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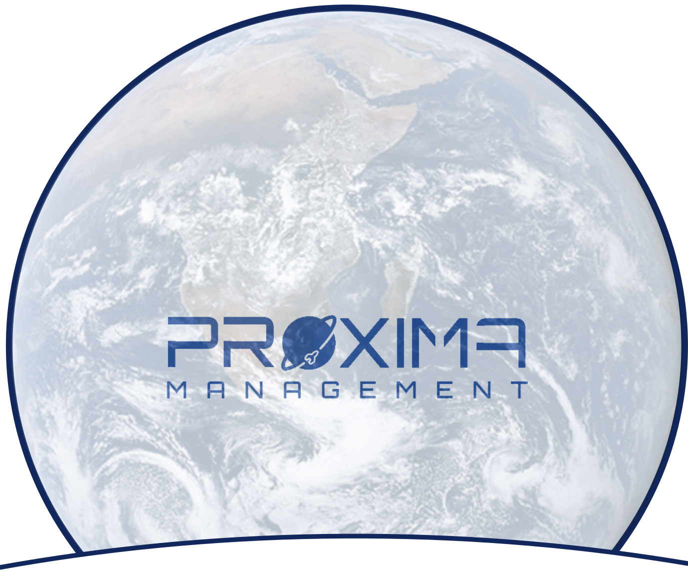

Technical Management Report
Thetys Space Mission

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Chapter 1

1. Main objective and scope

This document constitutes the Technical and Managerial Annex (TMA) to the Contract between the Italian Space Agency (ASI) and the University of Naples Federico II (Contractor) for the "**THETYS**" project.
The requirements specified in this document must be made applicable to the entire industrial structure involved in the execution of the activities.

1.1 Introduction

The **2030 Agenda for Sustainable Development**, adopted by all United Nations Member States in 2015, establishes a comprehensive framework for peace, prosperity, and environmental sustainability. Central to this agenda are 17 Sustainable Development Goals (SDGs), which aim to address a wide range of global challenges, including poverty, inequality, and environmental degradation. Among these, **Goal 7** stands as a pivotal objective: to ensure access to affordable, reliable, sustainable, and modern energy for all.
This goal emphasizes the urgent need to transition towards renewable energy sources, improve energy efficiency, and reduce the environmental impact of energy production and consumption.
In this context, the Thetys is an innovative space initiative designed to contribute to the achievement of Goal 7 by utilizing space-based technologies to produce clean, renewable energy. The mission aims to demonstrate how space exploration can serve as a catalyst for advancing clean energy solutions on Earth, while also ensuring sustainable energy for future space missions.

1.2 Thetys Mission Overview

The Thetys Mission is a **CubeSat** mission that seeks to explore the potential for electrolysis in space as a means of producing clean energy. Electrolysis is a well-established process on Earth, where water is split into hydrogen and oxygen using an electrical current. In space, this process could provide a sustainable solution for generating energy, with the hydrogen produced potentially serving as a propellant for spacecraft, and the oxygen being used to support life on long-duration missions. Currently, the Thetys Mission operates as a CubeSat, with the primary objective of demonstrating that electrolysis in space can be just as efficient as it is on Earth, provided that the process occurs at the correct speeds and is subjected to the appropriate centrifugal forces. By conducting this experiment in the unique microgravity environment of space, the mission aims to validate the feasibility of performing electrolysis with the same efficiency as on Earth, and to gather essential data for future space missions.

1.3 Thetys Mission's Contribution to Goal 7

The Thetys Mission represents a direct contribution to the achievement of Goal 7 of the 2030 Agenda by applying cutting-edge technologies to produce clean energy in space.
The hydrogen generated through the electrolysis process can potentially serve as a green fuel for space missions, while the oxygen produced can be used as a life-support resource for astronauts.
This not only supports the sustainability of space missions but also contributes to the growing need for clean, renewable energy solutions.
The data gathered from the Thetys CubeSat mission will provide valuable insights into the efficiency of space-based electrolysis, with implications for both space exploration and terrestrial energy production. If the process proves to be as efficient as its Earth-based counterpart, the results could lead to new possibilities for hydrogen production in space, which may be used as a clean fuel source for deep-space missions. Additionally, by producing oxygen in space, the mission could significantly reduce the need for Earth-based life-support supplies, thus advancing the sustainability of future space exploration.

1.4 Extending Clean Energy Solutions from Space to Earth

One of the most exciting aspects of the Thetys Mission is its potential to bridge the gap between space-based technologies and Earth's energy needs. While the immediate focus of the mission is to support space exploration, the results of the CubeSat experiment may also provide insights into new methods of producing green hydrogen on Earth. By demonstrating that electrolysis can be performed efficiently in space, we open the possibility of extending these technologies for clean energy production back on our planet.

The integration of space-based electrolysis into Earth's energy grid could support the broader transition to renewable energy by providing an additional source of sustainable hydrogen. This could help reduce reliance on fossil fuels and contribute to decarbonizing industries that are difficult to electrify. Moreover, the Thetys Mission emphasizes the concept of space as an extension of Earth, where technologies developed for space exploration can be repurposed to address the pressing need for sustainable energy here on Earth.

1.5 Thetys and the Future of Green Energy in Space Missions

Looking to the future, the Thetys Mission will provide the foundational data necessary to integrate clean energy technologies into space missions. As humanity embarks on more ambitious space endeavors, including long-term missions to the Moon, Mars, and beyond, the need for sustainable and renewable energy sources will become even more pressing. By validating the efficiency of electrolysis in space, the Thetys Mission will help pave the way for more sustainable spacecraft, reducing reliance on traditional fuel sources and enabling longer, more environmentally responsible missions.

In addition to its applications in space, the technologies demonstrated by Thetys could also influence Earth-based industries by promoting the use of green hydrogen as a clean fuel for various sectors, including transportation, industry, and power generation. This holistic approach to energy production aligns with the broader goals of the United Nations 2030 Agenda, supporting the transition to a more sustainable and resilient global energy system.

Chapter 2

2. Technical Part Description

2.1 Definition

The definitions contained in the ECSS-S-ST-00-01C standard are applicable.

Product	Contractual deliverable
Work Breakdown Structure	Organization of the relevant activities of the project
Baseline planning	Reference planning as defined at the start of the project. This planning serves as a baseline for performance evaluation.
System	A set of subsystems coordinated by requirements
Sub-system	A set of units coordinated by requirements
Units	A set of components coordinated by requirements

2.2 Acronyms

AOCS	Attitude and Orbit Control System
ASI	Italian Space Agency
ECSS	European Cooperation for Space Standardization
ESA	European Space Agency
HW	Hardware
KO	Kick-Off
MDR	Mission Definition Review
MRD	Mission Requirements Document
OBDH	On-Board Data Handling
PA	Product Assurance
PRR	Preliminary Requirements Review
RID	Review Item Discrepancy
SW	Software
TT&C	Telemetry Tracking and Command
WBS	Work Breakdown Structure
WP	Work Package
WPD	Work Package Description

2.3 State of the Art

The development of electrolysis technologies in space represents a promising frontier for sustainable energy production and resource utilization in extraterrestrial environments. Several pioneering initiatives underscore this progress.

The **International Space Station** (ISS) has integrated electrolysis into its Water Recovery System through the Oxygen Generation Assembly (OGA), which demonstrates the feasibility of producing oxygen for life support. Expanding on these principles, **Thales Alenia Space**, in collaboration with Leonardo and the European Space Agency (ESA), is advancing the production of oxygen from lunar regolith using electrolysis, aimed at supporting long-term lunar habitation.

Innovative propulsion systems are also emerging, such as **MIPRONS**, an Italian startup leveraging water electrolysis for a high-thrust propulsion system. This compact and scalable solution offers an eco-friendly alternative to traditional combustion-based fuels, capable of performing efficient maneuvers such as orbit-raising and de-orbiting.

Additionally, NASA's Pathfinder Technology Demonstration (PTD) CubeSat has successfully deployed **HYDROS**, the first electrolyser-based thruster to operate in space, showcasing water electrolysis propulsion in a compact, 2U subsystem integrated within a 6U CubeSat.

These advancements highlight the dual potential of electrolysis in space for supporting sustainable exploration and enabling green energy solutions applicable both off and on Earth.

2.4 Requirements Description

The **payload** subsystem includes tanks for water, hydrogen, and oxygen, alongside integrated valves, pipes, and sensors for precise measurements and redundancy. The scope of the electrolyser is to produce hydrogen and oxygen using only pure water and an external power source. Its total weight is 69.7 g, producing 7 mL/min for Hydrogen and 3.5 mL/min for oxygen, for a volume of 200 mL for Water Tank and 83 mL for Hydrogen and Oxygen Tanks. The tanks material is S-Glass.

Fig. 1 – Electolyser

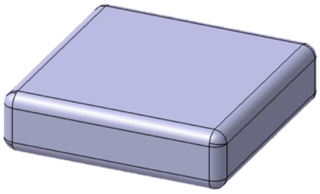


Fig. 2 – Water Tank

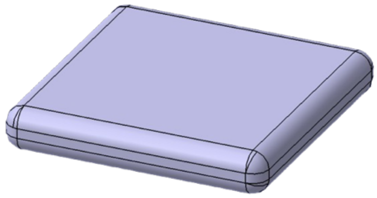


Fig. 3 – Hydrogen and Oxygen Tanks

The CubeSat will operate in **Low Earth Orbit** (LEO) starting December 1st, 2026, with a mission duration in orbit of 1 month.

The **Attitude Determination and Control System** (ADCS) uses photodiodes for sun tracking, magnetometers, GNSS receivers, and hysteresis dampers to maintain spin stabilization and reduce nutation.

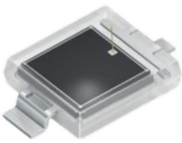


Fig. 4 – Photodiodes

Fig. 5 – Magnetometer (3-axis)

Fig. 6 – Horizon crossing indicator

Different sensors are employed to ensure precise orientation of the CubeSat in varying conditions. During daylight, photodiodes are used to track the Sun's position with an accuracy of over 96%. These *photodiodes* are strategically placed on the CubeSat's +z and –z planes to account for potential shadowing caused by the antennas, ensuring redundancy and reliability.

During the eclipse phase, when the Sun is not visible, the CubeSat relies on *magnetometers* to determine its orientation based on Earth's magnetic field. This enables continuous attitude determination even in the absence of solar input.

Additionally, the CubeSat incorporates a *Horizon Crossing Indicator* (HCI) as an Earth sensor. The HCI, with a fixed field of view of 4 degrees, provides accurate detection of Earth's horizon, further enhancing orientation control during critical mission phases.

For Attitude Control, the hysteresis dampers are critical components used to mitigate rotational oscillations and stabilize the CubeSat's attitude during its spin-stabilized phase. These dampers work by dissipating energy generated by internal disturbances, such as *sloshing* of water in the tanks, which can introduce unwanted torques and cause motion.

The **Telemetry, Tracking, and Command** (TT&C) subsystem employs UHF communication with omnidirectional antennas for reliable data transmission. Ground stations ensure consistent contact, with nearly one communication link per orbit. From *KSAT Ground Network*, Svalbard and Troll have been chosen in order to guarantee at least one contact per orbit during daylight.
Even though an S-band should be preferable instead of the UHF band, in THETYS mission it has been excluded S-band for reasons related to the Spin Stabilization.

The **Thermal Control System** (TCS) ensures temperature regulation with coatings, heaters, and antifreeze solutions, protecting the battery and water during operation. To prevent water from freezing during the eclipse phase, lithium chloride is dissolved in it. This substance does not interfere with the electrolysis process and lowers the freezing point to as low as -80°C.

The **Electrical Power System** (EPS) features high-efficiency solar arrays and batteries, providing reliable energy production and storage.

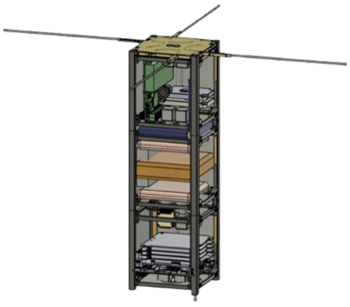


Fig. 7 – EPS Internal

Fig. 8 – Solar Arrays

The **On-Board Data Handling** (OBDH) system manages mission-critical functions and ensures reliability even in challenging scenarios.

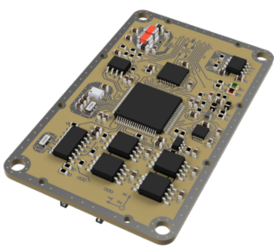


Fig. 9 – OBDH

To ensure the technical accuracy and compliance of the CubeSat's design, the *Tailored ECSS Engineering Standards for In-Orbit Demonstration CubeSat Projects* were thoroughly consulted. These standards provided critical guidelines for evaluating and validating the technical aspects of the mission.
By adhering to these standards, the CubeSat's design and operational parameters were rigorously verified, ensuring technical reliability and mission success.

#	ECSS Number	Title
1.	ECSS-E-ST-20C	Electrical and electronic systems
2.	ECSS-E-ST-31C	General thermal control requirements
3.	ECSS-E-ST-32-08C	Material selection
4.	ECSS-E-ST-35-01C	Liquid and electric propulsion for spacecraft
5.	ECSS-E-ST-50C	Communication systems
6.	ECSS-E-ST-50-05C Rev.2	Radio frequency and modulation requirements
7.	ECSS-E-ST-60-30C	Satellite attitude and orbit control systems (AOCS)

Chapter 3

3. Documentation and its applicability

3.1 Applicable Document (AD)

The following documents are an integral part of the TMA.
[AD 01] General Terms and Conditions for industrial contracts for research and development services concluded by ASI (CGA), available on the ASI website at the following address:
https://www.asi.it/wpcontent/uploads/2020/11/capitolato_generale_per_i_contratti_industriali_di_servizi_di_ricerca_e_sviluppo.pdf
[AD 02] ECSS-S-ST-00-01C, Glossary of Terms (*)
[AD 03] ECSS-M-ST-10C rev.1, Project Planning, and Implementation (*)
(*) Available on the European Cooperation for Space Standardization (ECSS) website at: www.ecss.nl.

3.2 Reference Document (RD)

The Reference Documents listed below must be used by the Contractor in order to derive guidelines, comparison data, supplementary information for better understanding of the requirements, management examples, etc.
In the absence of specific requirements, the reference documents should serve as the technical, operational, and managerial benchmark against which the Contractor must perform the contractual activities.
[RD 01] Technical and Managerial Proposal
[RD 02] ECSS Standards (*)
[RD 03] Quality Management Systems, document UNI EN ISO 9001:2015
[RD 04] Tailored ECSS Engineering Standards for In-Orbit Demonstration CubeSat
[RD 05] Projects (TEC-SY/128/2013/SPD/RW)
Product and Quality Assurance Requirements for In-Orbit Demonstration CubeSat Projects (TEC-SY/129/2013/SPD/RW).

Chapter 4

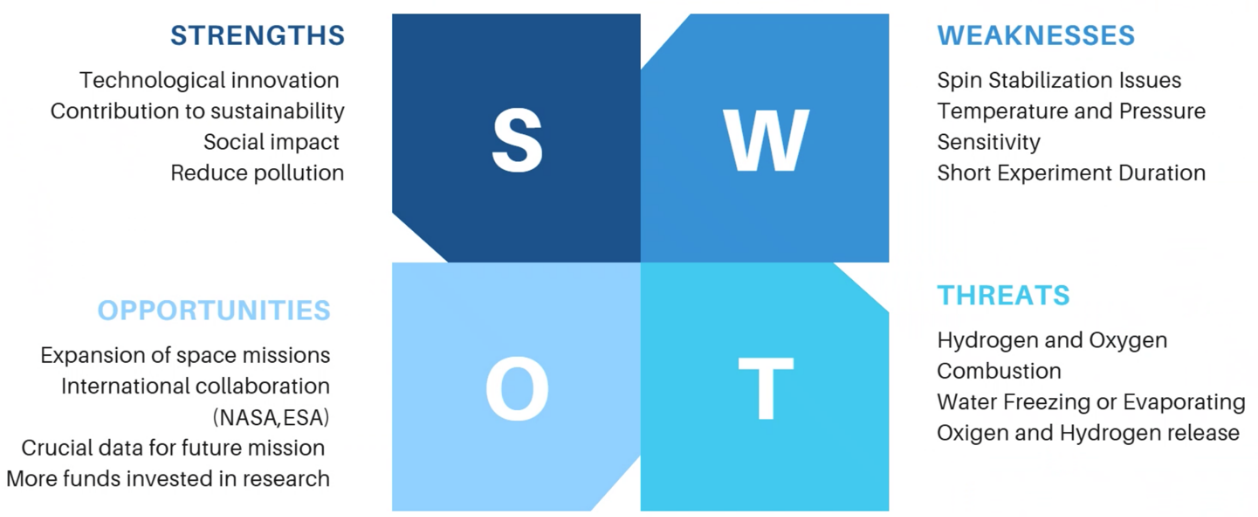
4. Objectives and Activities

4.1 Reference context and high-level objectives

The field of nanosatellites or CubeSats has become a well-established reality in the space sector and represents a reliable tool characterized by cutting-edge technologies, enabling its use in a wide range of applications and services. Nano-satellite platforms, by taking advantage of low-cost launch opportunities, allow the integration of technologies for in-orbit demonstration in short timelines. Furthermore, they can contribute to enabling new mission concepts, even in support of "traditional" satellites.
In recent years, ASI has been investing in this sector, both nationally and through programs of the European Space Agency (ESA), to carry out nano-satellite missions and develop onboard equipment. These activities position our country at the forefront of the global landscape, thanks to the large number of high-tech Small and Medium Enterprises (SMEs) operating in this sector.

4.2 SWOT

A **SWOT Analysis** is a strategic planning tool used to assess the Strengths, Weaknesses, Opportunities, and Threats related to a particular project, organization, or business. It helps to identify both internal and external factors that could impact the success or performance of an initiative. A SWOT analysis is useful for decision-making, as it allows organizations to understand their current position, make informed strategies, and identify areas for improvement or growth.



Strengths

- Technological Innovation: The Thetys Mission explores an innovative application of electrolysis in space, with the potential to sustainably produce hydrogen and oxygen for future space missions.
- Contribution to Sustainability: The mission supports 2030 Agenda (Goal 7), contributing to clean energy production and reducing dependence on fossil fuels.
- Social Impact: By advancing green hydrogen technology, the mission has the potential to promote clean energy solutions that can benefit communities on Earth, creating new opportunities for sustainable energy access.
- Reduce Pollution: The Thetys Mission aligns with efforts to reduce pollution by supporting the development of green hydrogen, which can contribute to reducing carbon emissions and mitigating environmental impact.

Opportunities

- Expansion of Space Missions: The use of hydrogen as a fuel and oxygen for life support could enhance the sustainability of future missions to the Moon, Mars, and beyond.
- International Collaboration: The mission could foster new partnerships among space agencies (NASA, ESA), universities, and tech industries, promoting the adoption of green technologies both in space and on Earth.
- Crucial Data for Future Missions: The results from the mission will provide key data on the efficiency of electrolysis in space, helping to design more sustainable and long-term space missions while reducing reliance on Earth-based supplies.
- More funds invested in research: There is growing investment in space-related research and clean energy technologies, which could provide additional funding and resources for the Thetys Mission and similar projects, driving innovation and expanding the scope of future experiments.

Weakness

- Spin Stabilization Issues: A 3U CubeSat could pose challenges for maintaining proper spin stabilization, potentially leading to instability during the mission.
- Temperature and Pressure Sensitivity: The experiments require specific temperature and pressure conditions to begin. If these conditions are not met, the experiments cannot be conducted, limiting the mission's flexibility and success rate.
- Short Experiment Duration: The experiments are limited to a brief 15 minute window, which may not be sufficient to gather comprehensive data. Additionally, the CubeSat requires 20 minutes to dissipate oxygen and hydrogen between experiments, further limiting the number of trials that can be conducted during the mission.

Threats

- Hydrogen and Oxygen Combustion: If hydrogen and oxygen mix in space, they can form an explosive mixture, posing a significant risk to the CubeSat and its components.
- Water Freezing or Evaporating: Depending on the CubeSat's distance from the Sun, the water onboard could either freeze or evaporate, jeopardizing the electrolysis process and potentially damaging the equipment.
- Oxygen and Hydrogen release: Their release in space environment could potentially leads to instability in cube sat assets but this problem can be faced by the application of mitigators, such as magnetorquers.

4.3 PESTEL

A **PESTEL Analysis** is a strategic tool used to evaluate the external macro-environmental factors that could impact an organization or project. It examines six key areas: Political, Economic, Social, Technological, Environmental, and Legal factors.

POLITICS	ECONOMY	SOCIETY	TECHNOLOGY	ENVIRONMENT	LAW
P	E	S	T	E	L
Political Interest	Relative Costs Savings	Increasing Public Interests	Advcanced Technology	Sustainable Energy	Patent Acquisition
International Collaboration	Economic Incomes	New Scientists Inspiration	Research	Reduce Pollution	Regulations
Strict regulation	High Barriers to Entry	Low Initial Interest	New Testing Opportunities	CO2 Emissions	Strict Law in Launch
Geopolitical Conflicts			Constraints in Electolysis in Microgravity	Debris Expultion	Responsability from debris damages
			Malfunctions		

Political Factors

- Positive:
  1) Government interest in technological innovation and space research, potentially fostering funding, and institutional support.
  2) International collaborations in the space sector, such as with ESA or NASA, encouraging resource and knowledge sharing.
- Negative:
  1) Strict regulations for satellite launch and operations, including compliance with the Outer Space Treaty and debris mitigation guidelines.
  2) Geopolitical conflicts that could delay approvals or limit access to launch infrastructure.

Economic Factors

- Positive:
  1) Relative Cost Savings for long-term missions.
  2) Potential Incomes from discoveries applicable to key industries like energy.
- Negative:
  1) High Barriers to entry due to low interests in using *green* fuel in space.

Social Factors

- Positive:
  1) Growing public and academic interest in science and sustainability, which could increase support for the mission.
  2) Opportunity to inspire new generations of scientists and engineers.
- Negative:
  1) Limited understanding of the value of space research among certain societal sectors, potentially reducing public approval.

Technological Factors

- Positive:
  1) Advances in CubeSat technology, making them increasingly reliable and accessible.
  2) Opportunity to test new energy management technologies in space.
  3) Research field.
- Negative:
  1) Technical limitations of the CubeSat format, such as payload capacity and operational lifespan.
  2) Risk of malfunctions due to exposure to extreme space conditions.

Environmental Factors

- Positive:
  1) The experiment could contribute to developing more sustainable energy production technologies.
  2) The space environment offers a unique opportunity to study physical and chemical phenomena free from Earth's influences.
- Negative:
  1) Creation of space debris in case of satellite loss of control.
  2) Environmental impact of rocket launches, such as CO2 emissions.

Legal Factors

- Positive:
  1) Opportunity to patent innovative discoveries or technologies resulting from the experiment.
  2) International regulations promoting collaboration and sustainability in space activities.
- Negative:
  1) Need to comply with strict laws for satellite launches and operations.
  2) Legal liability in case of damage caused by space debris.

4.4 TRL

TRL stands for Technology Readiness Level, a metric used to assess the maturity of a particular technology. It ranges from 1 to 9, with TRL 1 representing the earliest stage of research and basic concept development, and TRL 9 indicating that the technology has been fully developed, tested, and proven in an operational environment. TRL is used to measure the progress of a technology from the initial concept through to its deployment, helping organizations determine the level of development, the feasibility of implementation, and the readiness for commercial use or space missions.

Components	Suppliers	TRL	Explanation
Tank Water	*In-house*	2	Technology concept and/or application formulated
Tank Gas H2/O2	*In-house*	2	Technology concept and/or application formulated
Valves	Experimental	2	Technology concept and/or application formulated
Electrolytic Cell	Horizon Educational	2	Technology concept and/or application formulated
Celeste (GNSS)	Experimental	2	Technology concept and/or application formulated
Heater Battery	Clyde Space	7	System prototype demonstration in a target/space environment
Solar panels (3U – PHOTON SIDE)	AAA Clyde Space	7	System prototype demonstration in a target/space environment
Batteries OPTIMUS – 40	AAA Clyde Space	7	System prototype demonstration in a target/space environment
Transceiver	Clyde Space	7	System prototype demonstration in a target/space environment

Sun Sensor	Osram	9	Actual system “flight proven” through successful mission operations
Magnetometer	CubeSpace	9	Actual system “flight proven” through successful mission operations
Magnetorquer	Stras Space	9	Actual system “flight proven” through successful mission operations
Earth Sensor	Servo	9	Actual system “flight proven” through successful mission operations
Antenna UHF	ISIS Space	9	Actual system “flight proven” through successful mission operations

4.5 LLI

A **Long Lead Item (LLI)** refers to a component, subsystem, or piece of equipment that requires significantly longer procurement, manufacturing, or delivery times compared to standard items. Typical examples of LLIs in the space industry include propulsion systems, high-precision optical instruments, specialized electronics, or rare materials used in manufacturing.

LLIs have a profound impact on the supplier phase and the overall project lifecycle. Early identification and procurement planning become critical, as LLIs must be addressed during the initial stages of the project. Suppliers must be engaged well in advance, requiring clear technical specifications and a deep understanding of mission requirements.

Items	Estimated delivery	Notes
Electrolysis Membrane (PEM)	6-9 months	Requires high performance specifications and testing for space environments
Solar Panels and Batteries	4-5 months	Integration with CubeSat’s power requirements is necessary
Electric Propulsion Equipment	5-6 months	Includes propulsion cell integration and compatibility testing
Testing and Simulation Equipment	6-8 months	Preparation for microgravity and thermal simulations

Chapter 5

5. Contractual Responsibilities

5.1 ASI Responsibilities

The ASI, in accordance with the provisions of the CGA [DA 01], manages the contractual relationship with the Contractor through the designated personnel.
The responsibilities of the ASI are as follows:

- Technical and programmatic management of activities through the guidance provided to the Contractor.
- Administration of the Contact;
- Provision to the Contractor of the elements required as, where, and when necessary, including the necessary documentation, ensuring full support for their proper use, and taking responsibility for them as needed throughout the activities.

5.2 Contractor Responsibilities

The provisions outlined in the CGA [DA 01] apply.
The Contractor is solely responsible for the execution of the activities covered by the Contract, as well as for all activities not explicitly identified but necessary for the complete and compliant execution of the Contract, and in particular for:

- Achieving the objectives in compliance with the requirements and constraints.
- Defining, executing, and managing the related activities.
- Acquiring the elements (authorizations, licenses, etc.) necessary for this purpose.
- Implementing the elements previously defined.

Therefore, the Contractor is also responsible to ASI for the execution of activities entrusted to subcontractors, for their quality, and for adherence to the contractual timelines.
The Contractor must ensure full access to information, sites, and activities for all members of the ASI project management team, in accordance with the contractual provisions.
Should the need arise during the activities to better specify the requirements and/or pursue solutions different from those initially foreseen, the Contractor must take an active role to ensure this is done in compliance with the program constraints and to fully achieve the functionalities/performance/operability defined in the contract.

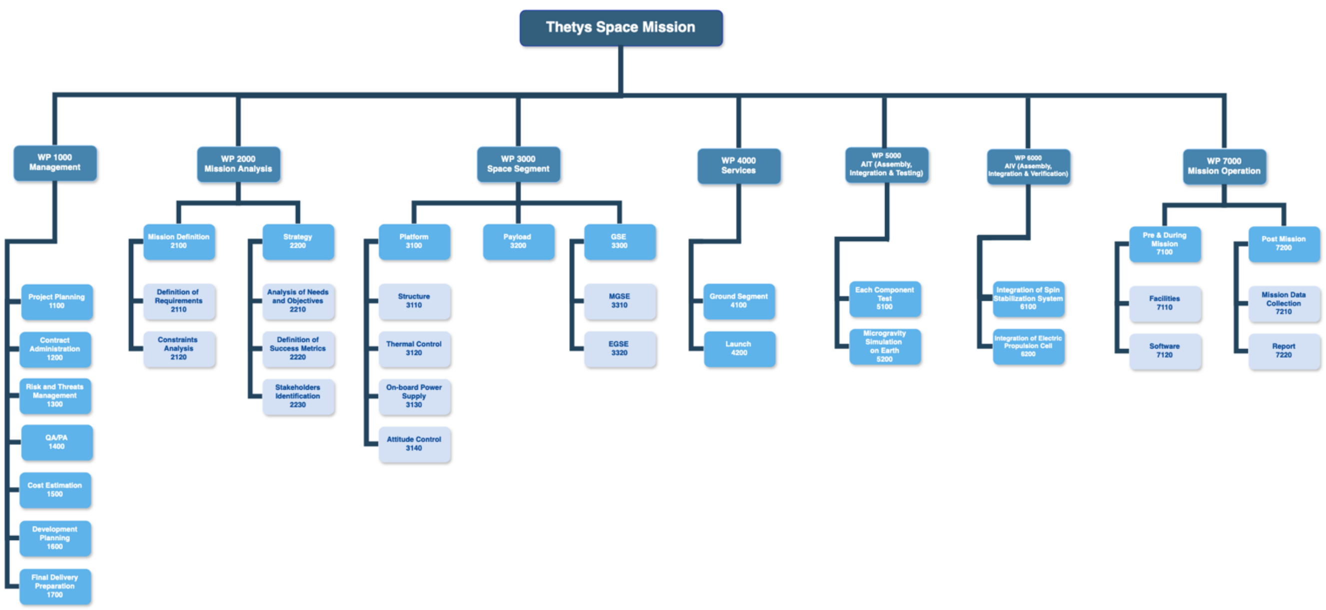
Chapter 6

6. Activity planning, Phases and Key Events

The **Thetys Space Mission** project has a total duration of two and a half years, starting on January 1, 2025, and concluding on July 1, 2027. The CubeSat is expected to be operational in orbit for a period of one month. Following the end of the CubeSat's operational phase, there will be a data collection and post-mission report development phase, estimated to last six months, allowing time for the final analysis and reporting of the mission's outcomes.

6.1 Work Breakdown Structure

The **Work Breakdown Structure** (WBS) is a fundamental tool in project management, used to break down a project into smaller, more manageable components. It is a decomposition of the project scope, where each level represents a more detailed definition of the work required to achieve the project's objectives, into smaller tasks and sub-tasks, making it easier to organize, assign, and track work.

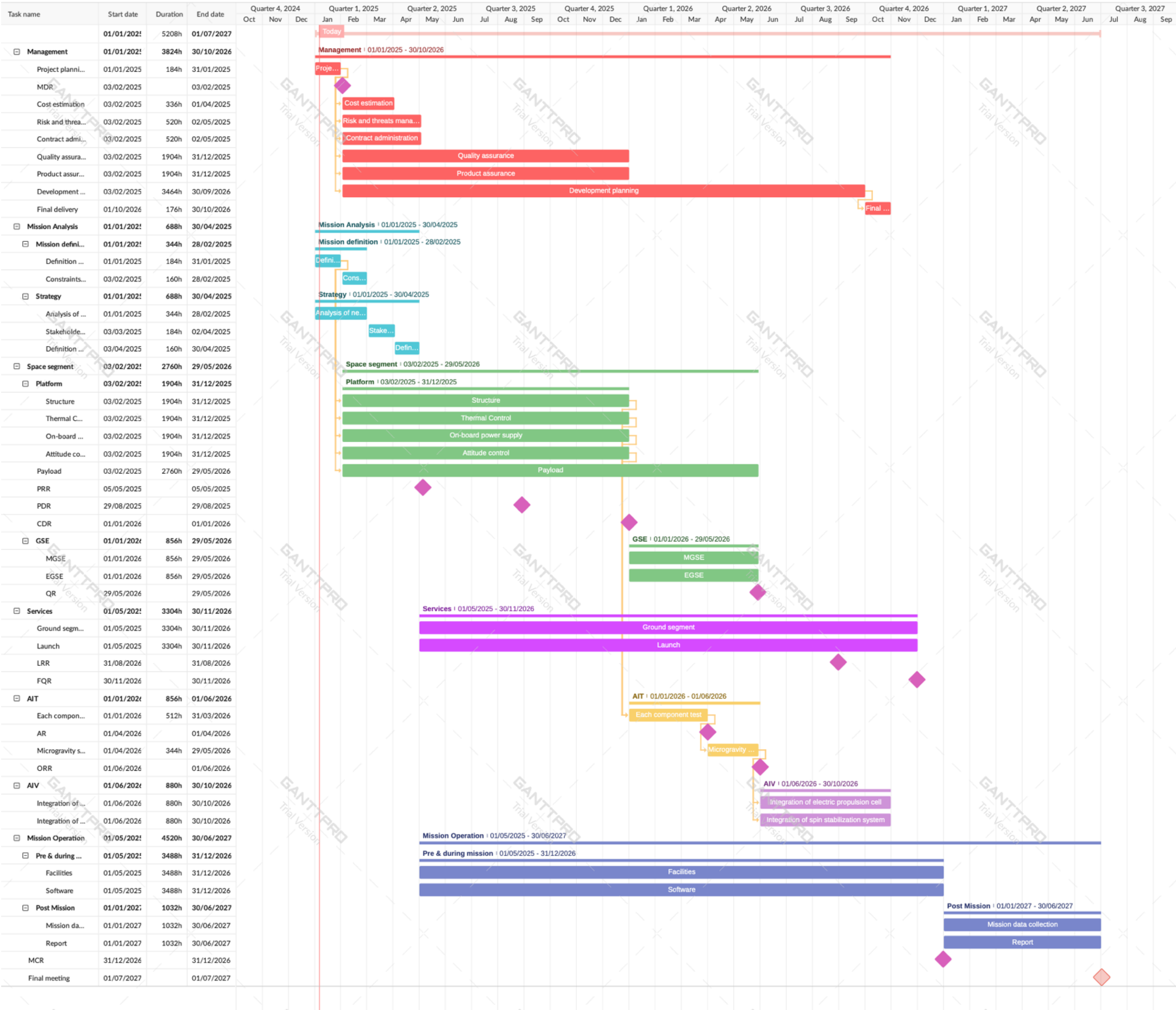


The WBS of the Thetys Space Mission is divided into seven main blocks at the first level, each representing a fundamental task of the project, which are:

1. **Management** (WP 1000). This block represents the core of overall coordination, including project planning, contract administration, risk, and threat management, as well as ensuring quality and cost control. It serves as the reference point to keep the mission aligned with objectives, timelines, and budget.
2. **Mission Analysis** (WP 2000). Here we find the strategic soul of the mission. This block focuses on defining requirements, analyzing constraints, and developing strategies that address identified objectives and needs.
3. **Space Segment** (WP 3000). This represents the technological heart of the mission. It includes the development of the space platform, the payload, and the ground support equipment (GSE).
4. **Services** (WP 4000). This block is dedicated to essential services, such as the ground segment and the launch. These are all the operational activities that ensure the mission's success, connecting ground preparations with operations in space.
5. **Assembly, Integration & Testing** (WP 5000). The fifth block represents the phase of testing and verification of each component. From individual component tests to microgravity simulation on Earth.
6. **Assembly, Integration & Verification** (WP 6000). This focuses on the integration and verification of critical systems, such as the spin stabilization system and the electric propulsion cell. It is the step that ensures the individual components work together harmoniously.
7. **Mission Operation** (WP 7000). The final block represents the life of the mission, from the start to the post-mission phase. It includes operations during the mission, data collection, analysis, and the drafting of the final report. This is the moment when the mission achieves its objectives and leaves a scientific and technical legacy.

6.2 Gantt

A **Gantt Chart** is a type of bar chart that represents a project schedule over time. It visually displays the start and end dates of the various elements or tasks of a project, allowing project managers and teams to easily see the timeline and progress of the entire project.
Each task is represented by a horizontal bar, where the length of the bar corresponds to the duration of the task.



The Gantt Chart for the Thetys mission outlines a structured timeline for the development, execution, and post-mission reporting. This mission, spanning two years with an additional six months allocated for data collection and final reporting, ensures a systematic approach to achieving its objectives while adhering to the milestones critical for success.

The mission officially begins on January 1, 2025, with **Phase 0**, focusing on concept and initial planning. During this phase, essential tasks include project planning, definition of requirements, and analysis of needs and objectives. Constraints analysis, an integral part of Phase 0, is followed by the Preliminary Requirements Review (**PRR**), validating the initial feasibility of the mission. Phase 0 concludes with the Mission Definition Review (**MDR**), which confirms the alignment of mission objectives with stakeholder goals and technical requirements.

Phase A builds upon the foundational work of Phase 0 by emphasizing the feasibility of the mission. During this phase, the definition of requirements extends from the previous phase, and the analysis of needs and objectives reaches completion, setting the stage for more detailed design work in Phase B.

In **Phase B**, the focus shifts to preliminary design. This phase initiates the development of the system architecture and key subsystems, including structure, thermal control, on-board power supply, attitude control, and payload.
The conclusion of these tasks marks a critical milestone, the Preliminary Design Review (**PDR**), which validate the system's readiness to proceed to more detailed design and assessment activities.

Phase C/D marks the transition from design to implementation. During this phase, the subsystems developed in Phase B are subjected to rigorous design, assessment, and feasibility evaluations. The Critical Design Review (**CDR**) represents a pivotal milestone, ensuring that the mission is ready to proceed to full-scale development and integration. Further in this phase, the Qualification Review (**QR**) validates the readiness of components and systems for operational conditions.

Phase D focuses on testing and integration, culminating in the Acceptance Review (**AR**). This milestone ensures that all components meet the required specifications and are prepared for operational deployment.
Phase E, the operational phase, involves utilization activities, beginning with tests in microgravity environments. The Operational Readiness Review (**ORR**) confirms that

all systems and procedures are prepared for launch. Subsequent milestones include the Launch Readiness Review (**LRR**) and the Flight Qualification Review (**FQR**), ensuring the cube satellite's readiness for deployment and operations in orbit.

Finally, the operational phase concludes with the disposal phase (**Phase F**), overseen by the Mission Completion Review (**MCR**). Although this phase is not explicitly detailed in the Gantt Chart, it remains a critical aspect of the mission lifecycle.

The additional six months following the mission's end are dedicated to collecting data and developing a comprehensive final report, ensuring that the insights gained contribute to future advancements in space missions. The end is defined by the milestone called "Final Meeting" on 1st July of 2027.

6.3 Work Package Description (WPD)

Management (WP 1000)

WP 1100	Issue Date: Sheet 1 of 28
Project Title: Thetys Space Mission	
WP Title: Project Planning	
Responsability: Esposito Luca	
Start Event: Kick off Meeting	
End Event: Project Planning Approval	
Input required ☐ All project relevant data and information by customer	
Tasks ☐ Focal point to customer in all project's relevant tasks ☐ Responsible for technical, financial, and programmatic aspects	
Output ☐ Monthly reports ☐ Phase summary reports ☐ Contribution to deliverable documents	

WP 1200	Issue Date: Sheet 2 of 28
Project Title: Thetys Space Mission	
WP Title: Contract Administration	
Responsability: Esposito Luca	
Start Event: Kick off Meeting	
End Event: Contract Agreement	

Input required

- Goal
- Specifications of Thetys Space Mission Experiment
- International regulation for Space Experiments

Tasks

- Compliance Supervision
- Revision (Contract changes)

Output

- Reviewed and updated contract
- Reached milestones

WP 1300	Issue Date: Sheet 3 of 28
Project Title: Thetys Space Mission	
WP Title: Risks & Threats Management	
Responsability: Esposito Luca	
Start Event: Mission Definition Review	
End Event: Mitigation and closure of risks	
Input required ☐ Technical specifications ☐ Historical data on risks from previous space missions	
Tasks ☐ Risks identification, Assessment, and monitoring	
Output ☐ Risks register ☐ Detailed mitigation plan	

WP 1400	Issue Date: Sheet 4 of 28
Project Title: Thetys Space Mission	
WP Title: QA/PA	
Responsability: D'Avino Maria Lucia	
Start Event: Mission Definition Review	
End Event: Quality Plan Approval	
Input required ☐ Standard and regulations for space mission ☐ Quality test	
Tasks ☐ Quality standard definition ☐ Verification protocol for Thetys space mission experiment ☐ Space conditions simulation	
Output ☐ Quality assurance plan ☐ Product assurance plan	

WP 1500	Issue Date: Sheet 5 of 28
Project Title: Thetys Space Mission	
WP Title: Cost Estimation	
Responsability: D'Avino Maria Lucia	
Start Event: Kick off Meeting	
End Event: Mission budget Approval	
Input required □ Technical specification □ Preliminary design □ Historical cost data from similar mission □ Launch costs □ Supplier and contractor cost estimations	
Tasks □ Data collection and analysis □ Breakdown mission costs (payload, spacecraft, testing, operations) □ Reporting	
Output □ Estimation report □ Cost tracking plan	

WP 1600	Issue Date: Sheet 6 of 28
Project Title: Thetys Space Mission	
WP Title: Development Planning	
Responsability: D'Avino Maria Lucia	
Start Event: Mission Definition Review	
End Event: Launch Readiness Review	
Input required ☐ Monthly reports ☐ Phase summary reports ☐ Minutes of meeting protocol ☐ Contribution to deliverable documents	
Tasks ☐ Mission analysis ☐ Space segment ☐ Services ☐ AIT ☐ AIV ☐ Mission operations	
Output ☐ Deliverable Documents	

WP 1700	Issue Date: Sheet 7 of 28
Project Title: Thetys Space Mission	
WP Title: Final Delivery Preparation	
Responsability: D'Avino Maria Lucia	
Start Event: Launch Readiness Review	
End Event: Flight Qualification Review	
Input required ☐ Finalized and validated payload/system ready for delivery ☐ Results of all testing	
Tasks ☐ Verification of final deliverables ☐ Stakeholders communication	
Output ☐ Final Delivery	

Mission Analysis (WP 2000)

WP 2110	Issue Date: Sheet 8 of 28
Project Title: Thetys Space Mission	
WP Title: Definition of Requirements	
Responsability: Creoli Andrea	
Start Event: Kick off Meeting	
End Event: Preliminary Requirement Review	
Input required - Mission objectives	
Tasks - Draft initial requirements - Conduct feasibility studies - Finalize and document requirements	
Output - Approved requirements document	

WP 2120	Issue Date: Sheet 9 of 28
Project Title: Thetys Space Mission	
WP Title: Constraints Analysis	
Responsability: Creoli Andrea	
Start Event: Mission Definition Review	
End Event: Preliminary Requirements Review	
Input required ☐ Available resources (budget, financial & technology)	
Tasks ☐ Identify constraints in all missions' areas ☐ Analyze impact of constraints on mission design ☐ Document findings and recommendations	
Output ☐ Constraints Analysis Report	

WP 2210	Issue Date: Sheet 10 of 28
Project Title: Thetys Space Mission	
WP Title: Analysis of Needs and Objectives	
Responsability: Creoli Andrea	
Start Event: Kick off Meeting	
End Event: Preliminary Requirements Review	
Input required - Initial concept of operations - Available resources and constraints	
Tasks - Prioritize mission need and objectives - Align objectives with feasibility and constraints	
Output - Mission objectives document	

WP 2220	Issue Date: Sheet 11 of 28
Project Title: Thetys Space Mission	
WP Title: Definition of Success Metrics (KPI)	
Responsability: Creoli Andrea	
Start Event: Kick off Meeting	
End Event: Approval of KPI Framework	
Input required - Historical data and benchmarks (if available)	
Tasks - Identify critical mission success factors - Develop measurable KPI for each factor	
Output - KPI dashboard	

WP 2230	Issue Date: Sheet 12 of 28
Project Title: Thetys Space Mission	
WP Title: Stakeholders Identification	
Responsability: Creoli Andrea	
Start Event: Preliminary Requirement Review	
End Event: Stakeholders Mapping	
Input required ☐ Mission objectives and scope ☐ Organizational charts and external networks ☐ Exiting stakeholders' data and communication records	
Tasks ☐ Conduct stakeholders' interviews ☐ Create stakeholders map based on their influences ☐ Develop a document for stakeholders' engagement	
Output ☐ Stakeholders Map	

Space Segment (WP 3000)

WP 3110 Issue Date: Sheet 12 of 28
Project Title: Thetys Space Mission
WP Title: Structure
Responsability: Catapano Giovanni
Start Event: Mission Definition Review
End Event: Critical Design Review
Input required ☐ Environmental and operations load data (vibration, thermal, and mechanical loads) ☐ Standards and guidelines for space structures
Tasks ☐ Define and analyze structural requirements based on mission and payload need ☐ Conduct material selection and validation for lightweight and durable components
Output ☐ Structural Validation ☐ Finalized structural design documentation

WP 3120	Issue Date: Sheet 13 of 28
Project Title: Thetys Space Mission	
WP Title: Thermal Control	
Responsability: Catapano Giovanni	
Start Event: Mission Definition Review	
End Event: Critical Design Review	
Input required ☐ Mission thermal requirements and constraints ☐ Payload and subsystem heat generation data	
Tasks ☐ Develop preliminary and detailed thermal control design ☐ Select and validate materials and components ☐ Platform thermal simulations and analysis (transient and steady state)	
Output ☐ Finalized thermal control system design documentation	

WP 3130	Issue Date: Sheet 14 of 28
Project Title: Thetys Space Mission	
WP Title: On Board Power Supply	
Responsability: Catapano Giovanni	
Start Event: Mission Definition Review	
End Event: Critical Design Review	
Input required - Payload and subsystem power consumptions data	
Tasks - Develop preliminary and detailed designs for power generation, storage, and distributions system - Select and validate power generation components	
Output - Finalized power supply system design documentation	

WP 3140	Issue Date: Sheet 15 of 28
Project Title: Thetys Space Mission	
WP Title: Attitude Control	
Responsability: Catapano Giovanni	
Start Event: Mission Definition Review	
End Event: Critical Design Review	
Input required - Payload and subsystem orientation constraints - Environmental data (gravitational forces, magnetic fields, solar pressure)	
Tasks - Select reaction wheels, gyroscopes, start trackers and magnetorquers - Design and implement control algorithms for attitude determination and control - Conduct ground testing	
Output - Control algorithms and simulation results	

WP 3200	Issue Date: Sheet 16 of 28
Project Title: Thetys Space Mission	
WP Title: Payload	
Responsability: Fiore Dario	
Start Event: Mission Definition Review	
End Event: Qualification Review	
Input required - Payload technical constraints	
Tasks - Selection of COTS material - Design of oxygen tank, hydrogen tank, and water tank for 200 ml - Definition of temperature and pressure measurements - Design of the electrolytic cell	
Output - Final Payload Deliverables	

WP 3310	Issue Date: Sheet 17 of 28
Project Title: Thetys Space Mission	
WP Title: MGSE	
Responsability: De Benedictis Lorenzo	
Start Event: Kick off meeting	
End Event: Qualification Review	
Input required - Spacecraft design and interface specifications - Standards and regulations for MGSE	
Tasks - Analyze mission specific MGSE needs - Design and development of MGSE components - Conduct validation tests for MGSE functionality and compatibility	
Output - MGSE design documents	

WP 3320	Issue Date: Sheet 18 of 28
Project Title: Thetys Space Mission	
WP Title: EGSE	
Responsability: De Benedictis Lorenzo	
Start Event: Kick off meeting	
End Event: Qualification Review	
Input required - Spacecraft electrical specifications - Standards and Testing protocols for electrical systems	
Tasks - Analyze mission specific EGSE requirements. - Develop software tools for EGSE operation and data analysis.	
Output - EGSE design and interface documents	

Services (WP 4000)

WP 4100	Issue Date: Sheet 19 of 28
Project Title: Thetys Space Mission	
WP Title: Ground segment	
Responsability: Gargiulo Marika	
Start Event: Design and development of ground infrastructure	
End Event: Successful operational readiness of ground system before mission start	
Input required - Technical specification of the payload and space system - Safety regulations and satellite communication protocols	
Tasks - Design and development of the ground segment - Verification and testing of ground operations - Planning and preparation for mission support	
Output - Documented and tested operational procedures for continuous mission support	

WP 4200	Issue Date: Sheet 20 of 28
Project Title: Thetys Space Mission	
WP Title: Launch	
Responsability: Gargiulo Marika	
Start Event: Selection of the launcher and confirmation of payload integration requirements	
End Event: Flight Qualification Review	
Input required ☐ Payload specification and design data ☐ Mission-specific launcher requirements	
Tasks ☐ Launcher payload integration ☐ Safety and risk management ☐ Launch campaign execution ☐ Post launch assessment	
Output ☐ Pre-launch operations completed and documented	

AIT (WP 5000)

WP 5100	Issue Date: Sheet 21 of 28
Project Title: Thetys Space Mission	
WP Title: Each component test	
Responsability: Del Prete Maria Laura	
Start Event: Component Delivery to Test Facility	
End Event: Acceptance Review	
Input required ☐ Technical specifications of each component. ☐ Test plans and procedures. ☐ Testing facility readiness.	
Tasks ☐ Prepare components for testing and ensure they meet safety protocols. ☐ Conduct functional, thermal, and mechanical tests on each component. ☐ Coordinate with design teams for troubleshooting and corrective actions	
Output ☐ Detailed test reports for each component, which document test results and provide an analysis of performance metrics	

WP 5200	Issue Date: Sheet 22 of 28
Project Title: Thetys Space Mission	
WP Title: Microgravity Simulation on Earth	
Responsability: Gargiulo Marika	
Start Event: Acceptance Review	
End Event: Operational readiness review	
Input required ☐ Simulation equipment and facility specifications. ☐ Mission system prototypes or components. ☐ Simulation scenarios and parameters.	
Tasks ☐ Configure simulation equipment to replicate microgravity conditions. ☐ Conduct tests to assess system performance and reliability. ☐ Record and analyze data to identify anomalies or improvements. ☐ Provide feedback to development teams based on simulation results..	
Output ☐ Performance analysis under microgravity conditions	

AIV (WP 6000)

WP 6100	Issue Date: Sheet 23 of 28
Project Title: Thetys Space Mission	
WP Title: Integration of Spin Stabilization System	
Responsability: Faraco Francesco	
Start Event: Operation readiness review	
End Event: System Fully Integrated and Validated	
Input required ☐ Spin stabilization system design specifications. ☐ Component compatibility and integration requirements. ☐ Environmental and operational constraints.	
Tasks ☐ Assemble and integrate spin stabilization components. ☐ Conduct functional and performance validation tests. ☐ Ensure alignment with mission requirements and constraints. ☐ Address and resolve integration challenges.	
Output ☐ Integration verification and certification documents.	

WP 6200	Issue Date: Sheet 24 of 28
Project Title: Thetys Space Mission	
WP Title: Integration of electric propulsion Cell	
Responsability: Faraco Francesco	
Start Event: Operational readiness review	
End Event: Propulsion System Fully Integrated and Validated	
Input required ☐ Electric propulsion system design documents. ☐ Component specifications and integration parameters. ☐ Power system compatibility data.	
Tasks ☐ Assemble and integrate electric propulsion components. ☐ Conduct performance and compatibility tests. ☐ Ensure compliance with mission power and structural constraints. ☐ Address integration issues and document resolutions.	
Output ☐ Certification and verification documents for the propulsion system.	

Mission Operation (WP 7000)

WP 7110	Issue Date: Sheet 25 of 28
Project Title: Thetys Space Mission	
WP Title: Facilities	
Responsability: Ienco Alessia	
Start Event: Kick off meeting	
End Event: Mission Completation review	
Input required ☐ Technical specifications of required facilities. ☐ Inventory and current status of available equipment.	
Tasks ☐ Ensure availability and proper functioning of utilities (power, water, environmental control systems). ☐ Supervise safety procedures for operational facilities. ☐ Implement improvements to maximize operational efficiency of the facilities. ☐ Manage emergency responses and resolve infrastructure issues during the mission.	
Output ☐ Operational documentation	

WP 7120	Issue Date: Sheet 26 of 28
Project Title: Thetys Space Mission	
WP Title: Software	
Responsability: Ienco Alessia	
Start Event: Kick off meeting	
End Event: Mission Completation Review	
Input required ☐ Software requirements and specifications provided by mission planners. ☐ Integration data with hardware and other system components.	
Tasks ☐ Develop and validate mission-critical software in compliance with requirements. ☐ Coordinate integration of software with onboard systems, ground control, and other mission components. ☐ Implement regular updates and patches to maintain system security and functionality..	
Output ☐ Software performance evaluation reports.	

WP 7210	Issue Date: Sheet 27 of 28
Project Title: Thetys Space Mission	
WP Title: Mission data collection	
Responsability: Ienco Alessia	
Start Event: Mission Completation Review	
End Event: Final meeting	
Input required - Data acquisition requirements and mission parameters. - Pre-configured software and hardware setup for data collection.	
Tasks - Operate onboard sensors and data acquisition systems. - Validate data in real-time and ensure compliance with mission objectives. - Manage storage and transmission of collected data to ground stations. - Troubleshoot and resolve issues with data collection systems during the mission.	
Output - Collected mission data package. - Data integrity verification report. - Transmission logs and error analysis reports.	

WP 7220	Issue Date: Sheet 28 of 28
Project Title: Thetys Space Mission	
WP Title: Report	
Responsability: Ienco Alessia	
Start Event: Mission Completation Review	
End Event: Final Meeting	
Input required - Mission data and transmission logs. - Analytical tools and guidelines for report preparation	
Tasks - Perform detailed analysis of mission data. - Prepare interim and final mission reports. - Coordinate with team members to ensure accuracy and completeness of the report. - Present findings and recommendations to stakeholders.	
Output - Final mission report	

Chapter 7

7. Risk Analysis

The **risk analysis** is a structured process aimed at identifying, assessing, and managing risks related to an activity, project, or decision. Its main purpose is to anticipate and reduce the potential negative consequences of uncertain events.
Risk is calculated as the product of the probability that a negative event will occur (P) and the impact that the event could have (I):

$$R = P \times I$$

This method complements reliability analysis, which measures the probability of avoiding a failure, by also including an assessment of the impact of a potential adverse event, which can range from a slight performance decrease to the complete failure of the mission.

Most of the risks listed below arise from the use of innovative technologies, the lack of similar past missions, and the resulting low Technology Readiness Level (TRL), which constitutes an additional risk factor.

Id Risk	Category	Risk description	Likelihood (1-5)	Severity (1-5)	Risk Index (LxS)	Mitigation Actions
1	Technical	Interruption in Hydrogen and Oxygen Production in the Electrolysis System	3	5	15	Redundant system design, thorough pre-launch testing, and implementation of real-time monitoring to detect and address malfunctions promptly
2	Technical	Technical failures	3	4	12	Preventive maintenance, use of sensors
3	Technical	Structural material issues	2	5	10	Use of certified materials, environmental tests
4	Technical	Sensor performance drop	3	3	9	Implementation of sensor redundancy
5	Technical	Software errors	4	4	16	Automated testing and code validation
6	Technical	Energy overload	3	5	15	Overload protection systems
7	Technical	Critical hardware failures	2	5	10	Duplication of critical hardware
8	Technical	Software update delays	3	3	9	Rollout planning and testing

9	Technical	System integration difficulties	2	4	8	Dedicated integration team
10	Technical	Lack of environmental data	4	4	16	Additional sensors and predictive modeling
11	Managerial	Supply chain delays	3	3	9	Supplier diversification
12	Managerial	Stakeholder issues	2	4	8	Regular communication
13	Managerial	Budget shortage	2	5	10	Rigorous financial management
14	Managerial	Human errors	3	3	9	Intensive training
15	Managerial	Team overload	3	4	12	Balanced planning
16	Managerial	Deadline delays	3	3	9	Strict progress monitoring
17	Managerial	Sensitive data loss	2	5	10	Regular backups and encryption
18	Managerial	Reputational risks	1	5	5	Transparent communication
19	Managerial	Inadequate resources	3	4	12	Adequate recruitment and training
20	Managerial	Internal conflicts	2	3	6	Facilitation of internal communication
21	Technical	Excessive vibrations	4	3	12	Advanced dampers
22	Technical	Component degradation	3	4	12	Long-lasting materials
23	Technical	Hardware production defects	2	5	10	Regular QA inspections
24	Managerial	Lack of backup policies	3	5	15	Implementation of backup policies
25	Managerial	Poor documentation management	2	3	6	Centralized documentation
26	Technical	Sloshing	2	3	6	Implementation of the hysteresis damper
27	Technical	Spin stabilization	1	5	5	ADCS

7.1 Fever chart

After identifying the risks, we recorded them in a data sheet and analyzed them using a fever chart. In the context of risk management, a fever chart visually represents residual risk on a graph with two axes:

- On the x-axis, the severity of the risk is shown, representing the potential impact of a negative event.
- On the y-axis, the likelihood of the event occurring is represented.

Each point on the chart represents a specific risk, and the "fever" is divided into three color zones:

- Green, when the product of severity and likelihood is between 0 and 8, indicating low risk.
- Yellow, when the product is between 8 and 15, signaling moderate risk.
- Red, when the product exceeds 15, highlighting high risk.

Likelihood						
	5					
	4			21	5,10	
	3			4,8,11,14,16	2,15,19,22	1,6,24
	2			20,25,26	9,12	3,7,13,17,23
	1					18,27
		1	2	3	4	5
		Severity				

Chapter 8

8. Cost estimation

Cost estimation is the process of predicting the financial resources required to complete a project or produce a product. It involves analyzing various factors, including materials, labor, equipment, overhead, and other expenses, to create a detailed projection of the total cost.
The primary purpose of cost estimation is to provide a clear understanding of the financial implications of a project before it begins.

Here, a representation of the Cost estimation based on Hardware for Space and Ground Segment, for a total cost of 243.998 €.

HARDWARE		QUANTITY	COST (€)
SPACE SEGMENT			
PAYLOAD	Tank Water	1	1000
	Tank Gas H2/O2	2	3660
	Valves	4	2900
	Misuratore	1	112
	Cell	1	100
ADCS	Sun sensor	17	26
	Magnetometer	1	2300
	Magnetorquer	3	24000
	Earth sensor	1	14900
	Hysteresis damper	12	25000
	Celeste (GNSS)	1	1700
TT&C	UHF antenna	1	25000
	Transciever	1	6300
TCS	Heater Battery	1	
EPS	Solar arrays	4	60000
	Battery Optimus-40	1	12000
	PCDU-STARBUCK-NANO	1	10000
OBDH	Eddie on board computer	1	25000
STRUCTURE	Structure	1	3100
	Deployer	1	40000
GROUND SEGMENT			
GROUND STATION	GS	2	30000
TOTAL COSTS			**287098**

Tab. 1

The following table (Tab. 2) presents the costs associated with each Work Package Deliverable (WPD) derived from the Work Breakdown Structure (WBS).
These costs are categorized into staff, service costs, hardware (previously estimated), and travel costs. As a company, we assess a gross hourly rate for staff at €52 per hour, which is factored into the overall cost estimation.

WPs	Name	Phase	Staff	Working days	Daily Hours	Hourly Rate [€/h]	Travel costs [€]	Services [€]	Hardware [€]	Total cost (€)
WP-1100	Project planning	0/A	1	23	6h	52				7176
WP-1200	Contract administration	0/A	1	65	5h	52	10000			16900
WP-1300	Risk and threats management	0/A	2	65	4h	52				27040
WP-1400	QA/PA	C/D	2	238	4h	52				99008
WP-1500	Cost estimation	B	1	42	4h	52				8736
WP-1600	Development planning	0/A-B-C-D-E	1	433	8h	52				180128
WP-1700	Final delivery	E	1	22	8h	52				9152
WP-2110	Definition of requirements	0/A	2	23	3h	52				7176
WP-2120	Constraints analysis	0/A	2	20	2h	52				4160
WP-2210	Analysis of needs and objectives	0/A	2	43	3h	52				13416
WP-2220	Definition of success metrics	0/A-B	2	20	2h	52				4160
WP-2230	Stakeholders identification	0/A-B	3	23	6h	52	10000			31528
WP-3110	Structure	B-C/D	2	238	5h	52			43100	166860
WP-3120	Thermal control	B-C/D	2	238	5h	52				123760
WP-3130	On-board power supply	B-C/D	2	238	5h	52			82000	205760
WP-3140	Attitude control	B-C/D	2	238	5h	52			99226	222986
WP-3200	Payload	B-C/D	4	345	6h	52			7772	438332
WP-3310	MGSE	C/D	2	107	5h	52				55640
WP-3320	EGSE	C/D	2	107	5h	52			25000	80640
WP-4100	Ground segment	B-C-D-E	1	413	2h	52		30000		72952
WP-4200	Launch	B-C-D-E	1	413	2h	52	10000	330000		382952
WP-5100	Each component test	D	3	64	4h	52				39936
WP-5200	Microgravity simulation on Earth	D-E	4	43	4h	52				35776
WP-6100	Integration of spin stabilization system	E	2	110	6h	52				68640
WP-6200	Integration of electric propulsion cell	E	2	110	6h	52				68640
WP-7110	Facilities	B-C-D-E-F	2	436	4h	52				181376
WP-7120	Software	B-C-D-E-F	2	436	4h	52				181376
WP-7210	Mission data collection	After	3	129	4h	52				80496
WP-7220	Report	After	3	129	4h	52				80496
TOTAL COSTS										**2839558**

Tab. 2

(*) Launch cost estimated considering 3.99 kg/3U Cube sat 10x10x30 cm on SpaceX (Falcon 9) website.
https://www.spacex.com/rideshare/

The cost we estimate is € 2,839,558.
Using the exchange rate 1.04, the total cost is approximately **$ 2,953,140**.

Given the cost of each WPD and the total mission cost, it is possible to calculate the percentage impact of each macro-task. This allows for a clear understanding of how each component contributes to the overall budget, enabling more effective cost management and resource allocation. By Tab. 3:

WP	Name	Costs [€]	Percentage (%)
1000	Management	348140	12%
2000	Mission Analysis	60440	2%
3000	Space Segment	1250878	45%
4000	Services	455904	16%
5000	AIT	75712	2%
6000	AIV	137280	5%
7000	Mission Operations	523744	18%

Tab. 3

8.1 Cost Model

Evaluating the costs of a space mission is a fundamental step in ensuring the success and feasibility of the project. For CubeSat missions, in particular, there is no officially established Cost Model dictated by ESA regulations. This lack of standardized guidance has been avoided by developing a cost model, tailored to the specific needs of CubeSat projects.

Using MATLAB, it has been implemented a model based on linear regression, capable of analyzing and predicting costs by translating categorical information, such as Scope, Continent and Agency into binary code (0 or 1). This approach allowed to process the string-based data present in the dataset effectively and integrate it into the regression framework.

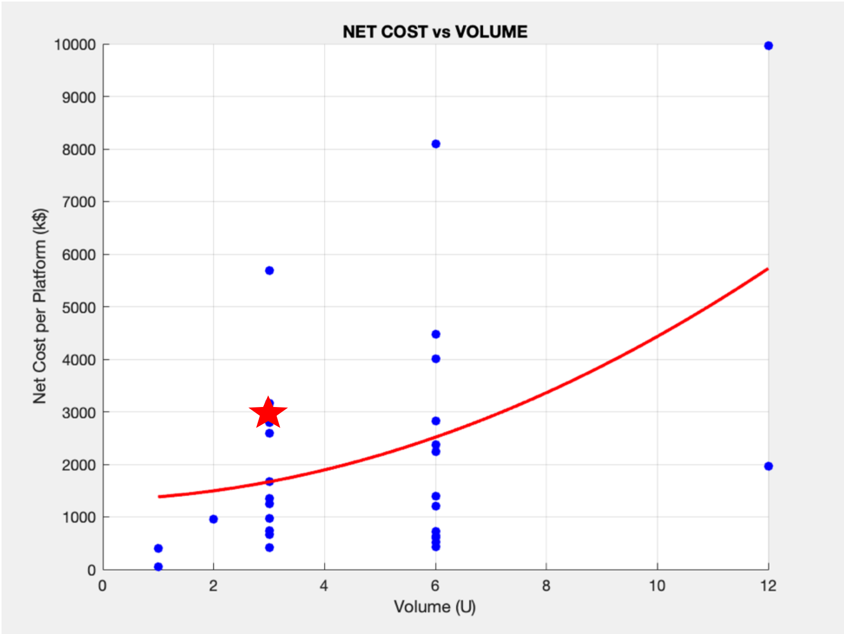
The dataset, compiled in the following *Excel table (Tab. 4)*, contains various attributes relevant to CubeSat missions. It includes information such as the satellite's name, its size expressed in U-units (1U, 3U, 6U, 12U), the Net Cost per Platform, the type of organization managing the mission (civil, military, or academic), the mission's purpose (communication, Earth observation, or in-orbit demonstration), and the continent associated with the project (EU, Africa, Asia, America). These parameters form the basis for cost estimation model and serve as key predictors in the regression analysis.

NAME	VOLUME (U)	NET COST PER PLATFORM (k$)	AGENCY	SCOPE	CONTINENT
MIR-SAT1	1	401,55	Civil	Communication	AFRICA
NARSSCube-2	1	56,55	Civil	IOD	AFRICA
KuwaitSat	2	963,08	Academic	Earth Observation	ASIA
SEAM 2.0	3	2928,58	Academic	IOD	EU
SOAR	3	5689,63	Academic	IOD	EU
OPS-SAT	3	2588,58	Civil	IOD	EU
NEPTUNO	3	2789,63	Civil	Earth Observation	EU
GEMS (Orbital Micro Systems)	3	415,74	Civil	IOD	EU
KELPIE-1	3	2939,63	Civil	Communication	EU
PIXL-1	3	1669,63	Civil	IOD	EU
AeroCube-14	3	970,74	Military	IOD	AMERICA
LLITED	3	1249,63	Civil	Earth Observation	AMERICA
DEORBITSAIL	3	3166,81	Civil	IOD	EU
IOD-1 GEMS	3	730,74	Civil	Earth Observation	EU
SeaHawk	3	1348,13	Academic	Earth Observation	AMERICA
Kepler 3 TARS	6	720,40	Civil	Communication	AMERICA
Kleos Space	6	604,25	Civil	Earth Observation	EU
VPM	6	4479,25	Military	IOD	AMERICA
CatSat	6	429,25	Academic	Earth Observation	AMERICA
DAILI	6	2829,25	Civil	Earth Observation	AMERICA
Unknown DARPA CubeSat	6	4479,25	Military	IOD	AMERICA
EPICHyper	6	4012,58	Civil	Earth Observation	EU
ET-SMART-RSS	6	1396,96	Civil	Earth Observation	AFRICA
FACSAT	3	666,08	Military	Earth Observation	AMERICA
NSLSat	6	607,16	Civil	IOD	ASIA
MACSAT	6	2240,40	Civil	Communication	EU
Tiger-2	6	2379,25	Civil	Communication	EU
Kleos scouting mission (KSM1)	6	639,17	Civil	Earth Observation	EU
BRO (ONE)	6	515,66	Civil	Earth Observation	EU
Faraday-1	6	1204,25	Civil	Communication	EU
TEMPEST-D	6	8091,47	Academic	Earth Observation	AMERICA
Exoterra CubeSat	12	1958,50	Civil	IOD	EU
XVI	12	9958,50	Military	Communication	AMERICA

Tab. 4

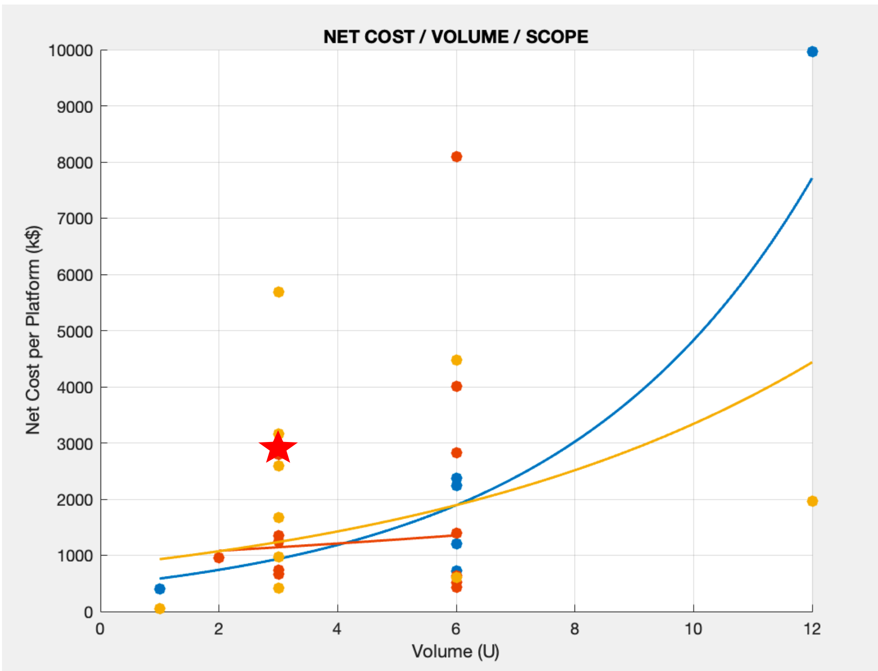
THETHYS mission involves a 3U CubeSat with an academic scope, focused on in-orbit demonstration (IOD), and geographically tied to Europe.

Using the MATLAB-based model, it has been interpolated the costs of missions with similar characteristics to generate an estimated cost value, referring to Volume (U). This estimated cost, derived from the regression line, was then compared to the actual cost of the mission, previously evaluated.



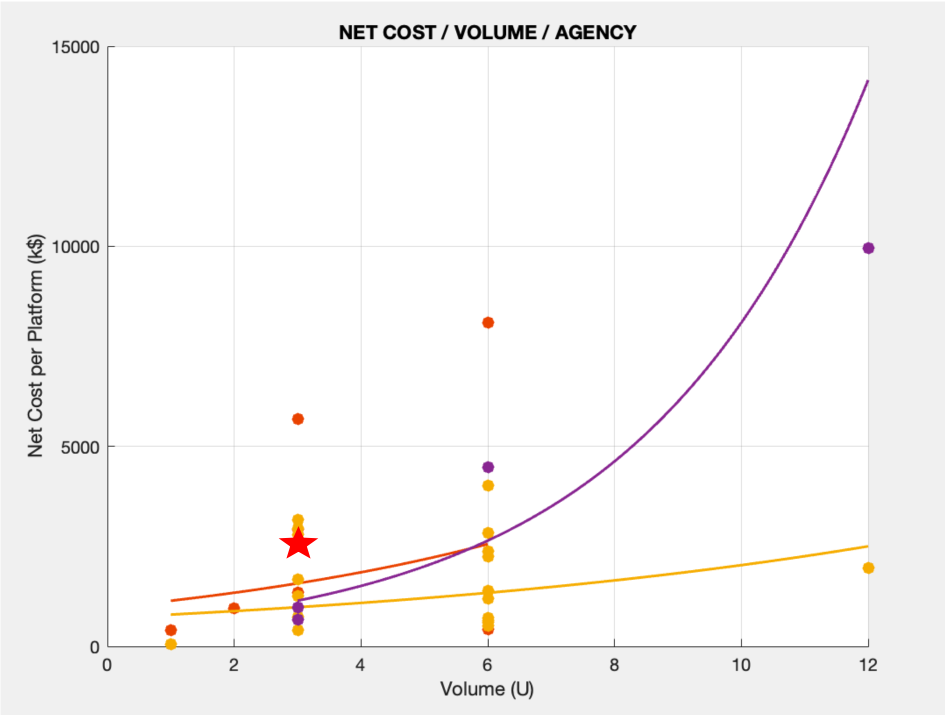
THETYS cost mission is approximately $ 2,908,316 (indicated with a star).
On the regression line, the value is $ 1,667,020.
Referring to **3U Volume**, the final GAP as difference between the two costs is:

$$GAP = 2{,}908{,}316 - 1{,}667{,}020 = 1{,}241{,}296\ \$$$



Referring to **IOD scope (red line)**, the GAP as difference between the two costs is:

$$GAP = 2{,}789{,}630 - 1{,}144{,}111 = 1{,}645{,}519\ \$$$



Referring to **Academic Agency (red line)**, the GAP as difference between the two costs is:

$$GAP = 2{,}928{,}580 - 1{,}575{,}975 = 1{,}352{,}605\ \$$$

These three significant gaps can be attributed to the experimental nature of the Thetys mission, which does not align with any of the missions previously recorded in the dataset.
The unique characteristics of this mission make it inherently challenging to fit within the boundaries of the regression model, which was developed based on historical data and relies on patterns observed in past CubeSat missions.

Chapter 9

9. Conclusion

The Thetys Mission represents a significant step forward in the pursuit of clean energy solutions, directly supporting Goal 7 of the United Nations 2030 Agenda, which aims to ensure access to affordable, reliable, sustainable, and modern energy for all, through its innovative approach to demonstrating the feasibility of electrolysis in space.

As a research-oriented mission with a Technology Readiness Level (TRL) of 2 for its payload, Thetys has included a dedicated six-month post-mission phase to thoroughly collect and analyze experimental data. This extended period allows for an in-depth evaluation of the electrolysis process in microgravity, ensuring that the findings contribute meaningfully to both the scientific community and future technological development.

The data and insights generated by Thetys hold considerable promise for the future. The validated processes could support long-duration space exploration by enabling the production of hydrogen as a clean propellant and oxygen for life-support systems.

The success of Thetys underscores the role of space exploration as a catalyst for innovation, with the potential to address some of the most pressing challenges on Earth. By demonstrating the feasibility of space-based clean energy production, the mission has paved the way for future initiatives that integrate sustainability into both space and Earth-bound energy systems.

This accomplishment highlights the profound interconnectedness of space research and global development goals, ensuring a legacy that extends well beyond the immediate scope of the mission.