Universidad Politécnica de Madrid
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MÁSTER UNIVERSITARIO EN SISTEMAS ESPACIALES

WBS and Gantt's chart

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1. Introduction

Project planning is one of the key points for the successful development of a project. It helps to meet the requirements for a given time and cost, to identify the possible risks along the mission in advance and to identify and distribute the tasks.

Some management visual tools are the Gantt's Chart and the WBS.

2. Gantt's chart

A Gantt chart, is a visual project management tool that displays tasks or activities on a timeline, helping to plan, coordinate, and track project progress over time.

In a Gantt chart, the critical path represents the sequence of tasks that directly affects the project's completion date. Any delay in a critical-path task will delay the entire project unless adjustments are made elsewhere. Identifying and monitoring the critical path is essential for ensuring that a project stays on schedule, especially in complex projects like space missions. In this specific case, the critical path is shown as the darker tasks marked in the chart.

The Gantt chart is just one but, since it is very big, we decided to split it into the different phases of the project even though all tasks are related on time and some phases can start while other are not finished yet.

2.1 Phase 0: Mission Analysis-Need Identification

This phase is essential for defining and assessing the initial idea, understanding the mission objectives, and evaluating technical and economic feasibility. It establishes the foundational scope, requirements, and constraints that will guide the project in later stages.

The mission definition review (MDR) is held at the end of Phase 0. After this is approved the project will move on to Phase A.

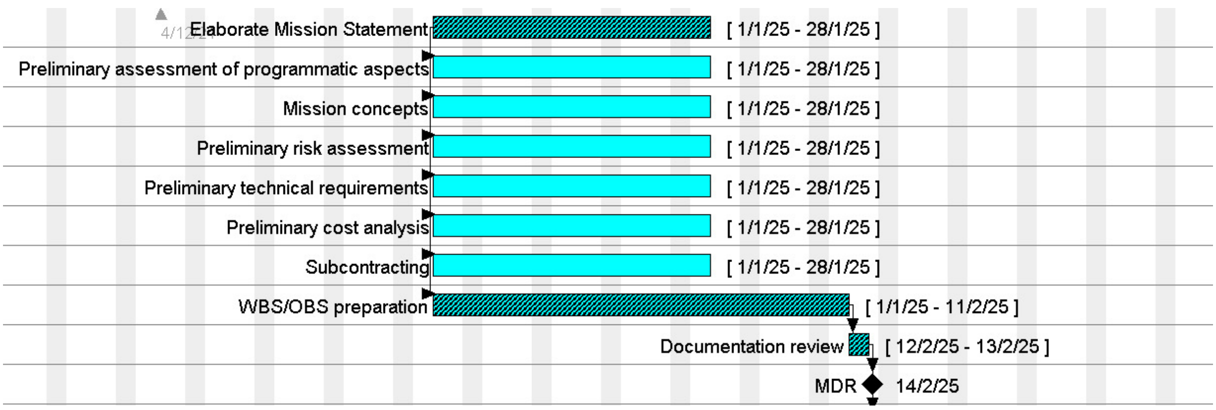


Figure 2.1: Phase 0 Gantt Chart

During Phase 0, the following key processes are carried out:

- **0.01.** Elaborate mission statement [20 days]
  - In terms of identification and characterization of the mission needs, expected performance, dependability and safety goals and mission operating constraints with respect to the physical and operational environment.

- **0.02.** Preliminary assessment of programmatic aspects [20 days]
  - Conduct an initial evaluation of the program's overall feasibility, including a review of scheduling, resource allocation, and any preliminary constraints.
  - Assess programmatic factors such as team organization, timeline, potential stakeholders, and funding requirements.
- **0.03.** Mission concepts [20 days]
  - Identify and explore multiple mission concepts that could meet the mission objectives.
  - Conduct an analysis of each concept's feasibility, considering factors like mission design, orbital configurations, and payload requirements.
  - Select the most promising mission concepts to carry forward based on an assessment of their technical feasibility, cost, and alignment with mission goals.
- **0.04.** Preliminary risk assessment [20 days]
  - Identify high-level risks that could impact the project, including technical, financial, and operational risks.
  - Analyze and categorize risks by severity and likelihood to form a preliminary risk register.
  - Develop initial strategies for risk mitigation and assign risk management responsibilities.
- **0.05.** Preliminary technical requirements [20 days]
  - Outline the preliminary technical requirements necessary to achieve mission objectives.
  - Include high-level specifications for the spacecraft, payloads, mission operations, and ground segment.
  - Ensure these requirements provide a baseline for design decisions in future phases.
- **0.06.** Preliminary cost analysis [20 days]
  - Perform an initial cost estimation for the project, accounting for major expense categories like design, development, testing, launch, and operations.
  - Provide an early budget breakdown to support financial feasibility studies and planning for resource allocation.
- **0.07.** Subcontract of organizations for tasks that our company can´t perform [20 days]
  - Identify specialized tasks or areas where the company lacks the in-house capability.
  - Select and subcontract suitable external organizations or partners to perform these tasks.

  - Define the scope, timeline, and deliverables for each subcontracted task, and integrate these into the project's broader schedule.

- **0.08.** WBS/OBS preparation (final fase A) [30 days]

- **0.09.** Documentation review [2 days]

- **0.10.** MDR [0 day]

  - Conduct the Mission Definition Review to formally assess the outputs of Phase 0.
  - Present findings, including the mission statement, concepts, risk assessment, technical requirements, cost analysis, and proposed WBS/OBS, to stakeholders for validation.
  - Obtain approval to proceed to Phase A, addressing any feedback or required modifications that may arise during the review.

2.2 Phase A: Feasibility

This is mainly an activity conducted by the top level customer and one or several first level suppliers with the outcome being reported to the project initiator, and representatives of the end users for consideration.

The preliminary requirements review (PRR) is held at the end of Phase A. The outcome of this review is used to judge the readiness of the project to move into Phase B.

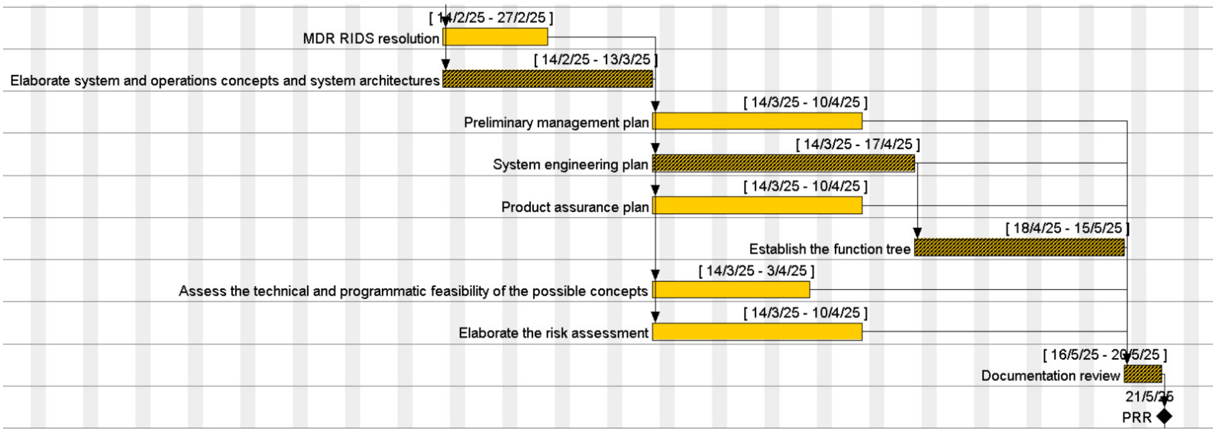


Figure 2.2: Phase A Gantt Chart

During Phase A, the following key processes are carried out:

- **A.01.** MDR RIDs resolution [20 days]

  - Adress the Requirements Identification Documents (RIDs) generated from the Mission Document Review (MDR)

- **A.02.** Elaborate system and operations concepts and system architectures [25 days]
  - Elaborate possible system and operations concepts and system architectures and compare these against the identified needs, to determine levels of uncertainty and risks
- **A.03.** Preliminary management plan [20 days]
  - The Preliminary Project Management Plan shall describe the project management philosophy, the plan, and schedule for executing the Project, and how Proposer plans to achieve and satisfy the requirements
- **A.04.** System engineering plan [25 days]
  - Describes the approaches, techniques, tools, organization, planning and scheduling of the technical effort to accomplish the project objectives.
- **A.05.** Product assurance plan [20 days]
  - The objective of the PAP is to describe the activities to be performed by the supplier to assure the quality of the space product with regard to the specified mission objectives and to demonstrate compliance to the applicable PA requirements.
- **A.06.** Establish the function tree [20 days]
  - The objective of the function tree document is to describe the hierarchical decomposition of a system or product capabilities into successive level of functions and sub-functions
- **A.07.** Assess the technical and programmatic feasibility of the possible concepts [15 days]
- **A.08.** Elaborate the risk assessment [20 days]
  - Identify critical technologies and propose pre-development activities. Quantify and characterize critical elements for technical and economic feasibility.
- **A.09.** Documentation review [3 days]
- **A.10.** PRR [0 days]
  - System and operations concept(s) and technical solutions, including model philosophy and verification approach, to be further elaborated during Phase B. The outcome of this revies is used to judge the readiness of the project to move into Phase B

2.3 Phase B: Preliminary Definition

During this phase, an initial project baseline is establish by the project team, which should be sufficiently matured. Its main purposes are to develop consistent project's planning, verification process, design, cost and schedule baselines.

The phase ends with the preliminary design review (PDR), which reflects the successful transformation of requirements into designs.

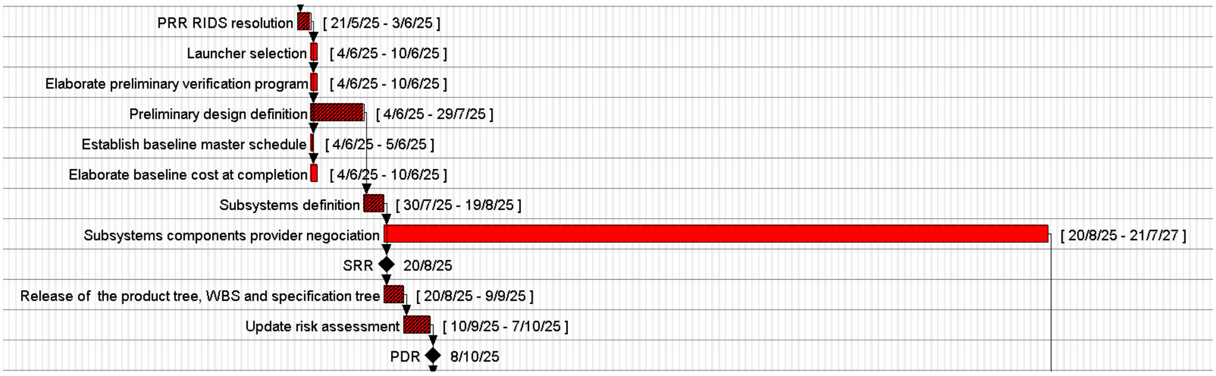


Figure 2.3: Phase B Gantt Chart

The critical path of phase B is composed of the following tasks: PER RIDS resolution, Preliminary design definition, Subsystem definition, Subsystems components provider negotiation, Launcher selection, SRR, Elaborate the product tree, WBS and specification tree, Update risk assessment and PDR, in that specific order. Given that proper planning of mission definition is crucial to avoid delays or lack of resources in subsequent phases, following the critical path without delays is crucial.

During Phase B, the following key processes are carried out:

- **B.01.** PRR RIDS resolution [10 days]
  - Address the Requirements Identification Documents (RIDs) generated from the Preliminary Requirements Review (PRR).
- **B.02.** Launcher selection [5 days]
  - Define launch requirements, including payload weight, orbit and other parameters.
  - Investigate launch options and make a selection based on compatibility, cost, availability and reliability.
- **B.03.** Elaborate preliminary verification program [5 days]
  - Define the preliminary verification methods.
  - Develop a preliminary verification matrix that links each requirement to a verification method.

- **B.04.** Preliminary design definition [40 days]
  - Create a preliminary design specifying the main components and their functions.
- **B.05.** Establish baseline master schedule [2 days]
  - Identify key deliverables of the project.
  - Create a Gantt's chart.
- **B.06.** Elaborate baseline cost at completion [5 days]
  - Estimate the cost of the project.
  - Identify risks of cost variations and establish contingencies for cost overruns.
- **B.07.** Subsystems definition [15 days]
  - Specify the functions, interfaces and responsibilities of each subsystem.
  - Create initial design concepts for each subsystem.
- **B.08.** Subsystems components provider negociation [501 days]
  - Identify and begin negotiations with potential suppliers for components.
- **B.09.** SRR (Systems Requirements Review) [1 days]
  - Ensure that requirements are complete, clear and feasible.
- **B.10.** Release the product tree, WBS and specification tree [15 days]
  - Define project planning and monitoring.
- **B.11.** Update risk assessment [20 days]
  - Review and update the project risk assessment to take into account new or changing risks.
- **B.12.** PDR [1 days]
  - Evaluate project readiness to proceed to detailed design.

2.4 Phase C: Detailed Definition and Planning for Production

Phase C of a space project is a critical stage dedicated to exhaustive planning and detailed design definition, without yet carrying out the physical production of the system. This phase occurs after establishing requirements and completing the preliminary design in previous phases (A and B), and its main objective is to ensure that the design is fully defined and ready to proceed to the manufacturing phase in Phase D.

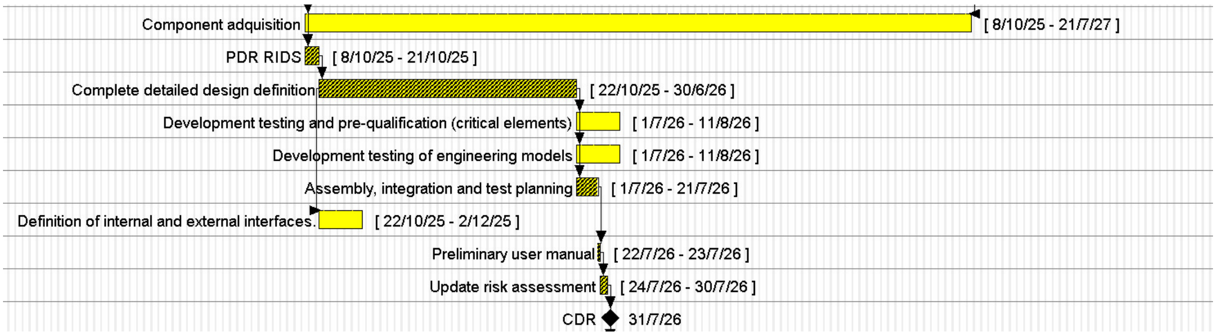


Figure 2.4: Phase C Gantt Chart

During Phase C, the following key processes are carried out:

- **C.01.** Resolution of PDR RIDs [10 days]
  - Address the Requirements Identification Documents (RIDs) generated from the Preliminary Design Review (PDR)
- **C.02.** Complete detailed design definition [180 days]
  - This process involves creating detailed specifications for each subsystem, ensuring that all components and subsystems are fully defined, compatible, and integrated within the overall system. It includes finalizing parameters, configurations, and resolving any design ambiguities.
- **C.03.** Selection and development testing for critical components [30 days]
  - Critical components are identified and planned for selection, along with defining the necessary pre-qualification tests.
- **C.04.** Definition of tests for engineering models [30 days]
  - Plan and document system-level integration tests to confirm that engineering models meet design requirements and mission needs. .
- **C.05.** Assembly, integration, and test Planning [15 days]
  - Create an integration and test plan, including a schedule and procedures to ensure smooth assembly and proper subsystem functioning.
- **C.06.** Definition of internal and external interfaces [30 days]
  - At this stage, specifications for interfaces between the various subsystems and with other external systems are formalized. This ensures that each subsystem can communicate and operate correctly with the others during final integration.
- **C.07.** Preliminary user manual [2 days]
  - A preliminary version of the user manual is created, containing basic operating and safety instructions. This initial manual will serve as the basis for the final manual, incorporating feedback from users or stakeholders.

- **C.08.** Risk assessment update [5 days]
  - As the detailed design is completed, the risk assessment is reviewed and updated. This helps to identify any risks associated with the new specifications and adjust mitigation strategies.
- **C.09.** Critical Design Review (CDR) [1 day]
  - The phase culminates in the Critical Design Review (CDR), an exhaustive review that evaluates the maturity of the design before moving to the following phase.
- **C/D.01.** Components acquisition and monitoring process. [466 days]
  - Although this task is defined in this section, it can be finished after the CDR, before the assembly starts. This activity covers the procurement and monitoring process for Commercial Off-The-Shelf (COTS) components required for the system. Since third-party components are used, rigorous oversight is necessary to ensure their availability and quality. This phase spans the entire development process to mitigate risks associated with logistics and component compatibility.

2.5 Phase D: Qualification and Production

The D phase is dedicated to production and system testing tasks. For our mission, two specific characteristics significantly impact this phase. Firstly, Commercial Off-The-Shelf (COTS) components will be used, meaning production tasks shift towards component procurement and synergy testing. Secondly, the system is a constellation, which requires assembling multiple platforms. The strategy will involve assembling a single platform for initial testing, followed by the assembly of additional platforms to ensure they all meet required standards.

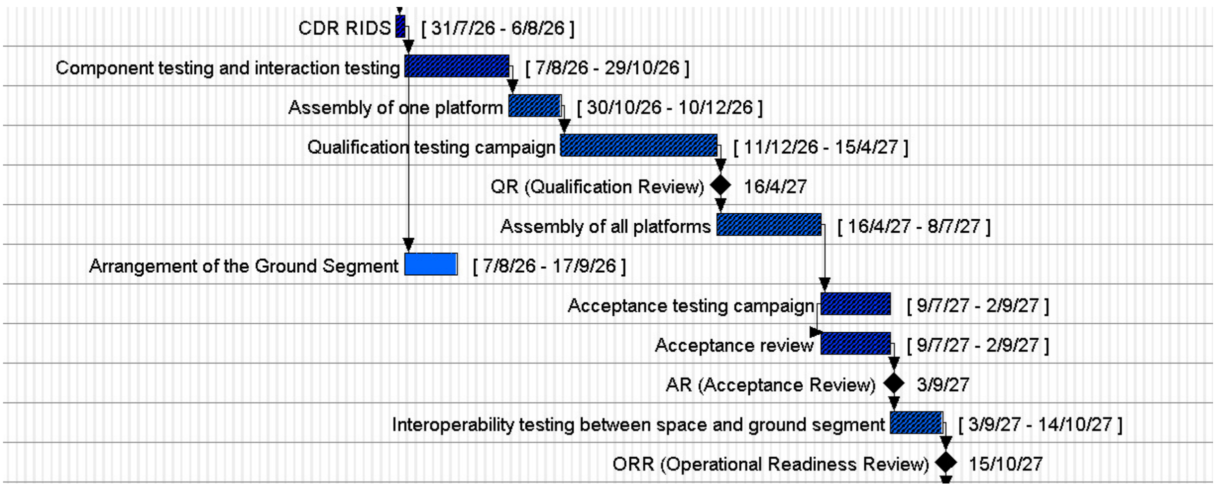


Figure 2.5: Phase D Gantt Chart

During Phase D, the following key processes are carried out:

- **D.01.** Resolution of Critical Design Review (CDR). [5 days]
  - This milestone marks the finalization of the Critical Design Review (CDR). Addressing any remaining issues from the CDR ensures that the design is ready for the subsequent phases of production and testing.
- **D.02.** Component testing and interaction testing. [60 days]
  - In this step, individual components are rigorously tested for functionality and quality. Furthermore, synergy tests are conducted to evaluate how well the components interact within the system, ensuring compatibility and optimal performance when integrated.
- **D.03.** Assembly of one platform. [30 days]
  - The first platform is assembled to serve as a prototype or baseline model for testing. This single-platform assembly allows for initial assessments of integration, ensuring that all components work together as expected before producing the remaining platforms.
- **D.04.** Qualification testing Campaign. [90 days]
  - This campaign involves testing the platform under simulated environmental conditions, such as temperature extremes, vacuum, and radiation, which it will encounter in space. These tests verify the durability and performance of the platform in harsh conditions, essential for mission reliability.
- **D.05.** QR (Qualification Review). [1 day]
  - The Qualification Review (QR) is a formal evaluation to confirm that the system meets all technical and functional requirements. This review marks the readiness of the system for final integration and operational testing.
- **D.06.** Assembly of all platforms.[60 days]
  - This campaign involves testing the platform under simulated environmental conditions, such as temperature extremes, vacuum, and radiation, which it will encounter in space. These tests verify the durability and performance of the platform in harsh conditions, essential for mission reliability.
- **D.07.** Arrangement of the Ground Segment.[30 days]
  - The ground segment, responsible for communication, control, and data handling for the constellation, is set up during this phase. This includes configuring hardware, software, and network systems necessary to support the mission's ground operations.
- **D.08.** Acceptance testing campaign. [40 days]
  - This phase focuses on performing the final integration and operational testing.
- **D.09.** AR (Acceptance Review). [1 day]

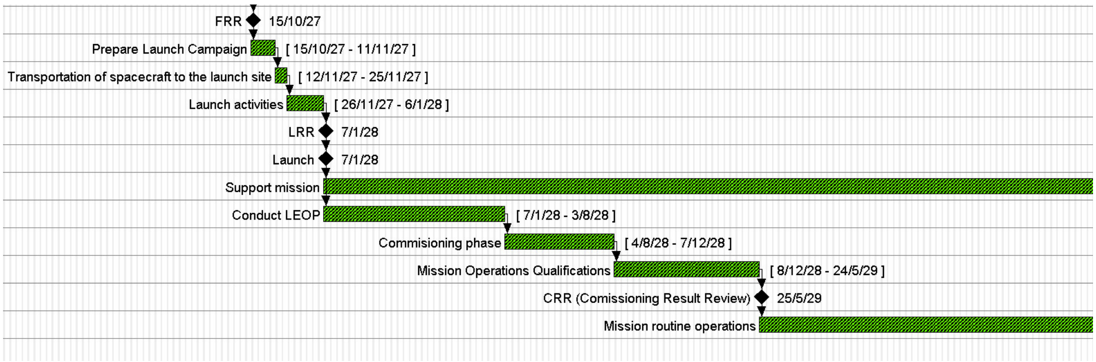
- The Acceptance Review (AR) is conducted to verify that the completed system meets all contractual and mission-specific requirements. This step serves as a final quality control check before full operational deployment.

- **D.10.** Interoperability testing between space and ground segment.[30 days]
  - This phase focuses on testing the communication and coordination between the space platforms and the ground segment. Interoperability testing ensures reliable data transmission and control commands, essential for successful mission operations.

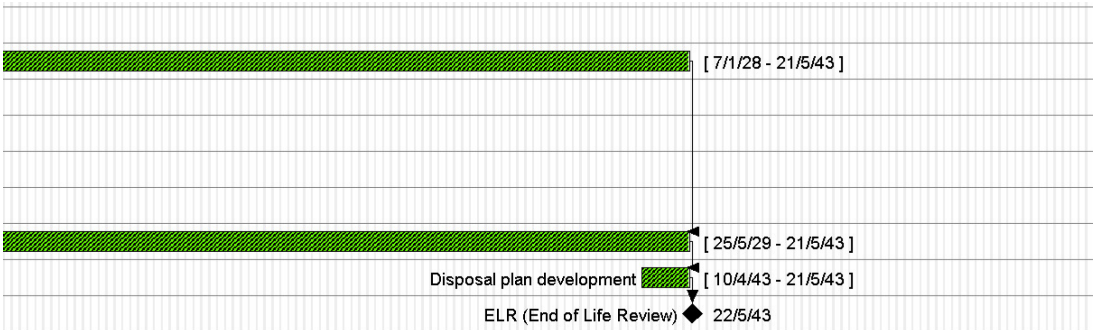
- **D.11.** ORR (Operational Readiness Review). [1 day]
  - The Operational Readiness Review (ORR) is the concluding evaluation to confirm that the entire system—including space and ground segments—is fully prepared for active operations. This review ensures that all necessary resources, personnel, and procedures are in place for mission launch and sustained operations.

2.6 Phase E: Utilization

Encompasses the active mission phase, where the satellite performs its operational tasks and provides the intended services. This includes routine monitoring and adjustments, data collection, and maintenance activities to ensure mission success. Toward the end of this phase, steps are taken to safely decommission the satellite, including developing and executing a disposal plan that aligns with space sustainability practices.



(a) Phase E first half Gantt chart



(b) Phase E second half Gantt chart

Figure 2.6: Phase E Gantt chart

In the Phase E Gantt chart we can see that all the tasks are part of the critical path, even though some are carried at the same time. Two paths can be distinguished:

- **First critical path:** This path focuses on mission support activities, which are essential for operational readiness and mission sustainment. These activities are driven by operational requirements, ensuring that the satellite functions correctly and meets mission objectives throughout its lifespan.
- **Second critical path:** This path is centered around maintenance qualifications and documentation. This path ensures that all operations are validated, properly documented, and meet the necessary standards for safety and compliance. It also addresses the procedural aspects of the mission, including the structured transition to end-of-life procedures and the final ELR (End of Life Review).

Having two critical paths allows the project to manage mission continuity and regulatory compliance separately. This approach reduces risks by ensuring that operational functionality and end-of-life disposal standards are both met independently.

Both critical paths are essential for mission success: the first ensures the satellite enters operational service, while the second ensures a controlled disposal.

During Phase E, the following key processes are carried out:

- **E.01.** FRR (Flight Readiness Review) [0 day]

  - Test the vehicles is flightworthy, correctly instrumented and conformed (if required). Assesses the readiness to initiate and conduct flight tests or operations.

- **E.02.** Prepare Launch Campaign [20 days]
  - The launch campaign includes the assembly of the satellite, integration of the payload and components, and the preparations of the ground stations.
- **E.03.** Transportation of spacecraft to the launch site [10 days]
  - Involves the safe transport of the satellite or constellation from manufacturing and integration facilities to the launch site, following all safety and protection protocols for the space vehicle.
- **E.04.** Launch activities [30 days]
  - Encompasses all pre-launch tasks, including final checkouts, fueling operations, and verification of launch windows availability.
- **E.05.** LRR (Launch Readiness Review) [0 days]
  - This review demonstrates that the spacecraft meets launch vehicle requirements.
- **E.06.** Launch [1 day]
  - The launch itself is executed, ensuring the satellite is placed into the intended orbit or transfer trajectory.
- **E.07.** Support mission [4010 days]
  - All necessary mission support operations are conducted, such as coordinating and monitoring systems from the ground to ensure proper performance.
- **E.08.** Conduct LEOP (Launch and early orbital operations) [150 days]
  - Consists of the insertion and stabilization of the satellite into its final orbit, ensuring it is in a safe and stable condition for continued operations.
- **E.09.** Commisioning phase [90 days]
  - This phase verifies and configures all satellite systems for full operability, performing validation tests for all subsystems and payloads.
- **E.10.** Mission Operations Qualifications [120 days]
  - Involves qualifying the mission operations, ensuring that all systems and operational procedures meet the mission's requirements.
- **E.11.** CRR (Comissioning Result Review) [0 days]
  - Final review of commissioning results to confirm that the satellite has achieved operational capability and is ready to begin its mission in optimal conditions.
- **E.12.** Mission routine operations [3650 days]

- Involves the ongoing monitoring, control, and maintenance of the satellite to ensure consistent performance and mission success. This includes tracking, telemetry analysis, and making any necessary adjustments to systems.

- **E.13.** Disposal plan development [30 days]
  - The development of a plan to safely decommission the satellite at the end of its operational life, following regulatory guidelines.
- **E.14.** ELR (End of life review) [0 day]
  - A final assessment that verifies that all end-of-life procedures are correctly executed, ensuring the safe disposal of the satellite in accordance with space sustainability practices.

2.7 Total duration of the project

The critical path of the project determines the total duration of the project, which is the minimum time needed to complete the project. In the following, the duration of each phase will be dictated:

- **Phase 0**: 32 days
- **Phase A**: 73 days
- **Phase B**: 102 days
- **Phase C**: 213 days
- **Phase D**: 318 days
- **Phase E**: 4010 days

The sum of the critical paths of each project phase determines the critical path of the project itself. In other words, it determines the time frame within which the project must be completed:

- **Total duration of the project**: 4449 days

The estimated time from project creation to launch is **799 days** ($\sim$ 2'20 years).

On the other hand, the mission time from launch is **4010 days** (years).

3. WBS

The Work Breakdown Structure (WBS) diagrams presented here breaks down the main activities of the Atlantis 2025 project into different work levels, organized hierarchically to provide a clear view of the tasks and responsibilities in each segment.

3.1 Nomenclature

The nomenclature used to number the Work Packages (WPs) in the Work Breakdown Structure (WBS) diagram is designed to be intuitive and logical, making it easier to identify each work package and its relationship within the overall project structure.

Detailed breakdown of the nomenclature:

- Main Work Packages:
  - The main Work Packages (WPs) are sequentially numbered from 0 to 4. Each of these numbers represents a fundamental block of work within the project.
  - This straightforward numbering allows for quick identification of key sections and provides a high-level view of the primary work areas.
- Secondary Work Packages:
  - Each main Work Package may be divided into several sub-packages, or secondary Work Packages.
  - These secondary WPs are numbered by adding a sub-number to the main number. For example, if the main WP is "1," the secondary WPs would be numbered "1.1," "1.2," "1.3," etc.
  - This scheme indicates that Work Packages "1.1" and "1.2" are part of the main WP "1" and break down specific activities within this main block.
- Subdivision of Secondary Work Packages:
  - The secondary WPs can be further divided into additional sublevels, creating tertiary WPs for more detailed tasks or activities.
  - The nomenclature for these tertiary WPs is achieved by adding a third number to the secondary sub-number, following the same hierarchical pattern. For example, within secondary WP "2.3," sub-packages would be labeled "2.3.1," "2.3.2," "2.3.3," and so forth.
  - This allows for a granular identification of each specific task or activity, facilitating the assignment of responsibilities and the tracking of detailed activities within the overall WBS structure.

3.2 WBS

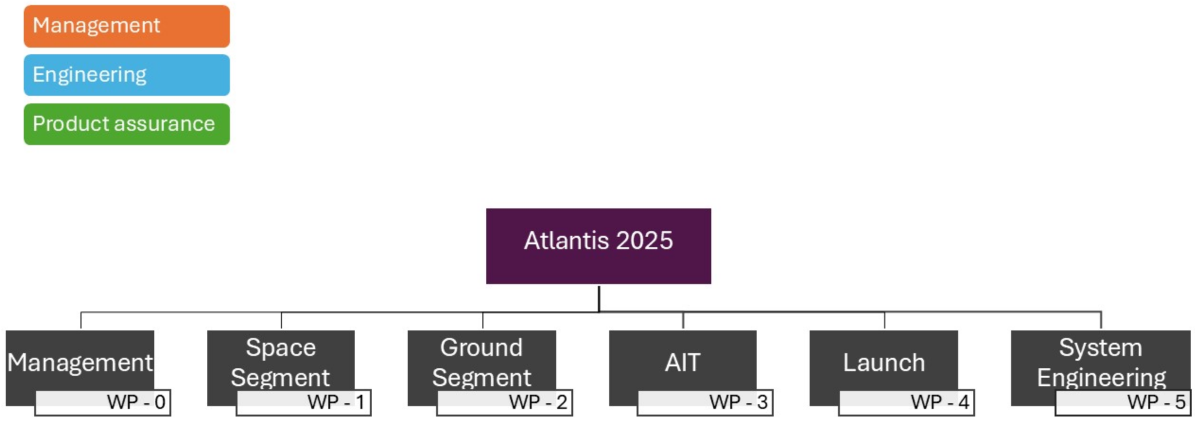


Figure 3.1: WBS Atlantis 2025

The first diagram shows the overall WBS structure for the "Atlantis 2025" project. This project is divided into five key segments:

- **Management (WP-0)**: Responsible for the planning, oversight, and overall control of the project, ensuring that objectives related to time, cost, and quality are met.
- **Space Segment (WP-1)**: Comprises all activities related to the development and construction of the space segment, which includes the satellites and any associated in-orbit equipment.
- **Ground Segment (WP-2)**: Includes the ground infrastructure necessary to control and operate the satellites, as well as data reception stations.
- **AIT Facilities (WP-3)**: Represents the facilities and resources needed for assembly, integration, and testing (AIT) of the project's components and subsystems.
- **Launch (WP-4)**: Focuses on launch-related activities, including logistics and coordination with launch service providers.
- **System Engineering (WP-5)**: Design, integrate, and manage systems, ensuring that each component functions efficiently together to meet the requirements.

Each segment is identified with a WP (Work Package) code and is visually highlighted according to "Management," "Engineering," and "Product Assurance" areas, providing clear guidance on the roles and approaches involved in each segment.

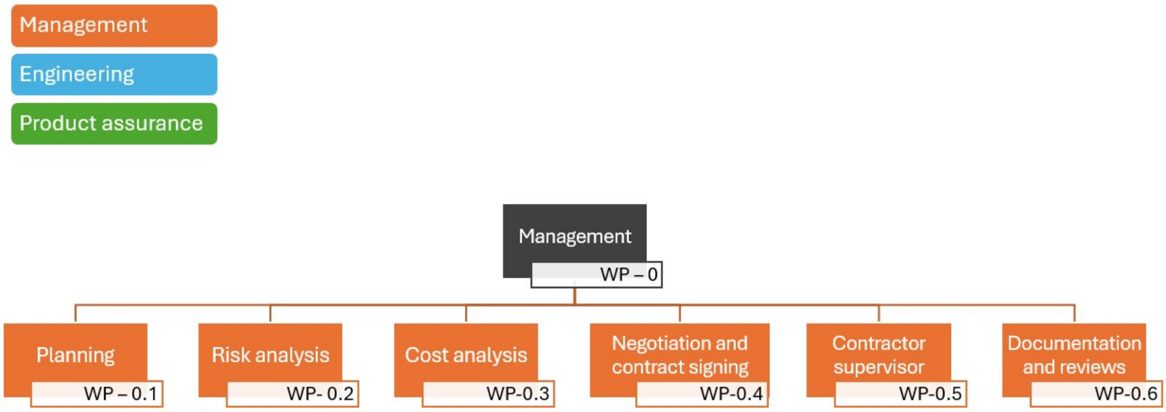


Figure 3.2: WBS Management subsystem

This diagram breaks down the Management (WP-0) work into specific tasks for effective project management:

- **Planning (WP-0.1)**: Includes strategic planning and scheduling for the entire project.
- **Risk Analysis (WP-0.2)**: Consists of identifying and analyzing potential project risks and developing mitigation strategies.
- **Cost Analysis (WP-0.3)**: Focuses on cost estimation and control, ensuring the project stays within the assigned budget.
- **Negotiation and Contract Signing (WP-0.4)**: Involves negotiating and signing contracts with suppliers and strategic partners.
- **Contractor Supervisor (WP-0.5)**: Oversees the work of contractors to ensure they meet agreed standards and timelines.
- **Documentation and Reviews (WP-0.6)**: Includes the creation and maintenance of necessary documentation and periodic project reviews.

This breakdown enables a clear administration of responsibilities and ensures that each aspect of project management is covered, minimizing risks and optimizing resources.

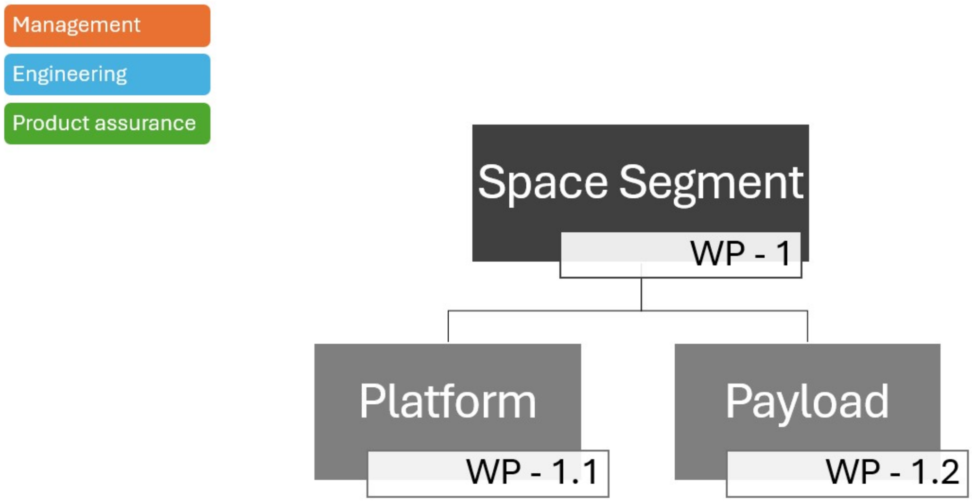


Figure 3.3: Space segment WBS

The diagram focuses on the "Space Segment" (WP-1) of the project, which is divided into two main categories:

- **Platform (WP-1.1)**: Encompasses all the basic subsystems that enable the satellite's operation, including power, attitude control, and communication systems. The platform is essential for supporting and operating the satellite in space.

- **Payload (WP-1.2)**: Refers to the specific instruments and equipment that will carry out the satellite's scientific or technical tasks. The payload is the component responsible for fulfilling the mission's primary objectives.

This initial breakdown organizes the space segment into its two fundamental components: the platform, which ensures the satellite's operation, and the payload, which achieves the mission's goals.

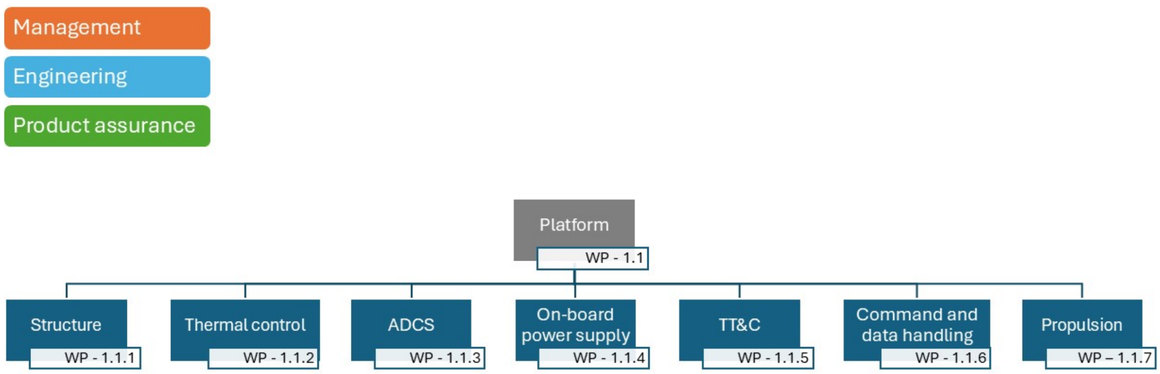


Figure 3.4: WBS for the different Subsystems

The diagram provides a detailed breakdown of the "Platform" (WP-1.1), dividing its functions into the following subsystems:

- **Structure (WP-1.1.1)**: Includes all structural elements that provide support and durability to the satellite.
- **Thermal Control (WP-1.1.2)**: Responsible for maintaining the satellite within operational temperature limits by managing heat.
- **Attitude and Orbit Control (WP-1.1.3)**: This system controls the satellite's orientation and adjusts its orbit as needed.
- **On-board Power Supply (WP-1.1.4)**: Provides and regulates the power supply that fuels all the satellite's systems and subsystems.
- **Telemetry and Communication (WP-1.1.5)**: Enables communication between the satellite and the ground station, including data transmission and telemetry for mission monitoring.
- **Command and Data Handling (WP-1.1.6)**: Manages control commands and data handling within the satellite, ensuring that all operations function correctly.
- **Propulsion (WP-1.1.7)**: Responsible for providing thrust and maneuverability, allowing the satellite to adjust its position and maintain its orbit as required by the mission.

This breakdown of the platform into specific subsystems allows precise management and ensures that each part of the system fulfills its role, optimizing the satellite's overall operation in space.

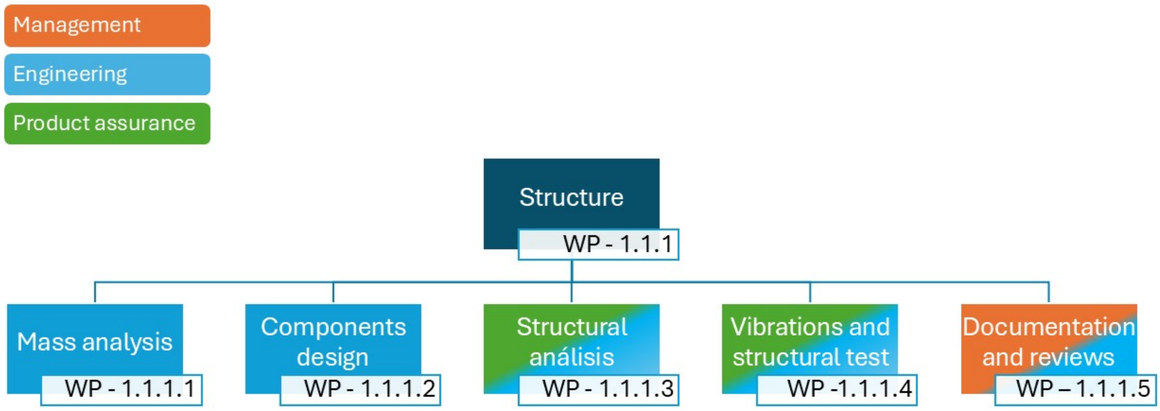


Figure 3.5: WBS for the Structure Subsystem

The diagram focuses on the structure Subsystem (WP-1.1.1) and includes the following tasks:

- **Mass Analysis (WP-1.1.1.1)**: Evaluates the mass distribution and ensures it meets project requirements.

- **Components Design (WP-1.1.1.2)**: Involves designing the structural components to meet system specifications.

- **Structural Analysis (WP-1.1.1.3)**: Analyzes the structural integrity and performance under various conditions.

- **Vibrations and Structural Test (WP-1.1.1.4)**: Conducts tests to verify the structure's ability to withstand vibrations and stresses.

- **Documentation and Reviews (WP-1.1.1.5)**: Involves maintaining documentation and conducting regular reviews for quality assurance.

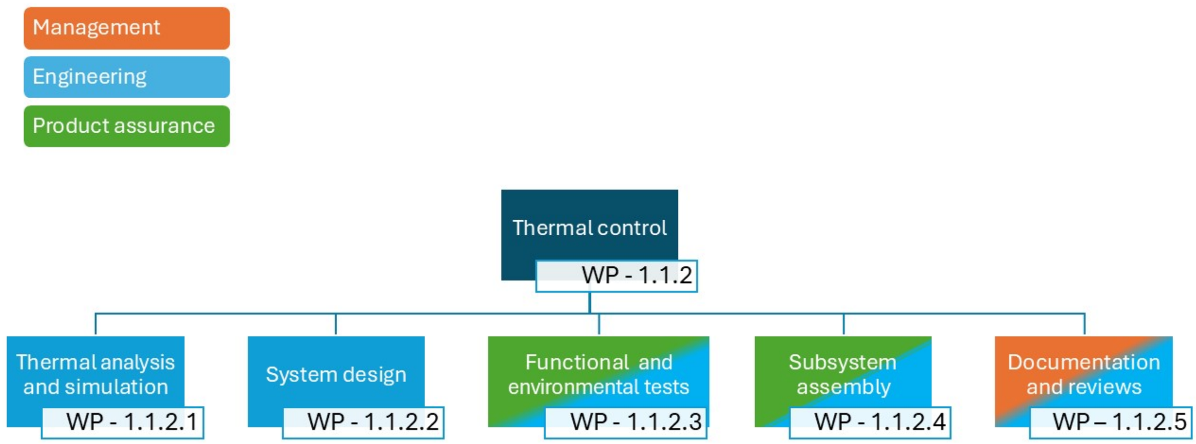


Figure 3.6: WBS for the Thermal control Subsystem

The diagram details the Thermal Control Subsystem (WP-1.1.2), which includes the following tasks:

- **Thermal Analysis and Simulation (WP-1.1.2.1)**: Performs simulations to evaluate thermal behavior under operational conditions.

- **System Design (WP-1.1.2.2)**: Develops the thermal control system design.

- **Functional and Environmental Tests (WP-1.1.2.3)**: Conducts tests to ensure the system operates correctly in its environment.

- **Subsystem Assembly (WP-1.1.2.4)**: Assembles the thermal control subsystem components.

- **Documentation and Reviews (WP-1.1.2.5)**: Involves documenting processes and holding reviews to ensure compliance.

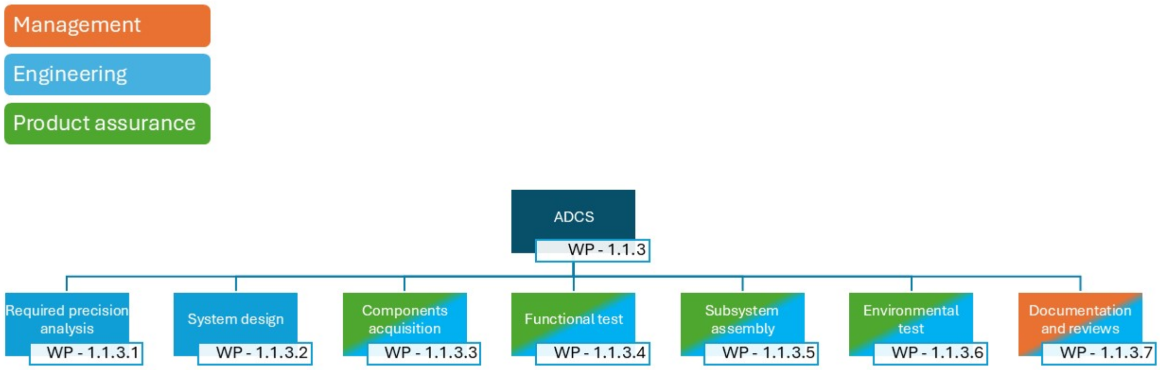


Figure 3.7: WBS for the Attitude and orbit control Subsystem

The diagram focuses on the ADCS Subsystem (WP-1.1.3) and includes these tasks:

- **Required Precision Analysis (WP-1.1.3.1)**: Assesses the precision requirements for attitude and orbit control.
- **System Design (WP-1.1.3.2)**: Designs the control system for attitude and orbit.
- **Components Acquisition (WP-1.1.3.3)**: Involves procuring the necessary components.
- **Functional Test (WP-1.1.3.4)**: Verifies that the system operates correctly.
- **Subsystem Assembly (WP-1.1.3.5)**: Assembles the attitude and orbit control subsystem.
- **Environmental Test (WP-1.1.3.6)**: Conducts tests to ensure environmental resilience.
- **Documentation and Review (WP-1.1.3.7)**: Maintains documentation and conducts reviews.

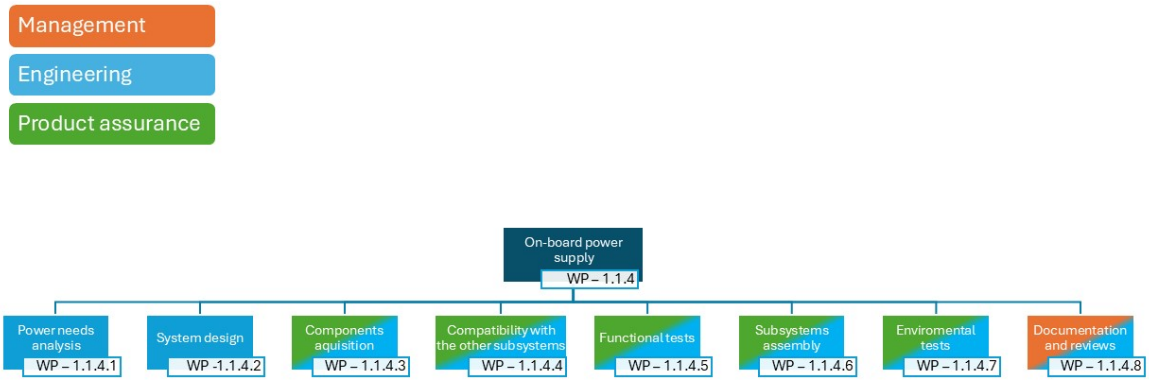


Figure 3.8: WBS for the On-board power supply Subsystem

The diagram provides details on the On-board Power Supply Subsystem (WP-1.1.4), which includes:

- **Power Needs Analysis (WP-1.1.4.1)**: Assesses the power requirements for the subsystem.
- **System Design (WP-1.1.4.2)**: Designs the power supply system.
- **Components Acquisition (WP-1.1.4.3)**: Acquires necessary components.
- **Compatibility with Other Subsystems (WP-1.1.4.4)**: Ensures compatibility across subsystems.
- **Functional Tests (WP-1.1.4.5)**: Verifies functional performance.
- **Subsystem Assembly (WP-1.1.4.6)**: Assembles the power supply components.
- **Environmental Test (WP-1.1.4.7)**: Conducts tests to ensure environmental resilience.
- **Documentation and Reviews (WP-1.1.4.8)**: Maintains documentation and reviews for quality assurance.

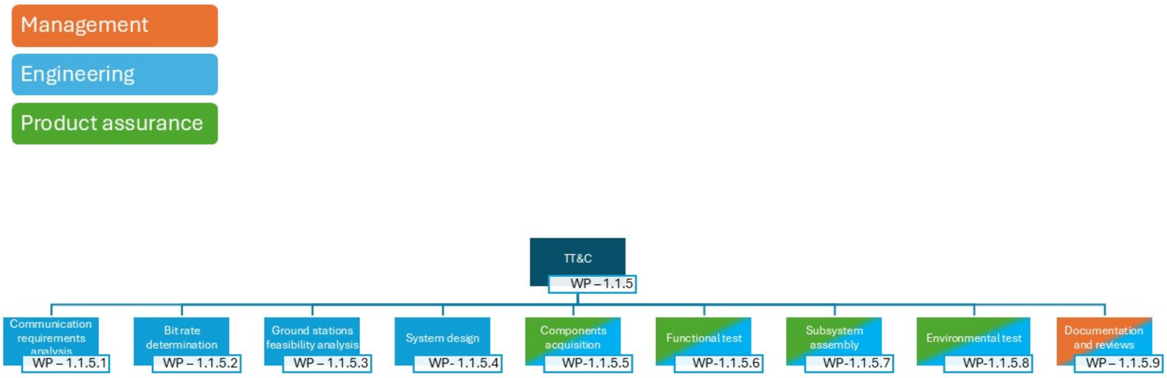


Figure 3.9: WBS for the TT&C Subsystem

The diagram focuses on the TT&C Subsystem (WP-1.1.5) and includes the following tasks:

- **Communication Requirements (WP-1.1.5.1)**: Defines the communication requirements for the subsystem.
- **Bit Rate Determination (WP-1.1.5.2)**: Determines the appropriate bit rate for data transmission.
- **Coordination Quality Analysis (WP-1.1.5.3)**: Analyzes the quality of communication coordination.
- **System Design (WP-1.1.5.4)**: Develops the system design for telemetry and communication.
- **Components Acquisition (WP-1.1.5.5)**: Procures necessary components.
- **Functional Test (WP-1.1.5.6)**: Conducts functional tests to ensure subsystem performance.
- **Subsystem Assembly (WP-1.1.5.7)**: Assembles subsystem components.
- **Environmental Test (WP-1.1.5.8)**: Performs tests to assess environmental resilience.
- **Documentation and Review (WP-1.1.5.9)**: Maintains documentation and performs reviews for quality assurance.

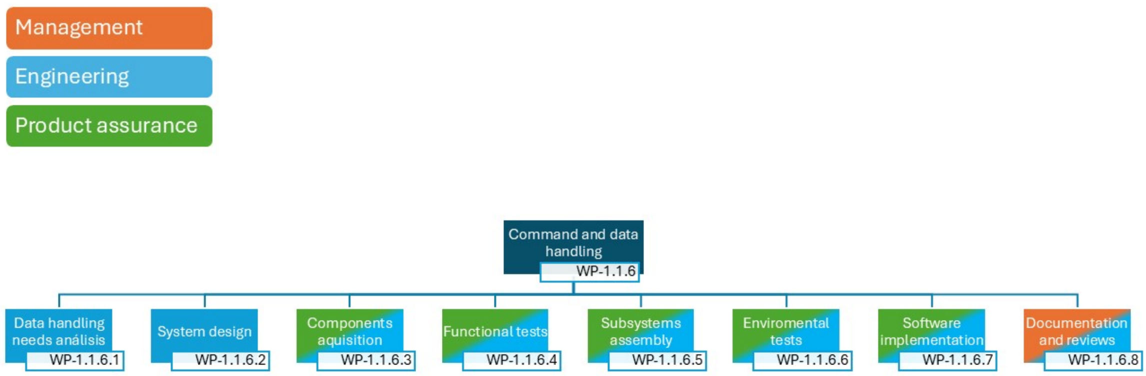


Figure 3.10: WBS for the Command and Data Handling Subsystem

The diagram details the Command and Data Handling Subsystem (WP-1.1.6), which includes the following tasks:

- **Data Handling Needs Analysis (WP-1.1.6.1)**: Analyzes data handling requirements.
- **System Design (WP-1.1.6.2)**: Designs the command and data handling system.
- **Components Acquisition (WP-1.1.6.3)**: Acquires necessary components.
- **Functional Test (WP-1.1.6.4)**: Conducts functional tests to ensure system performance.
- **Subsystem Assembly (WP-1.1.6.5)**: Assembles the subsystem components.
- **Environmental Test (WP-1.1.6.6)**: Performs environmental resilience tests.
- **Software Implementation (WP-1.1.6.7)**: Implements the software for data handling.
- **Documentation and Reviews (WP-1.1.6.8)**: Maintains documentation and performs quality assurance reviews.

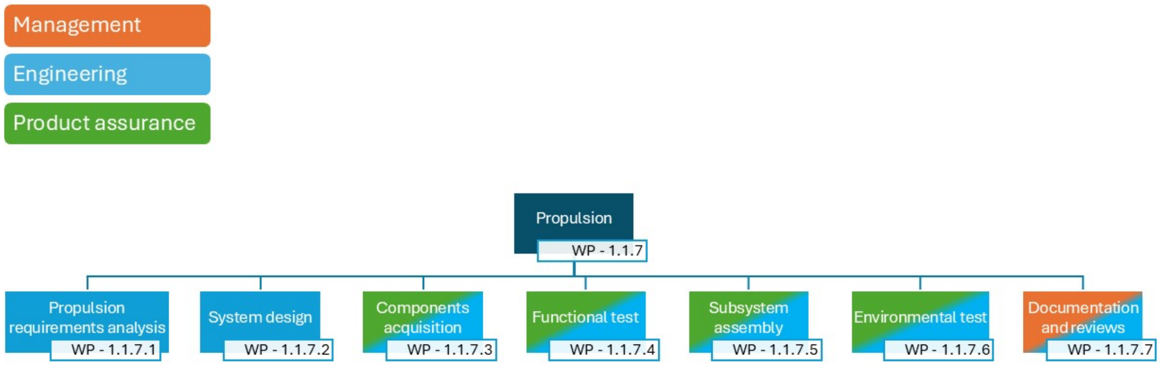


Figure 3.11: WBS for the Propulsion Subsystem

The diagram focuses on the Propulsion Subsystem (WP-1.1.7) and includes the following tasks:

- **Propulsion Requirements Analysis (WP-1.1.7.1)**: Defines the propulsion requirements necessary for achieving the satellite's desired maneuvers and orbital adjustments.
- **System Design (WP-1.1.7.2)**: Develops the propulsion system design, including component selection, layout, and integration with other subsystems.
- **Components Acquisition (WP-1.1.7.3)**: Procures all necessary components for the propulsion system, ensuring they meet technical specifications and compatibility needs.
- **Functional Test (WP-1.1.7.4)**: Conducts functional tests on propulsion components and systems to verify performance and responsiveness.
- **Subsystem Assembly (WP-1.1.7.5)**: Assembles the propulsion system components, preparing the subsystem for integration into the satellite.
- **Environmental Test (WP-1.1.7.6)**: Performs tests to assess the propulsion system's resilience under environmental conditions, such as temperature and vacuum.
- **Documentation and Reviews (WP-1.1.7.7)**: Maintains detailed documentation and conducts reviews to ensure quality standards and operational readiness.

This breakdown of the propulsion subsystem tasks ensures a structured approach, covering analysis, design, acquisition, testing, and integration, which are essential for the reliable operation of the propulsion system in space.

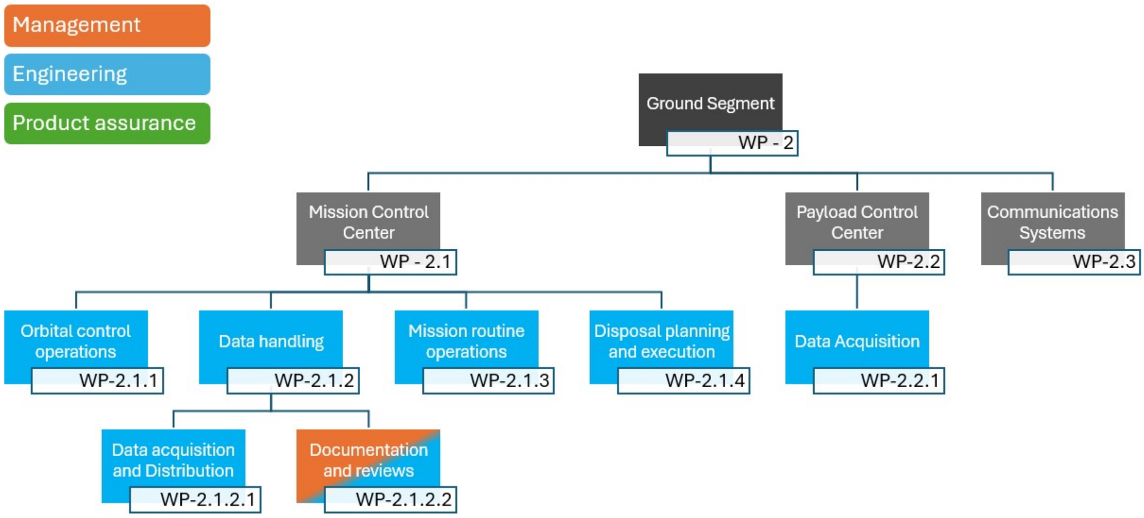


Figure 3.12: WBS for ground segment

The diagram shows the Ground Segment (WP-2), which includes the following components:

- **Mission Control Center (WP-2.1)**: Responsible for managing mission control operations, including:
  - **Orbital Control Operations (WP-2.1.1)**
  - **Data Handling (WP-2.1.2)**
  - **Mission Routine Operations (WP-2.1.3)**
  - **Disposal Planning and Execution (WP-2.1.4)**
- **Payload Control Center (WP-2.2)**: Manages payload operations, including:
  - **Data Acquisition (WP-2.2.1)**
- **Communications Systems (WP-2.3)**: Oversees communication systems for data transmission and reception.

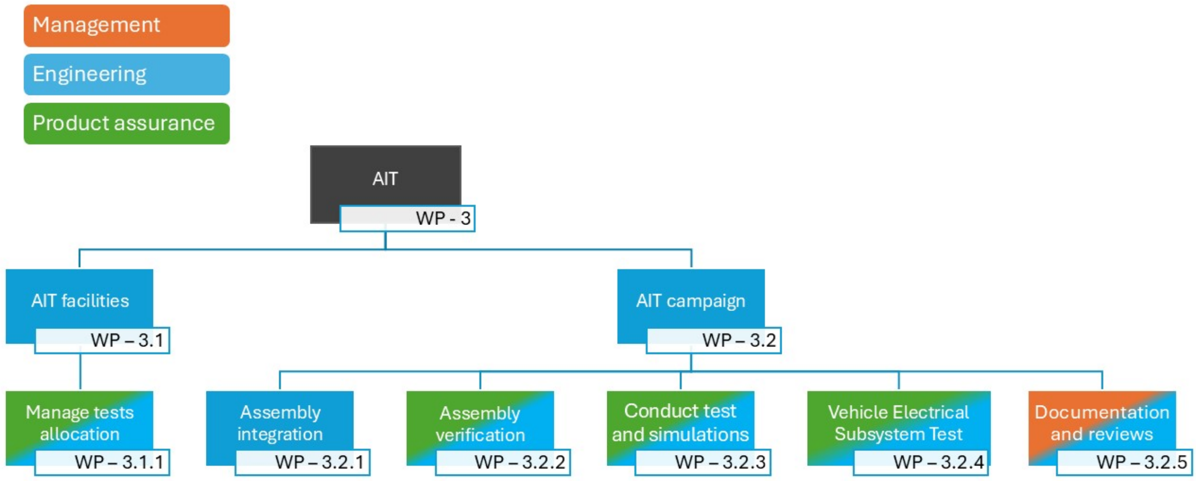


Figure 3.13: AIT WBS

The diagram represents the AIT (WP-3), which includes the following categorization:

- **AIT Facilities (WP-3.1)**: involves the preparation of the workplace.
  - **Manage Tests Allocation (WP-3.1.1)**: Manages the allocation of testing resources.
- **AIT Campaign (WP-3.2)**: includes the assembly, integration and testing activities.
  - **Assembly Integration (WP-3.2.1)**: Integrates subsystems into the main system.
  - **Assembly Verification (WP-3.2.2)**: Verifies subsystems integration.
  - **Conduct Tests and Simulations (WP-3.2.3)**: Executes tests and simulations to verify system functionality.
  - **Vehicle Electrical System Test (WP-3.2.4)**: Conducts electrical tests for the vehicle systems.
  - **Documentation and Reviews (WP-3.2.5)**: Maintains documentation and performs reviews for quality assurance.

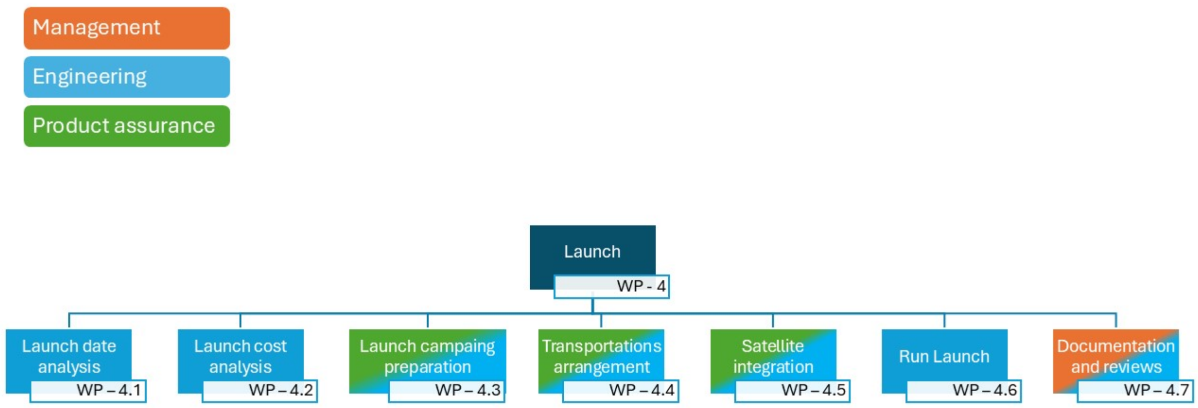


Figure 3.14: Launch WBS

The diagram focuses on the Launch (WP-4) phase, which includes the following tasks:

- **Launch Date Analysis (WP-4.1)**: Analyzes the optimal launch date.
- **Launch Cost Analysis (WP-4.2)**: Analyzes and manages launch costs.
- **Launch Campaign Preparation (WP-4.3)**: Prepares for the launch campaign.
- **Transportation Arrangements (WP-4.4)**: Manages transportation logistics for launch.
- **Satellite Integration (WP-4.5)**: Integrates the satellite for launch readiness.
- **Run Launch (WP-4.6)**: Executes the launch operations.
- **Documentation and Reviews (WP-4.7)**: Maintains documentation and performs final reviews.

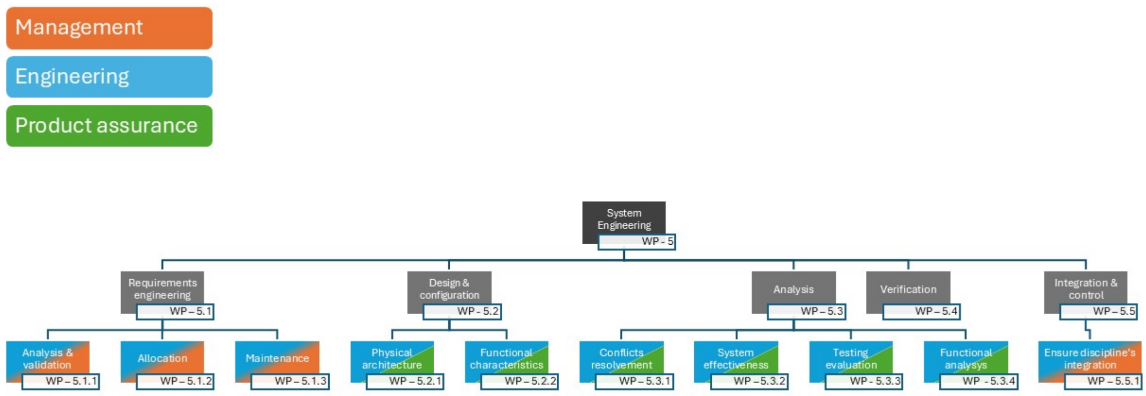


Figure 3.15: System Engineering WBS

This diagram shows the System Engineering (WP-5), which includes the following components:

- **Requirements Engineering (WP-5.1)**: Defines, documents, and manages system or product requirements.
  - **Analysis & Validation (WP-5.1.1)**: Verifies that requirements are complete, feasible, and meet stakeholder needs.
  - **Allocation (WP-5.1.2)**: Assigns requirements to specific components or teams for focused development.
  - **Maintenance (WP-5.1.3)**: Keeps requirements up-to-date as the system evolves, adapting to changes as needed.
- **Design & Configuration (WP-5.2)**: Develops the system's physical and functional architecture.
  - **Physical Architecture (WP-5.2.1)**: Defines the physical structure of the system, including components and hardware layout.
  - **Functional Characteristics (WP-5.2.2)**: Specifies system functions and behaviors to meet performance requirements.
- **Analysis (WP-5.3)**: Focuses on conflict resolution, effectiveness, and functional testing.
  - **Conflict Resolution (WP-5.3.1)**: Identifies and resolves conflicts in requirements or design to ensure alignment.
  - **System Effectiveness (WP-5.3.2)**: Evaluates system performance to verify it meets intended goals and objectives.

- **Testing Evaluation (WP-5.3.3)**: Assesses test results to confirm that the system functions as expected.
- **Functional Analysis (WP-5.3.4)**: Analyzes system functions to ensure they meet required operational needs.

- **Integration & Control (WP-5.5)**: Ensures seamless integration across disciplines.
  - **Discipline Integration (WP-5.5.1)**: Ensures effective coordination and integration of all disciplines involved in the system development.