cryocooling system necessary to keep the sample cool. The capsule also contains drag chutes to decelerate the capsule further during reentry. A radio antenna will be located either inside or on top of the capsule for accurate location to ensure the mid air retrieval can be carried out as quickly as possible. There is a 64 mm thick TPS layer of PICA X, selected to withstand the peak heat flux of 1400 W/cm^2.
The reentry capsule will enter the atmosphere at 13 km/s with a flight path angle of -10^circ and will experience a max deceleration of 64g. Whilst this is higher than previous missions (Stardust: 50 g), it is similar to ongoing and future missions (Marco Polo, Marco Polo 2: 60-70g).

4.8 Power

The main constraints of the mission are the high power demanded by the Electric Thrusters during the journey to the comet, and the low-intensity low-temperature (LILT) condition at comet arrival. Triple junction 3G28 solar cells, currently under LILT qualification for the ESA Juice mission, will provide. The solar generator structure relies on the Flex technology, developed by Northrop Grumman Corporation. With a total area of 120 m^2 and a power/weight ratio of 150 W/Kg at AM0, it fullfils the power requirement during the cruise phase.

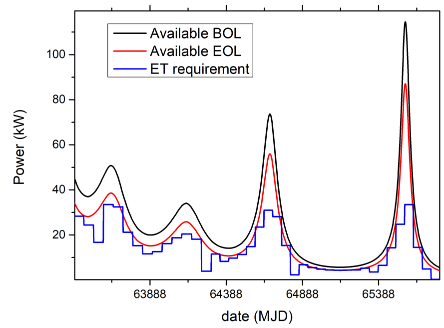

Figure 5: Power available as function of the time, for the BOL (black) and EOL (red) case. The power required by the space is plotted in blue.

At 4.8 AU, assuming a sun angle offset of 20° and power conversion efficiency of 90%, about 1 kW of power would be available for the spacecraft operation. The batteries are sized in order to guarantee at least 2 days of operation in the "Safe Mode" condition, where only TT&C, AOCS and OBC are operating.

4.9 Telemetry and Telecommunications

A Deep Space Transponder will provide a fully redundant dual X/S band telecommunication link. A 2.2 m diameter High-Gain antenna (HGA) will provide scientific data transmission in X-band, at a rate up to 100 Kbit/s below 4.5 AU distance from Earth. A Medium-Gain antenna (MGA) will be used during the commissioning phase and for emergency, providing telemetry data transmission up to 8 Kbit/s. Two Low-Gain antenna (LGA) will be used for S-band data link with the lander.

4.10 Onboard Computer and Data Handling

The Onboard Computer is based on the LEON 32-bit RISC microprocessor. The SSMM memory is sized according to the data stored during the scientific study. For a complete mapping of the surface with a resolution of about 20 cm to be made, a total amount of 1.5 GB is required. In the worst case, the system has to be able to acquire and store all the data if no proper communication link with Earth can be established. Therefore, taking in count redundancy and reasonable margin, a total data storage of 3 GB is recommended.

4.11 OWLY Lander

The OWLY Lander is planned as a small MASCOT-type lander of 10kg with a IR-hyperspectral Microscope. This will include a LGA to communicate with the spacecraft and its primary power will be from a battery.

5 Mass and Power Budgeting

Table 3 shows the mass budget produced for the space system, including the spacecraft bus, lander and payload.

Category	Mass, kg
Payload (excluding lander payload)	70
Spacecraft Bus	1715
OWLY Lander	10
System Dry Mass	1795
System Dry Mass (+20 % margin)	2154
Propellant Mass (+12 % margin)	2860
Wet Mass	5014

Table 3: Mass Budget

6 Mission Design

6.1 Earth-based observation campaign

There are several ways Earth-based observations can be of assistance to the OWL mission. As previously mentioned, Arecibo already has performed radar observations of 45P, from which we can directly construct an initial shape model which will assist in e.g. planning the spacecraft's initial orbit around the target before we gain a more accurate shape model from OWL itself. As OWL lacks spectrometers in the visible and mid-IR ranges, we propose performing Earth-based spectrometry of both the nucleus and the coma while the spacecraft is in orbit of the target to gain a more complete picture of the object.

To assist in characterizing 45P's activity, we plan for photometric images in both visual and infrared wavelengths, particularly before OWL's arrival. For ground-based telescopes we believe it is too early to make more elaborate plans such as telescope selection to keep our options open so that we may take the possibility of new, interesting telescopes or updates/new instruments to existing telescopes into account.

6.2 The orbital phase

The orbital trajectory is divided in three main phases: the outbound trajectory, the operational phase and the inbound trajectory. All the maneuvers are performed with low thrust engines with $I_{sp} = 4300\,s$ and a maximal thrust of $1\,N$. The totality of the trajectory is shown in Figure 6.2. The outbound trajectory in highlighted in green, the operational phase is depicted in red and the inbound trajectory is displayed in orange, magenta and blue. This last phase has been divided in three different parts: the first maneuver - close to the aphelion - to intersect Earth orbit, a cruise part with no maneuver and a last part - close to the perihelion - to reduce the reentry speed and fulfill the requirement of $v \leq 14\frac{km}{s}$. The most important dates are shown in Table 6.2.

Time of departure from Earth	6 Jun 2032 09:22:28 UTCG
Time of Mars gravity assist	23 Nov 2034 09:22:32 UTCG
Time of arrival at the comet	1 Jan 2039 09:22:22 UTCG
Time of departure from the comet	17 Oct 2041 09:22:22 UTCG
End of first maneuver	17 Oct 2041 09:22:22 UTCG
Time of beginning of braking maneuver	18 Nov 2043 09:35:24 UTCG
Time of arrival at Earth	12 Feb 2044 13:55:21 UTCG

Table 4: Dates of the interplanetary trajectory

7 Programmatic Analysis

7.1 Technology Development

A summary of the critical technologies identified for the OWL mission is shown in Table X. 6.

7.2 Cost

The total cost of the OWL mission has been estimated at €1.4 Billion, based upon system dry-mass, degree of

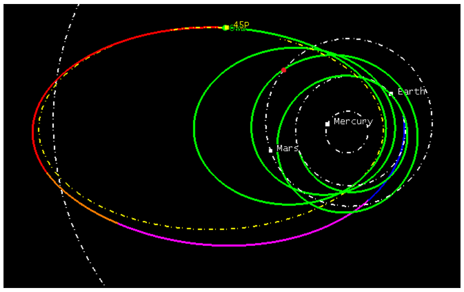

Figure 6: The complete interplanetary trajectory projected on the ecliptic plane. In details: in green the outbound trajectory with a Mars gravity assist at the red dot, in red the operational phase around the comet, in orange the departing maneuver, in purple the inbound cruise and in blue the braking maneuver.

Techology	TRL
Sampling Mechansim	2
Earth Return Capsule	3
Flexible Solar Array	3/4
Bio-Container	3/4
Manipulator	3/4
Phase Change Material	4
Rendezvous Material - Mid Air Retrieval	5

Table 5: Techology Readiness Levels

innovation/heritage and system complexity. This fits within ESA L-Class Cosmic Vision. A breakdown of cost is shown in Table. 6.

Component	Cost (€Million)
Main Spacecraft	1077
Lander	4
Re-entry/Sample Cannister Module	20
Operations	192
Launcher	90
Member States	41
Total Cost	1424

Table 6: Cost Budget of OWL Mission

7.3 Schedule

The total mission lifecycle is estimated to last 21 years. This includes a period of 2-3 years for Phase 0-A-B1, 5-6 years for Phase B1-C-D, 12 years for Phase E and 6 months for Phase F. Prior to launch (June 2032), ground based observations of the comet to determine an assessment of dyanmics such as spin axis or rotational period, and the abundance of volatile species in its coma, will be performed.

7.4 Risk Analysis

A total of 5 risks have been identified for mitigation. These related to delays in launch, development of critical technologies (TRL ≤ 4) and failure of mission critical elements. The likelihood for loss of the Earth Return Capsule is low with an extensive development programme, however the impact is mission failure. Minor risks such as a delay in sampling mechanism development may be addressed by an accelerated development program prior to Phase A/B1. A long-term delay in launch is considered mission critical due to the potential change in the orbit of 45P, as a result it is suggested that a backup target be selected.

7.5 Planetary Protection

According to the COSPAR PLANETARY PROTECTION POLICY any Earth return mission is considered as a "Category V" mission. Furthermore, this mission has been identified as an "restricted Earth return". This implies that the highest degree of concern is expressed and that a destructive impact must be inhibited. High requirements for the prohibition of contamination need to be addressed.

8 Conclusions

OWL concept is a sample return mission from a Jupiter-family comet, aiming to provide insight in fundamental scientific questions:

- the origin of life and water on Earth and the importance of comets in this aspect,
- the cometary evolution,

- the evolution of the Solar System

Complementing the main objective, in-situ experiments and orbital analysis of 45P/HMP enhance our probability for successfully addressing these questions. The selection of instruments that will be used to collect these data, was made prioritizing technical feasibility and efficiency. Adding to the heritage of previous missions, OWL will extend the limits of our knowledge and enable us to explore cometary science in great detail.

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